1.1 ./csharp/Platform.Data.Doublets/CriterionMatchers/TargetMatcher.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.CriterionMatchers
{
    public class TargetMatcher<TLink> : LinksOperatorBase<TLink>, ICriterionMatcher<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly TLink _targetToMatch;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TargetMatcher(ILinks<TLink> links, TLink targetToMatch) : base(links) =>
        ↪  _targetToMatch = targetToMatch;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool IsMatched(TLink link) => _equalityComparer.Equals(_links.GetTarget(link),
        ↪  _targetToMatch);
    }
}
```

1.2 ./csharp/Platform.Data.Doublets/Decorators/LinksCascadeUniquenessAndUsagesResolver.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Decorators
{
    public class LinksCascadeUniquenessAndUsagesResolver<TLink> : LinksUniquenessResolver<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinksCascadeUniquenessAndUsagesResolver(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink ResolveAddressChangeConflict(TLink oldLinkAddress, TLink
        ↪  newLinkAddress)
        {
            // Use Facade (the last decorator) to ensure recursion working correctly
            _facade.MergeUsages(oldLinkAddress, newLinkAddress);
            return base.ResolveAddressChangeConflict(oldLinkAddress, newLinkAddress);
        }
    }
}
```

1.3 ./csharp/Platform.Data.Doublets/Decorators/LinksCascadeUsagesResolver.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Decorators
{
    /// <remarks>
    /// <para>Must be used in conjunction with NonNullContentsLinkDeletionResolver.</para>
    /// <para>Должен использоваться вместе с NonNullContentsLinkDeletionResolver.</para>
    /// </remarks>
    public class LinksCascadeUsagesResolver<TLink> : LinksDecoratorBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinksCascadeUsagesResolver(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override void Delete(IList<TLink> restrictions)
        {
            var linkIndex = restrictions[_constants.IndexPart];
            // Use Facade (the last decorator) to ensure recursion working correctly
            _facade.DeleteAllUsages(linkIndex);
            _links.Delete(linkIndex);
        }
    }
}
```

1.4 ./csharp/Platform.Data.Doublets/Decorators/LinksDecoratorBase.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Decorators
{
    public abstract class LinksDecoratorBase<TLink> : LinksOperatorBase<TLink>, ILinks<TLink>
    {
        protected readonly LinksConstants<TLink> _constants;

        public LinksConstants<TLink> Constants
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get => _constants;
        }

        protected ILinks<TLink> _facade;

        public ILinks<TLink> Facade
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get => _facade;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set
            {
                _facade = value;
                if (_links is LinksDecoratorBase<TLink> decorator)
                {
                    decorator.Facade = value;
                }
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected LinksDecoratorBase(ILinks<TLink> links) : base(links)
        {
            _constants = links.Constants;
            Facade = this;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual TLink Count(IList<TLink> restrictions) => _links.Count(restrictions);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
        ↪  => _links.Each(handler, restrictions);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual TLink Create(IList<TLink> restrictions) => _links.Create(restrictions);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution) =>
        ↪  _links.Update(restrictions, substitution);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual void Delete(IList<TLink> restrictions) => _links.Delete(restrictions);
    }
}
```

1.5 ./csharp/Platform.Data.Doublets/Decorators/LinksDisposableDecoratorBase.cs

```
using System.Runtime.CompilerServices;
using Platform.Disposables;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
#pragma warning disable CA1063 // Implement IDisposable Correctly

namespace Platform.Data.Doublets.Decorators
{
    public abstract class LinksDisposableDecoratorBase<TLink> : LinksDecoratorBase<TLink>,
    ↪  ILinks<TLink>, System.IDisposable
    {
        protected class DisposableWithMultipleCallsAllowed : Disposable
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public DisposableWithMultipleCallsAllowed(Disposal disposal) : base(disposal) { }

            protected override bool AllowMultipleDisposeCalls
```

```
            {
                [MethodImpl(MethodImplOptions.AggressiveInlining)]
                get => true;
            }
        }

        protected readonly DisposableWithMultipleCallsAllowed Disposable;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected LinksDisposableDecoratorBase(ILinks<TLink> links) : base(links) => Disposable
        ↪  = new DisposableWithMultipleCallsAllowed(Dispose);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        ~LinksDisposableDecoratorBase() => Disposable.Destruct();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Dispose() => Disposable.Dispose();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual void Dispose(bool manual, bool wasDisposed)
        {
            if (!wasDisposed)
            {
                _links.DisposeIfPossible();
            }
        }
    }
}
```

1.6 ./csharp/Platform.Data.Doublets/Decorators/LinksInnerReferenceExistenceValidator.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Decorators
{
    // TODO: Make LinksExternalReferenceValidator. A layer that checks each link to exist or to
    ↪  be external (hybrid link's raw number).
    public class LinksInnerReferenceExistenceValidator<TLink> : LinksDecoratorBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinksInnerReferenceExistenceValidator(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
        {
            var links = _links;
            links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
            return links.Each(handler, restrictions);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
        {
            // TODO: Possible values: null, ExistentLink or NonExistentHybrid(ExternalReference)
            var links = _links;
            links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
            links.EnsureInnerReferenceExists(substitution, nameof(substitution));
            return links.Update(restrictions, substitution);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override void Delete(IList<TLink> restrictions)
        {
            var link = restrictions[_constants.IndexPart];
            var links = _links;
            links.EnsureLinkExists(link, nameof(link));
            links.Delete(link);
        }
    }
}
```

1.7 ./csharp/Platform.Data.Doublets/Decorators/LinksItselfConstantToSelfReferenceResolver.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

```

```
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Decorators
{
    public class LinksItselfConstantToSelfReferenceResolver<TLink> : LinksDecoratorBase<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinksItselfConstantToSelfReferenceResolver(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
        {
            var constants = _constants;
            var itselfConstant = constants.Itself;
            if (!_equalityComparer.Equals(constants.Any, itselfConstant) &&
            ↪  restrictions.Contains(itselfConstant))
            {
                // Itself constant is not supported for Each method right now, skipping execution
                return constants.Continue;
            }
            return _links.Each(handler, restrictions);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution) =>
        ↪  _links.Update(restrictions, _links.ResolveConstantAsSelfReference(_constants.Itself,
        ↪  restrictions, substitution));
    }
}
```

1.8 ./csharp/Platform.Data.Doublets/Decorators/LinksNonExistentDependenciesCreator.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Decorators
{
    /// <remarks>
    /// Not practical if newSource and newTarget are too big.
    /// To be able to use practical version we should allow to create link at any specific
    ↪  location inside ResizableDirectMemoryLinks.
    /// This in turn will require to implement not a list of empty links, but a list of ranges
    ↪  to store it more efficiently.
    /// </remarks>
    public class LinksNonExistentDependenciesCreator<TLink> : LinksDecoratorBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinksNonExistentDependenciesCreator(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
        {
            var constants = _constants;
            var links = _links;
            links.EnsureCreated(substitution[constants.SourcePart],
            ↪  substitution[constants.TargetPart]);
            return links.Update(restrictions, substitution);
        }
    }
}
```

1.9 ./csharp/Platform.Data.Doublets/Decorators/LinksNullConstantToSelfReferenceResolver.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Decorators
{
    public class LinksNullConstantToSelfReferenceResolver<TLink> : LinksDecoratorBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinksNullConstantToSelfReferenceResolver(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
14          public override TLink Create(IList<TLink> restrictions) => _links.CreatePoint();
15
16          [MethodImpl(MethodImplOptions.AggressiveInlining)]
17          public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution) =>
                ↪ _links.Update(restrictions, _links.ResolveConstantAsSelfReference(_constants.Null,
                ↪ restrictions, substitution));
18      }
19  }
```

1.10 ./csharp/Platform.Data.Doublets/Decorators/LinksUniquenessResolver.cs

```
1   using System.Collections.Generic;
2   using System.Runtime.CompilerServices;
3
4   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6   namespace Platform.Data.Doublets.Decorators
7   {
8       public class LinksUniquenessResolver<TLink> : LinksDecoratorBase<TLink>
9       {
10          private static readonly EqualityComparer<TLink> _equalityComparer =
                ↪ EqualityComparer<TLink>.Default;
11
12          [MethodImpl(MethodImplOptions.AggressiveInlining)]
13          public LinksUniquenessResolver(ILinks<TLink> links) : base(links) { }
14
15          [MethodImpl(MethodImplOptions.AggressiveInlining)]
16          public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
17          {
18              var constants = _constants;
19              var links = _links;
20              var newLinkAddress = links.SearchOrDefault(substitution[constants.SourcePart],
                    ↪ substitution[constants.TargetPart]);
21              if (_equalityComparer.Equals(newLinkAddress, default))
22              {
23                  return links.Update(restrictions, substitution);
24              }
25              return ResolveAddressChangeConflict(restrictions[constants.IndexPart],
                    ↪ newLinkAddress);
26          }
27
28          [MethodImpl(MethodImplOptions.AggressiveInlining)]
29          protected virtual TLink ResolveAddressChangeConflict(TLink oldLinkAddress, TLink
                ↪ newLinkAddress)
30          {
31              if (!_equalityComparer.Equals(oldLinkAddress, newLinkAddress) &&
                    ↪ _links.Exists(oldLinkAddress))
32              {
33                  _facade.Delete(oldLinkAddress);
34              }
35              return newLinkAddress;
36          }
37      }
38  }
```

1.11 ./csharp/Platform.Data.Doublets/Decorators/LinksUniquenessValidator.cs

```
1   using System.Collections.Generic;
2   using System.Runtime.CompilerServices;
3
4   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6   namespace Platform.Data.Doublets.Decorators
7   {
8       public class LinksUniquenessValidator<TLink> : LinksDecoratorBase<TLink>
9       {
10          [MethodImpl(MethodImplOptions.AggressiveInlining)]
11          public LinksUniquenessValidator(ILinks<TLink> links) : base(links) { }
12
13          [MethodImpl(MethodImplOptions.AggressiveInlining)]
14          public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
15          {
16              var links = _links;
17              var constants = _constants;
18              links.EnsureDoesNotExists(substitution[constants.SourcePart],
                    ↪ substitution[constants.TargetPart]);
19              return links.Update(restrictions, substitution);
20          }
21      }
22  }
```

1.12 ./csharp/Platform.Data.Doublets/Decorators/LinksUsagesValidator.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Decorators
{
    public class LinksUsagesValidator<TLink> : LinksDecoratorBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinksUsagesValidator(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
        {
            var links = _links;
            links.EnsureNoUsages(restrictions[_constants.IndexPart]);
            return links.Update(restrictions, substitution);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override void Delete(IList<TLink> restrictions)
        {
            var link = restrictions[_constants.IndexPart];
            var links = _links;
            links.EnsureNoUsages(link);
            links.Delete(link);
        }
    }
}
```

1.13 ./csharp/Platform.Data.Doublets/Decorators/NonNullContentsLinkDeletionResolver.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Decorators
{
    public class NonNullContentsLinkDeletionResolver<TLink> : LinksDecoratorBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public NonNullContentsLinkDeletionResolver(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override void Delete(IList<TLink> restrictions)
        {
            var linkIndex = restrictions[_constants.IndexPart];
            var links = _links;
            links.EnforceResetValues(linkIndex);
            links.Delete(linkIndex);
        }
    }
}
```

1.14 ./csharp/Platform.Data.Doublets/Decorators/UInt64Links.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Decorators
{
    /// <summary>
    /// <para>Represents a combined decorator that implements the basic logic for interacting
    ↪  with the links storage for links with addresses represented as <see cref="System.UInt64"
    ↪  />.</para>
    /// <para>Представляет комбинированный декоратор, реализующий основную логику по
    ↪  взаимодействии с хранилищем связей, для связей с адресами представленными в виде <see
    ↪  cref="System.UInt64"/>.</para>
    /// </summary>
    /// <remarks>
    /// Возможные оптимизации:
    /// Объединение в одном поле Source и Target с уменьшением до 32 бит.
    ///     + меньше объём БД
    ///     - меньше производительность
    ///     - больше ограничение на количество связей в БД)
    /// Ленивое хранение размеров поддеревьев (расчитываемое по мере использования БД)
```

```
19      ///     + меньше объём БД
20      ///     - больше сложность
21      ///
22      /// Текущее теоретическое ограничение на индекс связи, из-за использования 5 бит в размере
        ↪  поддеревьев для AVL баланса и флагов нитей: 2 в степени(64 минус 5 равно 59 ) равно 576
        ↪  460 752 303 423 488
23      /// Желательно реализовать поддержку переключения между деревьями и битовыми индексами
        ↪  (битовыми строками) - вариант матрицы (выстраеваемой лениво).
24      ///
25      /// Решить отключать ли проверки при компиляции под Release. Т.е. исключения будут
        ↪  выбрасываться только при #if DEBUG
26      /// </remarks>
27      public class UInt64Links : LinksDisposableDecoratorBase<ulong>
28      {
29          [MethodImpl(MethodImplOptions.AggressiveInlining)]
30          public UInt64Links(ILinks<ulong> links) : base(links) { }
31
32          [MethodImpl(MethodImplOptions.AggressiveInlining)]
33          public override ulong Create(IList<ulong> restrictions) => _links.CreatePoint();
34
35          [MethodImpl(MethodImplOptions.AggressiveInlining)]
36          public override ulong Update(IList<ulong> restrictions, IList<ulong> substitution)
37          {
38              var constants = _constants;
39              var indexPartConstant = constants.IndexPart;
40              var sourcePartConstant = constants.SourcePart;
41              var targetPartConstant = constants.TargetPart;
42              var nullConstant = constants.Null;
43              var itselfConstant = constants.Itself;
44              var existedLink = nullConstant;
45              var updatedLink = restrictions[indexPartConstant];
46              var newSource = substitution[sourcePartConstant];
47              var newTarget = substitution[targetPartConstant];
48              var links = _links;
49              if (newSource != itselfConstant && newTarget != itselfConstant)
50              {
51                  existedLink = links.SearchOrDefault(newSource, newTarget);
52              }
53              if (existedLink == nullConstant)
54              {
55                  var before = links.GetLink(updatedLink);
56                  if (before[sourcePartConstant] != newSource || before[targetPartConstant] !=
                    ↪  newTarget)
57                  {
58                      links.Update(updatedLink, newSource == itselfConstant ? updatedLink :
                        ↪  newSource,
59                                                newTarget == itselfConstant ? updatedLink :
                                                  ↪  newTarget);
60                  }
61                  return updatedLink;
62              }
63              else
64              {
65                  return _facade.MergeAndDelete(updatedLink, existedLink);
66              }
67          }
68
69          [MethodImpl(MethodImplOptions.AggressiveInlining)]
70          public override void Delete(IList<ulong> restrictions)
71          {
72              var linkIndex = restrictions[_constants.IndexPart];
73              var links = _links;
74              links.EnforceResetValues(linkIndex);
75              _facade.DeleteAllUsages(linkIndex);
76              links.Delete(linkIndex);
77          }
78      }
79  }
```

1.15 ./csharp/Platform.Data.Doublets/Decorators/UniLinks.cs

```
1   using System;
2   using System.Collections.Generic;
3   using System.Linq;
4   using Platform.Collections;
5   using Platform.Collections.Lists;
6   using Platform.Data.Universal;
7
8   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
```

```
namespace Platform.Data.Doublets.Decorators
{
    /// <remarks>
    /// What does empty pattern (for condition or substitution) mean? Nothing or Everything?
    /// Now we go with nothing. And nothing is something one, but empty, and cannot be changed by itself. But can cause creation (update from nothing) or deletion (update to nothing).
    ///
    /// TODO: Decide to change to IDoubletLinks or not to change. (Better to create DefaultUniLinksBase, that contains logic itself and can be implemented using both IDoubletLinks and ILinks.)
    /// </remarks>
    internal class UniLinks<TLink> : LinksDecoratorBase<TLink>, IUniLinks<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer = EqualityComparer<TLink>.Default;

        public UniLinks(ILinks<TLink> links) : base(links) { }

        private struct Transition
        {
            public IList<TLink> Before;
            public IList<TLink> After;

            public Transition(IList<TLink> before, IList<TLink> after)
            {
                Before = before;
                After = after;
            }
        }

        //public static readonly TLink NullConstant = Use<LinksConstants<TLink>>.Single.Null;
        //public static readonly IReadOnlyList<TLink> NullLink = new ReadOnlyCollection<TLink>(new List<TLink> { NullConstant, NullConstant, NullConstant });

        // TODO: Подумать о том, как реализовать древовидный Restriction и Substitution (Links-Expression)
        public TLink Trigger(IList<TLink> restriction, Func<IList<TLink>, IList<TLink>, TLink> matchedHandler, IList<TLink> substitution, Func<IList<TLink>, IList<TLink>, TLink> substitutedHandler)
        {
            ////List<Transition> transitions = null;
            ////if (!restriction.IsNullOrEmpty())
            ////{
            ////    // Есть причина делать проход (чтение)
            ////    if (matchedHandler != null)
            ////    {
            ////        if (!substitution.IsNullOrEmpty())
            ////        {
            ////            // restriction => { 0, 0, 0 } | { 0 } // Create
            ////            // substitution => { itself, 0, 0 } | { itself, itself, itself } // Create / Update
            ////            // substitution => { 0, 0, 0 } | { 0 } // Delete
            ////            transitions = new List<Transition>();
            ////            if (Equals(substitution[Constants.IndexPart], Constants.Null))
            ////            {
            ////                // If index is Null, that means we always ignore every other value (they are also Null by definition)
            ////                var matchDecision = matchedHandler(, NullLink);
            ////                if (Equals(matchDecision, Constants.Break))
            ////                    return false;
            ////                if (!Equals(matchDecision, Constants.Skip))
            ////                    transitions.Add(new Transition(matchedLink, newValue));
            ////            }
            ////            else
            ////            {
            ////                Func<T, bool> handler;
            ////                handler = link =>
            ////                {
            ////                    var matchedLink = Memory.GetLinkValue(link);
            ////                    var newValue = Memory.GetLinkValue(link);
            ////                    newValue[Constants.IndexPart] = Constants.Itself;
            ////                    newValue[Constants.SourcePart] = Equals(substitution[Constants.SourcePart], Constants.Itself) ? matchedLink[Constants.IndexPart] : substitution[Constants.SourcePart];
            ////                    newValue[Constants.TargetPart] = Equals(substitution[Constants.TargetPart], Constants.Itself) ? matchedLink[Constants.IndexPart] : substitution[Constants.TargetPart];
```

```
////                    var matchDecision = matchedHandler(matchedLink, newValue);
////                    if (Equals(matchDecision, Constants.Break))
////                        return false;
////                    if (!Equals(matchDecision, Constants.Skip))
////                        transitions.Add(new Transition(matchedLink, newValue));
////                    return true;
////                };
////                if (!Memory.Each(handler, restriction))
////                    return Constants.Break;
////            }
////        }
////        else
////        {
////            Func<T, bool> handler = link =>
////            {
////                var matchedLink = Memory.GetLinkValue(link);
////                var matchDecision = matchedHandler(matchedLink, matchedLink);
////                return !Equals(matchDecision, Constants.Break);
////            };
////            if (!Memory.Each(handler, restriction))
////                return Constants.Break;
////        }
////    }
////    else
////    {
////        if (substitution != null)
////        {
////            transitions = new List<IList<T>>();
////            Func<T, bool> handler = link =>
////            {
////                var matchedLink = Memory.GetLinkValue(link);
////                transitions.Add(matchedLink);
////                return true;
////            };
////            if (!Memory.Each(handler, restriction))
////                return Constants.Break;
////        }
////        else
////        {
////            return Constants.Continue;
////        }
////    }
////}
////if (substitution != null)
////{
////    // Есть причина делать замену (запись)
////    if (substitutedHandler != null)
////    {
////    }
////    else
////    {
////    }
////}
////return Constants.Continue;

//if (restriction.IsNullOrEmpty()) // Create
//{
//    substitution[Constants.IndexPart] = Memory.AllocateLink();
//    Memory.SetLinkValue(substitution);
//}
//else if (substitution.IsNullOrEmpty()) // Delete
//{
//    Memory.FreeLink(restriction[Constants.IndexPart]);
//}
//else if (restriction.EqualTo(substitution)) // Read or ("repeat" the state) // Each
//{
//    // No need to collect links to list
//    // Skip == Continue
//    // No need to check substituedHandler
//    if (!Memory.Each(link => !Equals(matchedHandler(Memory.GetLinkValue(link)),
↪  Constants.Break), restriction))
//        return Constants.Break;
//}
//else // Update
//{
//    //List<IList<T>> matchedLinks = null;
//    if (matchedHandler != null)
//    {
```

```
150             //        matchedLinks = new List<IList<T>>();
151             //        Func<T, bool> handler = link =>
152             //        {
153             //            var matchedLink = Memory.GetLinkValue(link);
154             //            var matchDecision = matchedHandler(matchedLink);
155             //            if (Equals(matchDecision, Constants.Break))
156             //                return false;
157             //            if (!Equals(matchDecision, Constants.Skip))
158             //                matchedLinks.Add(matchedLink);
159             //            return true;
160             //        };
161             //        if (!Memory.Each(handler, restriction))
162             //            return Constants.Break;
163             //    }
164             //    if (!matchedLinks.IsNullOrEmpty())
165             //    {
166             //        var totalMatchedLinks = matchedLinks.Count;
167             //        for (var i = 0; i < totalMatchedLinks; i++)
168             //        {
169             //            var matchedLink = matchedLinks[i];
170             //            if (substitutedHandler != null)
171             //            {
172             //                var newValue = new List<T>(); // TODO: Prepare value to update here
173             //                // TODO: Decide is it actually needed to use Before and After
                ↪  substitution handling.
174             //                var substitutedDecision = substitutedHandler(matchedLink,
                ↪  newValue);
175             //                if (Equals(substitutedDecision, Constants.Break))
176             //                    return Constants.Break;
177             //                if (Equals(substitutedDecision, Constants.Continue))
178             //                {
179             //                    // Actual update here
180             //                    Memory.SetLinkValue(newValue);
181             //                }
182             //                if (Equals(substitutedDecision, Constants.Skip))
183             //                {
184             //                    // Cancel the update. TODO: decide use separate Cancel
                ↪  constant or Skip is enough?
185             //                }
186             //            }
187             //        }
188             //    }
189             //}
190             return _constants.Continue;
191         }
192 
193         public TLink Trigger(IList<TLink> patternOrCondition, Func<IList<TLink>, TLink>
            ↪  matchHandler, IList<TLink> substitution, Func<IList<TLink>, IList<TLink>, TLink>
            ↪  substitutionHandler)
194         {
195             var constants = _constants;
196             if (patternOrCondition.IsNullOrEmpty() && substitution.IsNullOrEmpty())
197             {
198                 return constants.Continue;
199             }
200             else if (patternOrCondition.EqualTo(substitution)) // Should be Each here TODO:
                ↪  Check if it is a correct condition
201             {
202                 // Or it only applies to trigger without matchHandler.
203                 throw new NotImplementedException();
204             }
205             else if (!substitution.IsNullOrEmpty()) // Creation
206             {
207                 var before = Array.Empty<TLink>();
208                 // Что должно означать False здесь? Остановиться (перестать идти) или пропустить
                    ↪  (пройти мимо) или пустить (взять)?
209                 if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
                    ↪  constants.Break))
210                 {
211                     return constants.Break;
212                 }
213                 var after = (IList<TLink>)substitution.ToArray();
214                 if (_equalityComparer.Equals(after[0], default))
215                 {
216                     var newLink = _links.Create();
217                     after[0] = newLink;
218                 }
219                 if (substitution.Count == 1)
```

```
220                     {
221                         after = _links.GetLink(substitution[0]);
222                     }
223                     else if (substitution.Count == 3)
224                     {
225                         //Links.Create(after);
226                     }
227                     else
228                     {
229                         throw new NotSupportedException();
230                     }
231                     if (matchHandler != null)
232                     {
233                         return substitutionHandler(before, after);
234                     }
235                     return constants.Continue;
236                 }
237                 else if (!patternOrCondition.IsNullOrEmpty()) // Deletion
238                 {
239                     if (patternOrCondition.Count == 1)
240                     {
241                         var linkToDelete = patternOrCondition[0];
242                         var before = _links.GetLink(linkToDelete);
243                         if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
                            ↪ constants.Break))
244                         {
245                             return constants.Break;
246                         }
247                         var after = Array.Empty<TLink>();
248                         _links.Update(linkToDelete, constants.Null, constants.Null);
249                         _links.Delete(linkToDelete);
250                         if (matchHandler != null)
251                         {
252                             return substitutionHandler(before, after);
253                         }
254                         return constants.Continue;
255                     }
256                     else
257                     {
258                         throw new NotSupportedException();
259                     }
260                 }
261                 else // Replace / Update
262                 {
263                     if (patternOrCondition.Count == 1) //-V3125
264                     {
265                         var linkToUpdate = patternOrCondition[0];
266                         var before = _links.GetLink(linkToUpdate);
267                         if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
                            ↪ constants.Break))
268                         {
269                             return constants.Break;
270                         }
271                         var after = (IList<TLink>)substitution.ToArray(); //-V3125
272                         if (_equalityComparer.Equals(after[0], default))
273                         {
274                             after[0] = linkToUpdate;
275                         }
276                         if (substitution.Count == 1)
277                         {
278                             if (!_equalityComparer.Equals(substitution[0], linkToUpdate))
279                             {
280                                 after = _links.GetLink(substitution[0]);
281                                 _links.Update(linkToUpdate, constants.Null, constants.Null);
282                                 _links.Delete(linkToUpdate);
283                             }
284                         }
285                         else if (substitution.Count == 3)
286                         {
287                             //Links.Update(after);
288                         }
289                         else
290                         {
291                             throw new NotSupportedException();
292                         }
293                         if (matchHandler != null)
294                         {
295                             return substitutionHandler(before, after);
```

```
                    }
                    return constants.Continue;
                }
                else
                {
                    throw new NotSupportedException();
                }
            }
        }

        /// <remarks>
        /// IList[IList[IList[T]]]
        /// |      |      |      |||
        /// |      |      |      ------ ||
        /// |      |      |       link  ||
        /// |      |      -------------- |
        /// |      |         change     |
        ///  --------------------
        ///         changes
        /// </remarks>
        public IList<IList<IList<TLink>>> Trigger(IList<TLink> condition, IList<TLink>
        ↪  substitution)
        {
            var changes = new List<IList<IList<TLink>>>();
            var @continue = _constants.Continue;
            Trigger(condition, AlwaysContinue, substitution, (before, after) =>
            {
                var change = new[] { before, after };
                changes.Add(change);
                return @continue;
            });
            return changes;
        }

        private TLink AlwaysContinue(IList<TLink> linkToMatch) => _constants.Continue;
    }
}
```

1.16 ./csharp/Platform.Data.Doublets/Doublet.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets
{
    public struct Doublet<T> : IEquatable<Doublet<T>>
    {
        private static readonly EqualityComparer<T> _equalityComparer =
        ↪  EqualityComparer<T>.Default;

        public readonly T Source;

        public readonly T Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public Doublet(T source, T target)
        {
            Source = source;
            Target = target;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override string ToString() => $"{Source}->{Target}";

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Equals(Doublet<T> other) => _equalityComparer.Equals(Source, other.Source)
        ↪  && _equalityComparer.Equals(Target, other.Target);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override bool Equals(object obj) => obj is Doublet<T> doublet ?
        ↪  base.Equals(doublet) : false;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override int GetHashCode() => (Source, Target).GetHashCode();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool operator ==(Doublet<T> left, Doublet<T> right) => left.Equals(right);

```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool operator !=(Doublet<T> left, Doublet<T> right) => !(left == right);
    }
}
```

1.17 ./csharp/Platform.Data.Doublets/DoubletComparer.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets
{
    /// <remarks>
    /// TODO: Может стоит попробовать ref во всех методах (IRefEqualityComparer)
    /// 2x faster with comparer
    /// </remarks>
    public class DoubletComparer<T> : IEqualityComparer<Doublet<T>>
    {
        public static readonly DoubletComparer<T> Default = new DoubletComparer<T>();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Equals(Doublet<T> x, Doublet<T> y) => x.Equals(y);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public int GetHashCode(Doublet<T> obj) => obj.GetHashCode();
    }
}
```

1.18 ./csharp/Platform.Data.Doublets/ILinks.cs

```
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

using System.Collections.Generic;

namespace Platform.Data.Doublets
{
    public interface ILinks<TLink> : ILinks<TLink, LinksConstants<TLink>>
    {
    }
}
```

1.19 ./csharp/Platform.Data.Doublets/ILinksExtensions.cs

```
using System;
using System.Collections;
using System.Collections.Generic;
using System.Linq;
using System.Runtime.CompilerServices;
using Platform.Ranges;
using Platform.Collections.Arrays;
using Platform.Random;
using Platform.Setters;
using Platform.Converters;
using Platform.Numbers;
using Platform.Data.Exceptions;
using Platform.Data.Doublets.Decorators;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets
{
    public static class ILinksExtensions
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static void RunRandomCreations<TLink>(this ILinks<TLink> links, ulong
        ↪  amountOfCreations)
        {
            var random = RandomHelpers.Default;
            var addressToUInt64Converter = UncheckedConverter<TLink, ulong>.Default;
            var uInt64ToAddressConverter = UncheckedConverter<ulong, TLink>.Default;
            for (var i = 0UL; i < amountOfCreations; i++)
            {
                var linksAddressRange = new Range<ulong>(0,
                ↪  addressToUInt64Converter.Convert(links.Count()));
                var source =
                ↪  uInt64ToAddressConverter.Convert(random.NextUInt64(linksAddressRange));
                var target =
                ↪  uInt64ToAddressConverter.Convert(random.NextUInt64(linksAddressRange));
                links.GetOrCreate(source, target);
            }
        }
```

```
35
36          [MethodImpl(MethodImplOptions.AggressiveInlining)]
37          public static void RunRandomSearches<TLink>(this ILinks<TLink> links, ulong
            ↪ amountOfSearches)
38          {
39              var random = RandomHelpers.Default;
40              var addressToUInt64Converter = UncheckedConverter<TLink, ulong>.Default;
41              var uInt64ToAddressConverter = UncheckedConverter<ulong, TLink>.Default;
42              for (var i = 0UL; i < amountOfSearches; i++)
43              {
44                  var linksAddressRange = new Range<ulong>(0,
                    ↪ addressToUInt64Converter.Convert(links.Count()));
45                  var source =
                    ↪ uInt64ToAddressConverter.Convert(random.NextUInt64(linksAddressRange));
46                  var target =
                    ↪ uInt64ToAddressConverter.Convert(random.NextUInt64(linksAddressRange));
47                  links.SearchOrDefault(source, target);
48              }
49          }
50
51          [MethodImpl(MethodImplOptions.AggressiveInlining)]
52          public static void RunRandomDeletions<TLink>(this ILinks<TLink> links, ulong
            ↪ amountOfDeletions)
53          {
54              var random = RandomHelpers.Default;
55              var addressToUInt64Converter = UncheckedConverter<TLink, ulong>.Default;
56              var uInt64ToAddressConverter = UncheckedConverter<ulong, TLink>.Default;
57              var linksCount = addressToUInt64Converter.Convert(links.Count());
58              var min = amountOfDeletions > linksCount ? 0UL : linksCount - amountOfDeletions;
59              for (var i = 0UL; i < amountOfDeletions; i++)
60              {
61                  linksCount = addressToUInt64Converter.Convert(links.Count());
62                  if (linksCount <= min)
63                  {
64                      break;
65                  }
66                  var linksAddressRange = new Range<ulong>(min, linksCount);
67                  var link =
                    ↪ uInt64ToAddressConverter.Convert(random.NextUInt64(linksAddressRange));
68                  links.Delete(link);
69              }
70          }
71
72          [MethodImpl(MethodImplOptions.AggressiveInlining)]
73          public static void Delete<TLink>(this ILinks<TLink> links, TLink linkToDelete) =>
            ↪ links.Delete(new LinkAddress<TLink>(linkToDelete));
74
75          /// <remarks>
76          /// TODO: Возможно есть очень простой способ это сделать.
77          /// (Например просто удалить файл, или изменить его размер таким образом,
78          /// чтобы удалился весь контент)
79          /// Например через _header->AllocatedLinks в ResizableDirectMemoryLinks
80          /// </remarks>
81          [MethodImpl(MethodImplOptions.AggressiveInlining)]
82          public static void DeleteAll<TLink>(this ILinks<TLink> links)
83          {
84              var equalityComparer = EqualityComparer<TLink>.Default;
85              var comparer = Comparer<TLink>.Default;
86              for (var i = links.Count(); comparer.Compare(i, default) > 0; i =
                ↪ Arithmetic.Decrement(i))
87              {
88                  links.Delete(i);
89                  if (!equalityComparer.Equals(links.Count(), Arithmetic.Decrement(i)))
90                  {
91                      i = links.Count();
92                  }
93              }
94          }
95
96          [MethodImpl(MethodImplOptions.AggressiveInlining)]
97          public static TLink First<TLink>(this ILinks<TLink> links)
98          {
99              TLink firstLink = default;
100             var equalityComparer = EqualityComparer<TLink>.Default;
101             if (equalityComparer.Equals(links.Count(), default))
102             {
103                 throw new InvalidOperationException("В хранилище нет связей.");
104             }
```

```
105             links.Each(links.Constants.Any, links.Constants.Any, link =>
106             {
107                 firstLink = link[links.Constants.IndexPart];
108                 return links.Constants.Break;
109             });
110             if (equalityComparer.Equals(firstLink, default))
111             {
112                 throw new InvalidOperationException("В процессе поиска по хранилищу не было
                    ↪ найдено связей.");
113             }
114             return firstLink;
115         }
116 
117         #region Paths
118 
119         /// <remarks>
120         /// TODO: Как так? Как то что ниже может быть корректно?
121         /// Скорее всего практически не применимо
122         /// Предполагалось, что можно было конвертировать формируемый в проходе через
            ↪ SequenceWalker
123         /// Stack в конкретный путь из Source, Target до связи, но это не всегда так.
124         /// TODO: Возможно нужен метод, который именно выбрасывает исключения (EnsurePathExists)
125         /// </remarks>
126         [MethodImpl(MethodImplOptions.AggressiveInlining)]
127         public static bool CheckPathExistance<TLink>(this ILinks<TLink> links, params TLink[]
            ↪ path)
128         {
129             var current = path[0];
130             //EnsureLinkExists(current, "path");
131             if (!links.Exists(current))
132             {
133                 return false;
134             }
135             var equalityComparer = EqualityComparer<TLink>.Default;
136             var constants = links.Constants;
137             for (var i = 1; i < path.Length; i++)
138             {
139                 var next = path[i];
140                 var values = links.GetLink(current);
141                 var source = values[constants.SourcePart];
142                 var target = values[constants.TargetPart];
143                 if (equalityComparer.Equals(source, target) && equalityComparer.Equals(source,
                    ↪ next))
144                 {
145                     //throw new InvalidOperationException(string.Format("Невозможно выбрать
                        ↪ путь, так как и Source и Target совпадают с элементом пути {0}.", next));
146                     return false;
147                 }
148                 if (!equalityComparer.Equals(next, source) && !equalityComparer.Equals(next,
                    ↪ target))
149                 {
150                     //throw new InvalidOperationException(string.Format("Невозможно продолжить
                        ↪ путь через элемент пути {0}", next));
151                     return false;
152                 }
153                 current = next;
154             }
155             return true;
156         }
157 
158         /// <remarks>
159         /// Может потребовать дополнительного стека для PathElement's при использовании
            ↪ SequenceWalker.
160         /// </remarks>
161         [MethodImpl(MethodImplOptions.AggressiveInlining)]
162         public static TLink GetByKeys<TLink>(this ILinks<TLink> links, TLink root, params int[]
            ↪ path)
163         {
164             links.EnsureLinkExists(root, "root");
165             var currentLink = root;
166             for (var i = 0; i < path.Length; i++)
167             {
168                 currentLink = links.GetLink(currentLink)[path[i]];
169             }
170             return currentLink;
171         }
172 
173         [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
174         public static TLink GetSquareMatrixSequenceElementByIndex<TLink>(this ILinks<TLink>
            ↪ links, TLink root, ulong size, ulong index)
175         {
176             var constants = links.Constants;
177             var source = constants.SourcePart;
178             var target = constants.TargetPart;
179             if (!Platform.Numbers.Math.IsPowerOfTwo(size))
180             {
181                 throw new ArgumentOutOfRangeException(nameof(size), "Sequences with sizes other
                    ↪  than powers of two are not supported.");
182             }
183             var path = new BitArray(BitConverter.GetBytes(index));
184             var length = Bit.GetLowestPosition(size);
185             links.EnsureLinkExists(root, "root");
186             var currentLink = root;
187             for (var i = length - 1; i >= 0; i--)
188             {
189                 currentLink = links.GetLink(currentLink)[path[i] ? target : source];
190             }
191             return currentLink;
192         }
193 
194         #endregion
195 
196         /// <summary>
197         /// Возвращает индекс указанной связи.
198         /// </summary>
199         /// <param name="links">Хранилище связей.</param>
200         /// <param name="link">Связь представленная списком, состоящим из её адреса и
            ↪ содержимого.</param>
201         /// <returns>Индекс начальной связи для указанной связи.</returns>
202         [MethodImpl(MethodImplOptions.AggressiveInlining)]
203         public static TLink GetIndex<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
            ↪ link[links.Constants.IndexPart];
204 
205         /// <summary>
206         /// Возвращает индекс начальной (Source) связи для указанной связи.
207         /// </summary>
208         /// <param name="links">Хранилище связей.</param>
209         /// <param name="link">Индекс связи.</param>
210         /// <returns>Индекс начальной связи для указанной связи.</returns>
211         [MethodImpl(MethodImplOptions.AggressiveInlining)]
212         public static TLink GetSource<TLink>(this ILinks<TLink> links, TLink link) =>
            ↪ links.GetLink(link)[links.Constants.SourcePart];
213 
214         /// <summary>
215         /// Возвращает индекс начальной (Source) связи для указанной связи.
216         /// </summary>
217         /// <param name="links">Хранилище связей.</param>
218         /// <param name="link">Связь представленная списком, состоящим из её адреса и
            ↪ содержимого.</param>
219         /// <returns>Индекс начальной связи для указанной связи.</returns>
220         [MethodImpl(MethodImplOptions.AggressiveInlining)]
221         public static TLink GetSource<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
            ↪ link[links.Constants.SourcePart];
222 
223         /// <summary>
224         /// Возвращает индекс конечной (Target) связи для указанной связи.
225         /// </summary>
226         /// <param name="links">Хранилище связей.</param>
227         /// <param name="link">Индекс связи.</param>
228         /// <returns>Индекс конечной связи для указанной связи.</returns>
229         [MethodImpl(MethodImplOptions.AggressiveInlining)]
230         public static TLink GetTarget<TLink>(this ILinks<TLink> links, TLink link) =>
            ↪ links.GetLink(link)[links.Constants.TargetPart];
231 
232         /// <summary>
233         /// Возвращает индекс конечной (Target) связи для указанной связи.
234         /// </summary>
235         /// <param name="links">Хранилище связей.</param>
236         /// <param name="link">Связь представленная списком, состоящим из её адреса и
            ↪ содержимого.</param>
237         /// <returns>Индекс конечной связи для указанной связи.</returns>
238         [MethodImpl(MethodImplOptions.AggressiveInlining)]
239         public static TLink GetTarget<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
            ↪ link[links.Constants.TargetPart];
240 
241         /// <summary>
```

```
242         /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
            ↪ (handler) для каждой подходящей связи.
243         /// </summary>
244         /// <param name="links">Хранилище связей.</param>
245         /// <param name="handler">Обработчик каждой подходящей связи.</param>
246         /// <param name="restrictions">Ограничения на содержимое связей. Каждое ограничение
            ↪ может иметь значения: Constants.Null - 0-я связь, обозначающая ссылку на пустоту,
            ↪ Any - отсутствие ограничения, 1..∞ конкретный адрес связи.</param>
247         /// <returns>True, в случае если проход по связям не был прерван и False в обратном
            ↪ случае.</returns>
248         [MethodImpl(MethodImplOptions.AggressiveInlining)]
249         public static bool Each<TLink>(this ILinks<TLink> links, Func<IList<TLink>, TLink>
            ↪ handler, params TLink[] restrictions)
250             => EqualityComparer<TLink>.Default.Equals(links.Each(handler, restrictions),
                ↪ links.Constants.Continue);
251
252         /// <summary>
253         /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
            ↪ (handler) для каждой подходящей связи.
254         /// </summary>
255         /// <param name="links">Хранилище связей.</param>
256         /// <param name="source">Значение, определяющее соответствующие шаблону связи.
            ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве начала,
            ↪ Constants.Any - любое начало, 1..∞ конкретное начало)</param>
257         /// <param name="target">Значение, определяющее соответствующие шаблону связи.
            ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве конца,
            ↪ Constants.Any - любой конец, 1..∞ конкретный конец)</param>
258         /// <param name="handler">Обработчик каждой подходящей связи.</param>
259         /// <returns>True, в случае если проход по связям не был прерван и False в обратном
            ↪ случае.</returns>
260         [MethodImpl(MethodImplOptions.AggressiveInlining)]
261         public static bool Each<TLink>(this ILinks<TLink> links, TLink source, TLink target,
            ↪ Func<TLink, bool> handler)
262         {
263             var constants = links.Constants;
264             return links.Each(link => handler(link[constants.IndexPart]) ? constants.Continue :
                ↪ constants.Break, constants.Any, source, target);
265         }
266
267         /// <summary>
268         /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
            ↪ (handler) для каждой подходящей связи.
269         /// </summary>
270         /// <param name="links">Хранилище связей.</param>
271         /// <param name="source">Значение, определяющее соответствующие шаблону связи.
            ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве начала,
            ↪ Constants.Any - любое начало, 1..∞ конкретное начало)</param>
272         /// <param name="target">Значение, определяющее соответствующие шаблону связи.
            ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве конца,
            ↪ Constants.Any - любой конец, 1..∞ конкретный конец)</param>
273         /// <param name="handler">Обработчик каждой подходящей связи.</param>
274         /// <returns>True, в случае если проход по связям не был прерван и False в обратном
            ↪ случае.</returns>
275         [MethodImpl(MethodImplOptions.AggressiveInlining)]
276         public static bool Each<TLink>(this ILinks<TLink> links, TLink source, TLink target,
            ↪ Func<IList<TLink>, TLink> handler) => links.Each(handler, links.Constants.Any,
            ↪ source, target);
277
278         [MethodImpl(MethodImplOptions.AggressiveInlining)]
279         public static IList<IList<TLink>> All<TLink>(this ILinks<TLink> links, params TLink[]
            ↪ restrictions)
280         {
281             var arraySize = CheckedConverter<TLink,
                ↪ long>.Default.Convert(links.Count(restrictions));
282             if (arraySize > 0)
283             {
284                 var array = new IList<TLink>[arraySize];
285                 var filler = new ArrayFiller<IList<TLink>, TLink>(array,
                    ↪ links.Constants.Continue);
286                 links.Each(filler.AddAndReturnConstant, restrictions);
287                 return array;
288             }
289             else
290             {
291                 return Array.Empty<IList<TLink>>();
292             }
```

```
293         }
294
295         [MethodImpl(MethodImplOptions.AggressiveInlining)]
296         public static IList<TLink> AllIndices<TLink>(this ILinks<TLink> links, params TLink[]
            ↪ restrictions)
297         {
298             var arraySize = CheckedConverter<TLink,
                ↪ long>.Default.Convert(links.Count(restrictions));
299             if (arraySize > 0)
300             {
301                 var array = new TLink[arraySize];
302                 var filler = new ArrayFiller<TLink, TLink>(array, links.Constants.Continue);
303                 links.Each(filler.AddFirstAndReturnConstant, restrictions);
304                 return array;
305             }
306             else
307             {
308                 return Array.Empty<TLink>();
309             }
310         }
311
312         /// <summary>
313         /// Возвращает значение, определяющее существует ли связь с указанными началом и концом
            ↪ в хранилище связей.
314         /// </summary>
315         /// <param name="links">Хранилище связей.</param>
316         /// <param name="source">Начало связи.</param>
317         /// <param name="target">Конец связи.</param>
318         /// <returns>Значение, определяющее существует ли связь.</returns>
319         [MethodImpl(MethodImplOptions.AggressiveInlining)]
320         public static bool Exists<TLink>(this ILinks<TLink> links, TLink source, TLink target)
            ↪ => Comparer<TLink>.Default.Compare(links.Count(links.Constants.Any, source, target),
            ↪ default) > 0;
321
322         #region Ensure
323         // TODO: May be move to EnsureExtensions or make it both there and here
324
325         [MethodImpl(MethodImplOptions.AggressiveInlining)]
326         public static void EnsureLinkExists<TLink>(this ILinks<TLink> links, IList<TLink>
            ↪ restrictions)
327         {
328             for (var i = 0; i < restrictions.Count; i++)
329             {
330                 if (!links.Exists(restrictions[i]))
331                 {
332                     throw new ArgumentLinkDoesNotExistsException<TLink>(restrictions[i],
                        ↪ $"sequence[{i}]");
333                 }
334             }
335         }
336
337         [MethodImpl(MethodImplOptions.AggressiveInlining)]
338         public static void EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links, TLink
            ↪ reference, string argumentName)
339         {
340             if (links.Constants.IsInternalReference(reference) && !links.Exists(reference))
341             {
342                 throw new ArgumentLinkDoesNotExistsException<TLink>(reference, argumentName);
343             }
344         }
345
346         [MethodImpl(MethodImplOptions.AggressiveInlining)]
347         public static void EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links,
            ↪ IList<TLink> restrictions, string argumentName)
348         {
349             for (int i = 0; i < restrictions.Count; i++)
350             {
351                 links.EnsureInnerReferenceExists(restrictions[i], argumentName);
352             }
353         }
354
355         [MethodImpl(MethodImplOptions.AggressiveInlining)]
356         public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, IList<TLink>
            ↪ restrictions)
357         {
358             var equalityComparer = EqualityComparer<TLink>.Default;
359             var any = links.Constants.Any;
360             for (var i = 0; i < restrictions.Count; i++)
```

```
361                 {
362                     if (!equalityComparer.Equals(restrictions[i], any) &&
                        ↪  !links.Exists(restrictions[i]))
363                     {
364                         throw new ArgumentLinkDoesNotExistsException<TLink>(restrictions[i],
                            ↪  $"sequence[{i}]");
365                     }
366                 }
367             }
368
369             [MethodImpl(MethodImplOptions.AggressiveInlining)]
370             public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, TLink link,
                ↪  string argumentName)
371             {
372                 var equalityComparer = EqualityComparer<TLink>.Default;
373                 if (!equalityComparer.Equals(link, links.Constants.Any) && !links.Exists(link))
374                 {
375                     throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
376                 }
377             }
378
379             [MethodImpl(MethodImplOptions.AggressiveInlining)]
380             public static void EnsureLinkIsItselfOrExists<TLink>(this ILinks<TLink> links, TLink
                ↪  link, string argumentName)
381             {
382                 var equalityComparer = EqualityComparer<TLink>.Default;
383                 if (!equalityComparer.Equals(link, links.Constants.Itself) && !links.Exists(link))
384                 {
385                     throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
386                 }
387             }
388
389             /// <param name="links">Хранилище связей.</param>
390             [MethodImpl(MethodImplOptions.AggressiveInlining)]
391             public static void EnsureDoesNotExists<TLink>(this ILinks<TLink> links, TLink source,
                ↪  TLink target)
392             {
393                 if (links.Exists(source, target))
394                 {
395                     throw new LinkWithSameValueAlreadyExistsException();
396                 }
397             }
398
399             /// <param name="links">Хранилище связей.</param>
400             [MethodImpl(MethodImplOptions.AggressiveInlining)]
401             public static void EnsureNoUsages<TLink>(this ILinks<TLink> links, TLink link)
402             {
403                 if (links.HasUsages(link))
404                 {
405                     throw new ArgumentLinkHasDependenciesException<TLink>(link);
406                 }
407             }
408
409             /// <param name="links">Хранилище связей.</param>
410             [MethodImpl(MethodImplOptions.AggressiveInlining)]
411             public static void EnsureCreated<TLink>(this ILinks<TLink> links, params TLink[]
                ↪  addresses) => links.EnsureCreated(links.Create, addresses);
412
413             /// <param name="links">Хранилище связей.</param>
414             [MethodImpl(MethodImplOptions.AggressiveInlining)]
415             public static void EnsurePointsCreated<TLink>(this ILinks<TLink> links, params TLink[]
                ↪  addresses) => links.EnsureCreated(links.CreatePoint, addresses);
416
417             /// <param name="links">Хранилище связей.</param>
418             [MethodImpl(MethodImplOptions.AggressiveInlining)]
419             public static void EnsureCreated<TLink>(this ILinks<TLink> links, Func<TLink> creator,
                ↪  params TLink[] addresses)
420             {
421                 var addressToUInt64Converter = CheckedConverter<TLink, ulong>.Default;
422                 var uInt64ToAddressConverter = CheckedConverter<ulong, TLink>.Default;
423                 var nonExistentAddresses = new HashSet<TLink>(addresses.Where(x =>
                    ↪  !links.Exists(x)));
424                 if (nonExistentAddresses.Count > 0)
425                 {
426                     var max = nonExistentAddresses.Max();
```

```
427                 max = uInt64ToAddressConverter.Convert(System.Math.Min(addressToUInt64Converter.
                    ↪  Convert(max),
                    ↪  addressToUInt64Converter.Convert(links.Constants.InternalReferencesRange.Max
                    ↪  imum)));
428                 var createdLinks = new List<TLink>();
429                 var equalityComparer = EqualityComparer<TLink>.Default;
430                 TLink createdLink = creator();
431                 while (!equalityComparer.Equals(createdLink, max))
432                 {
433                     createdLinks.Add(createdLink);
434                 }
435                 for (var i = 0; i < createdLinks.Count; i++)
436                 {
437                     if (!nonExistentAddresses.Contains(createdLinks[i]))
438                     {
439                         links.Delete(createdLinks[i]);
440                     }
441                 }
442             }
443         }
444
445         #endregion
446
447         /// <param name="links">Хранилище связей.</param>
448         [MethodImpl(MethodImplOptions.AggressiveInlining)]
449         public static TLink CountUsages<TLink>(this ILinks<TLink> links, TLink link)
450         {
451             var constants = links.Constants;
452             var values = links.GetLink(link);
453             TLink usagesAsSource = links.Count(new Link<TLink>(constants.Any, link,
                    ↪  constants.Any));
454             var equalityComparer = EqualityComparer<TLink>.Default;
455             if (equalityComparer.Equals(values[constants.SourcePart], link))
456             {
457                 usagesAsSource = Arithmetic<TLink>.Decrement(usagesAsSource);
458             }
459             TLink usagesAsTarget = links.Count(new Link<TLink>(constants.Any, constants.Any,
                    ↪  link));
460             if (equalityComparer.Equals(values[constants.TargetPart], link))
461             {
462                 usagesAsTarget = Arithmetic<TLink>.Decrement(usagesAsTarget);
463             }
464             return Arithmetic<TLink>.Add(usagesAsSource, usagesAsTarget);
465         }
466
467         /// <param name="links">Хранилище связей.</param>
468         [MethodImpl(MethodImplOptions.AggressiveInlining)]
469         public static bool HasUsages<TLink>(this ILinks<TLink> links, TLink link) =>
                ↪  Comparer<TLink>.Default.Compare(links.CountUsages(link), default) > 0;
470
471         /// <param name="links">Хранилище связей.</param>
472         [MethodImpl(MethodImplOptions.AggressiveInlining)]
473         public static bool Equals<TLink>(this ILinks<TLink> links, TLink link, TLink source,
                ↪  TLink target)
474         {
475             var constants = links.Constants;
476             var values = links.GetLink(link);
477             var equalityComparer = EqualityComparer<TLink>.Default;
478             return equalityComparer.Equals(values[constants.SourcePart], source) &&
                    ↪  equalityComparer.Equals(values[constants.TargetPart], target);
479         }
480
481         /// <summary>
482         /// Выполняет поиск связи с указанными Source (началом) и Target (концом).
483         /// </summary>
484         /// <param name="links">Хранилище связей.</param>
485         /// <param name="source">Индекс связи, которая является началом для искомой
                ↪  связи.</param>
486         /// <param name="target">Индекс связи, которая является концом для искомой связи.</param>
487         /// <returns>Индекс искомой связи с указанными Source (началом) и Target
                ↪  (концом).</returns>
488         [MethodImpl(MethodImplOptions.AggressiveInlining)]
489         public static TLink SearchOrDefault<TLink>(this ILinks<TLink> links, TLink source, TLink
                ↪  target)
490         {
491             var contants = links.Constants;
492             var setter = new Setter<TLink, TLink>(contants.Continue, contants.Break, default);
493             links.Each(setter.SetFirstAndReturnFalse, contants.Any, source, target);
```

```
494             return setter.Result;
495         }
496 
497         /// <param name="links">Хранилище связей.</param>
498         [MethodImpl(MethodImplOptions.AggressiveInlining)]
499         public static TLink Create<TLink>(this ILinks<TLink> links) => links.Create(null);
500 
501         /// <param name="links">Хранилище связей.</param>
502         [MethodImpl(MethodImplOptions.AggressiveInlining)]
503         public static TLink CreatePoint<TLink>(this ILinks<TLink> links)
504         {
505             var link = links.Create();
506             return links.Update(link, link, link);
507         }
508 
509         /// <param name="links">Хранилище связей.</param>
510         [MethodImpl(MethodImplOptions.AggressiveInlining)]
511         public static TLink CreateAndUpdate<TLink>(this ILinks<TLink> links, TLink source, TLink
            ↪ target) => links.Update(links.Create(), source, target);
512 
513         /// <summary>
514         /// Обновляет связь с указанными началом (Source) и концом (Target)
515         /// на связь с указанными началом (NewSource) и концом (NewTarget).
516         /// </summary>
517         /// <param name="links">Хранилище связей.</param>
518         /// <param name="link">Индекс обновляемой связи.</param>
519         /// <param name="newSource">Индекс связи, которая является началом связи, на которую
            ↪ выполняется обновление.</param>
520         /// <param name="newTarget">Индекс связи, которая является концом связи, на которую
            ↪ выполняется обновление.</param>
521         /// <returns>Индекс обновлённой связи.</returns>
522         [MethodImpl(MethodImplOptions.AggressiveInlining)]
523         public static TLink Update<TLink>(this ILinks<TLink> links, TLink link, TLink newSource,
            ↪ TLink newTarget) => links.Update(new LinkAddress<TLink>(link), new Link<TLink>(link,
            ↪ newSource, newTarget));
524 
525         /// <summary>
526         /// Обновляет связь с указанными началом (Source) и концом (Target)
527         /// на связь с указанными началом (NewSource) и концом (NewTarget).
528         /// </summary>
529         /// <param name="links">Хранилище связей.</param>
530         /// <param name="restrictions">Ограничения на содержимое связей. Каждое ограничение
            ↪ может иметь значения: Constants.Null - 0-я связь, обозначающая ссылку на пустоту,
            ↪ Itself - требование установить ссылку на себя, 1..∞ конкретный адрес другой
            ↪ связи.</param>
531         /// <returns>Индекс обновлённой связи.</returns>
532         [MethodImpl(MethodImplOptions.AggressiveInlining)]
533         public static TLink Update<TLink>(this ILinks<TLink> links, params TLink[] restrictions)
534         {
535             if (restrictions.Length == 2)
536             {
537                 return links.MergeAndDelete(restrictions[0], restrictions[1]);
538             }
539             if (restrictions.Length == 4)
540             {
541                 return links.UpdateOrCreateOrGet(restrictions[0], restrictions[1],
                    ↪ restrictions[2], restrictions[3]);
542             }
543             else
544             {
545                 return links.Update(new LinkAddress<TLink>(restrictions[0]), restrictions);
546             }
547         }
548 
549         [MethodImpl(MethodImplOptions.AggressiveInlining)]
550         public static IList<TLink> ResolveConstantAsSelfReference<TLink>(this ILinks<TLink>
            ↪ links, TLink constant, IList<TLink> restrictions, IList<TLink> substitution)
551         {
552             var equalityComparer = EqualityComparer<TLink>.Default;
553             var constants = links.Constants;
554             var restrictionsIndex = restrictions[constants.IndexPart];
555             var substitutionIndex = substitution[constants.IndexPart];
556             if (equalityComparer.Equals(substitutionIndex, default))
557             {
558                 substitutionIndex = restrictionsIndex;
559             }
560             var source = substitution[constants.SourcePart];
561             var target = substitution[constants.TargetPart];
```

```
562             source = equalityComparer.Equals(source, constant) ? substitutionIndex : source;
563             target = equalityComparer.Equals(target, constant) ? substitutionIndex : target;
564             return new Link<TLink>(substitutionIndex, source, target);
565         }
566 
567         /// <summary>
568         /// Создаёт связь (если она не существовала), либо возвращает индекс существующей связи
        ↪  с указанными Source (началом) и Target (концом).
569         /// </summary>
570         /// <param name="links">Хранилище связей.</param>
571         /// <param name="source">Индекс связи, которая является началом на создаваемой
        ↪  связи.</param>
572         /// <param name="target">Индекс связи, которая является концом для создаваемой
        ↪  связи.</param>
573         /// <returns>Индекс связи, с указанным Source (началом) и Target (концом)</returns>
574         [MethodImpl(MethodImplOptions.AggressiveInlining)]
575         public static TLink GetOrCreate<TLink>(this ILinks<TLink> links, TLink source, TLink
        ↪  target)
576         {
577             var link = links.SearchOrDefault(source, target);
578             if (EqualityComparer<TLink>.Default.Equals(link, default))
579             {
580                 link = links.CreateAndUpdate(source, target);
581             }
582             return link;
583         }
584 
585         /// <summary>
586         /// Обновляет связь с указанными началом (Source) и концом (Target)
587         /// на связь с указанными началом (NewSource) и концом (NewTarget).
588         /// </summary>
589         /// <param name="links">Хранилище связей.</param>
590         /// <param name="source">Индекс связи, которая является началом обновляемой
        ↪  связи.</param>
591         /// <param name="target">Индекс связи, которая является концом обновляемой связи.</param>
592         /// <param name="newSource">Индекс связи, которая является началом связи, на которую
        ↪  выполняется обновление.</param>
593         /// <param name="newTarget">Индекс связи, которая является концом связи, на которую
        ↪  выполняется обновление.</param>
594         /// <returns>Индекс обновлённой связи.</returns>
595         [MethodImpl(MethodImplOptions.AggressiveInlining)]
596         public static TLink UpdateOrCreateOrGet<TLink>(this ILinks<TLink> links, TLink source,
        ↪  TLink target, TLink newSource, TLink newTarget)
597         {
598             var equalityComparer = EqualityComparer<TLink>.Default;
599             var link = links.SearchOrDefault(source, target);
600             if (equalityComparer.Equals(link, default))
601             {
602                 return links.CreateAndUpdate(newSource, newTarget);
603             }
604             if (equalityComparer.Equals(newSource, source) && equalityComparer.Equals(newTarget,
                ↪  target))
605             {
606                 return link;
607             }
608             return links.Update(link, newSource, newTarget);
609         }
610 
611         /// <summary>Удаляет связь с указанными началом (Source) и концом (Target).</summary>
612         /// <param name="links">Хранилище связей.</param>
613         /// <param name="source">Индекс связи, которая является началом удаляемой связи.</param>
614         /// <param name="target">Индекс связи, которая является концом удаляемой связи.</param>
615         [MethodImpl(MethodImplOptions.AggressiveInlining)]
616         public static TLink DeleteIfExists<TLink>(this ILinks<TLink> links, TLink source, TLink
        ↪  target)
617         {
618             var link = links.SearchOrDefault(source, target);
619             if (!EqualityComparer<TLink>.Default.Equals(link, default))
620             {
621                 links.Delete(link);
622                 return link;
623             }
624             return default;
625         }
626 
627         /// <summary>Удаляет несколько связей.</summary>
628         /// <param name="links">Хранилище связей.</param>
```

```
629             /// <param name="deletedLinks">Список адресов связей к удалению.</param>
630             [MethodImpl(MethodImplOptions.AggressiveInlining)]
631             public static void DeleteMany<TLink>(this ILinks<TLink> links, IList<TLink> deletedLinks)
632             {
633                 for (int i = 0; i < deletedLinks.Count; i++)
634                 {
635                     links.Delete(deletedLinks[i]);
636                 }
637             }
638 
639             /// <remarks>Before execution of this method ensure that deleted link is detached (all
                ↪  values - source and target are reset to null) or it might enter into infinite
                ↪  recursion.</remarks>
640             [MethodImpl(MethodImplOptions.AggressiveInlining)]
641             public static void DeleteAllUsages<TLink>(this ILinks<TLink> links, TLink linkIndex)
642             {
643                 var anyConstant = links.Constants.Any;
644                 var usagesAsSourceQuery = new Link<TLink>(anyConstant, linkIndex, anyConstant);
645                 links.DeleteByQuery(usagesAsSourceQuery);
646                 var usagesAsTargetQuery = new Link<TLink>(anyConstant, linkIndex, anyConstant);
647                 links.DeleteByQuery(usagesAsTargetQuery);
648             }
649 
650             [MethodImpl(MethodImplOptions.AggressiveInlining)]
651             public static void DeleteByQuery<TLink>(this ILinks<TLink> links, Link<TLink> query)
652             {
653                 var count = CheckedConverter<TLink, long>.Default.Convert(links.Count(query));
654                 if (count > 0)
655                 {
656                     var queryResult = new TLink[count];
657                     var queryResultFiller = new ArrayFiller<TLink, TLink>(queryResult,
                        ↪  links.Constants.Continue);
658                     links.Each(queryResultFiller.AddFirstAndReturnConstant, query);
659                     for (var i = count - 1; i >= 0; i--)
660                     {
661                         links.Delete(queryResult[i]);
662                     }
663                 }
664             }
665 
666             // TODO: Move to Platform.Data
667             [MethodImpl(MethodImplOptions.AggressiveInlining)]
668             public static bool AreValuesReset<TLink>(this ILinks<TLink> links, TLink linkIndex)
669             {
670                 var nullConstant = links.Constants.Null;
671                 var equalityComparer = EqualityComparer<TLink>.Default;
672                 var link = links.GetLink(linkIndex);
673                 for (int i = 1; i < link.Count; i++)
674                 {
675                     if (!equalityComparer.Equals(link[i], nullConstant))
676                     {
677                         return false;
678                     }
679                 }
680                 return true;
681             }
682 
683             // TODO: Create a universal version of this method in Platform.Data (with using of for
                ↪  loop)
684             [MethodImpl(MethodImplOptions.AggressiveInlining)]
685             public static void ResetValues<TLink>(this ILinks<TLink> links, TLink linkIndex)
686             {
687                 var nullConstant = links.Constants.Null;
688                 var updateRequest = new Link<TLink>(linkIndex, nullConstant, nullConstant);
689                 links.Update(updateRequest);
690             }
691 
692             // TODO: Create a universal version of this method in Platform.Data (with using of for
                ↪  loop)
693             [MethodImpl(MethodImplOptions.AggressiveInlining)]
694             public static void EnforceResetValues<TLink>(this ILinks<TLink> links, TLink linkIndex)
695             {
696                 if (!links.AreValuesReset(linkIndex))
697                 {
698                     links.ResetValues(linkIndex);
699                 }
700             }
701 
```

```
702         /// <summary>
703         /// Merging two usages graphs, all children of old link moved to be children of new link
            ↪  or deleted.
704         /// </summary>
705         [MethodImpl(MethodImplOptions.AggressiveInlining)]
706         public static TLink MergeUsages<TLink>(this ILinks<TLink> links, TLink oldLinkIndex,
            ↪  TLink newLinkIndex)
707         {
708             var addressToInt64Converter = CheckedConverter<TLink, long>.Default;
709             var equalityComparer = EqualityComparer<TLink>.Default;
710             if (!equalityComparer.Equals(oldLinkIndex, newLinkIndex))
711             {
712                 var constants = links.Constants;
713                 var usagesAsSourceQuery = new Link<TLink>(constants.Any, oldLinkIndex,
                    ↪  constants.Any);
714                 var usagesAsSourceCount =
                    ↪  addressToInt64Converter.Convert(links.Count(usagesAsSourceQuery));
715                 var usagesAsTargetQuery = new Link<TLink>(constants.Any, constants.Any,
                    ↪  oldLinkIndex);
716                 var usagesAsTargetCount =
                    ↪  addressToInt64Converter.Convert(links.Count(usagesAsTargetQuery));
717                 var isStandalonePoint = Point<TLink>.IsFullPoint(links.GetLink(oldLinkIndex)) &&
                    ↪  usagesAsSourceCount == 1 && usagesAsTargetCount == 1;
718                 if (!isStandalonePoint)
719                 {
720                     var totalUsages = usagesAsSourceCount + usagesAsTargetCount;
721                     if (totalUsages > 0)
722                     {
723                         var usages = ArrayPool.Allocate<TLink>(totalUsages);
724                         var usagesFiller = new ArrayFiller<TLink, TLink>(usages,
                            ↪  links.Constants.Continue);
725                         var i = 0L;
726                         if (usagesAsSourceCount > 0)
727                         {
728                             links.Each(usagesFiller.AddFirstAndReturnConstant,
                                ↪  usagesAsSourceQuery);
729                             for (; i < usagesAsSourceCount; i++)
730                             {
731                                 var usage = usages[i];
732                                 if (!equalityComparer.Equals(usage, oldLinkIndex))
733                                 {
734                                     links.Update(usage, newLinkIndex, links.GetTarget(usage));
735                                 }
736                             }
737                         }
738                         if (usagesAsTargetCount > 0)
739                         {
740                             links.Each(usagesFiller.AddFirstAndReturnConstant,
                                ↪  usagesAsTargetQuery);
741                             for (; i < usages.Length; i++)
742                             {
743                                 var usage = usages[i];
744                                 if (!equalityComparer.Equals(usage, oldLinkIndex))
745                                 {
746                                     links.Update(usage, links.GetSource(usage), newLinkIndex);
747                                 }
748                             }
749                         }
750                         ArrayPool.Free(usages);
751                     }
752                 }
753             }
754             return newLinkIndex;
755         }
756
757         /// <summary>
758         /// Replace one link with another (replaced link is deleted, children are updated or
            ↪  deleted).
759         /// </summary>
760         [MethodImpl(MethodImplOptions.AggressiveInlining)]
761         public static TLink MergeAndDelete<TLink>(this ILinks<TLink> links, TLink oldLinkIndex,
            ↪  TLink newLinkIndex)
762         {
763             var equalityComparer = EqualityComparer<TLink>.Default;
764             if (!equalityComparer.Equals(oldLinkIndex, newLinkIndex))
765             {
766                 links.MergeUsages(oldLinkIndex, newLinkIndex);
```

```
                links.Delete(oldLinkIndex);
            }
            return newLinkIndex;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static ILinks<TLink>
        ↪  DecorateWithAutomaticUniquenessAndUsagesResolution<TLink>(this ILinks<TLink> links)
        {
            links = new LinksCascadeUsagesResolver<TLink>(links);
            links = new NonNullContentsLinkDeletionResolver<TLink>(links);
            links = new LinksCascadeUniquenessAndUsagesResolver<TLink>(links);
            return links;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static string Format<TLink>(this ILinks<TLink> links, IList<TLink> link)
        {
            var constants = links.Constants;
            return $"({link[constants.IndexPart]}: {link[constants.SourcePart]}
            ↪  {link[constants.TargetPart]})";
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static string Format<TLink>(this ILinks<TLink> links, TLink link) =>
        ↪  links.Format(links.GetLink(link));
    }
}
```

1.20 ./csharp/Platform.Data.Doublets/ISynchronizedLinks.cs

```
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets
{
    public interface ISynchronizedLinks<TLink> : ISynchronizedLinks<TLink, ILinks<TLink>,
    ↪  LinksConstants<TLink>>, ILinks<TLink>
    {
    }
}
```

1.21 ./csharp/Platform.Data.Doublets/Incrementers/FrequencyIncrementer.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Incrementers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Incrementers
{
    public class FrequencyIncrementer<TLink> : LinksOperatorBase<TLink>, IIncrementer<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly TLink _frequencyMarker;
        private readonly TLink _unaryOne;
        private readonly IIncrementer<TLink> _unaryNumberIncrementer;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public FrequencyIncrementer(ILinks<TLink> links, TLink frequencyMarker, TLink unaryOne,
        ↪  IIncrementer<TLink> unaryNumberIncrementer)
            : base(links)
        {
            _frequencyMarker = frequencyMarker;
            _unaryOne = unaryOne;
            _unaryNumberIncrementer = unaryNumberIncrementer;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Increment(TLink frequency)
        {
            var links = _links;
            if (_equalityComparer.Equals(frequency, default))
            {
                return links.GetOrCreate(_unaryOne, _frequencyMarker);
            }
            var incrementedSource =
            ↪  _unaryNumberIncrementer.Increment(links.GetSource(frequency));
            return links.GetOrCreate(incrementedSource, _frequencyMarker);
```

```
        }
    }
}
```

1.22 ./csharp/Platform.Data.Doublets/Incrementers/UnaryNumberIncrementer.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Incrementers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Incrementers
{
    public class UnaryNumberIncrementer<TLink> : LinksOperatorBase<TLink>, IIncrementer<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly TLink _unaryOne;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnaryNumberIncrementer(ILinks<TLink> links, TLink unaryOne) : base(links) =>
        ↪  _unaryOne = unaryOne;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Increment(TLink unaryNumber)
        {
            var links = _links;
            if (_equalityComparer.Equals(unaryNumber, _unaryOne))
            {
                return links.GetOrCreate(_unaryOne, _unaryOne);
            }
            var source = links.GetSource(unaryNumber);
            var target = links.GetTarget(unaryNumber);
            if (_equalityComparer.Equals(source, target))
            {
                return links.GetOrCreate(unaryNumber, _unaryOne);
            }
            else
            {
                return links.GetOrCreate(source, Increment(target));
            }
        }
    }
}
```

1.23 ./csharp/Platform.Data.Doublets/Link.cs

```
using Platform.Collections.Lists;
using Platform.Exceptions;
using Platform.Ranges;
using Platform.Singletons;
using System;
using System.Collections;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets
{
    /// <summary>
    /// Структура описывающая уникальную связь.
    /// </summary>
    public struct Link<TLink> : IEquatable<Link<TLink>>, IReadOnlyList<TLink>, IList<TLink>
    {
        public static readonly Link<TLink> Null = new Link<TLink>();

        private static readonly LinksConstants<TLink> _constants =
        ↪  Default<LinksConstants<TLink>>.Instance;
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private const int Length = 3;

        public readonly TLink Index;
        public readonly TLink Source;
        public readonly TLink Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public Link(params TLink[] values) => SetValues(values, out Index, out Source, out
        ↪  Target);
```

```
32
33          [MethodImpl(MethodImplOptions.AggressiveInlining)]
34          public Link(IList<TLink> values) => SetValues(values, out Index, out Source, out Target);
35
36          [MethodImpl(MethodImplOptions.AggressiveInlining)]
37          public Link(object other)
38          {
39              if (other is Link<TLink> otherLink)
40              {
41                  SetValues(ref otherLink, out Index, out Source, out Target);
42              }
43              else if(other is IList<TLink> otherList)
44              {
45                  SetValues(otherList, out Index, out Source, out Target);
46              }
47              else
48              {
49                  throw new NotSupportedException();
50              }
51          }
52
53          [MethodImpl(MethodImplOptions.AggressiveInlining)]
54          public Link(ref Link<TLink> other) => SetValues(ref other, out Index, out Source, out
            ↪  Target);
55
56          [MethodImpl(MethodImplOptions.AggressiveInlining)]
57          public Link(TLink index, TLink source, TLink target)
58          {
59              Index = index;
60              Source = source;
61              Target = target;
62          }
63
64          [MethodImpl(MethodImplOptions.AggressiveInlining)]
65          private static void SetValues(ref Link<TLink> other, out TLink index, out TLink source,
            ↪  out TLink target)
66          {
67              index = other.Index;
68              source = other.Source;
69              target = other.Target;
70          }
71
72          [MethodImpl(MethodImplOptions.AggressiveInlining)]
73          private static void SetValues(IList<TLink> values, out TLink index, out TLink source,
            ↪  out TLink target)
74          {
75              switch (values.Count)
76              {
77                  case 3:
78                      index = values[0];
79                      source = values[1];
80                      target = values[2];
81                      break;
82                  case 2:
83                      index = values[0];
84                      source = values[1];
85                      target = default;
86                      break;
87                  case 1:
88                      index = values[0];
89                      source = default;
90                      target = default;
91                      break;
92                  default:
93                      index = default;
94                      source = default;
95                      target = default;
96                      break;
97              }
98          }
99
100         [MethodImpl(MethodImplOptions.AggressiveInlining)]
101         public override int GetHashCode() => (Index, Source, Target).GetHashCode();
102
103         [MethodImpl(MethodImplOptions.AggressiveInlining)]
104         public bool IsNull() => _equalityComparer.Equals(Index, _constants.Null)
105                                 && _equalityComparer.Equals(Source, _constants.Null)
106                                 && _equalityComparer.Equals(Target, _constants.Null);
107
108         [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
109         public override bool Equals(object other) => other is Link<TLink> &&
            ↪  Equals((Link<TLink>)other);
110
111         [MethodImpl(MethodImplOptions.AggressiveInlining)]
112         public bool Equals(Link<TLink> other) => _equalityComparer.Equals(Index, other.Index)
113                                                 && _equalityComparer.Equals(Source, other.Source)
114                                                 && _equalityComparer.Equals(Target, other.Target);
115
116         [MethodImpl(MethodImplOptions.AggressiveInlining)]
117         public static string ToString(TLink index, TLink source, TLink target) => $"({index}:
            ↪  {source}->{target})";
118
119         [MethodImpl(MethodImplOptions.AggressiveInlining)]
120         public static string ToString(TLink source, TLink target) => $"({source}->{target})";
121
122         [MethodImpl(MethodImplOptions.AggressiveInlining)]
123         public static implicit operator TLink[](Link<TLink> link) => link.ToArray();
124
125         [MethodImpl(MethodImplOptions.AggressiveInlining)]
126         public static implicit operator Link<TLink>(TLink[] linkArray) => new
            ↪  Link<TLink>(linkArray);
127
128         [MethodImpl(MethodImplOptions.AggressiveInlining)]
129         public override string ToString() => _equalityComparer.Equals(Index, _constants.Null) ?
            ↪  ToString(Source, Target) : ToString(Index, Source, Target);
130
131         #region IList
132
133         public int Count
134         {
135             [MethodImpl(MethodImplOptions.AggressiveInlining)]
136             get => Length;
137         }
138
139         public bool IsReadOnly
140         {
141             [MethodImpl(MethodImplOptions.AggressiveInlining)]
142             get => true;
143         }
144
145         public TLink this[int index]
146         {
147             [MethodImpl(MethodImplOptions.AggressiveInlining)]
148             get
149             {
150                 Ensure.OnDebug.ArgumentInRange(index, new Range<int>(0, Length - 1),
                    ↪  nameof(index));
151                 if (index == _constants.IndexPart)
152                 {
153                     return Index;
154                 }
155                 if (index == _constants.SourcePart)
156                 {
157                     return Source;
158                 }
159                 if (index == _constants.TargetPart)
160                 {
161                     return Target;
162                 }
163                 throw new NotSupportedException(); // Impossible path due to
                    ↪  Ensure.ArgumentInRange
164             }
165             [MethodImpl(MethodImplOptions.AggressiveInlining)]
166             set => throw new NotSupportedException();
167         }
168
169         [MethodImpl(MethodImplOptions.AggressiveInlining)]
170         IEnumerator IEnumerable.GetEnumerator() => GetEnumerator();
171
172         [MethodImpl(MethodImplOptions.AggressiveInlining)]
173         public IEnumerator<TLink> GetEnumerator()
174         {
175             yield return Index;
176             yield return Source;
177             yield return Target;
178         }
179
180         [MethodImpl(MethodImplOptions.AggressiveInlining)]
181         public void Add(TLink item) => throw new NotSupportedException();
```

```
182
183         [MethodImpl(MethodImplOptions.AggressiveInlining)]
184         public void Clear() => throw new NotSupportedException();
185
186         [MethodImpl(MethodImplOptions.AggressiveInlining)]
187         public bool Contains(TLink item) => IndexOf(item) >= 0;
188
189         [MethodImpl(MethodImplOptions.AggressiveInlining)]
190         public void CopyTo(TLink[] array, int arrayIndex)
191         {
192             Ensure.OnDebug.ArgumentNotNull(array, nameof(array));
193             Ensure.OnDebug.ArgumentInRange(arrayIndex, new Range<int>(0, array.Length - 1),
                ↪  nameof(arrayIndex));
194             if (arrayIndex + Length > array.Length)
195             {
196                 throw new InvalidOperationException();
197             }
198             array[arrayIndex++] = Index;
199             array[arrayIndex++] = Source;
200             array[arrayIndex] = Target;
201         }
202
203         [MethodImpl(MethodImplOptions.AggressiveInlining)]
204         public bool Remove(TLink item) => Throw.A.NotSupportedExceptionAndReturn<bool>();
205
206         [MethodImpl(MethodImplOptions.AggressiveInlining)]
207         public int IndexOf(TLink item)
208         {
209             if (_equalityComparer.Equals(Index, item))
210             {
211                 return _constants.IndexPart;
212             }
213             if (_equalityComparer.Equals(Source, item))
214             {
215                 return _constants.SourcePart;
216             }
217             if (_equalityComparer.Equals(Target, item))
218             {
219                 return _constants.TargetPart;
220             }
221             return -1;
222         }
223
224         [MethodImpl(MethodImplOptions.AggressiveInlining)]
225         public void Insert(int index, TLink item) => throw new NotSupportedException();
226
227         [MethodImpl(MethodImplOptions.AggressiveInlining)]
228         public void RemoveAt(int index) => throw new NotSupportedException();
229
230         [MethodImpl(MethodImplOptions.AggressiveInlining)]
231         public static bool operator ==(Link<TLink> left, Link<TLink> right) =>
            ↪  left.Equals(right);
232
233         [MethodImpl(MethodImplOptions.AggressiveInlining)]
234         public static bool operator !=(Link<TLink> left, Link<TLink> right) => !(left == right);
235
236         #endregion
237     }
238 }
```

1.24 ./csharp/Platform.Data.Doublets/LinkExtensions.cs

```
1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets
6  {
7      public static class LinkExtensions
8      {
9          [MethodImpl(MethodImplOptions.AggressiveInlining)]
10         public static bool IsFullPoint<TLink>(this Link<TLink> link) =>
            ↪  Point<TLink>.IsFullPoint(link);
11
12         [MethodImpl(MethodImplOptions.AggressiveInlining)]
13         public static bool IsPartialPoint<TLink>(this Link<TLink> link) =>
            ↪  Point<TLink>.IsPartialPoint(link);
14     }
15 }
```

1.25 ./csharp/Platform.Data.Doublets/LinksOperatorBase.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets
{
    public abstract class LinksOperatorBase<TLink>
    {
        protected readonly ILinks<TLink> _links;

        public ILinks<TLink> Links
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get => _links;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected LinksOperatorBase(ILinks<TLink> links) => _links = links;
    }
}
```

1.26 ./csharp/Platform.Data.Doublets/Memory/ILinksListMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory
{
    public interface ILinksListMethods<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        void Detach(TLink freeLink);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        void AttachAsFirst(TLink link);
    }
}
```

1.27 ./csharp/Platform.Data.Doublets/Memory/ILinksTreeMethods.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory
{
    public interface ILinksTreeMethods<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        TLink CountUsages(TLink root);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        TLink Search(TLink source, TLink target);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        TLink EachUsage(TLink root, Func<IList<TLink>, TLink> handler);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        void Detach(ref TLink root, TLink linkIndex);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        void Attach(ref TLink root, TLink linkIndex);
    }
}
```

1.28 ./csharp/Platform.Data.Doublets/Memory/IndexTreeType.cs

```
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory
{
    public enum IndexTreeType
    {
        Default = 0,
        SizeBalancedTree = 1,
        RecursionlessSizeBalancedTree = 2,
        SizedAndThreadedAVLBalancedTree = 3
    }
}
```

1.29 ./csharp/Platform.Data.Doublets/Memory/LinksHeader.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Unsafe;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory
{
    public struct LinksHeader<TLink> : IEquatable<LinksHeader<TLink>>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        public static readonly long SizeInBytes = Structure<LinksHeader<TLink>>.Size;

        public TLink AllocatedLinks;
        public TLink ReservedLinks;
        public TLink FreeLinks;
        public TLink FirstFreeLink;
        public TLink RootAsSource;
        public TLink RootAsTarget;
        public TLink LastFreeLink;
        public TLink Reserved8;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override bool Equals(object obj) => obj is LinksHeader<TLink> linksHeader ?
        ↪  Equals(linksHeader) : false;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Equals(LinksHeader<TLink> other)
            => _equalityComparer.Equals(AllocatedLinks, other.AllocatedLinks)
            && _equalityComparer.Equals(ReservedLinks, other.ReservedLinks)
            && _equalityComparer.Equals(FreeLinks, other.FreeLinks)
            && _equalityComparer.Equals(FirstFreeLink, other.FirstFreeLink)
            && _equalityComparer.Equals(RootAsSource, other.RootAsSource)
            && _equalityComparer.Equals(RootAsTarget, other.RootAsTarget)
            && _equalityComparer.Equals(LastFreeLink, other.LastFreeLink)
            && _equalityComparer.Equals(Reserved8, other.Reserved8);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override int GetHashCode() => (AllocatedLinks, ReservedLinks, FreeLinks,
        ↪  FirstFreeLink, RootAsSource, RootAsTarget, LastFreeLink, Reserved8).GetHashCode();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool operator ==(LinksHeader<TLink> left, LinksHeader<TLink> right) =>
        ↪  left.Equals(right);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool operator !=(LinksHeader<TLink> left, LinksHeader<TLink> right) =>
        ↪  !(left == right);
    }
}
```

1.30 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/ExternalLinksSizeBalancedTreeMethodsBase.cs

```
using System;
using System.Text;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Methods.Trees;
using Platform.Converters;
using static System.Runtime.CompilerServices.Unsafe;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Generic
{
    public unsafe abstract class ExternalLinksSizeBalancedTreeMethodsBase<TLink> :
    ↪  SizeBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
    {
        private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
        ↪  UncheckedConverter<TLink, long>.Default;

        protected readonly TLink Break;
        protected readonly TLink Continue;
        protected readonly byte* LinksDataParts;
        protected readonly byte* LinksIndexParts;
        protected readonly byte* Header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
        protected ExternalLinksSizeBalancedTreeMethodsBase(LinksConstants<TLink> constants,
        ↪  byte* linksDataParts, byte* linksIndexParts, byte* header)
        {
            LinksDataParts = linksDataParts;
            LinksIndexParts = linksIndexParts;
            Header = header;
            Break = constants.Break;
            Continue = constants.Continue;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract TLink GetTreeRoot();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract TLink GetBasePartValue(TLink link);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract bool FirstIsToTheRightOfSecond(TLink source, TLink target, TLink
        ↪  rootSource, TLink rootTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract bool FirstIsToTheLeftOfSecond(TLink source, TLink target, TLink
        ↪  rootSource, TLink rootTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
        ↪  AsRef<LinksHeader<TLink>>(Header);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) => ref
        ↪  AsRef<RawLinkDataPart<TLink>>(LinksDataParts + (RawLinkDataPart<TLink>.SizeInBytes *
        ↪  _addressToInt64Converter.Convert(link)));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink link) =>
        ↪  ref AsRef<RawLinkIndexPart<TLink>>(LinksIndexParts +
        ↪  (RawLinkIndexPart<TLink>.SizeInBytes * _addressToInt64Converter.Convert(link)));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
        {
            ref var link = ref GetLinkDataPartReference(linkIndex);
            return new Link<TLink>(linkIndex, link.Source, link.Target);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
        {
            ref var firstLink = ref GetLinkDataPartReference(first);
            ref var secondLink = ref GetLinkDataPartReference(second);
            return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
            ↪  secondLink.Source, secondLink.Target);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
        {
            ref var firstLink = ref GetLinkDataPartReference(first);
            ref var secondLink = ref GetLinkDataPartReference(second);
            return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
            ↪  secondLink.Source, secondLink.Target);
        }

        public TLink this[TLink index]
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get
            {
                var root = GetTreeRoot();
                if (GreaterOrEqualThan(index, GetSize(root)))
                {
                    return Zero;
                }
                while (!EqualToZero(root))
                {
                    var left = GetLeftOrDefault(root);
                    var leftSize = GetSizeOrZero(left);
                    if (LessThan(index, leftSize))
```

```
                {
                    root = left;
                    continue;
                }
                if (AreEqual(index, leftSize))
                {
                    return root;
                }
                root = GetRightOrDefault(root);
                index = Subtract(index, Increment(leftSize));
            }
            return Zero; // TODO: Impossible situation exception (only if tree structure broken)
        }
    }

    /// <summary>
    /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target (концом).
    /// </summary>
    /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
    /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
    /// <returns>Индекс искомой связи.</returns>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public TLink Search(TLink source, TLink target)
    {
        var root = GetTreeRoot();
        while (!EqualToZero(root))
        {
            ref var rootLink = ref GetLinkDataPartReference(root);
            var rootSource = rootLink.Source;
            var rootTarget = rootLink.Target;
            if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) // node.Key < root.Key
            {
                root = GetLeftOrDefault(root);
            }
            else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget)) // node.Key > root.Key
            {
                root = GetRightOrDefault(root);
            }
            else // node.Key == root.Key
            {
                return root;
            }
        }
        return Zero;
    }

    // TODO: Return indices range instead of references count
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public TLink CountUsages(TLink link)
    {
        var root = GetTreeRoot();
        var total = GetSize(root);
        var totalRightIgnore = Zero;
        while (!EqualToZero(root))
        {
            var @base = GetBasePartValue(root);
            if (LessOrEqualThan(@base, link))
            {
                root = GetRightOrDefault(root);
            }
            else
            {
                totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
                root = GetLeftOrDefault(root);
            }
        }
        root = GetTreeRoot();
        var totalLeftIgnore = Zero;
        while (!EqualToZero(root))
        {
            var @base = GetBasePartValue(root);
            if (GreaterOrEqualThan(@base, link))
            {
                root = GetLeftOrDefault(root);
```

```
                }
                else
                {
                    totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
                    root = GetRightOrDefault(root);
                }
            }
            return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink EachUsage(TLink @base, Func<IList<TLink>, TLink> handler) =>
        ↪  EachUsageCore(@base, GetTreeRoot(), handler);

        // TODO: 1. Move target, handler to separate object. 2. Use stack or walker 3. Use
        ↪  low-level MSIL stack.
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private TLink EachUsageCore(TLink @base, TLink link, Func<IList<TLink>, TLink> handler)
        {
            var @continue = Continue;
            if (EqualToZero(link))
            {
                return @continue;
            }
            var linkBasePart = GetBasePartValue(link);
            var @break = Break;
            if (GreaterThan(linkBasePart, @base))
            {
                if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
                {
                    return @break;
                }
            }
            else if (LessThan(linkBasePart, @base))
            {
                if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
                {
                    return @break;
                }
            }
            else //if (linkBasePart == @base)
            {
                if (AreEqual(handler(GetLinkValues(link)), @break))
                {
                    return @break;
                }
                if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
                {
                    return @break;
                }
                if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
                {
                    return @break;
                }
            }
            return @continue;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void PrintNodeValue(TLink node, StringBuilder sb)
        {
            ref var link = ref GetLinkDataPartReference(node);
            sb.Append(' ');
            sb.Append(link.Source);
            sb.Append('-');
            sb.Append('>');
            sb.Append(link.Target);
        }
    }
}
```

1.31 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/ExternalLinksSourcesSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Generic
{
```

```
    public unsafe class ExternalLinksSourcesSizeBalancedTreeMethods<TLink> : ExternalLinksSizeBalancedTreeMethodsBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ExternalLinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* linksDataParts, byte* linksIndexParts, byte* header) : base(constants, linksDataParts, linksIndexParts, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref GetLinkIndexPartReference(node).LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref GetLinkIndexPartReference(node).RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) => GetLinkIndexPartReference(node).LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) => GetLinkIndexPartReference(node).RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) => GetLinkIndexPartReference(node).LeftAsSource = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) => GetLinkIndexPartReference(node).RightAsSource = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) => GetLinkIndexPartReference(node).SizeAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) => GetLinkIndexPartReference(node).SizeAsSource = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot() => GetHeaderReference().RootAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink link) => GetLinkDataPartReference(link).Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget, TLink secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) || (AreEqual(firstSource, secondSource) && LessThan(firstTarget, secondTarget));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget, TLink secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) || (AreEqual(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref GetLinkIndexPartReference(node);
            link.LeftAsSource = Zero;
            link.RightAsSource = Zero;
            link.SizeAsSource = Zero;
        }
    }
}
```

1.32 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/ExternalLinksTargetsSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Generic
{
    public unsafe class ExternalLinksTargetsSizeBalancedTreeMethods<TLink> : ExternalLinksSizeBalancedTreeMethodsBase<TLink>
    {
```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ExternalLinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink> constants,
        ↪  byte* linksDataParts, byte* linksIndexParts, byte* header) : base(constants,
        ↪  linksDataParts, linksIndexParts, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref
        ↪  GetLinkIndexPartReference(node).LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref
        ↪  GetLinkIndexPartReference(node).RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) =>
        ↪  GetLinkIndexPartReference(node).LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) =>
        ↪  GetLinkIndexPartReference(node).RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        ↪  GetLinkIndexPartReference(node).LeftAsTarget = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        ↪  GetLinkIndexPartReference(node).RightAsTarget = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) =>
        ↪  GetLinkIndexPartReference(node).SizeAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪  GetLinkIndexPartReference(node).SizeAsTarget = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot() => GetHeaderReference().RootAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink link) =>
        ↪  GetLinkDataPartReference(link).Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
        ↪  (AreEqual(firstTarget, secondTarget) && LessThan(firstSource, secondSource));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
        ↪  (AreEqual(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref GetLinkIndexPartReference(node);
            link.LeftAsTarget = Zero;
            link.RightAsTarget = Zero;
            link.SizeAsTarget = Zero;
        }
    }
}
```

1.33 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/InternalLinksSizeBalancedTreeMethodsBase.cs

```
using System;
using System.Text;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Methods.Trees;
using Platform.Converters;
using static System.Runtime.CompilerServices.Unsafe;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Generic
{
```

```
13      public unsafe abstract class InternalLinksSizeBalancedTreeMethodsBase<TLink> :
        ↪ SizeBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
14      {
15          private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
            ↪ UncheckedConverter<TLink, long>.Default;
16
17          protected readonly TLink Break;
18          protected readonly TLink Continue;
19          protected readonly byte* LinksDataParts;
20          protected readonly byte* LinksIndexParts;
21          protected readonly byte* Header;
22
23          [MethodImpl(MethodImplOptions.AggressiveInlining)]
24          protected InternalLinksSizeBalancedTreeMethodsBase(LinksConstants<TLink> constants,
            ↪ byte* linksDataParts, byte* linksIndexParts, byte* header)
25          {
26              LinksDataParts = linksDataParts;
27              LinksIndexParts = linksIndexParts;
28              Header = header;
29              Break = constants.Break;
30              Continue = constants.Continue;
31          }
32
33          [MethodImpl(MethodImplOptions.AggressiveInlining)]
34          protected abstract TLink GetTreeRoot(TLink link);
35
36          [MethodImpl(MethodImplOptions.AggressiveInlining)]
37          protected abstract TLink GetBasePartValue(TLink link);
38
39          [MethodImpl(MethodImplOptions.AggressiveInlining)]
40          protected abstract TLink GetKeyPartValue(TLink link);
41
42          [MethodImpl(MethodImplOptions.AggressiveInlining)]
43          protected virtual ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) => ref
            ↪ AsRef<RawLinkDataPart<TLink>>(LinksDataParts + (RawLinkDataPart<TLink>.SizeInBytes *
            ↪ _addressToInt64Converter.Convert(link)));
44
45          [MethodImpl(MethodImplOptions.AggressiveInlining)]
46          protected virtual ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink link) =>
            ↪ ref AsRef<RawLinkIndexPart<TLink>>(LinksIndexParts +
            ↪ (RawLinkIndexPart<TLink>.SizeInBytes * _addressToInt64Converter.Convert(link)));
47
48          [MethodImpl(MethodImplOptions.AggressiveInlining)]
49          protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second) =>
            ↪ LessThan(GetKeyPartValue(first), GetKeyPartValue(second));
50
51          [MethodImpl(MethodImplOptions.AggressiveInlining)]
52          protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second) =>
            ↪ GreaterThan(GetKeyPartValue(first), GetKeyPartValue(second));
53
54          [MethodImpl(MethodImplOptions.AggressiveInlining)]
55          protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
56          {
57              ref var link = ref GetLinkDataPartReference(linkIndex);
58              return new Link<TLink>(linkIndex, link.Source, link.Target);
59          }
60
61          public TLink this[TLink link, TLink index]
62          {
63              [MethodImpl(MethodImplOptions.AggressiveInlining)]
64              get
65              {
66                  var root = GetTreeRoot(link);
67                  if (GreaterOrEqualThan(index, GetSize(root)))
68                  {
69                      return Zero;
70                  }
71                  while (!EqualToZero(root))
72                  {
73                      var left = GetLeftOrDefault(root);
74                      var leftSize = GetSizeOrZero(left);
75                      if (LessThan(index, leftSize))
76                      {
77                          root = left;
78                          continue;
79                      }
80                      if (AreEqual(index, leftSize))
81                      {
82                          return root;
```

```
                }
                root = GetRightOrDefault(root);
                index = Subtract(index, Increment(leftSize));
            }
            return Zero; // TODO: Impossible situation exception (only if tree structure broken)
        }
    }

    /// <summary>
    /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target (концом).
    /// </summary>
    /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
    /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
    /// <returns>Индекс искомой связи.</returns>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public abstract TLink Search(TLink source, TLink target);

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    protected TLink SearchCore(TLink root, TLink key)
    {
        while (!EqualToZero(root))
        {
            var rootKey = GetKeyPartValue(root);
            if (LessThan(key, rootKey)) // node.Key < root.Key
            {
                root = GetLeftOrDefault(root);
            }
            else if (GreaterThan(key, rootKey)) // node.Key > root.Key
            {
                root = GetRightOrDefault(root);
            }
            else // node.Key == root.Key
            {
                return root;
            }
        }
        return Zero;
    }

    // TODO: Return indices range instead of references count
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public TLink CountUsages(TLink link) => GetSizeOrZero(GetTreeRoot(link));

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public TLink EachUsage(TLink @base, Func<IList<TLink>, TLink> handler) => EachUsageCore(@base, GetTreeRoot(@base), handler);

    // TODO: 1. Move target, handler to separate object. 2. Use stack or walker 3. Use low-level MSIL stack.
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private TLink EachUsageCore(TLink @base, TLink link, Func<IList<TLink>, TLink> handler)
    {
        var @continue = Continue;
        if (EqualToZero(link))
        {
            return @continue;
        }
        var @break = Break;
        if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
        {
            return @break;
        }
        if (AreEqual(handler(GetLinkValues(link)), @break))
        {
            return @break;
        }
        if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
        {
            return @break;
        }
        return @continue;
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    protected override void PrintNodeValue(TLink node, StringBuilder sb)
    {
        ref var link = ref GetLinkDataPartReference(node);
```

```
            sb.Append(' ');
            sb.Append(link.Source);
            sb.Append('-');
            sb.Append('>');
            sb.Append(link.Target);
        }
    }
}
```

1.34 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/InternalLinksSourcesSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Generic
{
    public unsafe class InternalLinksSourcesSizeBalancedTreeMethods<TLink> :
    ↪ InternalLinksSizeBalancedTreeMethodsBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public InternalLinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink> constants,
        ↪ byte* linksDataParts, byte* linksIndexParts, byte* header) : base(constants,
        ↪ linksDataParts, linksIndexParts, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref
        ↪ GetLinkIndexPartReference(node).LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref
        ↪ GetLinkIndexPartReference(node).RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) =>
        ↪ GetLinkIndexPartReference(node).LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) =>
        ↪ GetLinkIndexPartReference(node).RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        ↪ GetLinkIndexPartReference(node).LeftAsSource = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        ↪ GetLinkIndexPartReference(node).RightAsSource = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) =>
        ↪ GetLinkIndexPartReference(node).SizeAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪ GetLinkIndexPartReference(node).SizeAsSource = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot(TLink link) =>
        ↪ GetLinkIndexPartReference(link).RootAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink link) =>
        ↪ GetLinkDataPartReference(link).Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetKeyPartValue(TLink link) =>
        ↪ GetLinkDataPartReference(link).Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref GetLinkIndexPartReference(node);
            link.LeftAsSource = Zero;
            link.RightAsSource = Zero;
            link.SizeAsSource = Zero;
        }

        public override TLink Search(TLink source, TLink target) =>
        ↪ SearchCore(GetTreeRoot(source), target);
```

```
    }
}
```

1.35 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/InternalLinksTargetsSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Generic
{
    public unsafe class InternalLinksTargetsSizeBalancedTreeMethods<TLink> : InternalLinksSizeBalancedTreeMethodsBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public InternalLinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* linksDataParts, byte* linksIndexParts, byte* header) : base(constants, linksDataParts, linksIndexParts, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref GetLinkIndexPartReference(node).LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref GetLinkIndexPartReference(node).RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) =>
        GetLinkIndexPartReference(node).LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) =>
        GetLinkIndexPartReference(node).RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        GetLinkIndexPartReference(node).LeftAsTarget = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        GetLinkIndexPartReference(node).RightAsTarget = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) =>
        GetLinkIndexPartReference(node).SizeAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        GetLinkIndexPartReference(node).SizeAsTarget = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot(TLink link) =>
        GetLinkIndexPartReference(link).RootAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink link) =>
        GetLinkDataPartReference(link).Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetKeyPartValue(TLink link) =>
        GetLinkDataPartReference(link).Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref GetLinkIndexPartReference(node);
            link.LeftAsTarget = Zero;
            link.RightAsTarget = Zero;
            link.SizeAsTarget = Zero;
        }

        public override TLink Search(TLink source, TLink target) =>
        SearchCore(GetTreeRoot(target), source);
    }
}
```

1.36 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/SplitMemoryLinks.cs

```
using System;
using System.Runtime.CompilerServices;
```

```
using Platform.Singletons;
using Platform.Memory;
using static System.Runtime.CompilerServices.Unsafe;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Generic
{
    public unsafe class SplitMemoryLinks<TLink> : SplitMemoryLinksBase<TLink>
    {
        private readonly Func<ILinksTreeMethods<TLink>> _createInternalSourceTreeMethods;
        private readonly Func<ILinksTreeMethods<TLink>> _createExternalSourceTreeMethods;
        private readonly Func<ILinksTreeMethods<TLink>> _createInternalTargetTreeMethods;
        private readonly Func<ILinksTreeMethods<TLink>> _createExternalTargetTreeMethods;
        private byte* _header;
        private byte* _linksDataParts;
        private byte* _linksIndexParts;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
        ↪  indexMemory) : this(dataMemory, indexMemory, DefaultLinksSizeStep) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
        ↪  indexMemory, long memoryReservationStep) : this(dataMemory, indexMemory,
        ↪  memoryReservationStep, Default<LinksConstants<TLink>>.Instance) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
        ↪  indexMemory, long memoryReservationStep, LinksConstants<TLink> constants) :
        ↪  base(dataMemory, indexMemory, memoryReservationStep, constants)
        {
            _createInternalSourceTreeMethods = () => new
            ↪  InternalLinksSourcesSizeBalancedTreeMethods<TLink>(Constants, _linksDataParts,
            ↪  _linksIndexParts, _header);
            _createExternalSourceTreeMethods = () => new
            ↪  ExternalLinksSourcesSizeBalancedTreeMethods<TLink>(Constants, _linksDataParts,
            ↪  _linksIndexParts, _header);
            _createInternalTargetTreeMethods = () => new
            ↪  InternalLinksTargetsSizeBalancedTreeMethods<TLink>(Constants, _linksDataParts,
            ↪  _linksIndexParts, _header);
            _createExternalTargetTreeMethods = () => new
            ↪  ExternalLinksTargetsSizeBalancedTreeMethods<TLink>(Constants, _linksDataParts,
            ↪  _linksIndexParts, _header);
            Init(dataMemory, indexMemory);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetPointers(IResizableDirectMemory dataMemory,
        ↪  IResizableDirectMemory indexMemory)
        {
            _linksDataParts = (byte*)dataMemory.Pointer;
            _linksIndexParts = (byte*)indexMemory.Pointer;
            _header = _linksIndexParts;
            InternalSourcesTreeMethods = _createInternalSourceTreeMethods();
            ExternalSourcesTreeMethods = _createExternalSourceTreeMethods();
            InternalTargetsTreeMethods = _createInternalTargetTreeMethods();
            ExternalTargetsTreeMethods = _createExternalTargetTreeMethods();
            UnusedLinksListMethods = new UnusedLinksListMethods<TLink>(_linksDataParts, _header);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ResetPointers()
        {
            base.ResetPointers();
            _linksDataParts = null;
            _linksIndexParts = null;
            _header = null;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref LinksHeader<TLink> GetHeaderReference() => ref
        ↪  AsRef<LinksHeader<TLink>>(_header);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink linkIndex)
        ↪  => ref AsRef<RawLinkDataPart<TLink>>(_linksDataParts + (LinkDataPartSizeInBytes *
        ↪  ConvertToInt64(linkIndex)));

```

```
65          [MethodImpl(MethodImplOptions.AggressiveInlining)]
66          protected override ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink
            ↪  linkIndex) => ref AsRef<RawLinkIndexPart<TLink>>(_linksIndexParts +
            ↪  (LinkIndexPartSizeInBytes * ConvertToInt64(linkIndex)));
67      }
68  }
```

1.37 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/SplitMemoryLinksBase.cs

```
1   using System;
2   using System.Collections.Generic;
3   using System.Runtime.CompilerServices;
4   using Platform.Disposables;
5   using Platform.Singletons;
6   using Platform.Converters;
7   using Platform.Numbers;
8   using Platform.Memory;
9   using Platform.Data.Exceptions;
10
11  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
12
13  namespace Platform.Data.Doublets.Memory.Split.Generic
14  {
15      public abstract class SplitMemoryLinksBase<TLink> : DisposableBase, ILinks<TLink>
16      {
17          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪  EqualityComparer<TLink>.Default;
18          private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
19          private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
            ↪  UncheckedConverter<TLink, long>.Default;
20          private static readonly UncheckedConverter<long, TLink> _int64ToAddressConverter =
            ↪  UncheckedConverter<long, TLink>.Default;
21
22          private static readonly TLink _zero = default;
23          private static readonly TLink _one = Arithmetic.Increment(_zero);
24
25          /// <summary>Возвращает размер одной связи в байтах.</summary>
26          /// <remarks>
27          /// Используется только во вне класса, не рекомедуется использовать внутри.
28          /// Так как во вне не обязательно будет доступен unsafe C#.
29          /// </remarks>
30          public static readonly long LinkDataPartSizeInBytes = RawLinkDataPart<TLink>.SizeInBytes;
31
32          public static readonly long LinkIndexPartSizeInBytes =
            ↪  RawLinkIndexPart<TLink>.SizeInBytes;
33
34          public static readonly long LinkHeaderSizeInBytes = LinksHeader<TLink>.SizeInBytes;
35
36          public static readonly long DefaultLinksSizeStep = 1 * 1024 * 1024;
37
38          protected readonly IResizableDirectMemory _dataMemory;
39          protected readonly IResizableDirectMemory _indexMemory;
40          protected readonly long _dataMemoryReservationStepInBytes;
41          protected readonly long _indexMemoryReservationStepInBytes;
42
43          protected ILinksTreeMethods<TLink> InternalSourcesTreeMethods;
44          protected ILinksTreeMethods<TLink> ExternalSourcesTreeMethods;
45          protected ILinksTreeMethods<TLink> InternalTargetsTreeMethods;
46          protected ILinksTreeMethods<TLink> ExternalTargetsTreeMethods;
47          // TODO: Возможно чтобы гарантированно проверять на то, является ли связь удалённой,
            ↪  нужно использовать не список а дерево, так как так можно быстрее проверить на
            ↪  наличие связи внутри
48          protected ILinksListMethods<TLink> UnusedLinksListMethods;
49
50          /// <summary>
51          /// Возвращает общее число связей находящихся в хранилище.
52          /// </summary>
53          protected virtual TLink Total
54          {
55              [MethodImpl(MethodImplOptions.AggressiveInlining)]
56              get
57              {
58                  ref var header = ref GetHeaderReference();
59                  return Subtract(header.AllocatedLinks, header.FreeLinks);
60              }
61          }
62
63          public virtual LinksConstants<TLink> Constants
64          {
65              [MethodImpl(MethodImplOptions.AggressiveInlining)]
66              get;
67          }
68
```

```
69          [MethodImpl(MethodImplOptions.AggressiveInlining)]
70          protected SplitMemoryLinksBase(IResizableDirectMemory dataMemory, IResizableDirectMemory
            ↪ indexMemory, long memoryReservationStep, LinksConstants<TLink> constants)
71          {
72              _dataMemory = dataMemory;
73              _indexMemory = indexMemory;
74              _dataMemoryReservationStepInBytes = memoryReservationStep * LinkDataPartSizeInBytes;
75              _indexMemoryReservationStepInBytes = memoryReservationStep *
                ↪ LinkIndexPartSizeInBytes;
76              Constants = constants;
77          }
78
79          [MethodImpl(MethodImplOptions.AggressiveInlining)]
80          protected SplitMemoryLinksBase(IResizableDirectMemory dataMemory, IResizableDirectMemory
            ↪ indexMemory, long memoryReservationStep) : this(dataMemory, indexMemory,
            ↪ memoryReservationStep, Default<LinksConstants<TLink>>.Instance) { }
81
82          [MethodImpl(MethodImplOptions.AggressiveInlining)]
83          protected virtual void Init(IResizableDirectMemory dataMemory, IResizableDirectMemory
            ↪ indexMemory)
84          {
85              if (dataMemory.ReservedCapacity < _dataMemoryReservationStepInBytes)
86              {
87                  dataMemory.ReservedCapacity = _dataMemoryReservationStepInBytes;
88              }
89              if (indexMemory.ReservedCapacity < _indexMemoryReservationStepInBytes)
90              {
91                  indexMemory.ReservedCapacity = _indexMemoryReservationStepInBytes;
92              }
93              SetPointers(dataMemory, indexMemory);
94              ref var header = ref GetHeaderReference();
95              // Ensure correctness _memory.UsedCapacity over _header->AllocatedLinks
96              // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
97              dataMemory.UsedCapacity = (ConvertToInt64(header.AllocatedLinks) *
                ↪ LinkDataPartSizeInBytes) + LinkDataPartSizeInBytes; // First link is read only
                ↪ zero link.
98              indexMemory.UsedCapacity = (ConvertToInt64(header.AllocatedLinks) *
                ↪ LinkIndexPartSizeInBytes) + LinkHeaderSizeInBytes;
99              // Ensure correctness _memory.ReservedLinks over _header->ReservedCapacity
100             // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
101             header.ReservedLinks = ConvertToAddress((dataMemory.ReservedCapacity -
                ↪ LinkDataPartSizeInBytes) / LinkDataPartSizeInBytes);
102         }
103
104         [MethodImpl(MethodImplOptions.AggressiveInlining)]
105         public virtual TLink Count(IList<TLink> restrictions)
106         {
107             // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
108             if (restrictions.Count == 0)
109             {
110                 return Total;
111             }
112             var constants = Constants;
113             var any = constants.Any;
114             var index = restrictions[constants.IndexPart];
115             if (restrictions.Count == 1)
116             {
117                 if (AreEqual(index, any))
118                 {
119                     return Total;
120                 }
121                 return Exists(index) ? GetOne() : GetZero();
122             }
123             if (restrictions.Count == 2)
124             {
125                 var value = restrictions[1];
126                 if (AreEqual(index, any))
127                 {
128                     if (AreEqual(value, any))
129                     {
130                         return Total; // Any - как отсутствие ограничения
131                     }
132                     var externalReferencesRange = constants.ExternalReferencesRange;
133                     if (externalReferencesRange.HasValue &&
                        ↪ externalReferencesRange.Value.Contains(value))
134                     {
135                         return Add(ExternalSourcesTreeMethods.CountUsages(value),
                            ↪ ExternalTargetsTreeMethods.CountUsages(value));
```

```
136                     }
137                     else
138                     {
139                         return Add(InternalSourcesTreeMethods.CountUsages(value),
                            ↪  InternalTargetsTreeMethods.CountUsages(value));
140                     }
141                 }
142                 else
143                 {
144                     if (!Exists(index))
145                     {
146                         return GetZero();
147                     }
148                     if (AreEqual(value, any))
149                     {
150                         return GetOne();
151                     }
152                     ref var storedLinkValue = ref GetLinkDataPartReference(index);
153                     if (AreEqual(storedLinkValue.Source, value) ||
                        ↪  AreEqual(storedLinkValue.Target, value))
154                     {
155                         return GetOne();
156                     }
157                     return GetZero();
158                 }
159             }
160             if (restrictions.Count == 3)
161             {
162                 var externalReferencesRange = constants.ExternalReferencesRange;
163                 var source = restrictions[constants.SourcePart];
164                 var target = restrictions[constants.TargetPart];
165                 if (AreEqual(index, any))
166                 {
167                     if (AreEqual(source, any) && AreEqual(target, any))
168                     {
169                         return Total;
170                     }
171                     else if (AreEqual(source, any))
172                     {
173                         if (externalReferencesRange.HasValue &&
                            ↪  externalReferencesRange.Value.Contains(target))
174                         {
175                             return ExternalTargetsTreeMethods.CountUsages(target);
176                         }
177                         else
178                         {
179                             return InternalTargetsTreeMethods.CountUsages(target);
180                         }
181                     }
182                     else if (AreEqual(target, any))
183                     {
184                         if (externalReferencesRange.HasValue &&
                            ↪  externalReferencesRange.Value.Contains(source))
185                         {
186                             return ExternalSourcesTreeMethods.CountUsages(source);
187                         }
188                         else
189                         {
190                             return InternalSourcesTreeMethods.CountUsages(source);
191                         }
192                     }
193                     else //if(source != Any && target != Any)
194                     {
195                         // Эквивалент Exists(source, target) => Count(Any, source, target) > 0
196                         TLink link;
197                         if (externalReferencesRange.HasValue)
198                         {
199                             if (externalReferencesRange.Value.Contains(source) &&
                                ↪  externalReferencesRange.Value.Contains(target))
200                             {
201                                 link = ExternalSourcesTreeMethods.Search(source, target);
202                             }
203                             else if (externalReferencesRange.Value.Contains(source))
204                             {
205                                 link = InternalTargetsTreeMethods.Search(source, target);
206                             }
207                             else if (externalReferencesRange.Value.Contains(target))
208                             {
```

```
                                link = InternalSourcesTreeMethods.Search(source, target);
                            }
                            else
                            {
                                if (GreaterThan(InternalSourcesTreeMethods.CountUsages(source),
                                ↪  InternalTargetsTreeMethods.CountUsages(target)))
                                {
                                    link = InternalTargetsTreeMethods.Search(source, target);
                                }
                                else
                                {
                                    link = InternalSourcesTreeMethods.Search(source, target);
                                }
                            }
                        }
                        else
                        {
                            if (GreaterThan(InternalSourcesTreeMethods.CountUsages(source),
                            ↪  InternalTargetsTreeMethods.CountUsages(target)))
                            {
                                link = InternalTargetsTreeMethods.Search(source, target);
                            }
                            else
                            {
                                link = InternalSourcesTreeMethods.Search(source, target);
                            }
                        }
                        return AreEqual(link, constants.Null) ? GetZero() : GetOne();
                    }
                }
                else
                {
                    if (!Exists(index))
                    {
                        return GetZero();
                    }
                    if (AreEqual(source, any) && AreEqual(target, any))
                    {
                        return GetOne();
                    }
                    ref var storedLinkValue = ref GetLinkDataPartReference(index);
                    if (!AreEqual(source, any) && !AreEqual(target, any))
                    {
                        if (AreEqual(storedLinkValue.Source, source) &&
                        ↪  AreEqual(storedLinkValue.Target, target))
                        {
                            return GetOne();
                        }
                        return GetZero();
                    }
                    var value = default(TLink);
                    if (AreEqual(source, any))
                    {
                        value = target;
                    }
                    if (AreEqual(target, any))
                    {
                        value = source;
                    }
                    if (AreEqual(storedLinkValue.Source, value) ||
                    ↪  AreEqual(storedLinkValue.Target, value))
                    {
                        return GetOne();
                    }
                    return GetZero();
                }
            }
            throw new NotSupportedException("Другие размеры и способы ограничений не
            ↪  поддерживаются.");
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
        {
            var constants = Constants;
            var @break = constants.Break;
            if (restrictions.Count == 0)
            {
```

```
282                     for (var link = GetOne(); LessOrEqualThan(link,
                        ↪  GetHeaderReference().AllocatedLinks); link = Increment(link))
283                     {
284                         if (Exists(link) && AreEqual(handler(GetLinkStruct(link)), @break))
285                         {
286                             return @break;
287                         }
288                     }
289                     return @break;
290                 }
291                 var @continue = constants.Continue;
292                 var any = constants.Any;
293                 var index = restrictions[constants.IndexPart];
294                 if (restrictions.Count == 1)
295                 {
296                     if (AreEqual(index, any))
297                     {
298                         return Each(handler, Array.Empty<TLink>());
299                     }
300                     if (!Exists(index))
301                     {
302                         return @continue;
303                     }
304                     return handler(GetLinkStruct(index));
305                 }
306                 if (restrictions.Count == 2)
307                 {
308                     var value = restrictions[1];
309                     if (AreEqual(index, any))
310                     {
311                         if (AreEqual(value, any))
312                         {
313                             return Each(handler, Array.Empty<TLink>());
314                         }
315                         if (AreEqual(Each(handler, new Link<TLink>(index, value, any)), @break))
316                         {
317                             return @break;
318                         }
319                         return Each(handler, new Link<TLink>(index, any, value));
320                     }
321                     else
322                     {
323                         if (!Exists(index))
324                         {
325                             return @continue;
326                         }
327                         if (AreEqual(value, any))
328                         {
329                             return handler(GetLinkStruct(index));
330                         }
331                         ref var storedLinkValue = ref GetLinkDataPartReference(index);
332                         if (AreEqual(storedLinkValue.Source, value) ||
333                             AreEqual(storedLinkValue.Target, value))
334                         {
335                             return handler(GetLinkStruct(index));
336                         }
337                         return @continue;
338                     }
339                 }
340                 if (restrictions.Count == 3)
341                 {
342                     var externalReferencesRange = constants.ExternalReferencesRange;
343                     var source = restrictions[constants.SourcePart];
344                     var target = restrictions[constants.TargetPart];
345                     if (AreEqual(index, any))
346                     {
347                         if (AreEqual(source, any) && AreEqual(target, any))
348                         {
349                             return Each(handler, Array.Empty<TLink>());
350                         }
351                         else if (AreEqual(source, any))
352                         {
353                             if (externalReferencesRange.HasValue &&
                                ↪  externalReferencesRange.Value.Contains(target))
354                             {
355                                 return ExternalTargetsTreeMethods.EachUsage(target, handler);
356                             }
357                             else
```

```
                    {
                        return InternalTargetsTreeMethods.EachUsage(target, handler);
                    }
                }
                else if (AreEqual(target, any))
                {
                    if (externalReferencesRange.HasValue &&
                    ↪  externalReferencesRange.Value.Contains(source))
                    {
                        return ExternalSourcesTreeMethods.EachUsage(source, handler);
                    }
                    else
                    {
                        return InternalSourcesTreeMethods.EachUsage(source, handler);
                    }
                }
                else //if(source != Any && target != Any)
                {
                    TLink link;
                    if (externalReferencesRange.HasValue)
                    {
                        if (externalReferencesRange.Value.Contains(source) &&
                        ↪  externalReferencesRange.Value.Contains(target))
                        {
                            link = ExternalSourcesTreeMethods.Search(source, target);
                        }
                        else if (externalReferencesRange.Value.Contains(source))
                        {
                            link = InternalTargetsTreeMethods.Search(source, target);
                        }
                        else if (externalReferencesRange.Value.Contains(target))
                        {
                            link = InternalSourcesTreeMethods.Search(source, target);
                        }
                        else
                        {
                            if (GreaterThan(InternalSourcesTreeMethods.CountUsages(source),
                            ↪  InternalTargetsTreeMethods.CountUsages(target)))
                            {
                                link = InternalTargetsTreeMethods.Search(source, target);
                            }
                            else
                            {
                                link = InternalSourcesTreeMethods.Search(source, target);
                            }
                        }
                    }
                    else
                    {
                        if (GreaterThan(InternalSourcesTreeMethods.CountUsages(source),
                        ↪  InternalTargetsTreeMethods.CountUsages(target)))
                        {
                            link = InternalTargetsTreeMethods.Search(source, target);
                        }
                        else
                        {
                            link = InternalSourcesTreeMethods.Search(source, target);
                        }
                    }
                    return AreEqual(link, constants.Null) ? @continue :
                    ↪  handler(GetLinkStruct(link));
                }
            }
            else
            {
                if (!Exists(index))
                {
                    return @continue;
                }
                if (AreEqual(source, any) && AreEqual(target, any))
                {
                    return handler(GetLinkStruct(index));
                }
                ref var storedLinkValue = ref GetLinkDataPartReference(index);
                if (!AreEqual(source, any) && !AreEqual(target, any))
                {
                    if (AreEqual(storedLinkValue.Source, source) &&
                        AreEqual(storedLinkValue.Target, target))
```

```
                    {
                        return handler(GetLinkStruct(index));
                    }
                    return @continue;
                }
                var value = default(TLink);
                if (AreEqual(source, any))
                {
                    value = target;
                }
                if (AreEqual(target, any))
                {
                    value = source;
                }
                if (AreEqual(storedLinkValue.Source, value) ||
                    AreEqual(storedLinkValue.Target, value))
                {
                    return handler(GetLinkStruct(index));
                }
                return @continue;
            }
        }
        throw new NotSupportedException("Другие размеры и способы ограничений не
        ↪  поддерживаются.");
    }

    /// <remarks>
    /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
    ↪  в другом месте (но не в менеджере памяти, а в логике Links)
    /// </remarks>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
    {
        var constants = Constants;
        var @null = constants.Null;
        var externalReferencesRange = constants.ExternalReferencesRange;
        var linkIndex = restrictions[constants.IndexPart];
        ref var link = ref GetLinkDataPartReference(linkIndex);
        var source = link.Source;
        var target = link.Target;
        ref var header = ref GetHeaderReference();
        ref var rootAsSource = ref header.RootAsSource;
        ref var rootAsTarget = ref header.RootAsTarget;
        // Будет корректно работать только в том случае, если пространство выделенной связи
        ↪  предварительно заполнено нулями
        if (!AreEqual(source, @null))
        {
            if (externalReferencesRange.HasValue &&
            ↪  externalReferencesRange.Value.Contains(source))
            {
                ExternalSourcesTreeMethods.Detach(ref rootAsSource, linkIndex);
            }
            else
            {
                InternalSourcesTreeMethods.Detach(ref
                ↪  GetLinkIndexPartReference(source).RootAsSource, linkIndex);
            }
        }
        if (!AreEqual(target, @null))
        {
            if (externalReferencesRange.HasValue &&
            ↪  externalReferencesRange.Value.Contains(target))
            {
                ExternalTargetsTreeMethods.Detach(ref rootAsTarget, linkIndex);
            }
            else
            {
                InternalTargetsTreeMethods.Detach(ref
                ↪  GetLinkIndexPartReference(target).RootAsTarget, linkIndex);
            }
        }
        source = link.Source = substitution[constants.SourcePart];
        target = link.Target = substitution[constants.TargetPart];
        if (!AreEqual(source, @null))
        {
            if (externalReferencesRange.HasValue &&
            ↪  externalReferencesRange.Value.Contains(source))
            {
```

```
501                     ExternalSourcesTreeMethods.Attach(ref rootAsSource, linkIndex);
502                 }
503                 else
504                 {
505                     InternalSourcesTreeMethods.Attach(ref
                        ↪  GetLinkIndexPartReference(source).RootAsSource, linkIndex);
506                 }
507             }
508             if (!AreEqual(target, @null))
509             {
510                 if (externalReferencesRange.HasValue &&
                    ↪  externalReferencesRange.Value.Contains(target))
511                 {
512                     ExternalTargetsTreeMethods.Attach(ref rootAsTarget, linkIndex);
513                 }
514                 else
515                 {
516                     InternalTargetsTreeMethods.Attach(ref
                        ↪  GetLinkIndexPartReference(target).RootAsTarget, linkIndex);
517                 }
518             }
519             return linkIndex;
520         }
521 
522         /// <remarks>
523         /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
            ↪  пространство
524         /// </remarks>
525         [MethodImpl(MethodImplOptions.AggressiveInlining)]
526         public virtual TLink Create(IList<TLink> restrictions)
527         {
528             ref var header = ref GetHeaderReference();
529             var freeLink = header.FirstFreeLink;
530             if (!AreEqual(freeLink, Constants.Null))
531             {
532                 UnusedLinksListMethods.Detach(freeLink);
533             }
534             else
535             {
536                 var maximumPossibleInnerReference = Constants.InternalReferencesRange.Maximum;
537                 if (GreaterThan(header.AllocatedLinks, maximumPossibleInnerReference))
538                 {
539                     throw new LinksLimitReachedException<TLink>(maximumPossibleInnerReference);
540                 }
541                 if (GreaterOrEqualThan(header.AllocatedLinks, Decrement(header.ReservedLinks)))
542                 {
543                     _dataMemory.ReservedCapacity += _dataMemoryReservationStepInBytes;
544                     _indexMemory.ReservedCapacity += _indexMemoryReservationStepInBytes;
545                     SetPointers(_dataMemory, _indexMemory);
546                     header = ref GetHeaderReference();
547                     header.ReservedLinks = ConvertToAddress(_dataMemory.ReservedCapacity /
                        ↪  LinkDataPartSizeInBytes);
548                 }
549                 header.AllocatedLinks = Increment(header.AllocatedLinks);
550                 _dataMemory.UsedCapacity += LinkDataPartSizeInBytes;
551                 _indexMemory.UsedCapacity += LinkIndexPartSizeInBytes;
552                 freeLink = header.AllocatedLinks;
553             }
554             return freeLink;
555         }
556 
557         [MethodImpl(MethodImplOptions.AggressiveInlining)]
558         public virtual void Delete(IList<TLink> restrictions)
559         {
560             ref var header = ref GetHeaderReference();
561             var link = restrictions[Constants.IndexPart];
562             if (LessThan(link, header.AllocatedLinks))
563             {
564                 UnusedLinksListMethods.AttachAsFirst(link);
565             }
566             else if (AreEqual(link, header.AllocatedLinks))
567             {
568                 header.AllocatedLinks = Decrement(header.AllocatedLinks);
569                 _dataMemory.UsedCapacity -= LinkDataPartSizeInBytes;
570                 _indexMemory.UsedCapacity -= LinkIndexPartSizeInBytes;
571                 // Убираем все связи, находящиеся в списке свободных в конце файла, до тех пор,
                    ↪  пока не дойдём до первой существующей связи
572                 // Позволяет оптимизировать количество выделенных связей (AllocatedLinks)
```

```
573                 while (GreaterThan(header.AllocatedLinks, GetZero()) &&
                    ↪  IsUnusedLink(header.AllocatedLinks))
574                 {
575                     UnusedLinksListMethods.Detach(header.AllocatedLinks);
576                     header.AllocatedLinks = Decrement(header.AllocatedLinks);
577                     _dataMemory.UsedCapacity -= LinkDataPartSizeInBytes;
578                     _indexMemory.UsedCapacity -= LinkIndexPartSizeInBytes;
579                 }
580             }
581         }
582
583         [MethodImpl(MethodImplOptions.AggressiveInlining)]
584         public IList<TLink> GetLinkStruct(TLink linkIndex)
585         {
586             ref var link = ref GetLinkDataPartReference(linkIndex);
587             return new Link<TLink>(linkIndex, link.Source, link.Target);
588         }
589
590         /// <remarks>
591         /// TODO: Возможно это должно быть событием, вызываемым из IMemory, в том случае, если
                ↪  адрес реально поменялся
592         ///
593         /// Указатель this.links может быть в том же месте,
594         /// так как 0-я связь не используется и имеет такой же размер как Header,
595         /// поэтому header размещается в том же месте, что и 0-я связь
596         /// </remarks>
597         [MethodImpl(MethodImplOptions.AggressiveInlining)]
598         protected abstract void SetPointers(IResizableDirectMemory dataMemory,
                ↪  IResizableDirectMemory indexMemory);
599
600         [MethodImpl(MethodImplOptions.AggressiveInlining)]
601         protected virtual void ResetPointers()
602         {
603             InternalSourcesTreeMethods = null;
604             ExternalSourcesTreeMethods = null;
605             InternalTargetsTreeMethods = null;
606             ExternalTargetsTreeMethods = null;
607             UnusedLinksListMethods = null;
608         }
609
610         [MethodImpl(MethodImplOptions.AggressiveInlining)]
611         protected abstract ref LinksHeader<TLink> GetHeaderReference();
612
613         [MethodImpl(MethodImplOptions.AggressiveInlining)]
614         protected abstract ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink linkIndex);
615
616         [MethodImpl(MethodImplOptions.AggressiveInlining)]
617         protected abstract ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink
                ↪  linkIndex);
618
619         [MethodImpl(MethodImplOptions.AggressiveInlining)]
620         protected virtual bool Exists(TLink link)
621             => GreaterOrEqualThan(link, Constants.InternalReferencesRange.Minimum)
622             && LessOrEqualThan(link, GetHeaderReference().AllocatedLinks)
623             && !IsUnusedLink(link);
624
625         [MethodImpl(MethodImplOptions.AggressiveInlining)]
626         protected virtual bool IsUnusedLink(TLink linkIndex)
627         {
628             if (!AreEqual(GetHeaderReference().FirstFreeLink, linkIndex)) // May be this check
                    ↪  is not needed
629             {
630                 // TODO: Reduce access to memory in different location (should be enough to use
                        ↪  just linkIndexPart)
631                 ref var linkDataPart = ref GetLinkDataPartReference(linkIndex);
632                 ref var linkIndexPart = ref GetLinkIndexPartReference(linkIndex);
633                 return AreEqual(linkIndexPart.SizeAsSource, default) &&
                        ↪  !AreEqual(linkDataPart.Source, default);
634             }
635             else
636             {
637                 return true;
638             }
639         }
640
641         [MethodImpl(MethodImplOptions.AggressiveInlining)]
642         protected virtual TLink GetOne() => _one;
643
644         [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
645         protected virtual TLink GetZero() => default;
646
647         [MethodImpl(MethodImplOptions.AggressiveInlining)]
648         protected virtual bool AreEqual(TLink first, TLink second) =>
            ↪ _equalityComparer.Equals(first, second);
649
650         [MethodImpl(MethodImplOptions.AggressiveInlining)]
651         protected virtual bool LessThan(TLink first, TLink second) => _comparer.Compare(first,
            ↪ second) < 0;
652
653         [MethodImpl(MethodImplOptions.AggressiveInlining)]
654         protected virtual bool LessOrEqualThan(TLink first, TLink second) =>
            ↪ _comparer.Compare(first, second) <= 0;
655
656         [MethodImpl(MethodImplOptions.AggressiveInlining)]
657         protected virtual bool GreaterThan(TLink first, TLink second) =>
            ↪ _comparer.Compare(first, second) > 0;
658
659         [MethodImpl(MethodImplOptions.AggressiveInlining)]
660         protected virtual bool GreaterOrEqualThan(TLink first, TLink second) =>
            ↪ _comparer.Compare(first, second) >= 0;
661
662         [MethodImpl(MethodImplOptions.AggressiveInlining)]
663         protected virtual long ConvertToInt64(TLink value) =>
            ↪ _addressToInt64Converter.Convert(value);
664
665         [MethodImpl(MethodImplOptions.AggressiveInlining)]
666         protected virtual TLink ConvertToAddress(long value) =>
            ↪ _int64ToAddressConverter.Convert(value);
667
668         [MethodImpl(MethodImplOptions.AggressiveInlining)]
669         protected virtual TLink Add(TLink first, TLink second) => Arithmetic<TLink>.Add(first,
            ↪ second);
670
671         [MethodImpl(MethodImplOptions.AggressiveInlining)]
672         protected virtual TLink Subtract(TLink first, TLink second) =>
            ↪ Arithmetic<TLink>.Subtract(first, second);
673
674         [MethodImpl(MethodImplOptions.AggressiveInlining)]
675         protected virtual TLink Increment(TLink link) => Arithmetic<TLink>.Increment(link);
676
677         [MethodImpl(MethodImplOptions.AggressiveInlining)]
678         protected virtual TLink Decrement(TLink link) => Arithmetic<TLink>.Decrement(link);
679
680         #region Disposable
681
682         protected override bool AllowMultipleDisposeCalls
683         {
684             [MethodImpl(MethodImplOptions.AggressiveInlining)]
685             get => true;
686         }
687
688         [MethodImpl(MethodImplOptions.AggressiveInlining)]
689         protected override void Dispose(bool manual, bool wasDisposed)
690         {
691             if (!wasDisposed)
692             {
693                 ResetPointers();
694                 _dataMemory.DisposeIfPossible();
695                 _indexMemory.DisposeIfPossible();
696             }
697         }
698
699         #endregion
700     }
701 }
```

1.38 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/UnusedLinksListMethods.cs

```
1  using System.Runtime.CompilerServices;
2  using Platform.Collections.Methods.Lists;
3  using Platform.Converters;
4  using static System.Runtime.CompilerServices.Unsafe;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Memory.Split.Generic
9  {
10     public unsafe class UnusedLinksListMethods<TLink> : CircularDoublyLinkedListMethods<TLink>,
       ↪ ILinksListMethods<TLink>
```

```
    {
        private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
        ↪  UncheckedConverter<TLink, long>.Default;

        private readonly byte* _links;
        private readonly byte* _header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnusedLinksListMethods(byte* links, byte* header)
        {
            _links = links;
            _header = header;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
        ↪  AsRef<LinksHeader<TLink>>(_header);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) => ref
        ↪  AsRef<RawLinkDataPart<TLink>>(_links + (RawLinkDataPart<TLink>.SizeInBytes *
        ↪  _addressToInt64Converter.Convert(link)));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetFirst() => GetHeaderReference().FirstFreeLink;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLast() => GetHeaderReference().LastFreeLink;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetPrevious(TLink element) =>
        ↪  GetLinkDataPartReference(element).Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetNext(TLink element) =>
        ↪  GetLinkDataPartReference(element).Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize() => GetHeaderReference().FreeLinks;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetFirst(TLink element) => GetHeaderReference().FirstFreeLink =
        ↪  element;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLast(TLink element) => GetHeaderReference().LastFreeLink =
        ↪  element;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetPrevious(TLink element, TLink previous) =>
        ↪  GetLinkDataPartReference(element).Source = previous;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetNext(TLink element, TLink next) =>
        ↪  GetLinkDataPartReference(element).Target = next;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink size) => GetHeaderReference().FreeLinks = size;
    }
}
```

1.39 ./csharp/Platform.Data.Doublets/Memory/Split/RawLinkDataPart.cs

```
using Platform.Unsafe;
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split
{
    public struct RawLinkDataPart<TLink> : IEquatable<RawLinkDataPart<TLink>>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        public static readonly long SizeInBytes = Structure<RawLinkDataPart<TLink>>.Size;

        public TLink Source;
        public TLink Target;
```

```

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override bool Equals(object obj) => obj is RawLinkDataPart<TLink> link ?
        ↪  Equals(link) : false;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Equals(RawLinkDataPart<TLink> other)
            => _equalityComparer.Equals(Source, other.Source)
            && _equalityComparer.Equals(Target, other.Target);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override int GetHashCode() => (Source, Target).GetHashCode();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool operator ==(RawLinkDataPart<TLink> left, RawLinkDataPart<TLink>
        ↪  right) => left.Equals(right);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool operator !=(RawLinkDataPart<TLink> left, RawLinkDataPart<TLink>
        ↪  right) => !(left == right);
    }
}
```

1.40 ./csharp/Platform.Data.Doublets/Memory/Split/RawLinkIndexPart.cs

```
using Platform.Unsafe;
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split
{
    public struct RawLinkIndexPart<TLink> : IEquatable<RawLinkIndexPart<TLink>>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        public static readonly long SizeInBytes = Structure<RawLinkIndexPart<TLink>>.Size;

        public TLink RootAsSource;
        public TLink LeftAsSource;
        public TLink RightAsSource;
        public TLink SizeAsSource;
        public TLink RootAsTarget;
        public TLink LeftAsTarget;
        public TLink RightAsTarget;
        public TLink SizeAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override bool Equals(object obj) => obj is RawLinkIndexPart<TLink> link ?
        ↪  Equals(link) : false;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Equals(RawLinkIndexPart<TLink> other)
            => _equalityComparer.Equals(RootAsSource, other.RootAsSource)
            && _equalityComparer.Equals(LeftAsSource, other.LeftAsSource)
            && _equalityComparer.Equals(RightAsSource, other.RightAsSource)
            && _equalityComparer.Equals(SizeAsSource, other.SizeAsSource)
            && _equalityComparer.Equals(RootAsTarget, other.RootAsTarget)
            && _equalityComparer.Equals(LeftAsTarget, other.LeftAsTarget)
            && _equalityComparer.Equals(RightAsTarget, other.RightAsTarget)
            && _equalityComparer.Equals(SizeAsTarget, other.SizeAsTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override int GetHashCode() => (RootAsSource, LeftAsSource, RightAsSource,
        ↪  SizeAsSource, RootAsTarget, LeftAsTarget, RightAsTarget, SizeAsTarget).GetHashCode();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool operator ==(RawLinkIndexPart<TLink> left, RawLinkIndexPart<TLink>
        ↪  right) => left.Equals(right);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool operator !=(RawLinkIndexPart<TLink> left, RawLinkIndexPart<TLink>
        ↪  right) => !(left == right);
    }
}
```

1.41 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt32ExternalLinksSizeBalancedTreeMethodsBase

```
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Memory.Split.Generic;
using TLink = System.UInt32;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe abstract class UInt32ExternalLinksSizeBalancedTreeMethodsBase :
    ↪ ExternalLinksSizeBalancedTreeMethodsBase<TLink>, ILinksTreeMethods<TLink>
    {
        protected new readonly RawLinkDataPart<TLink>* LinksDataParts;
        protected new readonly RawLinkIndexPart<TLink>* LinksIndexParts;
        protected new readonly LinksHeader<TLink>* Header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected UInt32ExternalLinksSizeBalancedTreeMethodsBase(LinksConstants<TLink>
        ↪ constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>*
        ↪ linksIndexParts, LinksHeader<TLink>* header)
            : base(constants, (byte*)linksDataParts, (byte*)linksIndexParts, (byte*)header)
        {
            LinksDataParts = linksDataParts;
            LinksIndexParts = linksIndexParts;
            Header = header;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetZero() => 0U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool EqualToZero(TLink value) => value == 0U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool AreEqual(TLink first, TLink second) => first == second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThanZero(TLink value) => value > 0U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThan(TLink first, TLink second) => first > second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThan(TLink first, TLink second) => first >= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThanZero(TLink value) => true; // value >= 0 is
        ↪ always true for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThanZero(TLink value) => value == 0UL; // value is
        ↪ always >= 0 for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThan(TLink first, TLink second) => first <= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThanZero(TLink value) => false; // value < 0 is always false
        ↪ for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThan(TLink first, TLink second) => first < second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Increment(TLink value) => ++value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Decrement(TLink value) => --value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Add(TLink first, TLink second) => first + second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Subtract(TLink first, TLink second) => first - second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref LinksHeader<TLink> GetHeaderReference() => ref *Header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
        protected override ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) =>
        ↪ ref LinksDataParts[link];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink link) =>
        ↪ ref LinksIndexParts[link];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
        {
            ref var firstLink = ref LinksDataParts[first];
            ref var secondLink = ref LinksDataParts[second];
            return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
            ↪ secondLink.Source, secondLink.Target);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
        {
            ref var firstLink = ref LinksDataParts[first];
            ref var secondLink = ref LinksDataParts[second];
            return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
            ↪ secondLink.Source, secondLink.Target);
        }
    }
}
```

1.42 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt32ExternalLinksSourcesSizeBalancedTreeMeth

```
using System.Runtime.CompilerServices;
using TLink = System.UInt32;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe class UInt32ExternalLinksSourcesSizeBalancedTreeMethods :
    ↪ UInt32ExternalLinksSizeBalancedTreeMethodsBase
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt32ExternalLinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink>
        ↪ constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>*
        ↪ linksIndexParts, LinksHeader<TLink>* header) : base(constants, linksDataParts,
        ↪ linksIndexParts, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref
        ↪ LinksIndexParts[node].LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref
        ↪ LinksIndexParts[node].RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) => LinksIndexParts[node].LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) => LinksIndexParts[node].RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        ↪ LinksIndexParts[node].LeftAsSource = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        ↪ LinksIndexParts[node].RightAsSource = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) => LinksIndexParts[node].SizeAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪ LinksIndexParts[node].SizeAsSource = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot() => Header->RootAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink node) => LinksDataParts[node].Source;

```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget)
            => firstSource < secondSource || firstSource == secondSource && firstTarget <
            ↪  secondTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget)
            => firstSource > secondSource || firstSource == secondSource && firstTarget >
            ↪  secondTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref LinksIndexParts[node];
            link.LeftAsSource = Zero;
            link.RightAsSource = Zero;
            link.SizeAsSource = Zero;
        }
    }
}
```

1.43 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt32ExternalLinksTargetsSizeBalancedTreeMetho

```
using System.Runtime.CompilerServices;
using TLink = System.UInt32;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe class UInt32ExternalLinksTargetsSizeBalancedTreeMethods :
    ↪  UInt32ExternalLinksSizeBalancedTreeMethodsBase
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt32ExternalLinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink>
        ↪  constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>*
        ↪  linksIndexParts, LinksHeader<TLink>* header) : base(constants, linksDataParts,
        ↪  linksIndexParts, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref
        ↪  LinksIndexParts[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref
        ↪  LinksIndexParts[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) => LinksIndexParts[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) => LinksIndexParts[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        ↪  LinksIndexParts[node].LeftAsTarget = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        ↪  LinksIndexParts[node].RightAsTarget = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) => LinksIndexParts[node].SizeAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪  LinksIndexParts[node].SizeAsTarget = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot() => Header->RootAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink node) => LinksDataParts[node].Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget)
```

```
            => firstTarget < secondTarget || firstTarget == secondTarget && firstSource <
            ↪  secondSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget)
            => firstTarget > secondTarget || firstTarget == secondTarget && firstSource >
            ↪  secondSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref LinksIndexParts[node];
            link.LeftAsTarget = Zero;
            link.RightAsTarget = Zero;
            link.SizeAsTarget = Zero;
        }
    }
}
```

1.44 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt32InternalLinksSizeBalancedTreeMethodsBase.

```
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Memory.Split.Generic;
using TLink = System.UInt32;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe abstract class UInt32InternalLinksSizeBalancedTreeMethodsBase :
    ↪  InternalLinksSizeBalancedTreeMethodsBase<TLink>
    {
        protected new readonly RawLinkDataPart<TLink>* LinksDataParts;
        protected new readonly RawLinkIndexPart<TLink>* LinksIndexParts;
        protected new readonly LinksHeader<TLink>* Header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected UInt32InternalLinksSizeBalancedTreeMethodsBase(LinksConstants<TLink>
        ↪  constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>*
        ↪  linksIndexParts, LinksHeader<TLink>* header)
            : base(constants, (byte*)linksDataParts, (byte*)linksIndexParts, (byte*)header)
        {
            LinksDataParts = linksDataParts;
            LinksIndexParts = linksIndexParts;
            Header = header;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetZero() => 0U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool EqualToZero(TLink value) => value == 0U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool AreEqual(TLink first, TLink second) => first == second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThanZero(TLink value) => value > 0U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThan(TLink first, TLink second) => first > second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThan(TLink first, TLink second) => first >= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThanZero(TLink value) => true; // value >= 0 is
        ↪  always true for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThanZero(TLink value) => value == 0UL; // value is
        ↪  always >= 0 for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThan(TLink first, TLink second) => first <= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThanZero(TLink value) => false; // value < 0 is always false
        ↪  for ulong

```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThan(TLink first, TLink second) => first < second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Increment(TLink value) => ++value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Decrement(TLink value) => --value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Add(TLink first, TLink second) => first + second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Subtract(TLink first, TLink second) => first - second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) =>
        ↪  ref LinksDataParts[link];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink link) =>
        ↪  ref LinksIndexParts[link];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second) =>
        ↪  GetKeyPartValue(first) < GetKeyPartValue(second);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second) =>
        ↪  GetKeyPartValue(first) > GetKeyPartValue(second);
    }
}
```

1.45 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt32InternalLinksSourcesSizeBalancedTreeMetho

```
using System.Runtime.CompilerServices;
using TLink = System.UInt32;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe class UInt32InternalLinksSourcesSizeBalancedTreeMethods :
    ↪  UInt32InternalLinksSizeBalancedTreeMethodsBase
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt32InternalLinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink>
        ↪  constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>*
        ↪  linksIndexParts, LinksHeader<TLink>* header) : base(constants, linksDataParts,
        ↪  linksIndexParts, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref
        ↪  LinksIndexParts[node].LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref
        ↪  LinksIndexParts[node].RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) => LinksIndexParts[node].LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) => LinksIndexParts[node].RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        ↪  LinksIndexParts[node].LeftAsSource = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        ↪  LinksIndexParts[node].RightAsSource = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) => LinksIndexParts[node].SizeAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪  LinksIndexParts[node].SizeAsSource = size;

```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot(TLink node) => LinksIndexParts[node].RootAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink node) => LinksDataParts[node].Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetKeyPartValue(TLink node) => LinksDataParts[node].Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref LinksIndexParts[node];
            link.LeftAsSource = Zero;
            link.RightAsSource = Zero;
            link.SizeAsSource = Zero;
        }

        public override TLink Search(TLink source, TLink target) =>
        ↪  SearchCore(GetTreeRoot(source), target);
    }
}
```

1.46 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt32InternalLinksTargetsSizeBalancedTreeMetho

```
using System.Runtime.CompilerServices;
using TLink = System.UInt32;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe class UInt32InternalLinksTargetsSizeBalancedTreeMethods :
    ↪  UInt32InternalLinksSizeBalancedTreeMethodsBase
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt32InternalLinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink>
        ↪  constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>*
        ↪  linksIndexParts, LinksHeader<TLink>* header) : base(constants, linksDataParts,
        ↪  linksIndexParts, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref
        ↪  LinksIndexParts[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref
        ↪  LinksIndexParts[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) => LinksIndexParts[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) => LinksIndexParts[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        ↪  LinksIndexParts[node].LeftAsTarget = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        ↪  LinksIndexParts[node].RightAsTarget = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) => LinksIndexParts[node].SizeAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪  LinksIndexParts[node].SizeAsTarget = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot(TLink node) => LinksIndexParts[node].RootAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink node) => LinksDataParts[node].Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetKeyPartValue(TLink node) => LinksDataParts[node].Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
47          protected override void ClearNode(TLink node)
48          {
49              ref var link = ref LinksIndexParts[node];
50              link.LeftAsTarget = Zero;
51              link.RightAsTarget = Zero;
52              link.SizeAsTarget = Zero;
53          }
54
55          public override TLink Search(TLink source, TLink target) =>
            ↪  SearchCore(GetTreeRoot(target), source);
56      }
57  }
```

1.47 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt32SplitMemoryLinks.cs

```
1   using System;
2   using System.Runtime.CompilerServices;
3   using Platform.Singletons;
4   using Platform.Memory;
5   using Platform.Data.Doublets.Memory.Split.Generic;
6   using TLink = System.UInt32;
7
8   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10  namespace Platform.Data.Doublets.Memory.Split.Specific
11  {
12      public unsafe class UInt32SplitMemoryLinks : SplitMemoryLinksBase<TLink>
13      {
14          private readonly Func<ILinksTreeMethods<TLink>> _createInternalSourceTreeMethods;
15          private readonly Func<ILinksTreeMethods<TLink>> _createExternalSourceTreeMethods;
16          private readonly Func<ILinksTreeMethods<TLink>> _createInternalTargetTreeMethods;
17          private readonly Func<ILinksTreeMethods<TLink>> _createExternalTargetTreeMethods;
18          private LinksHeader<TLink>* _header;
19          private RawLinkDataPart<TLink>* _linksDataParts;
20          private RawLinkIndexPart<TLink>* _linksIndexParts;
21
22          [MethodImpl(MethodImplOptions.AggressiveInlining)]
23          public UInt32SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
            ↪  indexMemory) : this(dataMemory, indexMemory, DefaultLinksSizeStep) { }
24
25          [MethodImpl(MethodImplOptions.AggressiveInlining)]
26          public UInt32SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
            ↪  indexMemory, long memoryReservationStep) : this(dataMemory, indexMemory,
            ↪  memoryReservationStep, Default<LinksConstants<TLink>>.Instance) { }
27
28          [MethodImpl(MethodImplOptions.AggressiveInlining)]
29          public UInt32SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
            ↪  indexMemory, long memoryReservationStep, LinksConstants<TLink> constants) :
            ↪  base(dataMemory, indexMemory, memoryReservationStep, constants)
30          {
31              _createInternalSourceTreeMethods = () => new
                ↪  UInt32InternalLinksSourcesSizeBalancedTreeMethods(Constants, _linksDataParts,
                ↪  _linksIndexParts, _header);
32              _createExternalSourceTreeMethods = () => new
                ↪  UInt32ExternalLinksSourcesSizeBalancedTreeMethods(Constants, _linksDataParts,
                ↪  _linksIndexParts, _header);
33              _createInternalTargetTreeMethods = () => new
                ↪  UInt32InternalLinksTargetsSizeBalancedTreeMethods(Constants, _linksDataParts,
                ↪  _linksIndexParts, _header);
34              _createExternalTargetTreeMethods = () => new
                ↪  UInt32ExternalLinksTargetsSizeBalancedTreeMethods(Constants, _linksDataParts,
                ↪  _linksIndexParts, _header);
35              Init(dataMemory, indexMemory);
36          }
37
38          [MethodImpl(MethodImplOptions.AggressiveInlining)]
39          protected override void SetPointers(IResizableDirectMemory dataMemory,
            ↪  IResizableDirectMemory indexMemory)
40          {
41              _linksDataParts = (RawLinkDataPart<TLink>*)dataMemory.Pointer;
42              _linksIndexParts = (RawLinkIndexPart<TLink>*)indexMemory.Pointer;
43              _header = (LinksHeader<TLink>*)indexMemory.Pointer;
44              InternalSourcesTreeMethods = _createInternalSourceTreeMethods();
45              ExternalSourcesTreeMethods = _createExternalSourceTreeMethods();
46              InternalTargetsTreeMethods = _createInternalTargetTreeMethods();
47              ExternalTargetsTreeMethods = _createExternalTargetTreeMethods();
48              UnusedLinksListMethods = new UInt32UnusedLinksListMethods(_linksDataParts, _header);
49          }
50
51          [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
        protected override void ResetPointers()
        {
            base.ResetPointers();
            _linksDataParts = null;
            _linksIndexParts = null;
            _header = null;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref LinksHeader<TLink> GetHeaderReference() => ref *_header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink linkIndex)
        ↪  => ref _linksDataParts[linkIndex];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink
        ↪  linkIndex) => ref _linksIndexParts[linkIndex];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool AreEqual(TLink first, TLink second) => first == second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThan(TLink first, TLink second) => first < second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThan(TLink first, TLink second) => first <= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThan(TLink first, TLink second) => first > second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThan(TLink first, TLink second) => first >= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetZero() => 0U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetOne() => 1U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override long ConvertToInt64(TLink value) => value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink ConvertToAddress(long value) => (TLink)value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Add(TLink first, TLink second) => first + second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Subtract(TLink first, TLink second) => first - second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Increment(TLink link) => ++link;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink Decrement(TLink link) => --link;
    }
}
```

1.48 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt32UnusedLinksListMethods.cs

```
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Memory.Split.Generic;
using TLink = System.UInt32;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe class UInt32UnusedLinksListMethods : UnusedLinksListMethods<TLink>
    {
        private readonly RawLinkDataPart<TLink>* _links;
        private readonly LinksHeader<TLink>* _header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt32UnusedLinksListMethods(RawLinkDataPart<TLink>* links, LinksHeader<TLink>*
        ↪  header)
            : base((byte*)links, (byte*)header)
        {
            _links = links;
```

```
            _header = header;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) =>
        ↪  ref _links[link];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref LinksHeader<TLink> GetHeaderReference() => ref *_header;
    }
}
```

1.49 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt64ExternalLinksSizeBalancedTreeMethodsBase

```
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Memory.Split.Generic;
using TLink = System.UInt64;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe abstract class UInt64ExternalLinksSizeBalancedTreeMethodsBase :
    ↪  ExternalLinksSizeBalancedTreeMethodsBase<TLink>, ILinksTreeMethods<TLink>
    {
        protected new readonly RawLinkDataPart<TLink>* LinksDataParts;
        protected new readonly RawLinkIndexPart<TLink>* LinksIndexParts;
        protected new readonly LinksHeader<TLink>* Header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected UInt64ExternalLinksSizeBalancedTreeMethodsBase(LinksConstants<TLink>
        ↪  constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>*
        ↪  linksIndexParts, LinksHeader<TLink>* header)
            : base(constants, (byte*)linksDataParts, (byte*)linksIndexParts, (byte*)header)
        {
            LinksDataParts = linksDataParts;
            LinksIndexParts = linksIndexParts;
            Header = header;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetZero() => 0UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool EqualToZero(ulong value) => value == 0UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool AreEqual(ulong first, ulong second) => first == second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThanZero(ulong value) => value > 0UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThan(ulong first, ulong second) => first > second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
        ↪  always true for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThanZero(ulong value) => value == 0UL; // value is
        ↪  always >= 0 for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThanZero(ulong value) => false; // value < 0 is always false
        ↪  for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThan(ulong first, ulong second) => first < second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Increment(ulong value) => ++value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Decrement(ulong value) => --value;
```

```
62
63          [MethodImpl(MethodImplOptions.AggressiveInlining)]
64          protected override ulong Add(ulong first, ulong second) => first + second;
65
66          [MethodImpl(MethodImplOptions.AggressiveInlining)]
67          protected override ulong Subtract(ulong first, ulong second) => first - second;
68
69          [MethodImpl(MethodImplOptions.AggressiveInlining)]
70          protected override ref LinksHeader<TLink> GetHeaderReference() => ref *Header;
71
72          [MethodImpl(MethodImplOptions.AggressiveInlining)]
73          protected override ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) =>
            ↪  ref LinksDataParts[link];
74
75          [MethodImpl(MethodImplOptions.AggressiveInlining)]
76          protected override ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink link) =>
            ↪  ref LinksIndexParts[link];
77
78          [MethodImpl(MethodImplOptions.AggressiveInlining)]
79          protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
80          {
81              ref var firstLink = ref LinksDataParts[first];
82              ref var secondLink = ref LinksDataParts[second];
83              return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
                ↪  secondLink.Source, secondLink.Target);
84          }
85
86          [MethodImpl(MethodImplOptions.AggressiveInlining)]
87          protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
88          {
89              ref var firstLink = ref LinksDataParts[first];
90              ref var secondLink = ref LinksDataParts[second];
91              return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
                ↪  secondLink.Source, secondLink.Target);
92          }
93      }
94  }
```

1.50 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt64ExternalLinksSourcesSizeBalancedTreeMeth

```
1   using System.Runtime.CompilerServices;
2   using TLink = System.UInt64;
3
4   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6   namespace Platform.Data.Doublets.Memory.Split.Specific
7   {
8       public unsafe class UInt64ExternalLinksSourcesSizeBalancedTreeMethods :
        ↪  UInt64ExternalLinksSizeBalancedTreeMethodsBase
9       {
10          [MethodImpl(MethodImplOptions.AggressiveInlining)]
11          public UInt64ExternalLinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink>
            ↪  constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>*
            ↪  linksIndexParts, LinksHeader<TLink>* header) : base(constants, linksDataParts,
            ↪  linksIndexParts, header) { }
12
13          [MethodImpl(MethodImplOptions.AggressiveInlining)]
14          protected override ref TLink GetLeftReference(TLink node) => ref
            ↪  LinksIndexParts[node].LeftAsSource;
15
16          [MethodImpl(MethodImplOptions.AggressiveInlining)]
17          protected override ref TLink GetRightReference(TLink node) => ref
            ↪  LinksIndexParts[node].RightAsSource;
18
19          [MethodImpl(MethodImplOptions.AggressiveInlining)]
20          protected override TLink GetLeft(TLink node) => LinksIndexParts[node].LeftAsSource;
21
22          [MethodImpl(MethodImplOptions.AggressiveInlining)]
23          protected override TLink GetRight(TLink node) => LinksIndexParts[node].RightAsSource;
24
25          [MethodImpl(MethodImplOptions.AggressiveInlining)]
26          protected override void SetLeft(TLink node, TLink left) =>
            ↪  LinksIndexParts[node].LeftAsSource = left;
27
28          [MethodImpl(MethodImplOptions.AggressiveInlining)]
29          protected override void SetRight(TLink node, TLink right) =>
            ↪  LinksIndexParts[node].RightAsSource = right;
30
31          [MethodImpl(MethodImplOptions.AggressiveInlining)]
32          protected override TLink GetSize(TLink node) => LinksIndexParts[node].SizeAsSource;
```

```

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪  LinksIndexParts[node].SizeAsSource = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot() => Header->RootAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink node) => LinksDataParts[node].Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget)
            => firstSource < secondSource || firstSource == secondSource && firstTarget <
            ↪  secondTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget)
            => firstSource > secondSource || firstSource == secondSource && firstTarget >
            ↪  secondTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref LinksIndexParts[node];
            link.LeftAsSource = Zero;
            link.RightAsSource = Zero;
            link.SizeAsSource = Zero;
        }
    }
}
```

1.51 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt64ExternalLinksTargetsSizeBalancedTreeMetho

```
using System.Runtime.CompilerServices;
using TLink = System.UInt64;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe class UInt64ExternalLinksTargetsSizeBalancedTreeMethods :
    ↪  UInt64ExternalLinksSizeBalancedTreeMethodsBase
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt64ExternalLinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink>
        ↪  constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>*
        ↪  linksIndexParts, LinksHeader<TLink>* header) : base(constants, linksDataParts,
        ↪  linksIndexParts, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref
        ↪  LinksIndexParts[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref
        ↪  LinksIndexParts[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) => LinksIndexParts[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) => LinksIndexParts[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        ↪  LinksIndexParts[node].LeftAsTarget = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        ↪  LinksIndexParts[node].RightAsTarget = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) => LinksIndexParts[node].SizeAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪  LinksIndexParts[node].SizeAsTarget = size;
```

```

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot() => Header->RootAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink node) => LinksDataParts[node].Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget)
            => firstTarget < secondTarget || firstTarget == secondTarget && firstSource <
            ↪  secondSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget)
            => firstTarget > secondTarget || firstTarget == secondTarget && firstSource >
            ↪  secondSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref LinksIndexParts[node];
            link.LeftAsTarget = Zero;
            link.RightAsTarget = Zero;
            link.SizeAsTarget = Zero;
        }
    }
}
```

1.52 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt64InternalLinksSizeBalancedTreeMethodsBase.

```
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Memory.Split.Generic;
using TLink = System.UInt64;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe abstract class UInt64InternalLinksSizeBalancedTreeMethodsBase :
    ↪  InternalLinksSizeBalancedTreeMethodsBase<TLink>
    {
        protected new readonly RawLinkDataPart<TLink>* LinksDataParts;
        protected new readonly RawLinkIndexPart<TLink>* LinksIndexParts;
        protected new readonly LinksHeader<TLink>* Header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected UInt64InternalLinksSizeBalancedTreeMethodsBase(LinksConstants<TLink>
        ↪  constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>*
        ↪  linksIndexParts, LinksHeader<TLink>* header)
            : base(constants, (byte*)linksDataParts, (byte*)linksIndexParts, (byte*)header)
        {
            LinksDataParts = linksDataParts;
            LinksIndexParts = linksIndexParts;
            Header = header;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetZero() => 0UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool EqualToZero(ulong value) => value == 0UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool AreEqual(ulong first, ulong second) => first == second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThanZero(ulong value) => value > 0UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThan(ulong first, ulong second) => first > second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
        ↪  always true for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
        protected override bool LessOrEqualThanZero(ulong value) => value == 0UL; // value is always >= 0 for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThanZero(ulong value) => false; // value < 0 is always false for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThan(ulong first, ulong second) => first < second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Increment(ulong value) => ++value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Decrement(ulong value) => --value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Add(ulong first, ulong second) => first + second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Subtract(ulong first, ulong second) => first - second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) => ref LinksDataParts[link];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink link) => ref LinksIndexParts[link];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second) => GetKeyPartValue(first) < GetKeyPartValue(second);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second) => GetKeyPartValue(first) > GetKeyPartValue(second);
    }
}
```

1.53 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt64InternalLinksSourcesSizeBalancedTreeMetho

```
using System.Runtime.CompilerServices;
using TLink = System.UInt64;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe class UInt64InternalLinksSourcesSizeBalancedTreeMethods : UInt64InternalLinksSizeBalancedTreeMethodsBase
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt64InternalLinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink> constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>* linksIndexParts, LinksHeader<TLink>* header) : base(constants, linksDataParts, linksIndexParts, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref LinksIndexParts[node].LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref LinksIndexParts[node].RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) => LinksIndexParts[node].LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) => LinksIndexParts[node].RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) => LinksIndexParts[node].LeftAsSource = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
        protected override void SetRight(TLink node, TLink right) =>
        ↪ LinksIndexParts[node].RightAsSource = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) => LinksIndexParts[node].SizeAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪ LinksIndexParts[node].SizeAsSource = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot(TLink node) => LinksIndexParts[node].RootAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink node) => LinksDataParts[node].Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetKeyPartValue(TLink node) => LinksDataParts[node].Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref LinksIndexParts[node];
            link.LeftAsSource = Zero;
            link.RightAsSource = Zero;
            link.SizeAsSource = Zero;
        }

        public override TLink Search(TLink source, TLink target) =>
        ↪ SearchCore(GetTreeRoot(source), target);
    }
}
```

1.54 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt64InternalLinksTargetsSizeBalancedTreeMetho

```
using System.Runtime.CompilerServices;
using TLink = System.UInt64;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe class UInt64InternalLinksTargetsSizeBalancedTreeMethods :
    ↪ UInt64InternalLinksSizeBalancedTreeMethodsBase
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt64InternalLinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink>
        ↪ constants, RawLinkDataPart<TLink>* linksDataParts, RawLinkIndexPart<TLink>*
        ↪ linksIndexParts, LinksHeader<TLink>* header) : base(constants, linksDataParts,
        ↪ linksIndexParts, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref ulong GetLeftReference(ulong node) => ref
        ↪ LinksIndexParts[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref ulong GetRightReference(ulong node) => ref
        ↪ LinksIndexParts[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) => LinksIndexParts[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) => LinksIndexParts[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        ↪ LinksIndexParts[node].LeftAsTarget = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        ↪ LinksIndexParts[node].RightAsTarget = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) => LinksIndexParts[node].SizeAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪ LinksIndexParts[node].SizeAsTarget = size;

```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot(TLink node) => LinksIndexParts[node].RootAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink node) => LinksDataParts[node].Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetKeyPartValue(TLink node) => LinksDataParts[node].Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref LinksIndexParts[node];
            link.LeftAsTarget = Zero;
            link.RightAsTarget = Zero;
            link.SizeAsTarget = Zero;
        }

        public override TLink Search(TLink source, TLink target) =>
        ↪ SearchCore(GetTreeRoot(target), source);
    }
}
```

1.55 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt64SplitMemoryLinks.cs

```
using System;
using System.Runtime.CompilerServices;
using Platform.Singletons;
using Platform.Memory;
using Platform.Data.Doublets.Memory.Split.Generic;
using TLink = System.UInt64;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe class UInt64SplitMemoryLinks : SplitMemoryLinksBase<TLink>
    {
        private readonly Func<ILinksTreeMethods<TLink>> _createInternalSourceTreeMethods;
        private readonly Func<ILinksTreeMethods<TLink>> _createExternalSourceTreeMethods;
        private readonly Func<ILinksTreeMethods<TLink>> _createInternalTargetTreeMethods;
        private readonly Func<ILinksTreeMethods<TLink>> _createExternalTargetTreeMethods;
        private LinksHeader<ulong>* _header;
        private RawLinkDataPart<ulong>* _linksDataParts;
        private RawLinkIndexPart<ulong>* _linksIndexParts;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt64SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
        ↪ indexMemory) : this(dataMemory, indexMemory, DefaultLinksSizeStep) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt64SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
        ↪ indexMemory, long memoryReservationStep) : this(dataMemory, indexMemory,
        ↪ memoryReservationStep, Default<LinksConstants<TLink>>.Instance) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt64SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
        ↪ indexMemory, long memoryReservationStep, LinksConstants<TLink> constants) :
        ↪ base(dataMemory, indexMemory, memoryReservationStep, constants)
        {
            _createInternalSourceTreeMethods = () => new
            ↪ UInt64InternalLinksSourcesSizeBalancedTreeMethods(Constants, _linksDataParts,
            ↪ _linksIndexParts, _header);
            _createExternalSourceTreeMethods = () => new
            ↪ UInt64ExternalLinksSourcesSizeBalancedTreeMethods(Constants, _linksDataParts,
            ↪ _linksIndexParts, _header);
            _createInternalTargetTreeMethods = () => new
            ↪ UInt64InternalLinksTargetsSizeBalancedTreeMethods(Constants, _linksDataParts,
            ↪ _linksIndexParts, _header);
            _createExternalTargetTreeMethods = () => new
            ↪ UInt64ExternalLinksTargetsSizeBalancedTreeMethods(Constants, _linksDataParts,
            ↪ _linksIndexParts, _header);
            Init(dataMemory, indexMemory);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetPointers(IResizableDirectMemory dataMemory,
        ↪ IResizableDirectMemory indexMemory)
        {
            _linksDataParts = (RawLinkDataPart<TLink>*)dataMemory.Pointer;
```

```
            _linksIndexParts = (RawLinkIndexPart<TLink>*)indexMemory.Pointer;
            _header = (LinksHeader<TLink>*)indexMemory.Pointer;
            InternalSourcesTreeMethods = _createInternalSourceTreeMethods();
            ExternalSourcesTreeMethods = _createExternalSourceTreeMethods();
            InternalTargetsTreeMethods = _createInternalTargetTreeMethods();
            ExternalTargetsTreeMethods = _createExternalTargetTreeMethods();
            UnusedLinksListMethods = new UInt64UnusedLinksListMethods(_linksDataParts, _header);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ResetPointers()
        {
            base.ResetPointers();
            _linksDataParts = null;
            _linksIndexParts = null;
            _header = null;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref LinksHeader<TLink> GetHeaderReference() => ref *_header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink linkIndex)
        ↪  => ref _linksDataParts[linkIndex];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink
        ↪  linkIndex) => ref _linksIndexParts[linkIndex];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool AreEqual(ulong first, ulong second) => first == second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThan(ulong first, ulong second) => first < second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThan(ulong first, ulong second) => first > second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetZero() => 0UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetOne() => 1UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override long ConvertToInt64(ulong value) => (long)value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong ConvertToAddress(long value) => (ulong)value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Add(ulong first, ulong second) => first + second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Subtract(ulong first, ulong second) => first - second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Increment(ulong link) => ++link;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Decrement(ulong link) => --link;
    }
}
```

1.56 ./csharp/Platform.Data.Doublets/Memory/Split/Specific/UInt64UnusedLinksListMethods.cs

```
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Memory.Split.Generic;
using TLink = System.UInt64;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.Split.Specific
{
    public unsafe class UInt64UnusedLinksListMethods : UnusedLinksListMethods<TLink>
```

```
    {
        private readonly RawLinkDataPart<ulong>* _links;
        private readonly LinksHeader<ulong>* _header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt64UnusedLinksListMethods(RawLinkDataPart<ulong>* links, LinksHeader<ulong>*
        ↪  header)
            : base((byte*)links, (byte*)header)
        {
            _links = links;
            _header = header;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) =>
        ↪  ref _links[link];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref LinksHeader<TLink> GetHeaderReference() => ref *_header;
    }
}
```

1.57 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksAvlBalancedTreeMethodsBase.cs

```
using System;
using System.Text;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Methods.Trees;
using Platform.Converters;
using Platform.Numbers;
using static System.Runtime.CompilerServices.Unsafe;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Generic
{
    public unsafe abstract class LinksAvlBalancedTreeMethodsBase<TLink> :
    ↪  SizedAndThreadedAVLBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
    {
        private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
        ↪  UncheckedConverter<TLink, long>.Default;
        private static readonly UncheckedConverter<TLink, int> _addressToInt32Converter =
        ↪  UncheckedConverter<TLink, int>.Default;
        private static readonly UncheckedConverter<bool, TLink> _boolToAddressConverter =
        ↪  UncheckedConverter<bool, TLink>.Default;
        private static readonly UncheckedConverter<TLink, bool> _addressToBoolConverter =
        ↪  UncheckedConverter<TLink, bool>.Default;
        private static readonly UncheckedConverter<int, TLink> _int32ToAddressConverter =
        ↪  UncheckedConverter<int, TLink>.Default;

        protected readonly TLink Break;
        protected readonly TLink Continue;
        protected readonly byte* Links;
        protected readonly byte* Header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected LinksAvlBalancedTreeMethodsBase(LinksConstants<TLink> constants, byte* links,
        ↪  byte* header)
        {
            Links = links;
            Header = header;
            Break = constants.Break;
            Continue = constants.Continue;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract TLink GetTreeRoot();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract TLink GetBasePartValue(TLink link);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract bool FirstIsToTheRightOfSecond(TLink source, TLink target, TLink
        ↪  rootSource, TLink rootTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract bool FirstIsToTheLeftOfSecond(TLink source, TLink target, TLink
        ↪  rootSource, TLink rootTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
49          protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
            ↪  AsRef<LinksHeader<TLink>>(Header);
50
51          [MethodImpl(MethodImplOptions.AggressiveInlining)]
52          protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
            ↪  AsRef<RawLink<TLink>>(Links + (RawLink<TLink>.SizeInBytes *
            ↪  _addressToInt64Converter.Convert(link)));
53
54          [MethodImpl(MethodImplOptions.AggressiveInlining)]
55          protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
56          {
57              ref var link = ref GetLinkReference(linkIndex);
58              return new Link<TLink>(linkIndex, link.Source, link.Target);
59          }
60
61          [MethodImpl(MethodImplOptions.AggressiveInlining)]
62          protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
63          {
64              ref var firstLink = ref GetLinkReference(first);
65              ref var secondLink = ref GetLinkReference(second);
66              return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
                ↪  secondLink.Source, secondLink.Target);
67          }
68
69          [MethodImpl(MethodImplOptions.AggressiveInlining)]
70          protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
71          {
72              ref var firstLink = ref GetLinkReference(first);
73              ref var secondLink = ref GetLinkReference(second);
74              return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
                ↪  secondLink.Source, secondLink.Target);
75          }
76
77          [MethodImpl(MethodImplOptions.AggressiveInlining)]
78          protected virtual TLink GetSizeValue(TLink value) => Bit<TLink>.PartialRead(value, 5,
            ↪  -5);
79
80          [MethodImpl(MethodImplOptions.AggressiveInlining)]
81          protected virtual void SetSizeValue(ref TLink storedValue, TLink size) => storedValue =
            ↪  Bit<TLink>.PartialWrite(storedValue, size, 5, -5);
82
83          [MethodImpl(MethodImplOptions.AggressiveInlining)]
84          protected virtual bool GetLeftIsChildValue(TLink value)
85          {
86              unchecked
87              {
88                  return _addressToBoolConverter.Convert(Bit<TLink>.PartialRead(value, 4, 1));
89                  //return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 4, 1), default);
90              }
91          }
92
93          [MethodImpl(MethodImplOptions.AggressiveInlining)]
94          protected virtual void SetLeftIsChildValue(ref TLink storedValue, bool value)
95          {
96              unchecked
97              {
98                  var previousValue = storedValue;
99                  var modified = Bit<TLink>.PartialWrite(previousValue,
                    ↪  _boolToAddressConverter.Convert(value), 4, 1);
100                 storedValue = modified;
101             }
102         }
103
104         [MethodImpl(MethodImplOptions.AggressiveInlining)]
105         protected virtual bool GetRightIsChildValue(TLink value)
106         {
107             unchecked
108             {
109                 return _addressToBoolConverter.Convert(Bit<TLink>.PartialRead(value, 3, 1));
110                 //return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 3, 1), default);
111             }
112         }
113
114         [MethodImpl(MethodImplOptions.AggressiveInlining)]
115         protected virtual void SetRightIsChildValue(ref TLink storedValue, bool value)
116         {
117             unchecked
118             {
```

```
                var previousValue = storedValue;
                var modified = Bit<TLink>.PartialWrite(previousValue,
                ↪  _boolToAddressConverter.Convert(value), 3, 1);
                storedValue = modified;
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected bool IsChild(TLink parent, TLink possibleChild)
        {
            var parentSize = GetSize(parent);
            var childSize = GetSizeOrZero(possibleChild);
            return GreaterThanZero(childSize) && LessOrEqualThan(childSize, parentSize);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual sbyte GetBalanceValue(TLink storedValue)
        {
            unchecked
            {
                var value = _addressToInt32Converter.Convert(Bit<TLink>.PartialRead(storedValue,
                ↪  0, 3));
                value |= 0xF8 * ((value & 4) >> 2); // if negative, then continue ones to the
                ↪  end of sbyte
                return (sbyte)value;
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual void SetBalanceValue(ref TLink storedValue, sbyte value)
        {
            unchecked
            {
                var packagedValue = _int32ToAddressConverter.Convert((byte)value >> 5 & 4 |
                ↪  value & 3);
                var modified = Bit<TLink>.PartialWrite(storedValue, packagedValue, 0, 3);
                storedValue = modified;
            }
        }

        public TLink this[TLink index]
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get
            {
                var root = GetTreeRoot();
                if (GreaterOrEqualThan(index, GetSize(root)))
                {
                    return Zero;
                }
                while (!EqualToZero(root))
                {
                    var left = GetLeftOrDefault(root);
                    var leftSize = GetSizeOrZero(left);
                    if (LessThan(index, leftSize))
                    {
                        root = left;
                        continue;
                    }
                    if (AreEqual(index, leftSize))
                    {
                        return root;
                    }
                    root = GetRightOrDefault(root);
                    index = Subtract(index, Increment(leftSize));
                }
                return Zero; // TODO: Impossible situation exception (only if tree structure
                ↪  broken)
            }
        }

        /// <summary>
        /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
        ↪  (концом).
        /// </summary>
        /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
        /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
        /// <returns>Индекс искомой связи.</returns>
```

```
191         [MethodImpl(MethodImplOptions.AggressiveInlining)]
192         public TLink Search(TLink source, TLink target)
193         {
194             var root = GetTreeRoot();
195             while (!EqualToZero(root))
196             {
197                 ref var rootLink = ref GetLinkReference(root);
198                 var rootSource = rootLink.Source;
199                 var rootTarget = rootLink.Target;
200                 if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
                    ↪ node.Key < root.Key
201                 {
202                     root = GetLeftOrDefault(root);
203                 }
204                 else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget)) //
                    ↪ node.Key > root.Key
205                 {
206                     root = GetRightOrDefault(root);
207                 }
208                 else // node.Key == root.Key
209                 {
210                     return root;
211                 }
212             }
213             return Zero;
214         }
215 
216         // TODO: Return indices range instead of references count
217         [MethodImpl(MethodImplOptions.AggressiveInlining)]
218         public TLink CountUsages(TLink link)
219         {
220             var root = GetTreeRoot();
221             var total = GetSize(root);
222             var totalRightIgnore = Zero;
223             while (!EqualToZero(root))
224             {
225                 var @base = GetBasePartValue(root);
226                 if (LessOrEqualThan(@base, link))
227                 {
228                     root = GetRightOrDefault(root);
229                 }
230                 else
231                 {
232                     totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
233                     root = GetLeftOrDefault(root);
234                 }
235             }
236             root = GetTreeRoot();
237             var totalLeftIgnore = Zero;
238             while (!EqualToZero(root))
239             {
240                 var @base = GetBasePartValue(root);
241                 if (GreaterOrEqualThan(@base, link))
242                 {
243                     root = GetLeftOrDefault(root);
244                 }
245                 else
246                 {
247                     totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
248 
249                     root = GetRightOrDefault(root);
250                 }
251             }
252             return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
253         }
254 
255         [MethodImpl(MethodImplOptions.AggressiveInlining)]
256         public TLink EachUsage(TLink link, Func<IList<TLink>, TLink> handler)
257         {
258             var root = GetTreeRoot();
259             if (EqualToZero(root))
260             {
261                 return Continue;
262             }
263             TLink first = Zero, current = root;
264             while (!EqualToZero(current))
265             {
266                 var @base = GetBasePartValue(current);
267                 if (GreaterOrEqualThan(@base, link))
```

```
                {
                    if (AreEqual(@base, link))
                    {
                        first = current;
                    }
                    current = GetLeftOrDefault(current);
                }
                else
                {
                    current = GetRightOrDefault(current);
                }
            }
            if (!EqualToZero(first))
            {
                current = first;
                while (true)
                {
                    if (AreEqual(handler(GetLinkValues(current)), Break))
                    {
                        return Break;
                    }
                    current = GetNext(current);
                    if (EqualToZero(current) || !AreEqual(GetBasePartValue(current), link))
                    {
                        break;
                    }
                }
            }
            return Continue;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void PrintNodeValue(TLink node, StringBuilder sb)
        {
            ref var link = ref GetLinkReference(node);
            sb.Append(' ');
            sb.Append(link.Source);
            sb.Append('-');
            sb.Append('>');
            sb.Append(link.Target);
        }
    }
}
```

1.58 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksSizeBalancedTreeMethodsBase.cs

```
using System;
using System.Text;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Methods.Trees;
using Platform.Converters;
using static System.Runtime.CompilerServices.Unsafe;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Generic
{
    public unsafe abstract class LinksSizeBalancedTreeMethodsBase<TLink> :
    ↪ SizeBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
    {
        private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
        ↪ UncheckedConverter<TLink, long>.Default;

        protected readonly TLink Break;
        protected readonly TLink Continue;
        protected readonly byte* Links;
        protected readonly byte* Header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected LinksSizeBalancedTreeMethodsBase(LinksConstants<TLink> constants, byte* links,
        ↪ byte* header)
        {
            Links = links;
            Header = header;
            Break = constants.Break;
            Continue = constants.Continue;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract TLink GetTreeRoot();
```

```
33
34          [MethodImpl(MethodImplOptions.AggressiveInlining)]
35          protected abstract TLink GetBasePartValue(TLink link);
36
37          [MethodImpl(MethodImplOptions.AggressiveInlining)]
38          protected abstract bool FirstIsToTheRightOfSecond(TLink source, TLink target, TLink
            ↪  rootSource, TLink rootTarget);
39
40          [MethodImpl(MethodImplOptions.AggressiveInlining)]
41          protected abstract bool FirstIsToTheLeftOfSecond(TLink source, TLink target, TLink
            ↪  rootSource, TLink rootTarget);
42
43          [MethodImpl(MethodImplOptions.AggressiveInlining)]
44          protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
            ↪  AsRef<LinksHeader<TLink>>(Header);
45
46          [MethodImpl(MethodImplOptions.AggressiveInlining)]
47          protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
            ↪  AsRef<RawLink<TLink>>(Links + (RawLink<TLink>.SizeInBytes *
            ↪  _addressToInt64Converter.Convert(link)));
48
49          [MethodImpl(MethodImplOptions.AggressiveInlining)]
50          protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
51          {
52              ref var link = ref GetLinkReference(linkIndex);
53              return new Link<TLink>(linkIndex, link.Source, link.Target);
54          }
55
56          [MethodImpl(MethodImplOptions.AggressiveInlining)]
57          protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
58          {
59              ref var firstLink = ref GetLinkReference(first);
60              ref var secondLink = ref GetLinkReference(second);
61              return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
                ↪  secondLink.Source, secondLink.Target);
62          }
63
64          [MethodImpl(MethodImplOptions.AggressiveInlining)]
65          protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
66          {
67              ref var firstLink = ref GetLinkReference(first);
68              ref var secondLink = ref GetLinkReference(second);
69              return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
                ↪  secondLink.Source, secondLink.Target);
70          }
71
72          public TLink this[TLink index]
73          {
74              [MethodImpl(MethodImplOptions.AggressiveInlining)]
75              get
76              {
77                  var root = GetTreeRoot();
78                  if (GreaterOrEqualThan(index, GetSize(root)))
79                  {
80                      return Zero;
81                  }
82                  while (!EqualToZero(root))
83                  {
84                      var left = GetLeftOrDefault(root);
85                      var leftSize = GetSizeOrZero(left);
86                      if (LessThan(index, leftSize))
87                      {
88                          root = left;
89                          continue;
90                      }
91                      if (AreEqual(index, leftSize))
92                      {
93                          return root;
94                      }
95                      root = GetRightOrDefault(root);
96                      index = Subtract(index, Increment(leftSize));
97                  }
98                  return Zero; // TODO: Impossible situation exception (only if tree structure
                    ↪  broken)
99              }
100         }
101
102         /// <summary>
```

```
103         /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
            ↪ (концом).
104         /// </summary>
105         /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
106         /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
107         /// <returns>Индекс искомой связи.</returns>
108         [MethodImpl(MethodImplOptions.AggressiveInlining)]
109         public TLink Search(TLink source, TLink target)
110         {
111             var root = GetTreeRoot();
112             while (!EqualToZero(root))
113             {
114                 ref var rootLink = ref GetLinkReference(root);
115                 var rootSource = rootLink.Source;
116                 var rootTarget = rootLink.Target;
117                 if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
                    ↪ node.Key < root.Key
118                 {
119                     root = GetLeftOrDefault(root);
120                 }
121                 else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget)) //
                    ↪ node.Key > root.Key
122                 {
123                     root = GetRightOrDefault(root);
124                 }
125                 else // node.Key == root.Key
126                 {
127                     return root;
128                 }
129             }
130             return Zero;
131         }
132
133         // TODO: Return indices range instead of references count
134         [MethodImpl(MethodImplOptions.AggressiveInlining)]
135         public TLink CountUsages(TLink link)
136         {
137             var root = GetTreeRoot();
138             var total = GetSize(root);
139             var totalRightIgnore = Zero;
140             while (!EqualToZero(root))
141             {
142                 var @base = GetBasePartValue(root);
143                 if (LessOrEqualThan(@base, link))
144                 {
145                     root = GetRightOrDefault(root);
146                 }
147                 else
148                 {
149                     totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
150                     root = GetLeftOrDefault(root);
151                 }
152             }
153             root = GetTreeRoot();
154             var totalLeftIgnore = Zero;
155             while (!EqualToZero(root))
156             {
157                 var @base = GetBasePartValue(root);
158                 if (GreaterOrEqualThan(@base, link))
159                 {
160                     root = GetLeftOrDefault(root);
161                 }
162                 else
163                 {
164                     totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
165                     root = GetRightOrDefault(root);
166                 }
167             }
168             return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
169         }
170
171         [MethodImpl(MethodImplOptions.AggressiveInlining)]
172         public TLink EachUsage(TLink @base, Func<IList<TLink>, TLink> handler) =>
            ↪ EachUsageCore(@base, GetTreeRoot(), handler);
173
174         // TODO: 1. Move target, handler to separate object. 2. Use stack or walker 3. Use
            ↪ low-level MSIL stack.
175         [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
        private TLink EachUsageCore(TLink @base, TLink link, Func<IList<TLink>, TLink> handler)
        {
            var @continue = Continue;
            if (EqualToZero(link))
            {
                return @continue;
            }
            var linkBasePart = GetBasePartValue(link);
            var @break = Break;
            if (GreaterThan(linkBasePart, @base))
            {
                if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
                {
                    return @break;
                }
            }
            else if (LessThan(linkBasePart, @base))
            {
                if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
                {
                    return @break;
                }
            }
            else //if (linkBasePart == @base)
            {
                if (AreEqual(handler(GetLinkValues(link)), @break))
                {
                    return @break;
                }
                if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
                {
                    return @break;
                }
                if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
                {
                    return @break;
                }
            }
            return @continue;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void PrintNodeValue(TLink node, StringBuilder sb)
        {
            ref var link = ref GetLinkReference(node);
            sb.Append(' ');
            sb.Append(link.Source);
            sb.Append('-');
            sb.Append('>');
            sb.Append(link.Target);
        }
    }
}
```

1.59 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksSourcesAvlBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Generic
{
    public unsafe class LinksSourcesAvlBalancedTreeMethods<TLink> :
    ↪ LinksAvlBalancedTreeMethodsBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinksSourcesAvlBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
        ↪ byte* header) : base(constants, links, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref
        ↪ GetLinkReference(node).LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref
        ↪ GetLinkReference(node).RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsSource;

```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        ↪ GetLinkReference(node).LeftAsSource = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        ↪ GetLinkReference(node).RightAsSource = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) =>
        ↪ GetSizeValue(GetLinkReference(node).SizeAsSource);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) => SetSizeValue(ref
        ↪ GetLinkReference(node).SizeAsSource, size);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GetLeftIsChild(TLink node) =>
        ↪ GetLeftIsChildValue(GetLinkReference(node).SizeAsSource);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeftIsChild(TLink node, bool value) =>
        ↪ SetLeftIsChildValue(ref GetLinkReference(node).SizeAsSource, value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GetRightIsChild(TLink node) =>
        ↪ GetRightIsChildValue(GetLinkReference(node).SizeAsSource);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRightIsChild(TLink node, bool value) =>
        ↪ SetRightIsChildValue(ref GetLinkReference(node).SizeAsSource, value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override sbyte GetBalance(TLink node) =>
        ↪ GetBalanceValue(GetLinkReference(node).SizeAsSource);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetBalance(TLink node, sbyte value) => SetBalanceValue(ref
        ↪ GetLinkReference(node).SizeAsSource, value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot() => GetHeaderReference().RootAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
        ↪ TLink secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) ||
        ↪ (AreEqual(firstSource, secondSource) && LessThan(firstTarget, secondTarget));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
        ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) ||
        ↪ (AreEqual(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref GetLinkReference(node);
            link.LeftAsSource = Zero;
            link.RightAsSource = Zero;
            link.SizeAsSource = Zero;
        }
    }
}
```

1.60 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksSourcesSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Generic
{
    public unsafe class LinksSourcesSizeBalancedTreeMethods<TLink> :
    ↪ LinksSizeBalancedTreeMethodsBase<TLink>
```

```
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
        ↪  byte* header) : base(constants, links, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref
        ↪  GetLinkReference(node).LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref
        ↪  GetLinkReference(node).RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        ↪  GetLinkReference(node).LeftAsSource = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        ↪  GetLinkReference(node).RightAsSource = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) => GetLinkReference(node).SizeAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪  GetLinkReference(node).SizeAsSource = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot() => GetHeaderReference().RootAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) ||
        ↪  (AreEqual(firstSource, secondSource) && LessThan(firstTarget, secondTarget));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
        ↪  TLink secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) ||
        ↪  (AreEqual(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref GetLinkReference(node);
            link.LeftAsSource = Zero;
            link.RightAsSource = Zero;
            link.SizeAsSource = Zero;
        }
    }
}
```

1.61 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksTargetsAvlBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Generic
{
    public unsafe class LinksTargetsAvlBalancedTreeMethods<TLink> :
    ↪  LinksAvlBalancedTreeMethodsBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinksTargetsAvlBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
        ↪  byte* header) : base(constants, links, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref
        ↪  GetLinkReference(node).LeftAsTarget;

```

```
15          [MethodImpl(MethodImplOptions.AggressiveInlining)]
16          protected override ref TLink GetRightReference(TLink node) => ref
            ↪  GetLinkReference(node).RightAsTarget;
17
18          [MethodImpl(MethodImplOptions.AggressiveInlining)]
19          protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsTarget;
20
21          [MethodImpl(MethodImplOptions.AggressiveInlining)]
22          protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsTarget;
23
24          [MethodImpl(MethodImplOptions.AggressiveInlining)]
25          protected override void SetLeft(TLink node, TLink left) =>
            ↪  GetLinkReference(node).LeftAsTarget = left;
26
27          [MethodImpl(MethodImplOptions.AggressiveInlining)]
28          protected override void SetRight(TLink node, TLink right) =>
            ↪  GetLinkReference(node).RightAsTarget = right;
29
30          [MethodImpl(MethodImplOptions.AggressiveInlining)]
31          protected override TLink GetSize(TLink node) =>
            ↪  GetSizeValue(GetLinkReference(node).SizeAsTarget);
32
33          [MethodImpl(MethodImplOptions.AggressiveInlining)]
34          protected override void SetSize(TLink node, TLink size) => SetSizeValue(ref
            ↪  GetLinkReference(node).SizeAsTarget, size);
35
36          [MethodImpl(MethodImplOptions.AggressiveInlining)]
37          protected override bool GetLeftIsChild(TLink node) =>
            ↪  GetLeftIsChildValue(GetLinkReference(node).SizeAsTarget);
38
39          [MethodImpl(MethodImplOptions.AggressiveInlining)]
40          protected override void SetLeftIsChild(TLink node, bool value) =>
            ↪  SetLeftIsChildValue(ref GetLinkReference(node).SizeAsTarget, value);
41
42          [MethodImpl(MethodImplOptions.AggressiveInlining)]
43          protected override bool GetRightIsChild(TLink node) =>
            ↪  GetRightIsChildValue(GetLinkReference(node).SizeAsTarget);
44
45          [MethodImpl(MethodImplOptions.AggressiveInlining)]
46          protected override void SetRightIsChild(TLink node, bool value) =>
            ↪  SetRightIsChildValue(ref GetLinkReference(node).SizeAsTarget, value);
47
48          [MethodImpl(MethodImplOptions.AggressiveInlining)]
49          protected override sbyte GetBalance(TLink node) =>
            ↪  GetBalanceValue(GetLinkReference(node).SizeAsTarget);
50
51          [MethodImpl(MethodImplOptions.AggressiveInlining)]
52          protected override void SetBalance(TLink node, sbyte value) => SetBalanceValue(ref
            ↪  GetLinkReference(node).SizeAsTarget, value);
53
54          [MethodImpl(MethodImplOptions.AggressiveInlining)]
55          protected override TLink GetTreeRoot() => GetHeaderReference().RootAsTarget;
56
57          [MethodImpl(MethodImplOptions.AggressiveInlining)]
58          protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Target;
59
60          [MethodImpl(MethodImplOptions.AggressiveInlining)]
61          protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
            ↪  TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
            ↪  (AreEqual(firstTarget, secondTarget) && LessThan(firstSource, secondSource));
62
63          [MethodImpl(MethodImplOptions.AggressiveInlining)]
64          protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
            ↪  TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
            ↪  (AreEqual(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource));
65
66          [MethodImpl(MethodImplOptions.AggressiveInlining)]
67          protected override void ClearNode(TLink node)
68          {
69              ref var link = ref GetLinkReference(node);
70              link.LeftAsTarget = Zero;
71              link.RightAsTarget = Zero;
72              link.SizeAsTarget = Zero;
73          }
74      }
75  }
```

1.62 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksTargetsSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Generic
{
    public unsafe class LinksTargetsSizeBalancedTreeMethods<TLink> :
    ↪ LinksSizeBalancedTreeMethodsBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
        ↪ byte* header) : base(constants, links, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetLeftReference(TLink node) => ref
        ↪ GetLinkReference(node).LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref TLink GetRightReference(TLink node) => ref
        ↪ GetLinkReference(node).RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(TLink node, TLink left) =>
        ↪ GetLinkReference(node).LeftAsTarget = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(TLink node, TLink right) =>
        ↪ GetLinkReference(node).RightAsTarget = right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetSize(TLink node) => GetLinkReference(node).SizeAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink node, TLink size) =>
        ↪ GetLinkReference(node).SizeAsTarget = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetTreeRoot() => GetHeaderReference().RootAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
        ↪ TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
        ↪ (AreEqual(firstTarget, secondTarget) && LessThan(firstSource, secondSource));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
        ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
        ↪ (AreEqual(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(TLink node)
        {
            ref var link = ref GetLinkReference(node);
            link.LeftAsTarget = Zero;
            link.RightAsTarget = Zero;
            link.SizeAsTarget = Zero;
        }
    }
}
```

1.63 ./csharp/Platform.Data.Doublets/Memory/United/Generic/UnitedMemoryLinks.cs

```
using System;
using System.Runtime.CompilerServices;
using Platform.Singletons;
using Platform.Memory;
using static System.Runtime.CompilerServices.Unsafe;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

```

```
9  namespace Platform.Data.Doublets.Memory.United.Generic
10 {
11     public unsafe class UnitedMemoryLinks<TLink> : UnitedMemoryLinksBase<TLink>
12     {
13         private readonly Func<ILinksTreeMethods<TLink>> _createSourceTreeMethods;
14         private readonly Func<ILinksTreeMethods<TLink>> _createTargetTreeMethods;
15         private byte* _header;
16         private byte* _links;
17 
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         public UnitedMemoryLinks(string address) : this(address, DefaultLinksSizeStep) { }
20 
21         /// <summary>
22         /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
            ↪ минимальным шагом расширения базы данных.
23         /// </summary>
24         /// <param name="address">Полный пусть к файлу базы данных.</param>
25         /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
            ↪ байтах.</param>
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         public UnitedMemoryLinks(string address, long memoryReservationStep) : this(new
            ↪ FileMappedResizableDirectMemory(address, memoryReservationStep),
            ↪ memoryReservationStep) { }
28 
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         public UnitedMemoryLinks(IResizableDirectMemory memory) : this(memory,
            ↪ DefaultLinksSizeStep) { }
31 
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         public UnitedMemoryLinks(IResizableDirectMemory memory, long memoryReservationStep) :
            ↪ this(memory, memoryReservationStep, Default<LinksConstants<TLink>>.Instance,
            ↪ IndexTreeType.Default) { }
34 
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         public UnitedMemoryLinks(IResizableDirectMemory memory, long memoryReservationStep,
            ↪ LinksConstants<TLink> constants, IndexTreeType indexTreeType) : base(memory,
            ↪ memoryReservationStep, constants)
37         {
38             if (indexTreeType == IndexTreeType.SizedAndThreadedAVLBalancedTree)
39             {
40                 _createSourceTreeMethods = () => new
                    ↪ LinksSourcesAvlBalancedTreeMethods<TLink>(Constants, _links, _header);
41                 _createTargetTreeMethods = () => new
                    ↪ LinksTargetsAvlBalancedTreeMethods<TLink>(Constants, _links, _header);
42             }
43             else
44             {
45                 _createSourceTreeMethods = () => new
                    ↪ LinksSourcesSizeBalancedTreeMethods<TLink>(Constants, _links, _header);
46                 _createTargetTreeMethods = () => new
                    ↪ LinksTargetsSizeBalancedTreeMethods<TLink>(Constants, _links, _header);
47             }
48             Init(memory, memoryReservationStep);
49         }
50 
51         [MethodImpl(MethodImplOptions.AggressiveInlining)]
52         protected override void SetPointers(IResizableDirectMemory memory)
53         {
54             _links = (byte*)memory.Pointer;
55             _header = _links;
56             SourcesTreeMethods = _createSourceTreeMethods();
57             TargetsTreeMethods = _createTargetTreeMethods();
58             UnusedLinksListMethods = new UnusedLinksListMethods<TLink>(_links, _header);
59         }
60 
61         [MethodImpl(MethodImplOptions.AggressiveInlining)]
62         protected override void ResetPointers()
63         {
64             base.ResetPointers();
65             _links = null;
66             _header = null;
67         }
68 
69         [MethodImpl(MethodImplOptions.AggressiveInlining)]
70         protected override ref LinksHeader<TLink> GetHeaderReference() => ref
            ↪ AsRef<LinksHeader<TLink>>(_header);
71 
72         [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
73          protected override ref RawLink<TLink> GetLinkReference(TLink linkIndex) => ref
            ↪  AsRef<RawLink<TLink>>(_links + (LinkSizeInBytes * ConvertToInt64(linkIndex)));
74      }
75  }
```

1.64 ./csharp/Platform.Data.Doublets/Memory/United/Generic/UnitedMemoryLinksBase.cs

```
1   using System;
2   using System.Collections.Generic;
3   using System.Runtime.CompilerServices;
4   using Platform.Disposables;
5   using Platform.Singletons;
6   using Platform.Converters;
7   using Platform.Numbers;
8   using Platform.Memory;
9   using Platform.Data.Exceptions;
10
11  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
12
13  namespace Platform.Data.Doublets.Memory.United.Generic
14  {
15      public abstract class UnitedMemoryLinksBase<TLink> : DisposableBase, ILinks<TLink>
16      {
17          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪  EqualityComparer<TLink>.Default;
18          private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
19          private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
            ↪  UncheckedConverter<TLink, long>.Default;
20          private static readonly UncheckedConverter<long, TLink> _int64ToAddressConverter =
            ↪  UncheckedConverter<long, TLink>.Default;
21
22          private static readonly TLink _zero = default;
23          private static readonly TLink _one = Arithmetic.Increment(_zero);
24
25          /// <summary>Возвращает размер одной связи в байтах.</summary>
26          /// <remarks>
27          /// Используется только во вне класса, не рекомедуется использовать внутри.
28          /// Так как во вне не обязательно будет доступен unsafe C#.
29          /// </remarks>
30          public static readonly long LinkSizeInBytes = RawLink<TLink>.SizeInBytes;
31
32          public static readonly long LinkHeaderSizeInBytes = LinksHeader<TLink>.SizeInBytes;
33
34          public static readonly long DefaultLinksSizeStep = LinkSizeInBytes * 1024 * 1024;
35
36          protected readonly IResizableDirectMemory _memory;
37          protected readonly long _memoryReservationStep;
38
39          protected ILinksTreeMethods<TLink> TargetsTreeMethods;
40          protected ILinksTreeMethods<TLink> SourcesTreeMethods;
41          // TODO: Возможно чтобы гарантированно проверять на то, является ли связь удалённой,
            ↪  нужно использовать не список а дерево, так как так можно быстрее проверить на
            ↪  наличие связи внутри
42          protected ILinksListMethods<TLink> UnusedLinksListMethods;
43
44          /// <summary>
45          /// Возвращает общее число связей находящихся в хранилище.
46          /// </summary>
47          protected virtual TLink Total
48          {
49              [MethodImpl(MethodImplOptions.AggressiveInlining)]
50              get
51              {
52                  ref var header = ref GetHeaderReference();
53                  return Subtract(header.AllocatedLinks, header.FreeLinks);
54              }
55          }
56
57          public virtual LinksConstants<TLink> Constants
58          {
59              [MethodImpl(MethodImplOptions.AggressiveInlining)]
60              get;
61          }
62
63          [MethodImpl(MethodImplOptions.AggressiveInlining)]
64          protected UnitedMemoryLinksBase(IResizableDirectMemory memory, long
            ↪  memoryReservationStep, LinksConstants<TLink> constants)
65          {
66              _memory = memory;
67              _memoryReservationStep = memoryReservationStep;
68              Constants = constants;
69          }
```

```
70
71          [MethodImpl(MethodImplOptions.AggressiveInlining)]
72          protected UnitedMemoryLinksBase(IResizableDirectMemory memory, long
            ↪  memoryReservationStep) : this(memory, memoryReservationStep,
            ↪  Default<LinksConstants<TLink>>.Instance) { }
73
74          [MethodImpl(MethodImplOptions.AggressiveInlining)]
75          protected virtual void Init(IResizableDirectMemory memory, long memoryReservationStep)
76          {
77              if (memory.ReservedCapacity < memoryReservationStep)
78              {
79                  memory.ReservedCapacity = memoryReservationStep;
80              }
81              SetPointers(memory);
82              ref var header = ref GetHeaderReference();
83              // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
84              memory.UsedCapacity = (ConvertToInt64(header.AllocatedLinks) * LinkSizeInBytes) +
                ↪  LinkHeaderSizeInBytes;
85              // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
86              header.ReservedLinks = ConvertToAddress((memory.ReservedCapacity -
                ↪  LinkHeaderSizeInBytes) / LinkSizeInBytes);
87          }
88
89          [MethodImpl(MethodImplOptions.AggressiveInlining)]
90          public virtual TLink Count(IList<TLink> restrictions)
91          {
92              // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
93              if (restrictions.Count == 0)
94              {
95                  return Total;
96              }
97              var constants = Constants;
98              var any = constants.Any;
99              var index = restrictions[constants.IndexPart];
100             if (restrictions.Count == 1)
101             {
102                 if (AreEqual(index, any))
103                 {
104                     return Total;
105                 }
106                 return Exists(index) ? GetOne() : GetZero();
107             }
108             if (restrictions.Count == 2)
109             {
110                 var value = restrictions[1];
111                 if (AreEqual(index, any))
112                 {
113                     if (AreEqual(value, any))
114                     {
115                         return Total; // Any - как отсутствие ограничения
116                     }
117                     return Add(SourcesTreeMethods.CountUsages(value),
                        ↪  TargetsTreeMethods.CountUsages(value));
118                 }
119                 else
120                 {
121                     if (!Exists(index))
122                     {
123                         return GetZero();
124                     }
125                     if (AreEqual(value, any))
126                     {
127                         return GetOne();
128                     }
129                     ref var storedLinkValue = ref GetLinkReference(index);
130                     if (AreEqual(storedLinkValue.Source, value) ||
                        ↪  AreEqual(storedLinkValue.Target, value))
131                     {
132                         return GetOne();
133                     }
134                     return GetZero();
135                 }
136             }
137             if (restrictions.Count == 3)
138             {
139                 var source = restrictions[constants.SourcePart];
140                 var target = restrictions[constants.TargetPart];
141                 if (AreEqual(index, any))
```

```
142                 {
143                     if (AreEqual(source, any) && AreEqual(target, any))
144                     {
145                         return Total;
146                     }
147                     else if (AreEqual(source, any))
148                     {
149                         return TargetsTreeMethods.CountUsages(target);
150                     }
151                     else if (AreEqual(target, any))
152                     {
153                         return SourcesTreeMethods.CountUsages(source);
154                     }
155                     else //if(source != Any && target != Any)
156                     {
157                         // Эквивалент Exists(source, target) => Count(Any, source, target) > 0
158                         var link = SourcesTreeMethods.Search(source, target);
159                         return AreEqual(link, constants.Null) ? GetZero() : GetOne();
160                     }
161                 }
162                 else
163                 {
164                     if (!Exists(index))
165                     {
166                         return GetZero();
167                     }
168                     if (AreEqual(source, any) && AreEqual(target, any))
169                     {
170                         return GetOne();
171                     }
172                     ref var storedLinkValue = ref GetLinkReference(index);
173                     if (!AreEqual(source, any) && !AreEqual(target, any))
174                     {
175                         if (AreEqual(storedLinkValue.Source, source) &&
                            ↪  AreEqual(storedLinkValue.Target, target))
176                         {
177                             return GetOne();
178                         }
179                         return GetZero();
180                     }
181                     var value = default(TLink);
182                     if (AreEqual(source, any))
183                     {
184                         value = target;
185                     }
186                     if (AreEqual(target, any))
187                     {
188                         value = source;
189                     }
190                     if (AreEqual(storedLinkValue.Source, value) ||
                        ↪  AreEqual(storedLinkValue.Target, value))
191                     {
192                         return GetOne();
193                     }
194                     return GetZero();
195                 }
196             }
197             throw new NotSupportedException("Другие размеры и способы ограничений не
                ↪  поддерживаются.");
198         }
199 
200         [MethodImpl(MethodImplOptions.AggressiveInlining)]
201         public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
202         {
203             var constants = Constants;
204             var @break = constants.Break;
205             if (restrictions.Count == 0)
206             {
207                 for (var link = GetOne(); LessOrEqualThan(link,
                    ↪  GetHeaderReference().AllocatedLinks); link = Increment(link))
208                 {
209                     if (Exists(link) && AreEqual(handler(GetLinkStruct(link)), @break))
210                     {
211                         return @break;
212                     }
213                 }
214                 return @break;
215             }
```

```
216             var @continue = constants.Continue;
217             var any = constants.Any;
218             var index = restrictions[constants.IndexPart];
219             if (restrictions.Count == 1)
220             {
221                 if (AreEqual(index, any))
222                 {
223                     return Each(handler, Array.Empty<TLink>());
224                 }
225                 if (!Exists(index))
226                 {
227                     return @continue;
228                 }
229                 return handler(GetLinkStruct(index));
230             }
231             if (restrictions.Count == 2)
232             {
233                 var value = restrictions[1];
234                 if (AreEqual(index, any))
235                 {
236                     if (AreEqual(value, any))
237                     {
238                         return Each(handler, Array.Empty<TLink>());
239                     }
240                     if (AreEqual(Each(handler, new Link<TLink>(index, value, any)), @break))
241                     {
242                         return @break;
243                     }
244                     return Each(handler, new Link<TLink>(index, any, value));
245                 }
246                 else
247                 {
248                     if (!Exists(index))
249                     {
250                         return @continue;
251                     }
252                     if (AreEqual(value, any))
253                     {
254                         return handler(GetLinkStruct(index));
255                     }
256                     ref var storedLinkValue = ref GetLinkReference(index);
257                     if (AreEqual(storedLinkValue.Source, value) ||
258                         AreEqual(storedLinkValue.Target, value))
259                     {
260                         return handler(GetLinkStruct(index));
261                     }
262                     return @continue;
263                 }
264             }
265             if (restrictions.Count == 3)
266             {
267                 var source = restrictions[constants.SourcePart];
268                 var target = restrictions[constants.TargetPart];
269                 if (AreEqual(index, any))
270                 {
271                     if (AreEqual(source, any) && AreEqual(target, any))
272                     {
273                         return Each(handler, Array.Empty<TLink>());
274                     }
275                     else if (AreEqual(source, any))
276                     {
277                         return TargetsTreeMethods.EachUsage(target, handler);
278                     }
279                     else if (AreEqual(target, any))
280                     {
281                         return SourcesTreeMethods.EachUsage(source, handler);
282                     }
283                     else //if(source != Any && target != Any)
284                     {
285                         var link = SourcesTreeMethods.Search(source, target);
286                         return AreEqual(link, constants.Null) ? @continue :
                            ↪  handler(GetLinkStruct(link));
287                     }
288                 }
289                 else
290                 {
291                     if (!Exists(index))
292                     {
```

```
                        return @continue;
                    }
                    if (AreEqual(source, any) && AreEqual(target, any))
                    {
                        return handler(GetLinkStruct(index));
                    }
                    ref var storedLinkValue = ref GetLinkReference(index);
                    if (!AreEqual(source, any) && !AreEqual(target, any))
                    {
                        if (AreEqual(storedLinkValue.Source, source) &&
                            AreEqual(storedLinkValue.Target, target))
                        {
                            return handler(GetLinkStruct(index));
                        }
                        return @continue;
                    }
                    var value = default(TLink);
                    if (AreEqual(source, any))
                    {
                        value = target;
                    }
                    if (AreEqual(target, any))
                    {
                        value = source;
                    }
                    if (AreEqual(storedLinkValue.Source, value) ||
                        AreEqual(storedLinkValue.Target, value))
                    {
                        return handler(GetLinkStruct(index));
                    }
                    return @continue;
                }
            }
            throw new NotSupportedException("Другие размеры и способы ограничений не
            ↪  поддерживаются.");
        }

        /// <remarks>
        /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
        ↪  в другом месте (но не в менеджере памяти, а в логике Links)
        /// </remarks>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
        {
            var constants = Constants;
            var @null = constants.Null;
            var linkIndex = restrictions[constants.IndexPart];
            ref var link = ref GetLinkReference(linkIndex);
            ref var header = ref GetHeaderReference();
            ref var firstAsSource = ref header.RootAsSource;
            ref var firstAsTarget = ref header.RootAsTarget;
            // Будет корректно работать только в том случае, если пространство выделенной связи
            ↪  предварительно заполнено нулями
            if (!AreEqual(link.Source, @null))
            {
                SourcesTreeMethods.Detach(ref firstAsSource, linkIndex);
            }
            if (!AreEqual(link.Target, @null))
            {
                TargetsTreeMethods.Detach(ref firstAsTarget, linkIndex);
            }
            link.Source = substitution[constants.SourcePart];
            link.Target = substitution[constants.TargetPart];
            if (!AreEqual(link.Source, @null))
            {
                SourcesTreeMethods.Attach(ref firstAsSource, linkIndex);
            }
            if (!AreEqual(link.Target, @null))
            {
                TargetsTreeMethods.Attach(ref firstAsTarget, linkIndex);
            }
            return linkIndex;
        }

        /// <remarks>
        /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
        ↪  пространство
        /// </remarks>
```

```
367         [MethodImpl(MethodImplOptions.AggressiveInlining)]
368         public virtual TLink Create(IList<TLink> restrictions)
369         {
370             ref var header = ref GetHeaderReference();
371             var freeLink = header.FirstFreeLink;
372             if (!AreEqual(freeLink, Constants.Null))
373             {
374                 UnusedLinksListMethods.Detach(freeLink);
375             }
376             else
377             {
378                 var maximumPossibleInnerReference = Constants.InternalReferencesRange.Maximum;
379                 if (GreaterThan(header.AllocatedLinks, maximumPossibleInnerReference))
380                 {
381                     throw new LinksLimitReachedException<TLink>(maximumPossibleInnerReference);
382                 }
383                 if (GreaterOrEqualThan(header.AllocatedLinks, Decrement(header.ReservedLinks)))
384                 {
385                     _memory.ReservedCapacity += _memoryReservationStep;
386                     SetPointers(_memory);
387                     header = ref GetHeaderReference();
388                     header.ReservedLinks = ConvertToAddress(_memory.ReservedCapacity /
                        ↪  LinkSizeInBytes);
389                 }
390                 header.AllocatedLinks = Increment(header.AllocatedLinks);
391                 _memory.UsedCapacity += LinkSizeInBytes;
392                 freeLink = header.AllocatedLinks;
393             }
394             return freeLink;
395         }
396 
397         [MethodImpl(MethodImplOptions.AggressiveInlining)]
398         public virtual void Delete(IList<TLink> restrictions)
399         {
400             ref var header = ref GetHeaderReference();
401             var link = restrictions[Constants.IndexPart];
402             if (LessThan(link, header.AllocatedLinks))
403             {
404                 UnusedLinksListMethods.AttachAsFirst(link);
405             }
406             else if (AreEqual(link, header.AllocatedLinks))
407             {
408                 header.AllocatedLinks = Decrement(header.AllocatedLinks);
409                 _memory.UsedCapacity -= LinkSizeInBytes;
410                 // Убираем все связи, находящиеся в списке свободных в конце файла, до тех пор,
                    ↪  пока не дойдём до первой существующей связи
411                 // Позволяет оптимизировать количество выделенных связей (AllocatedLinks)
412                 while (GreaterThan(header.AllocatedLinks, GetZero()) &&
                        ↪  IsUnusedLink(header.AllocatedLinks))
413                 {
414                     UnusedLinksListMethods.Detach(header.AllocatedLinks);
415                     header.AllocatedLinks = Decrement(header.AllocatedLinks);
416                     _memory.UsedCapacity -= LinkSizeInBytes;
417                 }
418             }
419         }
420 
421         [MethodImpl(MethodImplOptions.AggressiveInlining)]
422         public IList<TLink> GetLinkStruct(TLink linkIndex)
423         {
424             ref var link = ref GetLinkReference(linkIndex);
425             return new Link<TLink>(linkIndex, link.Source, link.Target);
426         }
427 
428         /// <remarks>
429         /// TODO: Возможно это должно быть событием, вызываемым из IMemory, в том случае, если
                ↪  адрес реально поменялся
430         ///
431         /// Указатель this.links может быть в том же месте,
432         /// так как 0-я связь не используется и имеет такой же размер как Header,
433         /// поэтому header размещается в том же месте, что и 0-я связь
434         /// </remarks>
435         [MethodImpl(MethodImplOptions.AggressiveInlining)]
436         protected abstract void SetPointers(IResizableDirectMemory memory);
437 
438         [MethodImpl(MethodImplOptions.AggressiveInlining)]
439         protected virtual void ResetPointers()
440         {
441             SourcesTreeMethods = null;
```

```
442             TargetsTreeMethods = null;
443             UnusedLinksListMethods = null;
444         }
445 
446         [MethodImpl(MethodImplOptions.AggressiveInlining)]
447         protected abstract ref LinksHeader<TLink> GetHeaderReference();
448 
449         [MethodImpl(MethodImplOptions.AggressiveInlining)]
450         protected abstract ref RawLink<TLink> GetLinkReference(TLink linkIndex);
451 
452         [MethodImpl(MethodImplOptions.AggressiveInlining)]
453         protected virtual bool Exists(TLink link)
454             => GreaterOrEqualThan(link, Constants.InternalReferencesRange.Minimum)
455             && LessOrEqualThan(link, GetHeaderReference().AllocatedLinks)
456             && !IsUnusedLink(link);
457 
458         [MethodImpl(MethodImplOptions.AggressiveInlining)]
459         protected virtual bool IsUnusedLink(TLink linkIndex)
460         {
461             if (!AreEqual(GetHeaderReference().FirstFreeLink, linkIndex)) // May be this check
                ↪  is not needed
462             {
463                 ref var link = ref GetLinkReference(linkIndex);
464                 return AreEqual(link.SizeAsSource, default) && !AreEqual(link.Source, default);
465             }
466             else
467             {
468                 return true;
469             }
470         }
471 
472         [MethodImpl(MethodImplOptions.AggressiveInlining)]
473         protected virtual TLink GetOne() => _one;
474 
475         [MethodImpl(MethodImplOptions.AggressiveInlining)]
476         protected virtual TLink GetZero() => default;
477 
478         [MethodImpl(MethodImplOptions.AggressiveInlining)]
479         protected virtual bool AreEqual(TLink first, TLink second) =>
                ↪  _equalityComparer.Equals(first, second);
480 
481         [MethodImpl(MethodImplOptions.AggressiveInlining)]
482         protected virtual bool LessThan(TLink first, TLink second) => _comparer.Compare(first,
                ↪  second) < 0;
483 
484         [MethodImpl(MethodImplOptions.AggressiveInlining)]
485         protected virtual bool LessOrEqualThan(TLink first, TLink second) =>
                ↪  _comparer.Compare(first, second) <= 0;
486 
487         [MethodImpl(MethodImplOptions.AggressiveInlining)]
488         protected virtual bool GreaterThan(TLink first, TLink second) =>
                ↪  _comparer.Compare(first, second) > 0;
489 
490         [MethodImpl(MethodImplOptions.AggressiveInlining)]
491         protected virtual bool GreaterOrEqualThan(TLink first, TLink second) =>
                ↪  _comparer.Compare(first, second) >= 0;
492 
493         [MethodImpl(MethodImplOptions.AggressiveInlining)]
494         protected virtual long ConvertToInt64(TLink value) =>
                ↪  _addressToInt64Converter.Convert(value);
495 
496         [MethodImpl(MethodImplOptions.AggressiveInlining)]
497         protected virtual TLink ConvertToAddress(long value) =>
                ↪  _int64ToAddressConverter.Convert(value);
498 
499         [MethodImpl(MethodImplOptions.AggressiveInlining)]
500         protected virtual TLink Add(TLink first, TLink second) => Arithmetic<TLink>.Add(first,
                ↪  second);
501 
502         [MethodImpl(MethodImplOptions.AggressiveInlining)]
503         protected virtual TLink Subtract(TLink first, TLink second) =>
                ↪  Arithmetic<TLink>.Subtract(first, second);
504 
505         [MethodImpl(MethodImplOptions.AggressiveInlining)]
506         protected virtual TLink Increment(TLink link) => Arithmetic<TLink>.Increment(link);
507 
508         [MethodImpl(MethodImplOptions.AggressiveInlining)]
509         protected virtual TLink Decrement(TLink link) => Arithmetic<TLink>.Decrement(link);
510 
```

```
511         #region Disposable
512
513         protected override bool AllowMultipleDisposeCalls
514         {
515             [MethodImpl(MethodImplOptions.AggressiveInlining)]
516             get => true;
517         }
518
519         [MethodImpl(MethodImplOptions.AggressiveInlining)]
520         protected override void Dispose(bool manual, bool wasDisposed)
521         {
522             if (!wasDisposed)
523             {
524                 ResetPointers();
525                 _memory.DisposeIfPossible();
526             }
527         }
528
529         #endregion
530     }
531 }
```

1.65 ./csharp/Platform.Data.Doublets/Memory/United/Generic/UnusedLinksListMethods.cs

```
1  using System.Runtime.CompilerServices;
2  using Platform.Collections.Methods.Lists;
3  using Platform.Converters;
4  using static System.Runtime.CompilerServices.Unsafe;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Memory.United.Generic
9  {
10     public unsafe class UnusedLinksListMethods<TLink> : CircularDoublyLinkedListMethods<TLink>,
       ↪  ILinksListMethods<TLink>
11     {
12         private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
           ↪  UncheckedConverter<TLink, long>.Default;
13
14         private readonly byte* _links;
15         private readonly byte* _header;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         public UnusedLinksListMethods(byte* links, byte* header)
19         {
20             _links = links;
21             _header = header;
22         }
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
           ↪  AsRef<LinksHeader<TLink>>(_header);
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
           ↪  AsRef<RawLink<TLink>>(_links + (RawLink<TLink>.SizeInBytes *
           ↪  _addressToInt64Converter.Convert(link)));
29
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]
31         protected override TLink GetFirst() => GetHeaderReference().FirstFreeLink;
32
33         [MethodImpl(MethodImplOptions.AggressiveInlining)]
34         protected override TLink GetLast() => GetHeaderReference().LastFreeLink;
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected override TLink GetPrevious(TLink element) => GetLinkReference(element).Source;
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override TLink GetNext(TLink element) => GetLinkReference(element).Target;
41
42         [MethodImpl(MethodImplOptions.AggressiveInlining)]
43         protected override TLink GetSize() => GetHeaderReference().FreeLinks;
44
45         [MethodImpl(MethodImplOptions.AggressiveInlining)]
46         protected override void SetFirst(TLink element) => GetHeaderReference().FirstFreeLink =
           ↪  element;
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         protected override void SetLast(TLink element) => GetHeaderReference().LastFreeLink =
           ↪  element;
50
```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetPrevious(TLink element, TLink previous) =>
        ↪ GetLinkReference(element).Source = previous;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetNext(TLink element, TLink next) =>
        ↪ GetLinkReference(element).Target = next;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(TLink size) => GetHeaderReference().FreeLinks = size;
    }
}
```

1.66 ./csharp/Platform.Data.Doublets/Memory/United/RawLink.cs

```
using Platform.Unsafe;
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United
{
    public struct RawLink<TLink> : IEquatable<RawLink<TLink>>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;

        public static readonly long SizeInBytes = Structure<RawLink<TLink>>.Size;

        public TLink Source;
        public TLink Target;
        public TLink LeftAsSource;
        public TLink RightAsSource;
        public TLink SizeAsSource;
        public TLink LeftAsTarget;
        public TLink RightAsTarget;
        public TLink SizeAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override bool Equals(object obj) => obj is RawLink<TLink> link ? Equals(link) :
        ↪ false;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Equals(RawLink<TLink> other)
            => _equalityComparer.Equals(Source, other.Source)
            && _equalityComparer.Equals(Target, other.Target)
            && _equalityComparer.Equals(LeftAsSource, other.LeftAsSource)
            && _equalityComparer.Equals(RightAsSource, other.RightAsSource)
            && _equalityComparer.Equals(SizeAsSource, other.SizeAsSource)
            && _equalityComparer.Equals(LeftAsTarget, other.LeftAsTarget)
            && _equalityComparer.Equals(RightAsTarget, other.RightAsTarget)
            && _equalityComparer.Equals(SizeAsTarget, other.SizeAsTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override int GetHashCode() => (Source, Target, LeftAsSource, RightAsSource,
        ↪ SizeAsSource, LeftAsTarget, RightAsTarget, SizeAsTarget).GetHashCode();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool operator ==(RawLink<TLink> left, RawLink<TLink> right) =>
        ↪ left.Equals(right);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool operator !=(RawLink<TLink> left, RawLink<TLink> right) => !(left ==
        ↪ right);
    }
}
```

1.67 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt32LinksSizeBalancedTreeMethodsBase.cs

```
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Memory.United.Generic;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Specific
{
    public unsafe abstract class UInt32LinksSizeBalancedTreeMethodsBase :
    ↪ LinksSizeBalancedTreeMethodsBase<uint>
    {
        protected new readonly RawLink<uint>* Links;
```

```
        protected new readonly LinksHeader<uint>* Header;

        protected UInt32LinksSizeBalancedTreeMethodsBase(LinksConstants<uint> constants,
        ↪  RawLink<uint>* links, LinksHeader<uint>* header)
            : base(constants, (byte*)links, (byte*)header)
        {
            Links = links;
            Header = header;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint GetZero() => 0U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool EqualToZero(uint value) => value == 0U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool AreEqual(uint first, uint second) => first == second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThanZero(uint value) => value > 0U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThan(uint first, uint second) => first > second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThan(uint first, uint second) => first >= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThanZero(uint value) => true; // value >= 0 is
        ↪  always true for uint

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThanZero(uint value) => value == 0U; // value is
        ↪  always >= 0 for uint

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThan(uint first, uint second) => first <= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThanZero(uint value) => false; // value < 0 is always false
        ↪  for uint

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThan(uint first, uint second) => first < second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint Increment(uint value) => ++value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint Decrement(uint value) => --value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint Add(uint first, uint second) => first + second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint Subtract(uint first, uint second) => first - second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(uint first, uint second)
        {
            ref var firstLink = ref Links[first];
            ref var secondLink = ref Links[second];
            return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
            ↪  secondLink.Source, secondLink.Target);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(uint first, uint second)
        {
            ref var firstLink = ref Links[first];
            ref var secondLink = ref Links[second];
            return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
            ↪  secondLink.Source, secondLink.Target);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref LinksHeader<uint> GetHeaderReference() => ref *Header;

```

```
84          [MethodImpl(MethodImplOptions.AggressiveInlining)]
85          protected override ref RawLink<uint> GetLinkReference(uint link) => ref Links[link];
86      }
87  }
```

1.68 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt32LinksSourcesSizeBalancedTreeMethods.cs

```
1   using System.Runtime.CompilerServices;
2
3   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5   namespace Platform.Data.Doublets.Memory.United.Specific
6   {
7       public unsafe class UInt32LinksSourcesSizeBalancedTreeMethods :
        ↪  UInt32LinksSizeBalancedTreeMethodsBase
8       {
9           public UInt32LinksSourcesSizeBalancedTreeMethods(LinksConstants<uint> constants,
            ↪  RawLink<uint>* links, LinksHeader<uint>* header) : base(constants, links, header) { }
10
11          [MethodImpl(MethodImplOptions.AggressiveInlining)]
12          protected override ref uint GetLeftReference(uint node) => ref Links[node].LeftAsSource;
13
14          [MethodImpl(MethodImplOptions.AggressiveInlining)]
15          protected override ref uint GetRightReference(uint node) => ref
            ↪  Links[node].RightAsSource;
16
17          [MethodImpl(MethodImplOptions.AggressiveInlining)]
18          protected override uint GetLeft(uint node) => Links[node].LeftAsSource;
19
20          [MethodImpl(MethodImplOptions.AggressiveInlining)]
21          protected override uint GetRight(uint node) => Links[node].RightAsSource;
22
23          [MethodImpl(MethodImplOptions.AggressiveInlining)]
24          protected override void SetLeft(uint node, uint left) => Links[node].LeftAsSource = left;
25
26          [MethodImpl(MethodImplOptions.AggressiveInlining)]
27          protected override void SetRight(uint node, uint right) => Links[node].RightAsSource =
            ↪  right;
28
29          [MethodImpl(MethodImplOptions.AggressiveInlining)]
30          protected override uint GetSize(uint node) => Links[node].SizeAsSource;
31
32          [MethodImpl(MethodImplOptions.AggressiveInlining)]
33          protected override void SetSize(uint node, uint size) => Links[node].SizeAsSource = size;
34
35          [MethodImpl(MethodImplOptions.AggressiveInlining)]
36          protected override uint GetTreeRoot() => Header->RootAsSource;
37
38          [MethodImpl(MethodImplOptions.AggressiveInlining)]
39          protected override uint GetBasePartValue(uint link) => Links[link].Source;
40
41          [MethodImpl(MethodImplOptions.AggressiveInlining)]
42          protected override bool FirstIsToTheLeftOfSecond(uint firstSource, uint firstTarget,
            ↪  uint secondSource, uint secondTarget)
43              => firstSource < secondSource || (firstSource == secondSource && firstTarget <
                ↪  secondTarget);
44
45          [MethodImpl(MethodImplOptions.AggressiveInlining)]
46          protected override bool FirstIsToTheRightOfSecond(uint firstSource, uint firstTarget,
            ↪  uint secondSource, uint secondTarget)
47              => firstSource > secondSource || (firstSource == secondSource && firstTarget >
                ↪  secondTarget);
48
49          [MethodImpl(MethodImplOptions.AggressiveInlining)]
50          protected override void ClearNode(uint node)
51          {
52              ref var link = ref Links[node];
53              link.LeftAsSource = 0U;
54              link.RightAsSource = 0U;
55              link.SizeAsSource = 0U;
56          }
57      }
58  }
```

1.69 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt32LinksTargetsSizeBalancedTreeMethods.cs

```
1   using System.Runtime.CompilerServices;
2
3   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5   namespace Platform.Data.Doublets.Memory.United.Specific
```

```
{
    public unsafe class UInt32LinksTargetsSizeBalancedTreeMethods :
    ↪ UInt32LinksSizeBalancedTreeMethodsBase
    {
        public UInt32LinksTargetsSizeBalancedTreeMethods(LinksConstants<uint> constants,
        ↪ RawLink<uint>* links, LinksHeader<uint>* header) : base(constants, links, header) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref uint GetLeftReference(uint node) => ref Links[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref uint GetRightReference(uint node) => ref
        ↪ Links[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint GetLeft(uint node) => Links[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint GetRight(uint node) => Links[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(uint node, uint left) => Links[node].LeftAsTarget = left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(uint node, uint right) => Links[node].RightAsTarget =
        ↪ right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint GetSize(uint node) => Links[node].SizeAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(uint node, uint size) => Links[node].SizeAsTarget = size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint GetTreeRoot() => Header->RootAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint GetBasePartValue(uint link) => Links[link].Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(uint firstSource, uint firstTarget,
        ↪ uint secondSource, uint secondTarget)
            => firstTarget < secondTarget || (firstTarget == secondTarget && firstSource <
            ↪ secondSource);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(uint firstSource, uint firstTarget,
        ↪ uint secondSource, uint secondTarget)
            => firstTarget > secondTarget || (firstTarget == secondTarget && firstSource >
            ↪ secondSource);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(uint node)
        {
            ref var link = ref Links[node];
            link.LeftAsTarget = 0U;
            link.RightAsTarget = 0U;
            link.SizeAsTarget = 0U;
        }
    }
}
```

1.70 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt32UnitedMemoryLinks.cs

```
using System;
using System.Runtime.CompilerServices;
using Platform.Memory;
using Platform.Singletons;
using Platform.Data.Doublets.Memory.United.Generic;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Specific
{
    /// <summary>
    /// <para>Represents a low-level implementation of direct access to resizable memory, for
    ↪ organizing the storage of links with addresses represented as <see cref="uint" />.</para>
    /// <para>Представляет низкоуровневую реализация прямого доступа к памяти с переменным
    ↪ размером, для организации хранения связей с адресами представленными в виде <see
    ↪ cref="uint"/>.</para>
```

```
14      /// </summary>
15      public unsafe class UInt32UnitedMemoryLinks : UnitedMemoryLinksBase<uint>
16      {
17          private readonly Func<ILinksTreeMethods<uint>> _createSourceTreeMethods;
18          private readonly Func<ILinksTreeMethods<uint>> _createTargetTreeMethods;
19          private LinksHeader<uint>* _header;
20          private RawLink<uint>* _links;
21
22          [MethodImpl(MethodImplOptions.AggressiveInlining)]
23          public UInt32UnitedMemoryLinks(string address) : this(address, DefaultLinksSizeStep) { }
24
25          /// <summary>
26          /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
            ↪  минимальным шагом расширения базы данных.
27          /// </summary>
28          /// <param name="address">Полный пусть к файлу базы данных.</param>
29          /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
            ↪  байтах.</param>
30          [MethodImpl(MethodImplOptions.AggressiveInlining)]
31          public UInt32UnitedMemoryLinks(string address, long memoryReservationStep) : this(new
            ↪  FileMappedResizableDirectMemory(address, memoryReservationStep),
            ↪  memoryReservationStep) { }
32
33          [MethodImpl(MethodImplOptions.AggressiveInlining)]
34          public UInt32UnitedMemoryLinks(IResizableDirectMemory memory) : this(memory,
            ↪  DefaultLinksSizeStep) { }
35
36          [MethodImpl(MethodImplOptions.AggressiveInlining)]
37          public UInt32UnitedMemoryLinks(IResizableDirectMemory memory, long
            ↪  memoryReservationStep) : this(memory, memoryReservationStep,
            ↪  Default<LinksConstants<uint>>.Instance, IndexTreeType.Default) { }
38
39          [MethodImpl(MethodImplOptions.AggressiveInlining)]
40          public UInt32UnitedMemoryLinks(IResizableDirectMemory memory, long
            ↪  memoryReservationStep, LinksConstants<uint> constants, IndexTreeType indexTreeType)
            ↪  : base(memory, memoryReservationStep, constants)
41          {
42              _createSourceTreeMethods = () => new
                ↪  UInt32LinksSourcesSizeBalancedTreeMethods(Constants, _links, _header);
43              _createTargetTreeMethods = () => new
                ↪  UInt32LinksTargetsSizeBalancedTreeMethods(Constants, _links, _header);
44              Init(memory, memoryReservationStep);
45          }
46
47          [MethodImpl(MethodImplOptions.AggressiveInlining)]
48          protected override void SetPointers(IResizableDirectMemory memory)
49          {
50              _header = (LinksHeader<uint>*)memory.Pointer;
51              _links = (RawLink<uint>*)memory.Pointer;
52              SourcesTreeMethods = _createSourceTreeMethods();
53              TargetsTreeMethods = _createTargetTreeMethods();
54              UnusedLinksListMethods = new UInt32UnusedLinksListMethods(_links, _header);
55          }
56
57          [MethodImpl(MethodImplOptions.AggressiveInlining)]
58          protected override void ResetPointers()
59          {
60              base.ResetPointers();
61              _links = null;
62              _header = null;
63          }
64
65          [MethodImpl(MethodImplOptions.AggressiveInlining)]
66          protected override ref LinksHeader<uint> GetHeaderReference() => ref *_header;
67
68          [MethodImpl(MethodImplOptions.AggressiveInlining)]
69          protected override ref RawLink<uint> GetLinkReference(uint linkIndex) => ref
            ↪  _links[linkIndex];
70
71          [MethodImpl(MethodImplOptions.AggressiveInlining)]
72          protected override bool AreEqual(uint first, uint second) => first == second;
73
74          [MethodImpl(MethodImplOptions.AggressiveInlining)]
75          protected override bool LessThan(uint first, uint second) => first < second;
76
77          [MethodImpl(MethodImplOptions.AggressiveInlining)]
78          protected override bool LessOrEqualThan(uint first, uint second) => first <= second;
79
```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThan(uint first, uint second) => first > second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThan(uint first, uint second) => first >= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint GetZero() => 0U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint GetOne() => 1U;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override long ConvertToInt64(uint value) => (long)value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint ConvertToAddress(long value) => (uint)value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint Add(uint first, uint second) => first + second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint Subtract(uint first, uint second) => first - second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint Increment(uint link) => ++link;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override uint Decrement(uint link) => --link;
    }
}
```

1.71 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt32UnusedLinksListMethods.cs

```
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Memory.United.Generic;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Specific
{
    public unsafe class UInt32UnusedLinksListMethods : UnusedLinksListMethods<uint>
    {
        private readonly RawLink<uint>* _links;
        private readonly LinksHeader<uint>* _header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt32UnusedLinksListMethods(RawLink<uint>* links, LinksHeader<uint>* header)
            : base((byte*)links, (byte*)header)
        {
            _links = links;
            _header = header;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLink<uint> GetLinkReference(uint link) => ref _links[link];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref LinksHeader<uint> GetHeaderReference() => ref *_header;
    }
}
```

1.72 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksAvlBalancedTreeMethodsBase.cs

```
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Memory.United.Generic;
using static System.Runtime.CompilerServices.Unsafe;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Specific
{
    public unsafe abstract class UInt64LinksAvlBalancedTreeMethodsBase :
    ↪ LinksAvlBalancedTreeMethodsBase<ulong>
    {
        protected new readonly RawLink<ulong>* Links;
        protected new readonly LinksHeader<ulong>* Header;

        protected UInt64LinksAvlBalancedTreeMethodsBase(LinksConstants<ulong> constants,
        ↪ RawLink<ulong>* links, LinksHeader<ulong>* header)
            : base(constants, (byte*)links, (byte*)header)
        {
```

```
17              Links = links;
18              Header = header;
19          }
20
21          [MethodImpl(MethodImplOptions.AggressiveInlining)]
22          protected override ulong GetZero() => 0UL;
23
24          [MethodImpl(MethodImplOptions.AggressiveInlining)]
25          protected override bool EqualToZero(ulong value) => value == 0UL;
26
27          [MethodImpl(MethodImplOptions.AggressiveInlining)]
28          protected override bool AreEqual(ulong first, ulong second) => first == second;
29
30          [MethodImpl(MethodImplOptions.AggressiveInlining)]
31          protected override bool GreaterThanZero(ulong value) => value > 0UL;
32
33          [MethodImpl(MethodImplOptions.AggressiveInlining)]
34          protected override bool GreaterThan(ulong first, ulong second) => first > second;
35
36          [MethodImpl(MethodImplOptions.AggressiveInlining)]
37          protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
38
39          [MethodImpl(MethodImplOptions.AggressiveInlining)]
40          protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
            ↪  always true for ulong
41
42          [MethodImpl(MethodImplOptions.AggressiveInlining)]
43          protected override bool LessOrEqualThanZero(ulong value) => value == 0UL; // value is
            ↪  always >= 0 for ulong
44
45          [MethodImpl(MethodImplOptions.AggressiveInlining)]
46          protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
47
48          [MethodImpl(MethodImplOptions.AggressiveInlining)]
49          protected override bool LessThanZero(ulong value) => false; // value < 0 is always false
            ↪  for ulong
50
51          [MethodImpl(MethodImplOptions.AggressiveInlining)]
52          protected override bool LessThan(ulong first, ulong second) => first < second;
53
54          [MethodImpl(MethodImplOptions.AggressiveInlining)]
55          protected override ulong Increment(ulong value) => ++value;
56
57          [MethodImpl(MethodImplOptions.AggressiveInlining)]
58          protected override ulong Decrement(ulong value) => --value;
59
60          [MethodImpl(MethodImplOptions.AggressiveInlining)]
61          protected override ulong Add(ulong first, ulong second) => first + second;
62
63          [MethodImpl(MethodImplOptions.AggressiveInlining)]
64          protected override ulong Subtract(ulong first, ulong second) => first - second;
65
66          [MethodImpl(MethodImplOptions.AggressiveInlining)]
67          protected override bool FirstIsToTheLeftOfSecond(ulong first, ulong second)
68          {
69              ref var firstLink = ref Links[first];
70              ref var secondLink = ref Links[second];
71              return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
                ↪  secondLink.Source, secondLink.Target);
72          }
73
74          [MethodImpl(MethodImplOptions.AggressiveInlining)]
75          protected override bool FirstIsToTheRightOfSecond(ulong first, ulong second)
76          {
77              ref var firstLink = ref Links[first];
78              ref var secondLink = ref Links[second];
79              return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
                ↪  secondLink.Source, secondLink.Target);
80          }
81
82          [MethodImpl(MethodImplOptions.AggressiveInlining)]
83          protected override ulong GetSizeValue(ulong value) => (value & 4294967264UL) >> 5;
84
85          [MethodImpl(MethodImplOptions.AggressiveInlining)]
86          protected override void SetSizeValue(ref ulong storedValue, ulong size) => storedValue =
            ↪  storedValue & 31UL | (size & 134217727UL) << 5;
87
88          [MethodImpl(MethodImplOptions.AggressiveInlining)]
89          protected override bool GetLeftIsChildValue(ulong value) => (value & 16UL) >> 4 == 1UL;
```

```

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeftIsChildValue(ref ulong storedValue, bool value) =>
        ↪  storedValue = storedValue & 4294967279UL | (As<bool, byte>(ref value) & 1UL) << 4;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GetRightIsChildValue(ulong value) => (value & 8UL) >> 3 == 1UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRightIsChildValue(ref ulong storedValue, bool value) =>
        ↪  storedValue = storedValue & 4294967287UL | (As<bool, byte>(ref value) & 1UL) << 3;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override sbyte GetBalanceValue(ulong value) => unchecked((sbyte)(value & 7UL |
        ↪  0xF8UL * ((value & 4UL) >> 2))); // if negative, then continue ones to the end of
        ↪  sbyte

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetBalanceValue(ref ulong storedValue, sbyte value) =>
        ↪  storedValue = unchecked(storedValue & 4294967288UL | (ulong)((byte)value >> 5 & 4 |
        ↪  value & 3) & 7UL);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref LinksHeader<ulong> GetHeaderReference() => ref *Header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref Links[link];
    }
}
```

1.73 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksSizeBalancedTreeMethodsBase.cs

```
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Memory.United.Generic;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Specific
{
    public unsafe abstract class UInt64LinksSizeBalancedTreeMethodsBase :
    ↪  LinksSizeBalancedTreeMethodsBase<ulong>
    {
        protected new readonly RawLink<ulong>* Links;
        protected new readonly LinksHeader<ulong>* Header;

        protected UInt64LinksSizeBalancedTreeMethodsBase(LinksConstants<ulong> constants,
        ↪  RawLink<ulong>* links, LinksHeader<ulong>* header)
            : base(constants, (byte*)links, (byte*)header)
        {
            Links = links;
            Header = header;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetZero() => 0UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool EqualToZero(ulong value) => value == 0UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool AreEqual(ulong first, ulong second) => first == second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThanZero(ulong value) => value > 0UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThan(ulong first, ulong second) => first > second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
        ↪  always true for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThanZero(ulong value) => value == 0UL; // value is
        ↪  always >= 0 for ulong

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
45          protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
46
47          [MethodImpl(MethodImplOptions.AggressiveInlining)]
48          protected override bool LessThanZero(ulong value) => false; // value < 0 is always false
            ↪  for ulong
49
50          [MethodImpl(MethodImplOptions.AggressiveInlining)]
51          protected override bool LessThan(ulong first, ulong second) => first < second;
52
53          [MethodImpl(MethodImplOptions.AggressiveInlining)]
54          protected override ulong Increment(ulong value) => ++value;
55
56          [MethodImpl(MethodImplOptions.AggressiveInlining)]
57          protected override ulong Decrement(ulong value) => --value;
58
59          [MethodImpl(MethodImplOptions.AggressiveInlining)]
60          protected override ulong Add(ulong first, ulong second) => first + second;
61
62          [MethodImpl(MethodImplOptions.AggressiveInlining)]
63          protected override ulong Subtract(ulong first, ulong second) => first - second;
64
65          [MethodImpl(MethodImplOptions.AggressiveInlining)]
66          protected override bool FirstIsToTheLeftOfSecond(ulong first, ulong second)
67          {
68              ref var firstLink = ref Links[first];
69              ref var secondLink = ref Links[second];
70              return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
                ↪  secondLink.Source, secondLink.Target);
71          }
72
73          [MethodImpl(MethodImplOptions.AggressiveInlining)]
74          protected override bool FirstIsToTheRightOfSecond(ulong first, ulong second)
75          {
76              ref var firstLink = ref Links[first];
77              ref var secondLink = ref Links[second];
78              return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
                ↪  secondLink.Source, secondLink.Target);
79          }
80
81          [MethodImpl(MethodImplOptions.AggressiveInlining)]
82          protected override ref LinksHeader<ulong> GetHeaderReference() => ref *Header;
83
84          [MethodImpl(MethodImplOptions.AggressiveInlining)]
85          protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref Links[link];
86      }
87  }
```

1.74 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksSourcesAvlBalancedTreeMethods.cs

```
1   using System.Runtime.CompilerServices;
2
3   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5   namespace Platform.Data.Doublets.Memory.United.Specific
6   {
7       public unsafe class UInt64LinksSourcesAvlBalancedTreeMethods :
        ↪  UInt64LinksAvlBalancedTreeMethodsBase
8       {
9           public UInt64LinksSourcesAvlBalancedTreeMethods(LinksConstants<ulong> constants,
            ↪  RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
            ↪  { }
10
11          [MethodImpl(MethodImplOptions.AggressiveInlining)]
12          protected override ref ulong GetLeftReference(ulong node) => ref
            ↪  Links[node].LeftAsSource;
13
14          [MethodImpl(MethodImplOptions.AggressiveInlining)]
15          protected override ref ulong GetRightReference(ulong node) => ref
            ↪  Links[node].RightAsSource;
16
17          [MethodImpl(MethodImplOptions.AggressiveInlining)]
18          protected override ulong GetLeft(ulong node) => Links[node].LeftAsSource;
19
20          [MethodImpl(MethodImplOptions.AggressiveInlining)]
21          protected override ulong GetRight(ulong node) => Links[node].RightAsSource;
22
23          [MethodImpl(MethodImplOptions.AggressiveInlining)]
24          protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsSource =
            ↪  left;
25
```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(ulong node, ulong right) => Links[node].RightAsSource =
        ↪  right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetSize(ulong node) => GetSizeValue(Links[node].SizeAsSource);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(ulong node, ulong size) => SetSizeValue(ref
        ↪  Links[node].SizeAsSource, size);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GetLeftIsChild(ulong node) =>
        ↪  GetLeftIsChildValue(Links[node].SizeAsSource);

        //[MethodImpl(MethodImplOptions.AggressiveInlining)]
        //protected override bool GetLeftIsChild(ulong node) => IsChild(node, GetLeft(node));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeftIsChild(ulong node, bool value) =>
        ↪  SetLeftIsChildValue(ref Links[node].SizeAsSource, value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GetRightIsChild(ulong node) =>
        ↪  GetRightIsChildValue(Links[node].SizeAsSource);

        //[MethodImpl(MethodImplOptions.AggressiveInlining)]
        //protected override bool GetRightIsChild(ulong node) => IsChild(node, GetRight(node));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRightIsChild(ulong node, bool value) =>
        ↪  SetRightIsChildValue(ref Links[node].SizeAsSource, value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override sbyte GetBalance(ulong node) =>
        ↪  GetBalanceValue(Links[node].SizeAsSource);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetBalance(ulong node, sbyte value) => SetBalanceValue(ref
        ↪  Links[node].SizeAsSource, value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetTreeRoot() => Header->RootAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetBasePartValue(ulong link) => Links[link].Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
        ↪  ulong secondSource, ulong secondTarget)
            => firstSource < secondSource || (firstSource == secondSource && firstTarget <
            ↪  secondTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
        ↪  ulong secondSource, ulong secondTarget)
            => firstSource > secondSource || (firstSource == secondSource && firstTarget >
            ↪  secondTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(ulong node)
        {
            ref var link = ref Links[node];
            link.LeftAsSource = 0UL;
            link.RightAsSource = 0UL;
            link.SizeAsSource = 0UL;
        }
    }
}
```

1.75 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksSourcesSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Specific
{
    public unsafe class UInt64LinksSourcesSizeBalancedTreeMethods :
    ↪  UInt64LinksSizeBalancedTreeMethodsBase
```

```
    {
        public UInt64LinksSourcesSizeBalancedTreeMethods(LinksConstants<ulong> constants,
        ↪  RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
        ↪  { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref ulong GetLeftReference(ulong node) => ref
        ↪  Links[node].LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref ulong GetRightReference(ulong node) => ref
        ↪  Links[node].RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetLeft(ulong node) => Links[node].LeftAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetRight(ulong node) => Links[node].RightAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsSource =
        ↪  left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(ulong node, ulong right) => Links[node].RightAsSource =
        ↪  right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetSize(ulong node) => Links[node].SizeAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(ulong node, ulong size) => Links[node].SizeAsSource =
        ↪  size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetTreeRoot() => Header->RootAsSource;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetBasePartValue(ulong link) => Links[link].Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
        ↪  ulong secondSource, ulong secondTarget)
            => firstSource < secondSource || (firstSource == secondSource && firstTarget <
            ↪  secondTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
        ↪  ulong secondSource, ulong secondTarget)
            => firstSource > secondSource || (firstSource == secondSource && firstTarget >
            ↪  secondTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(ulong node)
        {
            ref var link = ref Links[node];
            link.LeftAsSource = 0UL;
            link.RightAsSource = 0UL;
            link.SizeAsSource = 0UL;
        }
    }
}
```

1.76 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksTargetsAvlBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Specific
{
    public unsafe class UInt64LinksTargetsAvlBalancedTreeMethods :
    ↪  UInt64LinksAvlBalancedTreeMethodsBase
    {
        public UInt64LinksTargetsAvlBalancedTreeMethods(LinksConstants<ulong> constants,
        ↪  RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
        ↪  { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
12          protected override ref ulong GetLeftReference(ulong node) => ref
            ↪ Links[node].LeftAsTarget;
13
14          [MethodImpl(MethodImplOptions.AggressiveInlining)]
15          protected override ref ulong GetRightReference(ulong node) => ref
            ↪ Links[node].RightAsTarget;
16
17          [MethodImpl(MethodImplOptions.AggressiveInlining)]
18          protected override ulong GetLeft(ulong node) => Links[node].LeftAsTarget;
19
20          [MethodImpl(MethodImplOptions.AggressiveInlining)]
21          protected override ulong GetRight(ulong node) => Links[node].RightAsTarget;
22
23          [MethodImpl(MethodImplOptions.AggressiveInlining)]
24          protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsTarget =
            ↪ left;
25
26          [MethodImpl(MethodImplOptions.AggressiveInlining)]
27          protected override void SetRight(ulong node, ulong right) => Links[node].RightAsTarget =
            ↪ right;
28
29          [MethodImpl(MethodImplOptions.AggressiveInlining)]
30          protected override ulong GetSize(ulong node) => GetSizeValue(Links[node].SizeAsTarget);
31
32          [MethodImpl(MethodImplOptions.AggressiveInlining)]
33          protected override void SetSize(ulong node, ulong size) => SetSizeValue(ref
            ↪ Links[node].SizeAsTarget, size);
34
35          [MethodImpl(MethodImplOptions.AggressiveInlining)]
36          protected override bool GetLeftIsChild(ulong node) =>
            ↪ GetLeftIsChildValue(Links[node].SizeAsTarget);
37
38          [MethodImpl(MethodImplOptions.AggressiveInlining)]
39          protected override void SetLeftIsChild(ulong node, bool value) =>
            ↪ SetLeftIsChildValue(ref Links[node].SizeAsTarget, value);
40
41          [MethodImpl(MethodImplOptions.AggressiveInlining)]
42          protected override bool GetRightIsChild(ulong node) =>
            ↪ GetRightIsChildValue(Links[node].SizeAsTarget);
43
44          [MethodImpl(MethodImplOptions.AggressiveInlining)]
45          protected override void SetRightIsChild(ulong node, bool value) =>
            ↪ SetRightIsChildValue(ref Links[node].SizeAsTarget, value);
46
47          [MethodImpl(MethodImplOptions.AggressiveInlining)]
48          protected override sbyte GetBalance(ulong node) =>
            ↪ GetBalanceValue(Links[node].SizeAsTarget);
49
50          [MethodImpl(MethodImplOptions.AggressiveInlining)]
51          protected override void SetBalance(ulong node, sbyte value) => SetBalanceValue(ref
            ↪ Links[node].SizeAsTarget, value);
52
53          [MethodImpl(MethodImplOptions.AggressiveInlining)]
54          protected override ulong GetTreeRoot() => Header->RootAsTarget;
55
56          [MethodImpl(MethodImplOptions.AggressiveInlining)]
57          protected override ulong GetBasePartValue(ulong link) => Links[link].Target;
58
59          [MethodImpl(MethodImplOptions.AggressiveInlining)]
60          protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
            ↪ ulong secondSource, ulong secondTarget)
61              => firstTarget < secondTarget || (firstTarget == secondTarget && firstSource <
                ↪ secondSource);
62
63          [MethodImpl(MethodImplOptions.AggressiveInlining)]
64          protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
            ↪ ulong secondSource, ulong secondTarget)
65              => firstTarget > secondTarget || (firstTarget == secondTarget && firstSource >
                ↪ secondSource);
66
67          [MethodImpl(MethodImplOptions.AggressiveInlining)]
68          protected override void ClearNode(ulong node)
69          {
70              ref var link = ref Links[node];
71              link.LeftAsTarget = OUL;
72              link.RightAsTarget = OUL;
73              link.SizeAsTarget = OUL;
74          }
```

```
    }
}
```

1.77 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksTargetsSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Specific
{
    public unsafe class UInt64LinksTargetsSizeBalancedTreeMethods :
    ↪ UInt64LinksSizeBalancedTreeMethodsBase
    {
        public UInt64LinksTargetsSizeBalancedTreeMethods(LinksConstants<ulong> constants,
        ↪ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
        ↪ { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref ulong GetLeftReference(ulong node) => ref
        ↪ Links[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref ulong GetRightReference(ulong node) => ref
        ↪ Links[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetLeft(ulong node) => Links[node].LeftAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetRight(ulong node) => Links[node].RightAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsTarget =
        ↪ left;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRight(ulong node, ulong right) => Links[node].RightAsTarget =
        ↪ right;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetSize(ulong node) => Links[node].SizeAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(ulong node, ulong size) => Links[node].SizeAsTarget =
        ↪ size;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetTreeRoot() => Header->RootAsTarget;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetBasePartValue(ulong link) => Links[link].Target;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
        ↪ ulong secondSource, ulong secondTarget)
            => firstTarget < secondTarget || (firstTarget == secondTarget && firstSource <
            ↪ secondSource);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
        ↪ ulong secondSource, ulong secondTarget)
            => firstTarget > secondTarget || (firstTarget == secondTarget && firstSource >
            ↪ secondSource);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(ulong node)
        {
            ref var link = ref Links[node];
            link.LeftAsTarget = 0UL;
            link.RightAsTarget = 0UL;
            link.SizeAsTarget = 0UL;
        }
    }
}
```

1.78 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64UnitedMemoryLinks.cs

```
using System;
using System.Runtime.CompilerServices;
using Platform.Memory;
```

```
4  using Platform.Singletons;
5  using Platform.Data.Doublets.Memory.United.Generic;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets.Memory.United.Specific
10 {
11     /// <summary>
12     /// <para>Represents a low-level implementation of direct access to resizable memory, for
       ↪  organizing the storage of links with addresses represented as <see cref="ulong"
       ↪  />.</para>
13     /// <para>Представляет низкоуровневую реализация прямого доступа к памяти с переменным
       ↪  размером, для организации хранения связей с адресами представленными в виде <see
       ↪  cref="ulong"/>.</para>
14     /// </summary>
15     public unsafe class UInt64UnitedMemoryLinks : UnitedMemoryLinksBase<ulong>
16     {
17         private readonly Func<ILinksTreeMethods<ulong>> _createSourceTreeMethods;
18         private readonly Func<ILinksTreeMethods<ulong>> _createTargetTreeMethods;
19         private LinksHeader<ulong>* _header;
20         private RawLink<ulong>* _links;
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         public UInt64UnitedMemoryLinks(string address) : this(address, DefaultLinksSizeStep) { }
24
25         /// <summary>
26         /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
           ↪  минимальным шагом расширения базы данных.
27         /// </summary>
28         /// <param name="address">Полный пусть к файлу базы данных.</param>
29         /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
           ↪  байтах.</param>
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]
31         public UInt64UnitedMemoryLinks(string address, long memoryReservationStep) : this(new
           ↪  FileMappedResizableDirectMemory(address, memoryReservationStep),
           ↪  memoryReservationStep) { }
32
33         [MethodImpl(MethodImplOptions.AggressiveInlining)]
34         public UInt64UnitedMemoryLinks(IResizableDirectMemory memory) : this(memory,
           ↪  DefaultLinksSizeStep) { }
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         public UInt64UnitedMemoryLinks(IResizableDirectMemory memory, long
           ↪  memoryReservationStep) : this(memory, memoryReservationStep,
           ↪  Default<LinksConstants<ulong>>.Instance, IndexTreeType.Default) { }
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         public UInt64UnitedMemoryLinks(IResizableDirectMemory memory, long
           ↪  memoryReservationStep, LinksConstants<ulong> constants, IndexTreeType indexTreeType)
           ↪  : base(memory, memoryReservationStep, constants)
41         {
42             if (indexTreeType == IndexTreeType.SizedAndThreadedAVLBalancedTree)
43             {
44                 _createSourceTreeMethods = () => new
                   ↪  UInt64LinksSourcesAvlBalancedTreeMethods(Constants, _links, _header);
45                 _createTargetTreeMethods = () => new
                   ↪  UInt64LinksTargetsAvlBalancedTreeMethods(Constants, _links, _header);
46             }
47             else
48             {
49                 _createSourceTreeMethods = () => new
                   ↪  UInt64LinksSourcesSizeBalancedTreeMethods(Constants, _links, _header);
50                 _createTargetTreeMethods = () => new
                   ↪  UInt64LinksTargetsSizeBalancedTreeMethods(Constants, _links, _header);
51             }
52             Init(memory, memoryReservationStep);
53         }
54
55         [MethodImpl(MethodImplOptions.AggressiveInlining)]
56         protected override void SetPointers(IResizableDirectMemory memory)
57         {
58             _header = (LinksHeader<ulong>*)memory.Pointer;
59             _links = (RawLink<ulong>*)memory.Pointer;
60             SourcesTreeMethods = _createSourceTreeMethods();
61             TargetsTreeMethods = _createTargetTreeMethods();
62             UnusedLinksListMethods = new UInt64UnusedLinksListMethods(_links, _header);
63         }
64
```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ResetPointers()
        {
            base.ResetPointers();
            _links = null;
            _header = null;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref LinksHeader<ulong> GetHeaderReference() => ref *_header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLink<ulong> GetLinkReference(ulong linkIndex) => ref
        ↪  _links[linkIndex];

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool AreEqual(ulong first, ulong second) => first == second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessThan(ulong first, ulong second) => first < second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterThan(ulong first, ulong second) => first > second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetZero() => 0UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong GetOne() => 1UL;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override long ConvertToInt64(ulong value) => (long)value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong ConvertToAddress(long value) => (ulong)value;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Add(ulong first, ulong second) => first + second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Subtract(ulong first, ulong second) => first - second;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Increment(ulong link) => ++link;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ulong Decrement(ulong link) => --link;
    }
}
```

1.79 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64UnusedLinksListMethods.cs

```
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Memory.United.Generic;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Memory.United.Specific
{
    public unsafe class UInt64UnusedLinksListMethods : UnusedLinksListMethods<ulong>
    {
        private readonly RawLink<ulong>* _links;
        private readonly LinksHeader<ulong>* _header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt64UnusedLinksListMethods(RawLink<ulong>* links, LinksHeader<ulong>* header)
            : base((byte*)links, (byte*)header)
        {
            _links = links;
            _header = header;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref _links[link];

```

```
24          [MethodImpl(MethodImplOptions.AggressiveInlining)]
25          protected override ref LinksHeader<ulong> GetHeaderReference() => ref *_header;
26      }
27  }
```

1.80 ./csharp/Platform.Data.Doublets/Numbers/Unary/AddressToUnaryNumberConverter.cs

```
1   using System.Collections.Generic;
2   using Platform.Reflection;
3   using Platform.Converters;
4   using Platform.Numbers;
5   using System.Runtime.CompilerServices;
6
7   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9   namespace Platform.Data.Doublets.Numbers.Unary
10  {
11      public class AddressToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
        ↪  IConverter<TLink>
12      {
13          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪  EqualityComparer<TLink>.Default;
14          private static readonly TLink _zero = default;
15          private static readonly TLink _one = Arithmetic.Increment(_zero);
16
17          private readonly IConverter<int, TLink> _powerOf2ToUnaryNumberConverter;
18
19          [MethodImpl(MethodImplOptions.AggressiveInlining)]
20          public AddressToUnaryNumberConverter(ILinks<TLink> links, IConverter<int, TLink>
            ↪  powerOf2ToUnaryNumberConverter) : base(links) => _powerOf2ToUnaryNumberConverter =
            ↪  powerOf2ToUnaryNumberConverter;
21
22          [MethodImpl(MethodImplOptions.AggressiveInlining)]
23          public TLink Convert(TLink number)
24          {
25              var links = _links;
26              var nullConstant = links.Constants.Null;
27              var target = nullConstant;
28              for (var i = 0; !_equalityComparer.Equals(number, _zero) && i <
                ↪  NumericType<TLink>.BitsSize; i++)
29              {
30                  if (_equalityComparer.Equals(Bit.And(number, _one), _one))
31                  {
32                      target = _equalityComparer.Equals(target, nullConstant)
33                          ? _powerOf2ToUnaryNumberConverter.Convert(i)
34                          : links.GetOrCreate(_powerOf2ToUnaryNumberConverter.Convert(i), target);
35                  }
36                  number = Bit.ShiftRight(number, 1);
37              }
38              return target;
39          }
40      }
41  }
```

1.81 ./csharp/Platform.Data.Doublets/Numbers/Unary/LinkToItsFrequencyNumberConveter.cs

```
1   using System;
2   using System.Collections.Generic;
3   using Platform.Interfaces;
4   using Platform.Converters;
5   using System.Runtime.CompilerServices;
6
7   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9   namespace Platform.Data.Doublets.Numbers.Unary
10  {
11      public class LinkToItsFrequencyNumberConveter<TLink> : LinksOperatorBase<TLink>,
        ↪  IConverter<Doublet<TLink>, TLink>
12      {
13          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪  EqualityComparer<TLink>.Default;
14
15          private readonly IProperty<TLink, TLink> _frequencyPropertyOperator;
16          private readonly IConverter<TLink> _unaryNumberToAddressConverter;
17
18          [MethodImpl(MethodImplOptions.AggressiveInlining)]
19          public LinkToItsFrequencyNumberConveter(
20              ILinks<TLink> links,
21              IProperty<TLink, TLink> frequencyPropertyOperator,
22              IConverter<TLink> unaryNumberToAddressConverter)
23              : base(links)
24          {
```

```
            _frequencyPropertyOperator = frequencyPropertyOperator;
            _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(Doublet<TLink> doublet)
        {
            var links = _links;
            var link = links.SearchOrDefault(doublet.Source, doublet.Target);
            if (_equalityComparer.Equals(link, default))
            {
                throw new ArgumentException($"Link ({doublet}) not found.", nameof(doublet));
            }
            var frequency = _frequencyPropertyOperator.Get(link);
            if (_equalityComparer.Equals(frequency, default))
            {
                return default;
            }
            var frequencyNumber = links.GetSource(frequency);
            return _unaryNumberToAddressConverter.Convert(frequencyNumber);
        }
    }
}
```

1.82 ./csharp/Platform.Data.Doublets/Numbers/Unary/PowerOf2ToUnaryNumberConverter.cs

```
using System.Collections.Generic;
using Platform.Exceptions;
using Platform.Ranges;
using Platform.Converters;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Unary
{
    public class PowerOf2ToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<int, TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;

        private readonly TLink[] _unaryNumberPowersOf2;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public PowerOf2ToUnaryNumberConverter(ILinks<TLink> links, TLink one) : base(links)
        {
            _unaryNumberPowersOf2 = new TLink[64];
            _unaryNumberPowersOf2[0] = one;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(int power)
        {
            Ensure.Always.ArgumentInRange(power, new Range<int>(0, _unaryNumberPowersOf2.Length
            ↪ - 1), nameof(power));
            if (!_equalityComparer.Equals(_unaryNumberPowersOf2[power], default))
            {
                return _unaryNumberPowersOf2[power];
            }
            var previousPowerOf2 = Convert(power - 1);
            var powerOf2 = _links.GetOrCreate(previousPowerOf2, previousPowerOf2);
            _unaryNumberPowersOf2[power] = powerOf2;
            return powerOf2;
        }
    }
}
```

1.83 ./csharp/Platform.Data.Doublets/Numbers/Unary/UnaryNumberToAddressAddOperationConverter.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Unary
{
    public class UnaryNumberToAddressAddOperationConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<TLink>
```

```
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;
        private static readonly UncheckedConverter<TLink, ulong> _addressToUInt64Converter =
        ↪  UncheckedConverter<TLink, ulong>.Default;
        private static readonly UncheckedConverter<ulong, TLink> _uInt64ToAddressConverter =
        ↪  UncheckedConverter<ulong, TLink>.Default;
        private static readonly TLink _zero = default;
        private static readonly TLink _one = Arithmetic.Increment(_zero);

        private readonly Dictionary<TLink, TLink> _unaryToUInt64;
        private readonly TLink _unaryOne;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnaryNumberToAddressAddOperationConverter(ILinks<TLink> links, TLink unaryOne)
            : base(links)
        {
            _unaryOne = unaryOne;
            _unaryToUInt64 = CreateUnaryToUInt64Dictionary(links, unaryOne);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(TLink unaryNumber)
        {
            if (_equalityComparer.Equals(unaryNumber, default))
            {
                return default;
            }
            if (_equalityComparer.Equals(unaryNumber, _unaryOne))
            {
                return _one;
            }
            var links = _links;
            var source = links.GetSource(unaryNumber);
            var target = links.GetTarget(unaryNumber);
            if (_equalityComparer.Equals(source, target))
            {
                return _unaryToUInt64[unaryNumber];
            }
            else
            {
                var result = _unaryToUInt64[source];
                TLink lastValue;
                while (!_unaryToUInt64.TryGetValue(target, out lastValue))
                {
                    source = links.GetSource(target);
                    result = Arithmetic<TLink>.Add(result, _unaryToUInt64[source]);
                    target = links.GetTarget(target);
                }
                result = Arithmetic<TLink>.Add(result, lastValue);
                return result;
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static Dictionary<TLink, TLink> CreateUnaryToUInt64Dictionary(ILinks<TLink>
        ↪  links, TLink unaryOne)
        {
            var unaryToUInt64 = new Dictionary<TLink, TLink>
            {
                { unaryOne, _one }
            };
            var unary = unaryOne;
            var number = _one;
            for (var i = 1; i < 64; i++)
            {
                unary = links.GetOrCreate(unary, unary);
                number = Double(number);
                unaryToUInt64.Add(unary, number);
            }
            return unaryToUInt64;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static TLink Double(TLink number) =>
        ↪  _uInt64ToAddressConverter.Convert(_addressToUInt64Converter.Convert(number) * 2UL);
    }
}
```

1.84 ./csharp/Platform.Data.Doublets/Numbers/Unary/UnaryNumberToAddressOrOperationConverter.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Reflection;
using Platform.Converters;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Unary
{
    public class UnaryNumberToAddressOrOperationConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;
        private static readonly TLink _zero = default;
        private static readonly TLink _one = Arithmetic.Increment(_zero);

        private readonly IDictionary<TLink, int> _unaryNumberPowerOf2Indicies;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnaryNumberToAddressOrOperationConverter(ILinks<TLink> links, IConverter<int,
        ↪ TLink> powerOf2ToUnaryNumberConverter) : base(links) => _unaryNumberPowerOf2Indicies
        ↪ = CreateUnaryNumberPowerOf2IndiciesDictionary(powerOf2ToUnaryNumberConverter);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(TLink sourceNumber)
        {
            var links = _links;
            var nullConstant = links.Constants.Null;
            var source = sourceNumber;
            var target = nullConstant;
            if (!_equalityComparer.Equals(source, nullConstant))
            {
                while (true)
                {
                    if (_unaryNumberPowerOf2Indicies.TryGetValue(source, out int powerOf2Index))
                    {
                        SetBit(ref target, powerOf2Index);
                        break;
                    }
                    else
                    {
                        powerOf2Index = _unaryNumberPowerOf2Indicies[links.GetSource(source)];
                        SetBit(ref target, powerOf2Index);
                        source = links.GetTarget(source);
                    }
                }
            }
            return target;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static Dictionary<TLink, int>
        ↪ CreateUnaryNumberPowerOf2IndiciesDictionary(IConverter<int, TLink>
        ↪ powerOf2ToUnaryNumberConverter)
        {
            var unaryNumberPowerOf2Indicies = new Dictionary<TLink, int>();
            for (int i = 0; i < NumericType<TLink>.BitsSize; i++)
            {
                unaryNumberPowerOf2Indicies.Add(powerOf2ToUnaryNumberConverter.Convert(i), i);
            }
            return unaryNumberPowerOf2Indicies;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static void SetBit(ref TLink target, int powerOf2Index) => target =
        ↪ Bit.Or(target, Bit.ShiftLeft(_one, powerOf2Index));
    }
}
```

1.85 ./csharp/Platform.Data.Doublets/PropertyOperators/PropertiesOperator.cs

```
using System.Linq;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

```

```
namespace Platform.Data.Doublets.PropertyOperators
{
    public class PropertiesOperator<TLink> : LinksOperatorBase<TLink>, IProperties<TLink, TLink,
    ↪ TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public PropertiesOperator(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink GetValue(TLink @object, TLink property)
        {
            var links = _links;
            var objectProperty = links.SearchOrDefault(@object, property);
            if (_equalityComparer.Equals(objectProperty, default))
            {
                return default;
            }
            var constants = links.Constants;
            var valueLink = links.All(constants.Any, objectProperty).SingleOrDefault();
            if (valueLink == null)
            {
                return default;
            }
            return links.GetTarget(valueLink[constants.IndexPart]);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void SetValue(TLink @object, TLink property, TLink value)
        {
            var links = _links;
            var objectProperty = links.GetOrCreate(@object, property);
            links.DeleteMany(links.AllIndices(links.Constants.Any, objectProperty));
            links.GetOrCreate(objectProperty, value);
        }
    }
}
```

1.86 ./csharp/Platform.Data.Doublets/PropertyOperators/PropertyOperator.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.PropertyOperators
{
    public class PropertyOperator<TLink> : LinksOperatorBase<TLink>, IProperty<TLink, TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;

        private readonly TLink _propertyMarker;
        private readonly TLink _propertyValueMarker;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public PropertyOperator(ILinks<TLink> links, TLink propertyMarker, TLink
        ↪ propertyValueMarker) : base(links)
        {
            _propertyMarker = propertyMarker;
            _propertyValueMarker = propertyValueMarker;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Get(TLink link)
        {
            var property = _links.SearchOrDefault(link, _propertyMarker);
            return GetValue(GetContainer(property));
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private TLink GetContainer(TLink property)
        {
            var valueContainer = default(TLink);
            if (_equalityComparer.Equals(property, default))
            {
                return valueContainer;
            }
```

```
            var links = _links;
            var constants = links.Constants;
            var countinueConstant = constants.Continue;
            var breakConstant = constants.Break;
            var anyConstant = constants.Any;
            var query = new Link<TLink>(anyConstant, property, anyConstant);
            links.Each(candidate =>
            {
                var candidateTarget = links.GetTarget(candidate);
                var valueTarget = links.GetTarget(candidateTarget);
                if (_equalityComparer.Equals(valueTarget, _propertyValueMarker))
                {
                    valueContainer = links.GetIndex(candidate);
                    return breakConstant;
                }
                return countinueConstant;
            }, query);
            return valueContainer;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private TLink GetValue(TLink container) => _equalityComparer.Equals(container, default)
        ↪  ? default : _links.GetTarget(container);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Set(TLink link, TLink value)
        {
            var links = _links;
            var property = links.GetOrCreate(link, _propertyMarker);
            var container = GetContainer(property);
            if (_equalityComparer.Equals(container, default))
            {
                links.GetOrCreate(property, value);
            }
            else
            {
                links.Update(container, property, value);
            }
        }
    }
}
```

1.87 ./csharp/Platform.Data.Doublets/Sequences/Converters/BalancedVariantConverter.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Converters
{
    public class BalancedVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public BalancedVariantConverter(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Convert(IList<TLink> sequence)
        {
            var length = sequence.Count;
            if (length < 1)
            {
                return default;
            }
            if (length == 1)
            {
                return sequence[0];
            }
            // Make copy of next layer
            if (length > 2)
            {
                // TODO: Try to use stackalloc (which at the moment is not working with
                ↪  generics) but will be possible with Sigil
                var halvedSequence = new TLink[(length / 2) + (length % 2)];
                HalveSequence(halvedSequence, sequence, length);
                sequence = halvedSequence;
                length = halvedSequence.Length;
            }
            // Keep creating layer after layer
            while (length > 2)
```

```
            {
                HalveSequence(sequence, sequence, length);
                length = (length / 2) + (length % 2);
            }
            return _links.GetOrCreate(sequence[0], sequence[1]);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void HalveSequence(IList<TLink> destination, IList<TLink> source, int length)
        {
            var loopedLength = length - (length % 2);
            for (var i = 0; i < loopedLength; i += 2)
            {
                destination[i / 2] = _links.GetOrCreate(source[i], source[i + 1]);
            }
            if (length > loopedLength)
            {
                destination[length / 2] = source[length - 1];
            }
        }
    }
}
```

1.88 ./csharp/Platform.Data.Doublets/Sequences/Converters/CompressingConverter.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections;
using Platform.Converters;
using Platform.Singletons;
using Platform.Numbers;
using Platform.Data.Doublets.Sequences.Frequencies.Cache;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Converters
{
    /// <remarks>
    /// TODO: Возможно будет лучше если алгоритм будет выполняться полностью изолированно от Links на этапе сжатия.
    ///     А именно будет создаваться временный список пар необходимых для выполнения сжатия, в таком случае тип значения элемента массива может быть любым, как char так и ulong.
    ///     Как только список/словарь пар был выявлен можно разом выполнить создание всех этих пар, а так же разом выполнить замену.
    /// </remarks>
    public class CompressingConverter<TLink> : LinksListToSequenceConverterBase<TLink>
    {
        private static readonly LinksConstants<TLink> _constants = Default<LinksConstants<TLink>>.Instance;
        private static readonly EqualityComparer<TLink> _equalityComparer = EqualityComparer<TLink>.Default;
        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;

        private static readonly TLink _zero = default;
        private static readonly TLink _one = Arithmetic.Increment(_zero);

        private readonly IConverter<IList<TLink>, TLink> _baseConverter;
        private readonly LinkFrequenciesCache<TLink> _doubletFrequenciesCache;
        private readonly TLink _minFrequencyToCompress;
        private readonly bool _doInitialFrequenciesIncrement;
        private Doublet<TLink> _maxDoublet;
        private LinkFrequency<TLink> _maxDoubletData;

        private struct HalfDoublet
        {
            public TLink Element;
            public LinkFrequency<TLink> DoubletData;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public HalfDoublet(TLink element, LinkFrequency<TLink> doubletData)
            {
                Element = element;
                DoubletData = doubletData;
            }

            public override string ToString() => $"{Element}: ({DoubletData})";
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink> baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache)
```

```
52              : this(links, baseConverter, doubletFrequenciesCache, _one, true) { }
53
54          [MethodImpl(MethodImplOptions.AggressiveInlining)]
55          public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
            ↪ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, bool
            ↪ doInitialFrequenciesIncrement)
56              : this(links, baseConverter, doubletFrequenciesCache, _one,
                ↪ doInitialFrequenciesIncrement) { }
57
58          [MethodImpl(MethodImplOptions.AggressiveInlining)]
59          public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
            ↪ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, TLink
            ↪ minFrequencyToCompress, bool doInitialFrequenciesIncrement)
60              : base(links)
61          {
62              _baseConverter = baseConverter;
63              _doubletFrequenciesCache = doubletFrequenciesCache;
64              if (_comparer.Compare(minFrequencyToCompress, _one) < 0)
65              {
66                  minFrequencyToCompress = _one;
67              }
68              _minFrequencyToCompress = minFrequencyToCompress;
69              _doInitialFrequenciesIncrement = doInitialFrequenciesIncrement;
70              ResetMaxDoublet();
71          }
72
73          [MethodImpl(MethodImplOptions.AggressiveInlining)]
74          public override TLink Convert(IList<TLink> source) =>
            ↪ _baseConverter.Convert(Compress(source));
75
76          /// <remarks>
77          /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte_pair_encoding .
78          /// Faster version (doublets' frequencies dictionary is not recreated).
79          /// </remarks>
80          [MethodImpl(MethodImplOptions.AggressiveInlining)]
81          private IList<TLink> Compress(IList<TLink> sequence)
82          {
83              if (sequence.IsNullOrEmpty())
84              {
85                  return null;
86              }
87              if (sequence.Count == 1)
88              {
89                  return sequence;
90              }
91              if (sequence.Count == 2)
92              {
93                  return new[] { _links.GetOrCreate(sequence[0], sequence[1]) };
94              }
95              // TODO: arraypool with min size (to improve cache locality) or stackallow with Sigil
96              var copy = new HalfDoublet[sequence.Count];
97              Doublet<TLink> doublet = default;
98              for (var i = 1; i < sequence.Count; i++)
99              {
100                 doublet = new Doublet<TLink>(sequence[i - 1], sequence[i]);
101                 LinkFrequency<TLink> data;
102                 if (_doInitialFrequenciesIncrement)
103                 {
104                     data = _doubletFrequenciesCache.IncrementFrequency(ref doublet);
105                 }
106                 else
107                 {
108                     data = _doubletFrequenciesCache.GetFrequency(ref doublet);
109                     if (data == null)
110                     {
111                         throw new NotSupportedException("If you ask not to increment
                            ↪ frequencies, it is expected that all frequencies for the sequence
                            ↪ are prepared.");
112                     }
113                 }
114                 copy[i - 1].Element = sequence[i - 1];
115                 copy[i - 1].DoubletData = data;
116                 UpdateMaxDoublet(ref doublet, data);
117             }
118             copy[sequence.Count - 1].Element = sequence[sequence.Count - 1];
119             copy[sequence.Count - 1].DoubletData = new LinkFrequency<TLink>();
120             if (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
121             {
```

```
122                 var newLength = ReplaceDoublets(copy);
123                 sequence = new TLink[newLength];
124                 for (int i = 0; i < newLength; i++)
125                 {
126                     sequence[i] = copy[i].Element;
127                 }
128             }
129             return sequence;
130         }
131 
132         /// <remarks>
133         /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte_pair_encoding
134         /// </remarks>
135         [MethodImpl(MethodImplOptions.AggressiveInlining)]
136         private int ReplaceDoublets(HalfDoublet[] copy)
137         {
138             var oldLength = copy.Length;
139             var newLength = copy.Length;
140             while (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
141             {
142                 var maxDoubletSource = _maxDoublet.Source;
143                 var maxDoubletTarget = _maxDoublet.Target;
144                 if (_equalityComparer.Equals(_maxDoubletData.Link, _constants.Null))
145                 {
146                     _maxDoubletData.Link = _links.GetOrCreate(maxDoubletSource,
                        ↪  maxDoubletTarget);
147                 }
148                 var maxDoubletReplacementLink = _maxDoubletData.Link;
149                 oldLength--;
150                 var oldLengthMinusTwo = oldLength - 1;
151                 // Substitute all usages
152                 int w = 0, r = 0; // (r == read, w == write)
153                 for (; r < oldLength; r++)
154                 {
155                     if (_equalityComparer.Equals(copy[r].Element, maxDoubletSource) &&
                        ↪  _equalityComparer.Equals(copy[r + 1].Element, maxDoubletTarget))
156                     {
157                         if (r > 0)
158                         {
159                             var previous = copy[w - 1].Element;
160                             copy[w - 1].DoubletData.DecrementFrequency();
161                             copy[w - 1].DoubletData =
                                ↪  _doubletFrequenciesCache.IncrementFrequency(previous,
                                ↪  maxDoubletReplacementLink);
162                         }
163                         if (r < oldLengthMinusTwo)
164                         {
165                             var next = copy[r + 2].Element;
166                             copy[r + 1].DoubletData.DecrementFrequency();
167                             copy[w].DoubletData = _doubletFrequenciesCache.IncrementFrequency(ma
                                ↪  xDoubletReplacementLink,
                                ↪  next);
168                         }
169                         copy[w++].Element = maxDoubletReplacementLink;
170                         r++;
171                         newLength--;
172                     }
173                     else
174                     {
175                         copy[w++] = copy[r];
176                     }
177                 }
178                 if (w < newLength)
179                 {
180                     copy[w] = copy[r];
181                 }
182                 oldLength = newLength;
183                 ResetMaxDoublet();
184                 UpdateMaxDoublet(copy, newLength);
185             }
186             return newLength;
187         }
188 
189         [MethodImpl(MethodImplOptions.AggressiveInlining)]
190         private void ResetMaxDoublet()
191         {
192             _maxDoublet = new Doublet<TLink>();
193             _maxDoubletData = new LinkFrequency<TLink>();
```

```
194         }
195
196         [MethodImpl(MethodImplOptions.AggressiveInlining)]
197         private void UpdateMaxDoublet(HalfDoublet[] copy, int length)
198         {
199             Doublet<TLink> doublet = default;
200             for (var i = 1; i < length; i++)
201             {
202                 doublet = new Doublet<TLink>(copy[i - 1].Element, copy[i].Element);
203                 UpdateMaxDoublet(ref doublet, copy[i - 1].DoubletData);
204             }
205         }
206
207         [MethodImpl(MethodImplOptions.AggressiveInlining)]
208         private void UpdateMaxDoublet(ref Doublet<TLink> doublet, LinkFrequency<TLink> data)
209         {
210             var frequency = data.Frequency;
211             var maxFrequency = _maxDoubletData.Frequency;
212             //if (frequency > _minFrequencyToCompress && (maxFrequency < frequency ||
                ↪  (maxFrequency == frequency && doublet.Source + doublet.Target < /* gives better
                ↪  compression string data (and gives collisions quickly) */ _maxDoublet.Source +
                ↪  _maxDoublet.Target)))
213             if (_comparer.Compare(frequency, _minFrequencyToCompress) > 0 &&
214                (_comparer.Compare(maxFrequency, frequency) < 0 ||
                    ↪  (_equalityComparer.Equals(maxFrequency, frequency) &&
                    ↪  _comparer.Compare(Arithmetic.Add(doublet.Source, doublet.Target),
                    ↪  Arithmetic.Add(_maxDoublet.Source, _maxDoublet.Target)) > 0))) /* gives
                    ↪  better stability and better compression on sequent data and even on rundom
                    ↪  numbers data (but gives collisions anyway) */
215             {
216                 _maxDoublet = doublet;
217                 _maxDoubletData = data;
218             }
219         }
220     }
221 }
```

1.89 ./csharp/Platform.Data.Doublets/Sequences/Converters/LinksListToSequenceConverterBase.cs

```
1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Converters;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Sequences.Converters
8  {
9      public abstract class LinksListToSequenceConverterBase<TLink> : LinksOperatorBase<TLink>,
       ↪  IConverter<IList<TLink>, TLink>
10     {
11         [MethodImpl(MethodImplOptions.AggressiveInlining)]
12         protected LinksListToSequenceConverterBase(ILinks<TLink> links) : base(links) { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         public abstract TLink Convert(IList<TLink> source);
16     }
17 }
```

1.90 ./csharp/Platform.Data.Doublets/Sequences/Converters/OptimalVariantConverter.cs

```
1  using System.Collections.Generic;
2  using System.Linq;
3  using System.Runtime.CompilerServices;
4  using Platform.Converters;
5  using Platform.Data.Doublets.Sequences.Frequencies.Cache;
6  using Platform.Data.Doublets.Sequences.Frequencies.Counters;
7
8  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets.Sequences.Converters
11 {
12     public class OptimalVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
13     {
14         private static readonly EqualityComparer<TLink> _equalityComparer =
           ↪  EqualityComparer<TLink>.Default;
15         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
16
17         private readonly IConverter<IList<TLink>> _sequenceToItsLocalElementLevelsConverter;
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         public OptimalVariantConverter(ILinks<TLink> links, IConverter<IList<TLink>>
           ↪  sequenceToItsLocalElementLevelsConverter) : base(links)
```

```
21              => _sequenceToItsLocalElementLevelsConverter =
                ↪ sequenceToItsLocalElementLevelsConverter;
22
23          [MethodImpl(MethodImplOptions.AggressiveInlining)]
24          public OptimalVariantConverter(ILinks<TLink> links, LinkFrequenciesCache<TLink>
            ↪ linkFrequenciesCache)
25              : this(links, new SequenceToItsLocalElementLevelsConverter<TLink>(links, new Frequen
                ↪ ciesCacheBasedLinkToItsFrequencyNumberConverter<TLink>(linkFrequenciesCache))) {
                ↪ }
26
27          [MethodImpl(MethodImplOptions.AggressiveInlining)]
28          public OptimalVariantConverter(ILinks<TLink> links)
29              : this(links, new LinkFrequenciesCache<TLink>(links, new
                ↪ TotalSequenceSymbolFrequencyCounter<TLink>(links))) { }
30
31          [MethodImpl(MethodImplOptions.AggressiveInlining)]
32          public override TLink Convert(IList<TLink> sequence)
33          {
34              var length = sequence.Count;
35              if (length == 1)
36              {
37                  return sequence[0];
38              }
39              if (length == 2)
40              {
41                  return _links.GetOrCreate(sequence[0], sequence[1]);
42              }
43              sequence = sequence.ToArray();
44              var levels = _sequenceToItsLocalElementLevelsConverter.Convert(sequence);
45              while (length > 2)
46              {
47                  var levelRepeat = 1;
48                  var currentLevel = levels[0];
49                  var previousLevel = levels[0];
50                  var skipOnce = false;
51                  var w = 0;
52                  for (var i = 1; i < length; i++)
53                  {
54                      if (_equalityComparer.Equals(currentLevel, levels[i]))
55                      {
56                          levelRepeat++;
57                          skipOnce = false;
58                          if (levelRepeat == 2)
59                          {
60                              sequence[w] = _links.GetOrCreate(sequence[i - 1], sequence[i]);
61                              var newLevel = i >= length - 1 ?
62                                  GetPreviousLowerThanCurrentOrCurrent(previousLevel,
                                    ↪ currentLevel) :
63                                  i < 2 ?
64                                  GetNextLowerThanCurrentOrCurrent(currentLevel, levels[i + 1]) :
65                                  GetGreatestNeigbourLowerThanCurrentOrCurrent(previousLevel,
                                    ↪ currentLevel, levels[i + 1]);
66                              levels[w] = newLevel;
67                              previousLevel = currentLevel;
68                              w++;
69                              levelRepeat = 0;
70                              skipOnce = true;
71                          }
72                          else if (i == length - 1)
73                          {
74                              sequence[w] = sequence[i];
75                              levels[w] = levels[i];
76                              w++;
77                          }
78                      }
79                      else
80                      {
81                          currentLevel = levels[i];
82                          levelRepeat = 1;
83                          if (skipOnce)
84                          {
85                              skipOnce = false;
86                          }
87                          else
88                          {
89                              sequence[w] = sequence[i - 1];
90                              levels[w] = levels[i - 1];
91                              previousLevel = levels[w];
92                              w++;
```

```
                        }
                        if (i == length - 1)
                        {
                            sequence[w] = sequence[i];
                            levels[w] = levels[i];
                            w++;
                        }
                    }
                }
                length = w;
            }
            return _links.GetOrCreate(sequence[0], sequence[1]);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static TLink GetGreatestNeigbourLowerThanCurrentOrCurrent(TLink previous, TLink current, TLink next)
        {
            return _comparer.Compare(previous, next) > 0
                ? _comparer.Compare(previous, current) < 0 ? previous : current
                : _comparer.Compare(next, current) < 0 ? next : current;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static TLink GetNextLowerThanCurrentOrCurrent(TLink current, TLink next) => _comparer.Compare(next, current) < 0 ? next : current;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static TLink GetPreviousLowerThanCurrentOrCurrent(TLink previous, TLink current) => _comparer.Compare(previous, current) < 0 ? previous : current;
    }
}
```

1.91 ./csharp/Platform.Data.Doublets/Sequences/Converters/SequenceToItsLocalElementLevelsConverter.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Converters
{
    public class SequenceToItsLocalElementLevelsConverter<TLink> : LinksOperatorBase<TLink>, IConverter<IList<TLink>>
    {
        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;

        private readonly IConverter<Doublet<TLink>, TLink> _linkToItsFrequencyToNumberConveter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SequenceToItsLocalElementLevelsConverter(ILinks<TLink> links, IConverter<Doublet<TLink>, TLink> linkToItsFrequencyToNumberConveter) : base(links) => _linkToItsFrequencyToNumberConveter = linkToItsFrequencyToNumberConveter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public IList<TLink> Convert(IList<TLink> sequence)
        {
            var levels = new TLink[sequence.Count];
            levels[0] = GetFrequencyNumber(sequence[0], sequence[1]);
            for (var i = 1; i < sequence.Count - 1; i++)
            {
                var previous = GetFrequencyNumber(sequence[i - 1], sequence[i]);
                var next = GetFrequencyNumber(sequence[i], sequence[i + 1]);
                levels[i] = _comparer.Compare(previous, next) > 0 ? previous : next;
            }
            levels[levels.Length - 1] = GetFrequencyNumber(sequence[sequence.Count - 2], sequence[sequence.Count - 1]);
            return levels;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink GetFrequencyNumber(TLink source, TLink target) => _linkToItsFrequencyToNumberConveter.Convert(new Doublet<TLink>(source, target));
    }
}
```

1.92 ./csharp/Platform.Data.Doublets/Sequences/CriterionMatchers/DefaultSequenceElementCriterionMatcher.cs

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;
```

```

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.CriterionMatchers
{
    public class DefaultSequenceElementCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
    ↪  ICriterionMatcher<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DefaultSequenceElementCriterionMatcher(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool IsMatched(TLink argument) => _links.IsPartialPoint(argument);
    }
}
```

1.93 ./csharp/Platform.Data.Doublets/Sequences/CriterionMatchers/MarkedSequenceCriterionMatcher.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.CriterionMatchers
{
    public class MarkedSequenceCriterionMatcher<TLink> : ICriterionMatcher<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly ILinks<TLink> _links;
        private readonly TLink _sequenceMarkerLink;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public MarkedSequenceCriterionMatcher(ILinks<TLink> links, TLink sequenceMarkerLink)
        {
            _links = links;
            _sequenceMarkerLink = sequenceMarkerLink;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool IsMatched(TLink sequenceCandidate)
            => _equalityComparer.Equals(_links.GetSource(sequenceCandidate), _sequenceMarkerLink)
            || !_equalityComparer.Equals(_links.SearchOrDefault(_sequenceMarkerLink,
            ↪  sequenceCandidate), _links.Constants.Null);
    }
}
```

1.94 ./csharp/Platform.Data.Doublets/Sequences/DefaultSequenceAppender.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Stacks;
using Platform.Data.Doublets.Sequences.HeightProviders;
using Platform.Data.Sequences;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    public class DefaultSequenceAppender<TLink> : LinksOperatorBase<TLink>,
    ↪  ISequenceAppender<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly IStack<TLink> _stack;
        private readonly ISequenceHeightProvider<TLink> _heightProvider;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DefaultSequenceAppender(ILinks<TLink> links, IStack<TLink> stack,
        ↪  ISequenceHeightProvider<TLink> heightProvider)
            : base(links)
        {
            _stack = stack;
            _heightProvider = heightProvider;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Append(TLink sequence, TLink appendant)
        {
```

```
            var cursor = sequence;
            var links = _links;
            while (!_equalityComparer.Equals(_heightProvider.Get(cursor), default))
            {
                var source = links.GetSource(cursor);
                var target = links.GetTarget(cursor);
                if (_equalityComparer.Equals(_heightProvider.Get(source),
                ↪  _heightProvider.Get(target)))
                {
                    break;
                }
                else
                {
                    _stack.Push(source);
                    cursor = target;
                }
            }
            var left = cursor;
            var right = appendant;
            while (!_equalityComparer.Equals(cursor = _stack.Pop(), links.Constants.Null))
            {
                right = links.GetOrCreate(left, right);
                left = cursor;
            }
            return links.GetOrCreate(left, right);
        }
    }
}
```

1.95 ./csharp/Platform.Data.Doublets/Sequences/DuplicateSegmentsCounter.cs

```
using System.Collections.Generic;
using System.Linq;
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    public class DuplicateSegmentsCounter<TLink> : ICounter<int>
    {
        private readonly IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
        ↪  _duplicateFragmentsProvider;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DuplicateSegmentsCounter(IProvider<IList<KeyValuePair<IList<TLink>,
        ↪  IList<TLink>>>> duplicateFragmentsProvider) => _duplicateFragmentsProvider =
        ↪  duplicateFragmentsProvider;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public int Count() => _duplicateFragmentsProvider.Get().Sum(x => x.Value.Count);
    }
}
```

1.96 ./csharp/Platform.Data.Doublets/Sequences/DuplicateSegmentsProvider.cs

```
using System;
using System.Linq;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Collections;
using Platform.Collections.Lists;
using Platform.Collections.Segments;
using Platform.Collections.Segments.Walkers;
using Platform.Singletons;
using Platform.Converters;
using Platform.Data.Doublets.Unicode;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    public class DuplicateSegmentsProvider<TLink> :
    ↪  DictionaryBasedDuplicateSegmentsWalkerBase<TLink>,
    ↪  IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
    {
        private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
        ↪  UncheckedConverter<TLink, long>.Default;
        private static readonly UncheckedConverter<TLink, ulong> _addressToUInt64Converter =
        ↪  UncheckedConverter<TLink, ulong>.Default;
```

```
22          private static readonly UncheckedConverter<ulong, TLink> _uInt64ToAddressConverter =
            ↪ UncheckedConverter<ulong, TLink>.Default;
23
24          private readonly ILinks<TLink> _links;
25          private readonly ILinks<TLink> _sequences;
26          private HashSet<KeyValuePair<IList<TLink>, IList<TLink>>> _groups;
27          private BitString _visited;
28
29          private class ItemEquilityComparer : IEqualityComparer<KeyValuePair<IList<TLink>,
            ↪ IList<TLink>>>
30          {
31              private readonly IListEqualityComparer<TLink> _listComparer;
32
33              public ItemEquilityComparer() => _listComparer =
                ↪ Default<IListEqualityComparer<TLink>>.Instance;
34
35              [MethodImpl(MethodImplOptions.AggressiveInlining)]
36              public bool Equals(KeyValuePair<IList<TLink>, IList<TLink>> left,
                ↪ KeyValuePair<IList<TLink>, IList<TLink>> right) =>
                ↪ _listComparer.Equals(left.Key, right.Key) && _listComparer.Equals(left.Value,
                ↪ right.Value);
37
38              [MethodImpl(MethodImplOptions.AggressiveInlining)]
39              public int GetHashCode(KeyValuePair<IList<TLink>, IList<TLink>> pair) =>
                ↪ (_listComparer.GetHashCode(pair.Key),
                ↪ _listComparer.GetHashCode(pair.Value)).GetHashCode();
40          }
41
42          private class ItemComparer : IComparer<KeyValuePair<IList<TLink>, IList<TLink>>>
43          {
44              private readonly IListComparer<TLink> _listComparer;
45
46              [MethodImpl(MethodImplOptions.AggressiveInlining)]
47              public ItemComparer() => _listComparer = Default<IListComparer<TLink>>.Instance;
48
49              [MethodImpl(MethodImplOptions.AggressiveInlining)]
50              public int Compare(KeyValuePair<IList<TLink>, IList<TLink>> left,
                ↪ KeyValuePair<IList<TLink>, IList<TLink>> right)
51              {
52                  var intermediateResult = _listComparer.Compare(left.Key, right.Key);
53                  if (intermediateResult == 0)
54                  {
55                      intermediateResult = _listComparer.Compare(left.Value, right.Value);
56                  }
57                  return intermediateResult;
58              }
59          }
60
61          [MethodImpl(MethodImplOptions.AggressiveInlining)]
62          public DuplicateSegmentsProvider(ILinks<TLink> links, ILinks<TLink> sequences)
63              : base(minimumStringSegmentLength: 2)
64          {
65              _links = links;
66              _sequences = sequences;
67          }
68
69          [MethodImpl(MethodImplOptions.AggressiveInlining)]
70          public IList<KeyValuePair<IList<TLink>, IList<TLink>>> Get()
71          {
72              _groups = new HashSet<KeyValuePair<IList<TLink>,
                ↪ IList<TLink>>>(Default<ItemEquilityComparer>.Instance);
73              var links = _links;
74              var count = links.Count();
75              _visited = new BitString(_addressToInt64Converter.Convert(count) + 1L);
76              links.Each(link =>
77              {
78                  var linkIndex = links.GetIndex(link);
79                  var linkBitIndex = _addressToInt64Converter.Convert(linkIndex);
80                  var constants = links.Constants;
81                  if (!_visited.Get(linkBitIndex))
82                  {
83                      var sequenceElements = new List<TLink>();
84                      var filler = new ListFiller<TLink, TLink>(sequenceElements, constants.Break);
85                      _sequences.Each(filler.AddSkipFirstAndReturnConstant, new
                        ↪ LinkAddress<TLink>(linkIndex));
86                      if (sequenceElements.Count > 2)
87                      {
88                          WalkAll(sequenceElements);
89                      }
```

```
                }
                return constants.Continue;
            });
            var resultList = _groups.ToList();
            var comparer = Default<ItemComparer>.Instance;
            resultList.Sort(comparer);
#if DEBUG
            foreach (var item in resultList)
            {
                PrintDuplicates(item);
            }
#endif
            return resultList;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override Segment<TLink> CreateSegment(IList<TLink> elements, int offset, int
        ↪  length) => new Segment<TLink>(elements, offset, length);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void OnDublicateFound(Segment<TLink> segment)
        {
            var duplicates = CollectDuplicatesForSegment(segment);
            if (duplicates.Count > 1)
            {
                _groups.Add(new KeyValuePair<IList<TLink>, IList<TLink>>(segment.ToArray(),
                ↪  duplicates));
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private List<TLink> CollectDuplicatesForSegment(Segment<TLink> segment)
        {
            var duplicates = new List<TLink>();
            var readAsElement = new HashSet<TLink>();
            var restrictions = segment.ShiftRight();
            var constants = _links.Constants;
            restrictions[0] = constants.Any;
            _sequences.Each(sequence =>
            {
                var sequenceIndex = sequence[constants.IndexPart];
                duplicates.Add(sequenceIndex);
                readAsElement.Add(sequenceIndex);
                return constants.Continue;
            }, restrictions);
            if (duplicates.Any(x => _visited.Get(_addressToInt64Converter.Convert(x))))
            {
                return new List<TLink>();
            }
            foreach (var duplicate in duplicates)
            {
                var duplicateBitIndex = _addressToInt64Converter.Convert(duplicate);
                _visited.Set(duplicateBitIndex);
            }
            if (_sequences is Sequences sequencesExperiments)
            {
                var partiallyMatched = sequencesExperiments.GetAllPartiallyMatchingSequences4((H
                ↪  ashSet<ulong>)(object)readAsElement,
                ↪  (IList<ulong>)segment);
                foreach (var partiallyMatchedSequence in partiallyMatched)
                {
                    var sequenceIndex =
                    ↪  _uInt64ToAddressConverter.Convert(partiallyMatchedSequence);
                    duplicates.Add(sequenceIndex);
                }
            }
            duplicates.Sort();
            return duplicates;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void PrintDuplicates(KeyValuePair<IList<TLink>, IList<TLink>> duplicatesItem)
        {
            if (!(_links is ILinks<ulong> ulongLinks))
            {
                return;
            }
            var duplicatesKey = duplicatesItem.Key;
```

```
163             var keyString = UnicodeMap.FromLinksToString((IList<ulong>)duplicatesKey);
164             Console.WriteLine($"> {keyString} ({string.Join(", ", duplicatesKey)})");
165             var duplicatesList = duplicatesItem.Value;
166             for (int i = 0; i < duplicatesList.Count; i++)
167             {
168                 var sequenceIndex = _addressToUInt64Converter.Convert(duplicatesList[i]);
169                 var formatedSequenceStructure = ulongLinks.FormatStructure(sequenceIndex, x =>
                    ↪ Point<ulong>.IsPartialPoint(x), (sb, link) => _ =
                    ↪ UnicodeMap.IsCharLink(link.Index) ?
                    ↪ sb.Append(UnicodeMap.FromLinkToChar(link.Index)) : sb.Append(link.Index));
170                 Console.WriteLine(formatedSequenceStructure);
171                 var sequenceString = UnicodeMap.FromSequenceLinkToString(sequenceIndex,
                    ↪ ulongLinks);
172                 Console.WriteLine(sequenceString);
173             }
174             Console.WriteLine();
175         }
176     }
177 }
```

1.97 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Cache/LinkFrequenciesCache.cs

```
1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Interfaces;
5  using Platform.Numbers;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
10 {
11     /// <remarks>
12     /// Can be used to operate with many CompressingConverters (to keep global frequencies data
       ↪ between them).
13     /// TODO: Extract interface to implement frequencies storage inside Links storage
14     /// </remarks>
15     public class LinkFrequenciesCache<TLink> : LinksOperatorBase<TLink>
16     {
17         private static readonly EqualityComparer<TLink> _equalityComparer =
           ↪ EqualityComparer<TLink>.Default;
18         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
19
20         private static readonly TLink _zero = default;
21         private static readonly TLink _one = Arithmetic.Increment(_zero);
22
23         private readonly Dictionary<Doublet<TLink>, LinkFrequency<TLink>> _doubletsCache;
24         private readonly ICounter<TLink, TLink> _frequencyCounter;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         public LinkFrequenciesCache(ILinks<TLink> links, ICounter<TLink, TLink> frequencyCounter)
28             : base(links)
29         {
30             _doubletsCache = new Dictionary<Doublet<TLink>, LinkFrequency<TLink>>(4096,
               ↪ DoubletComparer<TLink>.Default);
31             _frequencyCounter = frequencyCounter;
32         }
33
34         [MethodImpl(MethodImplOptions.AggressiveInlining)]
35         public LinkFrequency<TLink> GetFrequency(TLink source, TLink target)
36         {
37             var doublet = new Doublet<TLink>(source, target);
38             return GetFrequency(ref doublet);
39         }
40
41         [MethodImpl(MethodImplOptions.AggressiveInlining)]
42         public LinkFrequency<TLink> GetFrequency(ref Doublet<TLink> doublet)
43         {
44             _doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data);
45             return data;
46         }
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         public void IncrementFrequencies(IList<TLink> sequence)
50         {
51             for (var i = 1; i < sequence.Count; i++)
52             {
53                 IncrementFrequency(sequence[i - 1], sequence[i]);
54             }
55         }
```

```
56
57          [MethodImpl(MethodImplOptions.AggressiveInlining)]
58          public LinkFrequency<TLink> IncrementFrequency(TLink source, TLink target)
59          {
60              var doublet = new Doublet<TLink>(source, target);
61              return IncrementFrequency(ref doublet);
62          }
63
64          [MethodImpl(MethodImplOptions.AggressiveInlining)]
65          public void PrintFrequencies(IList<TLink> sequence)
66          {
67              for (var i = 1; i < sequence.Count; i++)
68              {
69                  PrintFrequency(sequence[i - 1], sequence[i]);
70              }
71          }
72
73          [MethodImpl(MethodImplOptions.AggressiveInlining)]
74          public void PrintFrequency(TLink source, TLink target)
75          {
76              var number = GetFrequency(source, target).Frequency;
77              Console.WriteLine("({0},{1}) - {2}", source, target, number);
78          }
79
80          [MethodImpl(MethodImplOptions.AggressiveInlining)]
81          public LinkFrequency<TLink> IncrementFrequency(ref Doublet<TLink> doublet)
82          {
83              if (_doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data))
84              {
85                  data.IncrementFrequency();
86              }
87              else
88              {
89                  var link = _links.SearchOrDefault(doublet.Source, doublet.Target);
90                  data = new LinkFrequency<TLink>(_one, link);
91                  if (!_equalityComparer.Equals(link, default))
92                  {
93                      data.Frequency = Arithmetic.Add(data.Frequency,
                        ↪  _frequencyCounter.Count(link));
94                  }
95                  _doubletsCache.Add(doublet, data);
96              }
97              return data;
98          }
99
100         [MethodImpl(MethodImplOptions.AggressiveInlining)]
101         public void ValidateFrequencies()
102         {
103             foreach (var entry in _doubletsCache)
104             {
105                 var value = entry.Value;
106                 var linkIndex = value.Link;
107                 if (!_equalityComparer.Equals(linkIndex, default))
108                 {
109                     var frequency = value.Frequency;
110                     var count = _frequencyCounter.Count(linkIndex);
111                     // TODO: Why `frequency` always greater than `count` by 1?
112                     if (((_comparer.Compare(frequency, count) > 0) &&
                        ↪  (_comparer.Compare(Arithmetic.Subtract(frequency, count), _one) > 0))
113                      || ((_comparer.Compare(count, frequency) > 0) &&
                        ↪  (_comparer.Compare(Arithmetic.Subtract(count, frequency), _one) > 0)))
114                     {
115                         throw new InvalidOperationException("Frequencies validation failed.");
116                     }
117                 }
118                 //else
119                 //{
120                 //    if (value.Frequency > 0)
121                 //    {
122                 //        var frequency = value.Frequency;
123                 //        linkIndex = _createLink(entry.Key.Source, entry.Key.Target);
124                 //        var count = _countLinkFrequency(linkIndex);
125
126                 //        if ((frequency > count && frequency - count > 1) || (count > frequency
                    ↪  && count - frequency > 1))
127                 //            throw new InvalidOperationException("Frequencies validation
                    ↪  failed.");
128                 //    }
```

```
                //}
            }
        }
    }
}
```

1.98 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Cache/LinkFrequency.cs

```
using System.Runtime.CompilerServices;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
{
    public class LinkFrequency<TLink>
    {
        public TLink Frequency { get; set; }
        public TLink Link { get; set; }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkFrequency(TLink frequency, TLink link)
        {
            Frequency = frequency;
            Link = link;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkFrequency() { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void IncrementFrequency() => Frequency = Arithmetic<TLink>.Increment(Frequency);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void DecrementFrequency() => Frequency = Arithmetic<TLink>.Decrement(Frequency);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override string ToString() => $"F: {Frequency}, L: {Link}";
    }
}
```

1.99 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Cache/LinkToItsFrequencyValueConverter.cs

```
using System.Runtime.CompilerServices;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
{
    public class FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<TLink> :
    ↪ IConverter<Doublet<TLink>, TLink>
    {
        private readonly LinkFrequenciesCache<TLink> _cache;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public
        ↪ FrequenciesCacheBasedLinkToItsFrequencyNumberConverter(LinkFrequenciesCache<TLink>
        ↪ cache) => _cache = cache;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(Doublet<TLink> source) => _cache.GetFrequency(ref source).Frequency;
    }
}
```

1.100 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/MarkedSequenceSymbolFrequencyOneO

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class MarkedSequenceSymbolFrequencyOneOffCounter<TLink> :
    ↪ SequenceSymbolFrequencyOneOffCounter<TLink>
    {
        private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public MarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
        ↪ ICriterionMatcher<TLink> markedSequenceMatcher, TLink sequenceLink, TLink symbol)
```

```
            : base(links, sequenceLink, symbol)
            => _markedSequenceMatcher = markedSequenceMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Count()
        {
            if (!_markedSequenceMatcher.IsMatched(_sequenceLink))
            {
                return default;
            }
            return base.Count();
        }
    }
}
```

1.101 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/SequenceSymbolFrequencyOneOffCoun

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Numbers;
using Platform.Data.Sequences;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class SequenceSymbolFrequencyOneOffCounter<TLink> : ICounter<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;
        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;

        protected readonly ILinks<TLink> _links;
        protected readonly TLink _sequenceLink;
        protected readonly TLink _symbol;
        protected TLink _total;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink sequenceLink,
        ↪  TLink symbol)
        {
            _links = links;
            _sequenceLink = sequenceLink;
            _symbol = symbol;
            _total = default;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual TLink Count()
        {
            if (_comparer.Compare(_total, default) > 0)
            {
                return _total;
            }
            StopableSequenceWalker.WalkRight(_sequenceLink, _links.GetSource, _links.GetTarget,
            ↪  IsElement, VisitElement);
            return _total;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool IsElement(TLink x) => _equalityComparer.Equals(x, _symbol) ||
        ↪  _links.IsPartialPoint(x); // TODO: Use SequenceElementCreteriaMatcher instead of
        ↪  IsPartialPoint

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool VisitElement(TLink element)
        {
            if (_equalityComparer.Equals(element, _symbol))
            {
                _total = Arithmetic.Increment(_total);
            }
            return true;
        }
    }
}
```

1.102 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalMarkedSequenceSymbolFrequency

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;

```

```
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class TotalMarkedSequenceSymbolFrequencyCounter<TLink> : ICounter<TLink, TLink>
    {
        private readonly ILinks<TLink> _links;
        private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TotalMarkedSequenceSymbolFrequencyCounter(ILinks<TLink> links,
        ↪  ICriterionMatcher<TLink> markedSequenceMatcher)
        {
            _links = links;
            _markedSequenceMatcher = markedSequenceMatcher;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Count(TLink argument) => new
        ↪  TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
        ↪  _markedSequenceMatcher, argument).Count();
    }
}
```

1.103 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalMarkedSequenceSymbolFrequency

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink> :
    ↪  TotalSequenceSymbolFrequencyOneOffCounter<TLink>
    {
        private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TotalMarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
        ↪  ICriterionMatcher<TLink> markedSequenceMatcher, TLink symbol)
            : base(links, symbol)
            => _markedSequenceMatcher = markedSequenceMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void CountSequenceSymbolFrequency(TLink link)
        {
            var symbolFrequencyCounter = new
            ↪  MarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
            ↪  _markedSequenceMatcher, link, _symbol);
            _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
        }
    }
}
```

1.104 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalSequenceSymbolFrequencyCounte

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class TotalSequenceSymbolFrequencyCounter<TLink> : ICounter<TLink, TLink>
    {
        private readonly ILinks<TLink> _links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TotalSequenceSymbolFrequencyCounter(ILinks<TLink> links) => _links = links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Count(TLink symbol) => new
        ↪  TotalSequenceSymbolFrequencyOneOffCounter<TLink>(_links, symbol).Count();
    }
}
```

1.105 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalSequenceSymbolFrequencyOneOff

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
```

```
using Platform.Interfaces;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class TotalSequenceSymbolFrequencyOneOffCounter<TLink> : ICounter<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;
        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;

        protected readonly ILinks<TLink> _links;
        protected readonly TLink _symbol;
        protected readonly HashSet<TLink> _visits;
        protected TLink _total;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TotalSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink symbol)
        {
            _links = links;
            _symbol = symbol;
            _visits = new HashSet<TLink>();
            _total = default;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Count()
        {
            if (_comparer.Compare(_total, default) > 0 || _visits.Count > 0)
            {
                return _total;
            }
            CountCore(_symbol);
            return _total;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void CountCore(TLink link)
        {
            var any = _links.Constants.Any;
            if (_equalityComparer.Equals(_links.Count(any, link), default))
            {
                CountSequenceSymbolFrequency(link);
            }
            else
            {
                _links.Each(EachElementHandler, any, link);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual void CountSequenceSymbolFrequency(TLink link)
        {
            var symbolFrequencyCounter = new SequenceSymbolFrequencyOneOffCounter<TLink>(_links,
            ↪  link, _symbol);
            _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private TLink EachElementHandler(IList<TLink> doublet)
        {
            var constants = _links.Constants;
            var doubletIndex = doublet[constants.IndexPart];
            if (_visits.Add(doubletIndex))
            {
                CountCore(doubletIndex);
            }
            return constants.Continue;
        }
    }
}
```

1.106 ./csharp/Platform.Data.Doublets/Sequences/HeightProviders/CachedSequenceHeightProvider.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Converters;

```

```
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.HeightProviders
{
    public class CachedSequenceHeightProvider<TLink> : ISequenceHeightProvider<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly TLink _heightPropertyMarker;
        private readonly ISequenceHeightProvider<TLink> _baseHeightProvider;
        private readonly IConverter<TLink> _addressToUnaryNumberConverter;
        private readonly IConverter<TLink> _unaryNumberToAddressConverter;
        private readonly IProperties<TLink, TLink, TLink> _propertyOperator;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public CachedSequenceHeightProvider(
            ISequenceHeightProvider<TLink> baseHeightProvider,
            IConverter<TLink> addressToUnaryNumberConverter,
            IConverter<TLink> unaryNumberToAddressConverter,
            TLink heightPropertyMarker,
            IProperties<TLink, TLink, TLink> propertyOperator)
        {
            _heightPropertyMarker = heightPropertyMarker;
            _baseHeightProvider = baseHeightProvider;
            _addressToUnaryNumberConverter = addressToUnaryNumberConverter;
            _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
            _propertyOperator = propertyOperator;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Get(TLink sequence)
        {
            TLink height;
            var heightValue = _propertyOperator.GetValue(sequence, _heightPropertyMarker);
            if (_equalityComparer.Equals(heightValue, default))
            {
                height = _baseHeightProvider.Get(sequence);
                heightValue = _addressToUnaryNumberConverter.Convert(height);
                _propertyOperator.SetValue(sequence, _heightPropertyMarker, heightValue);
            }
            else
            {
                height = _unaryNumberToAddressConverter.Convert(heightValue);
            }
            return height;
        }
    }
}
```

1.107 ./csharp/Platform.Data.Doublets/Sequences/HeightProviders/DefaultSequenceRightHeightProvider.cs

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.HeightProviders
{
    public class DefaultSequenceRightHeightProvider<TLink> : LinksOperatorBase<TLink>,
    ↪  ISequenceHeightProvider<TLink>
    {
        private readonly ICriterionMatcher<TLink> _elementMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DefaultSequenceRightHeightProvider(ILinks<TLink> links, ICriterionMatcher<TLink>
        ↪  elementMatcher) : base(links) => _elementMatcher = elementMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Get(TLink sequence)
        {
            var height = default(TLink);
            var pairOrElement = sequence;
            while (!_elementMatcher.IsMatched(pairOrElement))
            {
                pairOrElement = _links.GetTarget(pairOrElement);
                height = Arithmetic.Increment(height);
            }
            return height;
        }
```

```
    }
}
```

1.108 ./csharp/Platform.Data.Doublets/Sequences/HeightProviders/ISequenceHeightProvider.cs

```
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.HeightProviders
{
    public interface ISequenceHeightProvider<TLink> : IProvider<TLink, TLink>
    {
    }
}
```

1.109 ./csharp/Platform.Data.Doublets/Sequences/Indexes/CachedFrequencyIncrementingSequenceIndex.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Data.Doublets.Sequences.Frequencies.Cache;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public class CachedFrequencyIncrementingSequenceIndex<TLink> : ISequenceIndex<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly LinkFrequenciesCache<TLink> _cache;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public CachedFrequencyIncrementingSequenceIndex(LinkFrequenciesCache<TLink> cache) =>
        ↪  _cache = cache;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Add(IList<TLink> sequence)
        {
            var indexed = true;
            var i = sequence.Count;
            while (--i >= 1 && (indexed = IsIndexedWithIncrement(sequence[i - 1], sequence[i])))
            ↪  { }
            for (; i >= 1; i--)
            {
                _cache.IncrementFrequency(sequence[i - 1], sequence[i]);
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool IsIndexedWithIncrement(TLink source, TLink target)
        {
            var frequency = _cache.GetFrequency(source, target);
            if (frequency == null)
            {
                return false;
            }
            var indexed = !_equalityComparer.Equals(frequency.Frequency, default);
            if (indexed)
            {
                _cache.IncrementFrequency(source, target);
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool MightContain(IList<TLink> sequence)
        {
            var indexed = true;
            var i = sequence.Count;
            while (--i >= 1 && (indexed = IsIndexed(sequence[i - 1], sequence[i]))) { }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool IsIndexed(TLink source, TLink target)
        {
            var frequency = _cache.GetFrequency(source, target);
            if (frequency == null)
            {
```

```
                return false;
            }
            return !_equalityComparer.Equals(frequency.Frequency, default);
        }
    }
}
```

1.110 ./csharp/Platform.Data.Doublets/Sequences/Indexes/FrequencyIncrementingSequenceIndex.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Incrementers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public class FrequencyIncrementingSequenceIndex<TLink> : SequenceIndex<TLink>, ISequenceIndex<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer = EqualityComparer<TLink>.Default;

        private readonly IProperty<TLink, TLink> _frequencyPropertyOperator;
        private readonly IIncrementer<TLink> _frequencyIncrementer;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public FrequencyIncrementingSequenceIndex(ILinks<TLink> links, IProperty<TLink, TLink> frequencyPropertyOperator, IIncrementer<TLink> frequencyIncrementer)
            : base(links)
        {
            _frequencyPropertyOperator = frequencyPropertyOperator;
            _frequencyIncrementer = frequencyIncrementer;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override bool Add(IList<TLink> sequence)
        {
            var indexed = true;
            var i = sequence.Count;
            while (--i >= 1 && (indexed = IsIndexedWithIncrement(sequence[i - 1], sequence[i]))) { }
            for (; i >= 1; i--)
            {
                Increment(_links.GetOrCreate(sequence[i - 1], sequence[i]));
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool IsIndexedWithIncrement(TLink source, TLink target)
        {
            var link = _links.SearchOrDefault(source, target);
            var indexed = !_equalityComparer.Equals(link, default);
            if (indexed)
            {
                Increment(link);
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void Increment(TLink link)
        {
            var previousFrequency = _frequencyPropertyOperator.Get(link);
            var frequency = _frequencyIncrementer.Increment(previousFrequency);
            _frequencyPropertyOperator.Set(link, frequency);
        }
    }
}
```

1.111 ./csharp/Platform.Data.Doublets/Sequences/Indexes/ISequenceIndex.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Indexes
{
```

```
    public interface ISequenceIndex<TLink>
    {
        /// <summary>
        /// Индексирует последовательность глобально, и возвращает значение,
        /// определяющие была ли запрошенная последовательность проиндексирована ранее.
        /// </summary>
        /// <param name="sequence">Последовательность для индексации.</param>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        bool Add(IList<TLink> sequence);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        bool MightContain(IList<TLink> sequence);
    }
}
```

1.112 ./csharp/Platform.Data.Doublets/Sequences/Indexes/SequenceIndex.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public class SequenceIndex<TLink> : LinksOperatorBase<TLink>, ISequenceIndex<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SequenceIndex(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual bool Add(IList<TLink> sequence)
        {
            var indexed = true;
            var i = sequence.Count;
            while (--i >= 1 && (indexed =
            ↪  !_equalityComparer.Equals(_links.SearchOrDefault(sequence[i - 1], sequence[i]),
            ↪  default))) { }
            for (; i >= 1; i--)
            {
                _links.GetOrCreate(sequence[i - 1], sequence[i]);
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual bool MightContain(IList<TLink> sequence)
        {
            var indexed = true;
            var i = sequence.Count;
            while (--i >= 1 && (indexed =
            ↪  !_equalityComparer.Equals(_links.SearchOrDefault(sequence[i - 1], sequence[i]),
            ↪  default))) { }
            return indexed;
        }
    }
}
```

1.113 ./csharp/Platform.Data.Doublets/Sequences/Indexes/SynchronizedSequenceIndex.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public class SynchronizedSequenceIndex<TLink> : ISequenceIndex<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly ISynchronizedLinks<TLink> _links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SynchronizedSequenceIndex(ISynchronizedLinks<TLink> links) => _links = links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Add(IList<TLink> sequence)
```

```
        {
            var indexed = true;
            var i = sequence.Count;
            var links = _links.Unsync;
            _links.SyncRoot.ExecuteReadOperation(() =>
            {
                while (--i >= 1 && (indexed =
                ↪  !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
                ↪  sequence[i]), default))) { }
            });
            if (!indexed)
            {
                _links.SyncRoot.ExecuteWriteOperation(() =>
                {
                    for (; i >= 1; i--)
                    {
                        links.GetOrCreate(sequence[i - 1], sequence[i]);
                    }
                });
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool MightContain(IList<TLink> sequence)
        {
            var links = _links.Unsync;
            return _links.SyncRoot.ExecuteReadOperation(() =>
            {
                var indexed = true;
                var i = sequence.Count;
                while (--i >= 1 && (indexed =
                ↪  !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
                ↪  sequence[i]), default))) { }
                return indexed;
            });
        }
    }
}
```

1.114 ./csharp/Platform.Data.Doublets/Sequences/Indexes/Unindex.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public class Unindex<TLink> : ISequenceIndex<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual bool Add(IList<TLink> sequence) => false;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual bool MightContain(IList<TLink> sequence) => true;
    }
}
```

1.115 ./csharp/Platform.Data.Doublets/Sequences/Sequences.Experiments.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using System.Linq;
using System.Text;
using Platform.Collections;
using Platform.Collections.Sets;
using Platform.Collections.Stacks;
using Platform.Data.Exceptions;
using Platform.Data.Sequences;
using Platform.Data.Doublets.Sequences.Frequencies.Counters;
using Platform.Data.Doublets.Sequences.Walkers;
using LinkIndex = System.UInt64;
using Stack = System.Collections.Generic.Stack<ulong>;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    partial class Sequences
    {
```

```
22          #region Create All Variants (Not Practical)
23
24          /// <remarks>
25          /// Number of links that is needed to generate all variants for
26          /// sequence of length N corresponds to https://oeis.org/A014143/list sequence.
27          /// </remarks>
28          [MethodImpl(MethodImplOptions.AggressiveInlining)]
29          public ulong[] CreateAllVariants2(ulong[] sequence)
30          {
31              return _sync.ExecuteWriteOperation(() =>
32              {
33                  if (sequence.IsNullOrEmpty())
34                  {
35                      return Array.Empty<ulong>();
36                  }
37                  Links.EnsureLinkExists(sequence);
38                  if (sequence.Length == 1)
39                  {
40                      return sequence;
41                  }
42                  return CreateAllVariants2Core(sequence, 0, sequence.Length - 1);
43              });
44          }
45
46          [MethodImpl(MethodImplOptions.AggressiveInlining)]
47          private ulong[] CreateAllVariants2Core(ulong[] sequence, long startAt, long stopAt)
48          {
49  #if DEBUG
50              if ((stopAt - startAt) < 0)
51              {
52                  throw new ArgumentOutOfRangeException(nameof(startAt), "startAt должен быть
                        ↪  меньше или равен stopAt");
53              }
54  #endif
55              if ((stopAt - startAt) == 0)
56              {
57                  return new[] { sequence[startAt] };
58              }
59              if ((stopAt - startAt) == 1)
60              {
61                  return new[] { Links.Unsync.GetOrCreate(sequence[startAt], sequence[stopAt]) };
62              }
63              var variants = new ulong[(ulong)Platform.Numbers.Math.Catalan(stopAt - startAt)];
64              var last = 0;
65              for (var splitter = startAt; splitter < stopAt; splitter++)
66              {
67                  var left = CreateAllVariants2Core(sequence, startAt, splitter);
68                  var right = CreateAllVariants2Core(sequence, splitter + 1, stopAt);
69                  for (var i = 0; i < left.Length; i++)
70                  {
71                      for (var j = 0; j < right.Length; j++)
72                      {
73                          var variant = Links.Unsync.GetOrCreate(left[i], right[j]);
74                          if (variant == Constants.Null)
75                          {
76                              throw new NotImplementedException("Creation cancellation is not
                                ↪  implemented.");
77                          }
78                          variants[last++] = variant;
79                      }
80                  }
81              }
82              return variants;
83          }
84
85          [MethodImpl(MethodImplOptions.AggressiveInlining)]
86          public List<ulong> CreateAllVariants1(params ulong[] sequence)
87          {
88              return _sync.ExecuteWriteOperation(() =>
89              {
90                  if (sequence.IsNullOrEmpty())
91                  {
92                      return new List<ulong>();
93                  }
94                  Links.Unsync.EnsureLinkExists(sequence);
95                  if (sequence.Length == 1)
96                  {
97                      return new List<ulong> { sequence[0] };
```

```
98                  }
99                  var results = new
                    ↪  List<ulong>((int)Platform.Numbers.Math.Catalan(sequence.Length));
100                 return CreateAllVariants1Core(sequence, results);
101             });
102         }
103
104         [MethodImpl(MethodImplOptions.AggressiveInlining)]
105         private List<ulong> CreateAllVariants1Core(ulong[] sequence, List<ulong> results)
106         {
107             if (sequence.Length == 2)
108             {
109                 var link = Links.Unsync.GetOrCreate(sequence[0], sequence[1]);
110                 if (link == Constants.Null)
111                 {
112                     throw new NotImplementedException("Creation cancellation is not
                        ↪  implemented.");
113                 }
114                 results.Add(link);
115                 return results;
116             }
117             var innerSequenceLength = sequence.Length - 1;
118             var innerSequence = new ulong[innerSequenceLength];
119             for (var li = 0; li < innerSequenceLength; li++)
120             {
121                 var link = Links.Unsync.GetOrCreate(sequence[li], sequence[li + 1]);
122                 if (link == Constants.Null)
123                 {
124                     throw new NotImplementedException("Creation cancellation is not
                        ↪  implemented.");
125                 }
126                 for (var isi = 0; isi < li; isi++)
127                 {
128                     innerSequence[isi] = sequence[isi];
129                 }
130                 innerSequence[li] = link;
131                 for (var isi = li + 1; isi < innerSequenceLength; isi++)
132                 {
133                     innerSequence[isi] = sequence[isi + 1];
134                 }
135                 CreateAllVariants1Core(innerSequence, results);
136             }
137             return results;
138         }
139
140         #endregion
141
142         [MethodImpl(MethodImplOptions.AggressiveInlining)]
143         public HashSet<ulong> Each1(params ulong[] sequence)
144         {
145             var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
146             Each1(link =>
147             {
148                 if (!visitedLinks.Contains(link))
149                 {
150                     visitedLinks.Add(link); // изучить почему случаются повторы
151                 }
152                 return true;
153             }, sequence);
154             return visitedLinks;
155         }
156
157         [MethodImpl(MethodImplOptions.AggressiveInlining)]
158         private void Each1(Func<ulong, bool> handler, params ulong[] sequence)
159         {
160             if (sequence.Length == 2)
161             {
162                 Links.Unsync.Each(sequence[0], sequence[1], handler);
163             }
164             else
165             {
166                 var innerSequenceLength = sequence.Length - 1;
167                 for (var li = 0; li < innerSequenceLength; li++)
168                 {
169                     var left = sequence[li];
170                     var right = sequence[li + 1];
171                     if (left == 0 && right == 0)
172                     {
```

```
                    continue;
                }
                var linkIndex = li;
                ulong[] innerSequence = null;
                Links.Unsync.Each(doublet =>
                {
                    if (innerSequence == null)
                    {
                        innerSequence = new ulong[innerSequenceLength];
                        for (var isi = 0; isi < linkIndex; isi++)
                        {
                            innerSequence[isi] = sequence[isi];
                        }
                        for (var isi = linkIndex + 1; isi < innerSequenceLength; isi++)
                        {
                            innerSequence[isi] = sequence[isi + 1];
                        }
                    }
                    innerSequence[linkIndex] = doublet[Constants.IndexPart];
                    Each1(handler, innerSequence);
                    return Constants.Continue;
                }, Constants.Any, left, right);
            }
        }
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public HashSet<ulong> EachPart(params ulong[] sequence)
    {
        var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
        EachPartCore(link =>
        {
            var linkIndex = link[Constants.IndexPart];
            if (!visitedLinks.Contains(linkIndex))
            {
                visitedLinks.Add(linkIndex); // изучить почему случаются повторы
            }
            return Constants.Continue;
        }, sequence);
        return visitedLinks;
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public void EachPart(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[] sequence)
    {
        var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
        EachPartCore(link =>
        {
            var linkIndex = link[Constants.IndexPart];
            if (!visitedLinks.Contains(linkIndex))
            {
                visitedLinks.Add(linkIndex); // изучить почему случаются повторы
                return handler(new LinkAddress<LinkIndex>(linkIndex));
            }
            return Constants.Continue;
        }, sequence);
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private void EachPartCore(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[]
    ↪ sequence)
    {
        if (sequence.IsNullOrEmpty())
        {
            return;
        }
        Links.EnsureLinkIsAnyOrExists(sequence);
        if (sequence.Length == 1)
        {
            var link = sequence[0];
            if (link > 0)
            {
                handler(new LinkAddress<LinkIndex>(link));
            }
            else
            {
                Links.Each(Constants.Any, Constants.Any, handler);
            }
```

```
250             }
251             else if (sequence.Length == 2)
252             {
253                 //_links.Each(sequence[0], sequence[1], handler);
254                 //  o_|      x_o ...
255                 // x_|        |___|
256                 Links.Each(sequence[1], Constants.Any, doublet =>
257                 {
258                     var match = Links.SearchOrDefault(sequence[0], doublet);
259                     if (match != Constants.Null)
260                     {
261                         handler(new LinkAddress<LinkIndex>(match));
262                     }
263                     return true;
264                 });
265                 // |_x      ... x_o
266                 //  |_o      |___|
267                 Links.Each(Constants.Any, sequence[0], doublet =>
268                 {
269                     var match = Links.SearchOrDefault(doublet, sequence[1]);
270                     if (match != 0)
271                     {
272                         handler(new LinkAddress<LinkIndex>(match));
273                     }
274                     return true;
275                 });
276                 //           ._x o_.
277                 //            |___|
278                 PartialStepRight(x => handler(x), sequence[0], sequence[1]);
279             }
280             else
281             {
282                 throw new NotImplementedException();
283             }
284         }
285 
286         [MethodImpl(MethodImplOptions.AggressiveInlining)]
287         private void PartialStepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
288         {
289             Links.Unsync.Each(Constants.Any, left, doublet =>
290             {
291                 StepRight(handler, doublet, right);
292                 if (left != doublet)
293                 {
294                     PartialStepRight(handler, doublet, right);
295                 }
296                 return true;
297             });
298         }
299 
300         [MethodImpl(MethodImplOptions.AggressiveInlining)]
301         private void StepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
302         {
303             Links.Unsync.Each(left, Constants.Any, rightStep =>
304             {
305                 TryStepRightUp(handler, right, rightStep);
306                 return true;
307             });
308         }
309 
310         [MethodImpl(MethodImplOptions.AggressiveInlining)]
311         private void TryStepRightUp(Action<IList<LinkIndex>> handler, ulong right, ulong
            ↪ stepFrom)
312         {
313             var upStep = stepFrom;
314             var firstSource = Links.Unsync.GetTarget(upStep);
315             while (firstSource != right && firstSource != upStep)
316             {
317                 upStep = firstSource;
318                 firstSource = Links.Unsync.GetSource(upStep);
319             }
320             if (firstSource == right)
321             {
322                 handler(new LinkAddress<LinkIndex>(stepFrom));
323             }
324         }
325 
326         // TODO: Test
```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void PartialStepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
        {
            Links.Unsync.Each(right, Constants.Any, doublet =>
            {
                StepLeft(handler, left, doublet);
                if (right != doublet)
                {
                    PartialStepLeft(handler, left, doublet);
                }
                return true;
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void StepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
        {
            Links.Unsync.Each(Constants.Any, right, leftStep =>
            {
                TryStepLeftUp(handler, left, leftStep);
                return true;
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void TryStepLeftUp(Action<IList<LinkIndex>> handler, ulong left, ulong stepFrom)
        {
            var upStep = stepFrom;
            var firstTarget = Links.Unsync.GetSource(upStep);
            while (firstTarget != left && firstTarget != upStep)
            {
                upStep = firstTarget;
                firstTarget = Links.Unsync.GetTarget(upStep);
            }
            if (firstTarget == left)
            {
                handler(new LinkAddress<LinkIndex>(stepFrom));
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool StartsWith(ulong sequence, ulong link)
        {
            var upStep = sequence;
            var firstSource = Links.Unsync.GetSource(upStep);
            while (firstSource != link && firstSource != upStep)
            {
                upStep = firstSource;
                firstSource = Links.Unsync.GetSource(upStep);
            }
            return firstSource == link;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool EndsWith(ulong sequence, ulong link)
        {
            var upStep = sequence;
            var lastTarget = Links.Unsync.GetTarget(upStep);
            while (lastTarget != link && lastTarget != upStep)
            {
                upStep = lastTarget;
                lastTarget = Links.Unsync.GetTarget(upStep);
            }
            return lastTarget == link;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public List<ulong> GetAllMatchingSequences0(params ulong[] sequence)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                var results = new List<ulong>();
                if (sequence.Length > 0)
                {
                    Links.EnsureLinkExists(sequence);
                    var firstElement = sequence[0];
                    if (sequence.Length == 1)
                    {
                        results.Add(firstElement);
```

```
                    return results;
                }
                if (sequence.Length == 2)
                {
                    var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
                    if (doublet != Constants.Null)
                    {
                        results.Add(doublet);
                    }
                    return results;
                }
                var linksInSequence = new HashSet<ulong>(sequence);
                void handler(IList<LinkIndex> result)
                {
                    var resultIndex = result[Links.Constants.IndexPart];
                    var filterPosition = 0;
                    StopableSequenceWalker.WalkRight(resultIndex, Links.Unsync.GetSource,
                    ↪  Links.Unsync.GetTarget,
                        x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
                        ↪  x =>
                        {
                            if (filterPosition == sequence.Length)
                            {
                                filterPosition = -2; // Длиннее чем нужно
                                return false;
                            }
                            if (x != sequence[filterPosition])
                            {
                                filterPosition = -1;
                                return false; // Начинается иначе
                            }
                            filterPosition++;

                            return true;
                        });
                    if (filterPosition == sequence.Length)
                    {
                        results.Add(resultIndex);
                    }
                }
                if (sequence.Length >= 2)
                {
                    StepRight(handler, sequence[0], sequence[1]);
                }
                var last = sequence.Length - 2;
                for (var i = 1; i < last; i++)
                {
                    PartialStepRight(handler, sequence[i], sequence[i + 1]);
                }
                if (sequence.Length >= 3)
                {
                    StepLeft(handler, sequence[sequence.Length - 2],
                    ↪  sequence[sequence.Length - 1]);
                }
            }
            return results;
        });
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public HashSet<ulong> GetAllMatchingSequences1(params ulong[] sequence)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            var results = new HashSet<ulong>();
            if (sequence.Length > 0)
            {
                Links.EnsureLinkExists(sequence);
                var firstElement = sequence[0];
                if (sequence.Length == 1)
                {
                    results.Add(firstElement);
                    return results;
                }
                if (sequence.Length == 2)
                {
                    var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
                    if (doublet != Constants.Null)
```

```
                    {
                        results.Add(doublet);
                    }
                    return results;
                }
                var matcher = new Matcher(this, sequence, results, null);
                if (sequence.Length >= 2)
                {
                    StepRight(matcher.AddFullMatchedToResults, sequence[0], sequence[1]);
                }
                var last = sequence.Length - 2;
                for (var i = 1; i < last; i++)
                {
                    PartialStepRight(matcher.AddFullMatchedToResults, sequence[i],
                    ↪  sequence[i + 1]);
                }
                if (sequence.Length >= 3)
                {
                    StepLeft(matcher.AddFullMatchedToResults, sequence[sequence.Length - 2],
                    ↪  sequence[sequence.Length - 1]);
                }
            }
            return results;
        });
    }

    public const int MaxSequenceFormatSize = 200;

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public string FormatSequence(LinkIndex sequenceLink, params LinkIndex[] knownElements)
    ↪  => FormatSequence(sequenceLink, (sb, x) => sb.Append(x), true, knownElements);

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public string FormatSequence(LinkIndex sequenceLink, Action<StringBuilder, LinkIndex>
    ↪  elementToString, bool insertComma, params LinkIndex[] knownElements) =>
    ↪  Links.SyncRoot.ExecuteReadOperation(() => FormatSequence(Links.Unsync, sequenceLink,
    ↪  elementToString, insertComma, knownElements));

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private string FormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
    ↪  Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
    ↪  LinkIndex[] knownElements)
    {
        var linksInSequence = new HashSet<ulong>(knownElements);
        //var entered = new HashSet<ulong>();
        var sb = new StringBuilder();
        sb.Append('{');
        if (links.Exists(sequenceLink))
        {
            StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
                x => linksInSequence.Contains(x) || links.IsPartialPoint(x), element => //
                ↪  entered.AddAndReturnVoid, x => { }, entered.DoNotContains
                {
                    if (insertComma && sb.Length > 1)
                    {
                        sb.Append(',');
                    }
                    //if (entered.Contains(element))
                    //{
                    //    sb.Append('{');
                    //    elementToString(sb, element);
                    //    sb.Append('}');
                    //}
                    //else
                    elementToString(sb, element);
                    if (sb.Length < MaxSequenceFormatSize)
                    {
                        return true;
                    }
                    sb.Append(insertComma ? ", ..." : "...");
                    return false;
                });
        }
        sb.Append('}');
        return sb.ToString();
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
550         public string SafeFormatSequence(LinkIndex sequenceLink, params LinkIndex[]
            ↪ knownElements) => SafeFormatSequence(sequenceLink, (sb, x) => sb.Append(x), true,
            ↪ knownElements);
551
552         [MethodImpl(MethodImplOptions.AggressiveInlining)]
553         public string SafeFormatSequence(LinkIndex sequenceLink, Action<StringBuilder,
            ↪ LinkIndex> elementToString, bool insertComma, params LinkIndex[] knownElements) =>
            ↪ Links.SyncRoot.ExecuteReadOperation(() => SafeFormatSequence(Links.Unsync,
            ↪ sequenceLink, elementToString, insertComma, knownElements));
554
555         [MethodImpl(MethodImplOptions.AggressiveInlining)]
556         private string SafeFormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
            ↪ Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
            ↪ LinkIndex[] knownElements)
557         {
558             var linksInSequence = new HashSet<ulong>(knownElements);
559             var entered = new HashSet<ulong>();
560             var sb = new StringBuilder();
561             sb.Append('{');
562             if (links.Exists(sequenceLink))
563             {
564                 StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
565                     x => linksInSequence.Contains(x) || links.IsFullPoint(x),
                        ↪ entered.AddAndReturnVoid, x => { }, entered.DoNotContains, element =>
566                     {
567                         if (insertComma && sb.Length > 1)
568                         {
569                             sb.Append(',');
570                         }
571                         if (entered.Contains(element))
572                         {
573                             sb.Append('{');
574                             elementToString(sb, element);
575                             sb.Append('}');
576                         }
577                         else
578                         {
579                             elementToString(sb, element);
580                         }
581                         if (sb.Length < MaxSequenceFormatSize)
582                         {
583                             return true;
584                         }
585                         sb.Append(insertComma ? ", ..." : "...");
586                         return false;
587                     });
588             }
589             sb.Append('}');
590             return sb.ToString();
591         }
592
593         [MethodImpl(MethodImplOptions.AggressiveInlining)]
594         public List<ulong> GetAllPartiallyMatchingSequences0(params ulong[] sequence)
595         {
596             return _sync.ExecuteReadOperation(() =>
597             {
598                 if (sequence.Length > 0)
599                 {
600                     Links.EnsureLinkExists(sequence);
601                     var results = new HashSet<ulong>();
602                     for (var i = 0; i < sequence.Length; i++)
603                     {
604                         AllUsagesCore(sequence[i], results);
605                     }
606                     var filteredResults = new List<ulong>();
607                     var linksInSequence = new HashSet<ulong>(sequence);
608                     foreach (var result in results)
609                     {
610                         var filterPosition = -1;
611                         StopableSequenceWalker.WalkRight(result, Links.Unsync.GetSource,
                            ↪ Links.Unsync.GetTarget,
612                             x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
                                ↪ x =>
613                             {
614                                 if (filterPosition == (sequence.Length - 1))
615                                 {
616                                     return false;
617                                 }
```

```
                                if (filterPosition >= 0)
                                {
                                    if (x == sequence[filterPosition + 1])
                                    {
                                        filterPosition++;
                                    }
                                    else
                                    {
                                        return false;
                                    }
                                }
                                if (filterPosition < 0)
                                {
                                    if (x == sequence[0])
                                    {
                                        filterPosition = 0;
                                    }
                                }
                                return true;
                            });
                        if (filterPosition == (sequence.Length - 1))
                        {
                            filteredResults.Add(result);
                        }
                    }
                    return filteredResults;
                }
                return new List<ulong>();
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> GetAllPartiallyMatchingSequences1(params ulong[] sequence)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                if (sequence.Length > 0)
                {
                    Links.EnsureLinkExists(sequence);
                    var results = new HashSet<ulong>();
                    for (var i = 0; i < sequence.Length; i++)
                    {
                        AllUsagesCore(sequence[i], results);
                    }
                    var filteredResults = new HashSet<ulong>();
                    var matcher = new Matcher(this, sequence, filteredResults, null);
                    matcher.AddAllPartialMatchedToResults(results);
                    return filteredResults;
                }
                return new HashSet<ulong>();
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool GetAllPartiallyMatchingSequences2(Func<IList<LinkIndex>, LinkIndex> handler,
        ↪  params ulong[] sequence)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                if (sequence.Length > 0)
                {
                    Links.EnsureLinkExists(sequence);

                    var results = new HashSet<ulong>();
                    var filteredResults = new HashSet<ulong>();
                    var matcher = new Matcher(this, sequence, filteredResults, handler);
                    for (var i = 0; i < sequence.Length; i++)
                    {
                        if (!AllUsagesCore1(sequence[i], results, matcher.HandlePartialMatched))
                        {
                            return false;
                        }
                    }
                    return true;
                }
                return true;
            });
        }

```

```
696         //public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
697         //{
698         //    return Sync.ExecuteReadOperation(() =>
699         //    {
700         //        if (sequence.Length > 0)
701         //        {
702         //            _links.EnsureEachLinkIsAnyOrExists(sequence);
703 
704         //            var firstResults = new HashSet<ulong>();
705         //            var lastResults = new HashSet<ulong>();
706 
707         //            var first = sequence.First(x => x != LinksConstants.Any);
708         //            var last = sequence.Last(x => x != LinksConstants.Any);
709 
710         //            AllUsagesCore(first, firstResults);
711         //            AllUsagesCore(last, lastResults);
712 
713         //            firstResults.IntersectWith(lastResults);
714 
715         //            //for (var i = 0; i < sequence.Length; i++)
716         //            //    AllUsagesCore(sequence[i], results);
717 
718         //            var filteredResults = new HashSet<ulong>();
719         //            var matcher = new Matcher(this, sequence, filteredResults, null);
720         //            matcher.AddAllPartialMatchedToResults(firstResults);
721         //            return filteredResults;
722         //        }
723 
724         //        return new HashSet<ulong>();
725         //    });
726         //}
727 
728         [MethodImpl(MethodImplOptions.AggressiveInlining)]
729         public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
730         {
731             return _sync.ExecuteReadOperation((Func<HashSet<ulong>>)(() =>
732             {
733                 if (sequence.Length > 0)
734                 {
735                     ILinksExtensions.EnsureLinkIsAnyOrExists<ulong>(Links,
                        ↪  (IList<ulong>)sequence);
736                     var firstResults = new HashSet<ulong>();
737                     var lastResults = new HashSet<ulong>();
738                     var first = sequence.First(x => x != Constants.Any);
739                     var last = sequence.Last(x => x != Constants.Any);
740                     AllUsagesCore(first, firstResults);
741                     AllUsagesCore(last, lastResults);
742                     firstResults.IntersectWith(lastResults);
743                     //for (var i = 0; i < sequence.Length; i++)
744                     //    AllUsagesCore(sequence[i], results);
745                     var filteredResults = new HashSet<ulong>();
746                     var matcher = new Matcher(this, sequence, filteredResults, null);
747                     matcher.AddAllPartialMatchedToResults(firstResults);
748                     return filteredResults;
749                 }
750                 return new HashSet<ulong>();
751             }));
752         }
753 
754         [MethodImpl(MethodImplOptions.AggressiveInlining)]
755         public HashSet<ulong> GetAllPartiallyMatchingSequences4(HashSet<ulong> readAsElements,
            ↪  IList<ulong> sequence)
756         {
757             return _sync.ExecuteReadOperation(() =>
758             {
759                 if (sequence.Count > 0)
760                 {
761                     Links.EnsureLinkExists(sequence);
762                     var results = new HashSet<LinkIndex>();
763                     //var nextResults = new HashSet<ulong>();
764                     //for (var i = 0; i < sequence.Length; i++)
765                     //{
766                     //    AllUsagesCore(sequence[i], nextResults);
767                     //    if (results.IsNullOrEmpty())
768                     //    {
769                     //        results = nextResults;
770                     //        nextResults = new HashSet<ulong>();
771                     //    }
```

```
                    //    else
                    //    {
                    //        results.IntersectWith(nextResults);
                    //        nextResults.Clear();
                    //    }
                    //}
                    var collector1 = new AllUsagesCollector1(Links.Unsync, results);
                    collector1.Collect(Links.Unsync.GetLink(sequence[0]));
                    var next = new HashSet<ulong>();
                    for (var i = 1; i < sequence.Count; i++)
                    {
                        var collector = new AllUsagesCollector1(Links.Unsync, next);
                        collector.Collect(Links.Unsync.GetLink(sequence[i]));

                        results.IntersectWith(next);
                        next.Clear();
                    }
                    var filteredResults = new HashSet<ulong>();
                    var matcher = new Matcher(this, sequence, filteredResults, null,
                    ↪  readAsElements);
                    matcher.AddAllPartialMatchedToResultsAndReadAsElements(results.OrderBy(x =>
                    ↪  x)); // OrderBy is a Hack
                    return filteredResults;
                }
                return new HashSet<ulong>();
            });
        }

        // Does not work
        //public HashSet<ulong> GetAllPartiallyMatchingSequences5(HashSet<ulong> readAsElements,
        ↪  params ulong[] sequence)
        //{
        //    var visited = new HashSet<ulong>();
        //    var results = new HashSet<ulong>();
        //    var matcher = new Matcher(this, sequence, visited, x => { results.Add(x); return
        ↪  true; }, readAsElements);
        //    var last = sequence.Length - 1;
        //    for (var i = 0; i < last; i++)
        //    {
        //        PartialStepRight(matcher.PartialMatch, sequence[i], sequence[i + 1]);
        //    }
        //    return results;
        //}

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public List<ulong> GetAllPartiallyMatchingSequences(params ulong[] sequence)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                if (sequence.Length > 0)
                {
                    Links.EnsureLinkExists(sequence);
                    //var firstElement = sequence[0];
                    //if (sequence.Length == 1)
                    //{
                    //    //results.Add(firstElement);
                    //    return results;
                    //}
                    //if (sequence.Length == 2)
                    //{
                    //    //var doublet = _links.SearchCore(firstElement, sequence[1]);
                    //    //if (doublet != Doublets.Links.Null)
                    //    //    results.Add(doublet);
                    //    return results;
                    //}
                    //var lastElement = sequence[sequence.Length - 1];
                    //Func<ulong, bool> handler = x =>
                    //{
                    //    if (StartsWith(x, firstElement) && EndsWith(x, lastElement))
                    ↪  results.Add(x);
                    //    return true;
                    //};
                    //if (sequence.Length >= 2)
                    //    StepRight(handler, sequence[0], sequence[1]);
                    //var last = sequence.Length - 2;
                    //for (var i = 1; i < last; i++)
                    //    PartialStepRight(handler, sequence[i], sequence[i + 1]);
```

```
                    //if (sequence.Length >= 3)
                    //    StepLeft(handler, sequence[sequence.Length - 2],
                    ↪  sequence[sequence.Length - 1]);
                    //////if (sequence.Length == 1)
                    //////{
                    //////    throw new NotImplementedException(); // all sequences, containing
                    ↪  this element?
                    //////}
                    //////if (sequence.Length == 2)
                    //////{
                    //////    var results = new List<ulong>();
                    //////    PartialStepRight(results.Add, sequence[0], sequence[1]);
                    //////    return results;
                    //////}
                    //////var matches = new List<List<ulong>>();
                    //////var last = sequence.Length - 1;
                    //////for (var i = 0; i < last; i++)
                    //////{
                    //////    var results = new List<ulong>();
                    //////    //StepRight(results.Add, sequence[i], sequence[i + 1]);
                    //////    PartialStepRight(results.Add, sequence[i], sequence[i + 1]);
                    //////    if (results.Count > 0)
                    //////        matches.Add(results);
                    //////    else
                    //////        return results;
                    //////    if (matches.Count == 2)
                    //////    {
                    //////        var merged = new List<ulong>();
                    //////        for (var j = 0; j < matches[0].Count; j++)
                    //////            for (var k = 0; k < matches[1].Count; k++)
                    //////                CloseInnerConnections(merged.Add, matches[0][j],
                    ↪  matches[1][k]);
                    //////        if (merged.Count > 0)
                    //////            matches = new List<List<ulong>> { merged };
                    //////        else
                    //////            return new List<ulong>();
                    //////    }
                    //////}
                    //////if (matches.Count > 0)
                    //////{
                    //////    var usages = new HashSet<ulong>();
                    //////    for (int i = 0; i < sequence.Length; i++)
                    //////    {
                    //////        AllUsagesCore(sequence[i], usages);
                    //////    }
                    //////    //for (int i = 0; i < matches[0].Count; i++)
                    //////    //    AllUsagesCore(matches[0][i], usages);
                    //////    //usages.UnionWith(matches[0]);
                    //////    return usages.ToList();
                    //////}
                    var firstLinkUsages = new HashSet<ulong>();
                    AllUsagesCore(sequence[0], firstLinkUsages);
                    firstLinkUsages.Add(sequence[0]);
                    //var previousMatchings = firstLinkUsages.ToList(); //new List<ulong>() {
                    ↪  sequence[0] }; // or all sequences, containing this element?
                    //return GetAllPartiallyMatchingSequencesCore(sequence, firstLinkUsages,
                    ↪  1).ToList();
                    var results = new HashSet<ulong>();
                    foreach (var match in GetAllPartiallyMatchingSequencesCore(sequence,
                    ↪  firstLinkUsages, 1))
                    {
                        AllUsagesCore(match, results);
                    }
                    return results.ToList();
                }
                return new List<ulong>();
            });
        }

        /// <remarks>
        /// TODO: Может потробоваться ограничение на уровень глубины рекурсии
        /// </remarks>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> AllUsages(ulong link)
        {
            return _sync.ExecuteReadOperation(() =>
            {
```

```
915                 var usages = new HashSet<ulong>();
916                 AllUsagesCore(link, usages);
917                 return usages;
918             });
919         }
920 
921         // При сборе всех использований (последовательностей) можно сохранять обратный путь к
    ↪  той связи с которой начинался поиск (STTTSSSTT),
922         // причём достаточно одного бита для хранения перехода влево или вправо
923         [MethodImpl(MethodImplOptions.AggressiveInlining)]
924         private void AllUsagesCore(ulong link, HashSet<ulong> usages)
925         {
926             bool handler(ulong doublet)
927             {
928                 if (usages.Add(doublet))
929                 {
930                     AllUsagesCore(doublet, usages);
931                 }
932                 return true;
933             }
934             Links.Unsync.Each(link, Constants.Any, handler);
935             Links.Unsync.Each(Constants.Any, link, handler);
936         }
937 
938         [MethodImpl(MethodImplOptions.AggressiveInlining)]
939         public HashSet<ulong> AllBottomUsages(ulong link)
940         {
941             return _sync.ExecuteReadOperation(() =>
942             {
943                 var visits = new HashSet<ulong>();
944                 var usages = new HashSet<ulong>();
945                 AllBottomUsagesCore(link, visits, usages);
946                 return usages;
947             });
948         }
949 
950         [MethodImpl(MethodImplOptions.AggressiveInlining)]
951         private void AllBottomUsagesCore(ulong link, HashSet<ulong> visits, HashSet<ulong>
    ↪  usages)
952         {
953             bool handler(ulong doublet)
954             {
955                 if (visits.Add(doublet))
956                 {
957                     AllBottomUsagesCore(doublet, visits, usages);
958                 }
959                 return true;
960             }
961             if (Links.Unsync.Count(Constants.Any, link) == 0)
962             {
963                 usages.Add(link);
964             }
965             else
966             {
967                 Links.Unsync.Each(link, Constants.Any, handler);
968                 Links.Unsync.Each(Constants.Any, link, handler);
969             }
970         }
971 
972         [MethodImpl(MethodImplOptions.AggressiveInlining)]
973         public ulong CalculateTotalSymbolFrequencyCore(ulong symbol)
974         {
975             if (Options.UseSequenceMarker)
976             {
977                 var counter = new TotalMarkedSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
    ↪  Options.MarkedSequenceMatcher, symbol);
978                 return counter.Count();
979             }
980             else
981             {
982                 var counter = new TotalSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
    ↪  symbol);
983                 return counter.Count();
984             }
985         }
986 
987         [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
988             private bool AllUsagesCore1(ulong link, HashSet<ulong> usages, Func<IList<LinkIndex>,
                ↪  LinkIndex> outerHandler)
989             {
990                 bool handler(ulong doublet)
991                 {
992                     if (usages.Add(doublet))
993                     {
994                         if (outerHandler(new LinkAddress<LinkIndex>(doublet)) != Constants.Continue)
995                         {
996                             return false;
997                         }
998                         if (!AllUsagesCore1(doublet, usages, outerHandler))
999                         {
1000                            return false;
1001                        }
1002                    }
1003                    return true;
1004                }
1005                return Links.Unsync.Each(link, Constants.Any, handler)
1006                    && Links.Unsync.Each(Constants.Any, link, handler);
1007            }
1008
1009            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1010            public void CalculateAllUsages(ulong[] totals)
1011            {
1012                var calculator = new AllUsagesCalculator(Links, totals);
1013                calculator.Calculate();
1014            }
1015
1016            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1017            public void CalculateAllUsages2(ulong[] totals)
1018            {
1019                var calculator = new AllUsagesCalculator2(Links, totals);
1020                calculator.Calculate();
1021            }
1022
1023            private class AllUsagesCalculator
1024            {
1025                private readonly SynchronizedLinks<ulong> _links;
1026                private readonly ulong[] _totals;
1027
1028                [MethodImpl(MethodImplOptions.AggressiveInlining)]
1029                public AllUsagesCalculator(SynchronizedLinks<ulong> links, ulong[] totals)
1030                {
1031                    _links = links;
1032                    _totals = totals;
1033                }
1034
1035                [MethodImpl(MethodImplOptions.AggressiveInlining)]
1036                public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
                    ↪  CalculateCore);
1037
1038                [MethodImpl(MethodImplOptions.AggressiveInlining)]
1039                private bool CalculateCore(ulong link)
1040                {
1041                    if (_totals[link] == 0)
1042                    {
1043                        var total = 1UL;
1044                        _totals[link] = total;
1045                        var visitedChildren = new HashSet<ulong>();
1046                        bool linkCalculator(ulong child)
1047                        {
1048                            if (link != child && visitedChildren.Add(child))
1049                            {
1050                                total += _totals[child] == 0 ? 1 : _totals[child];
1051                            }
1052                            return true;
1053                        }
1054                        _links.Unsync.Each(link, _links.Constants.Any, linkCalculator);
1055                        _links.Unsync.Each(_links.Constants.Any, link, linkCalculator);
1056                        _totals[link] = total;
1057                    }
1058                    return true;
1059                }
1060            }
1061
1062            private class AllUsagesCalculator2
1063            {
1064                private readonly SynchronizedLinks<ulong> _links;
```

```
1065            private readonly ulong[] _totals;
1066
1067            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1068            public AllUsagesCalculator2(SynchronizedLinks<ulong> links, ulong[] totals)
1069            {
1070                _links = links;
1071                _totals = totals;
1072            }
1073
1074            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1075            public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
                ↪  CalculateCore);
1076
1077            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1078            private bool IsElement(ulong link)
1079            {
1080                //_linksInSequence.Contains(link) ||
1081                return _links.Unsync.GetTarget(link) == link || _links.Unsync.GetSource(link) ==
                    ↪  link;
1082            }
1083
1084            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1085            private bool CalculateCore(ulong link)
1086            {
1087                // TODO: Проработать защиту от зацикливания
1088                // Основано на SequenceWalker.WalkLeft
1089                Func<ulong, ulong> getSource = _links.Unsync.GetSource;
1090                Func<ulong, ulong> getTarget = _links.Unsync.GetTarget;
1091                Func<ulong, bool> isElement = IsElement;
1092                void visitLeaf(ulong parent)
1093                {
1094                    if (link != parent)
1095                    {
1096                        _totals[parent]++;
1097                    }
1098                }
1099                void visitNode(ulong parent)
1100                {
1101                    if (link != parent)
1102                    {
1103                        _totals[parent]++;
1104                    }
1105                }
1106                var stack = new Stack();
1107                var element = link;
1108                if (isElement(element))
1109                {
1110                    visitLeaf(element);
1111                }
1112                else
1113                {
1114                    while (true)
1115                    {
1116                        if (isElement(element))
1117                        {
1118                            if (stack.Count == 0)
1119                            {
1120                                break;
1121                            }
1122                            element = stack.Pop();
1123                            var source = getSource(element);
1124                            var target = getTarget(element);
1125                            // Обработка элемента
1126                            if (isElement(target))
1127                            {
1128                                visitLeaf(target);
1129                            }
1130                            if (isElement(source))
1131                            {
1132                                visitLeaf(source);
1133                            }
1134                            element = source;
1135                        }
1136                        else
1137                        {
1138                            stack.Push(element);
1139                            visitNode(element);
1140                            element = getTarget(element);
1141                        }
```

```
                }
            }
            _totals[link]++;
            return true;
        }
    }

    private class AllUsagesCollector
    {
        private readonly ILinks<ulong> _links;
        private readonly HashSet<ulong> _usages;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public AllUsagesCollector(ILinks<ulong> links, HashSet<ulong> usages)
        {
            _links = links;
            _usages = usages;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Collect(ulong link)
        {
            if (_usages.Add(link))
            {
                _links.Each(link, _links.Constants.Any, Collect);
                _links.Each(_links.Constants.Any, link, Collect);
            }
            return true;
        }
    }

    private class AllUsagesCollector1
    {
        private readonly ILinks<ulong> _links;
        private readonly HashSet<ulong> _usages;
        private readonly ulong _continue;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public AllUsagesCollector1(ILinks<ulong> links, HashSet<ulong> usages)
        {
            _links = links;
            _usages = usages;
            _continue = _links.Constants.Continue;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ulong Collect(IList<ulong> link)
        {
            var linkIndex = _links.GetIndex(link);
            if (_usages.Add(linkIndex))
            {
                _links.Each(Collect, _links.Constants.Any, linkIndex);
            }
            return _continue;
        }
    }

    private class AllUsagesCollector2
    {
        private readonly ILinks<ulong> _links;
        private readonly BitString _usages;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public AllUsagesCollector2(ILinks<ulong> links, BitString usages)
        {
            _links = links;
            _usages = usages;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Collect(ulong link)
        {
            if (_usages.Add((long)link))
            {
                _links.Each(link, _links.Constants.Any, Collect);
                _links.Each(_links.Constants.Any, link, Collect);
            }
            return true;
        }
    }
```

```
1222
1223        private class AllUsagesIntersectingCollector
1224        {
1225            private readonly SynchronizedLinks<ulong> _links;
1226            private readonly HashSet<ulong> _intersectWith;
1227            private readonly HashSet<ulong> _usages;
1228            private readonly HashSet<ulong> _enter;
1229
1230            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1231            public AllUsagesIntersectingCollector(SynchronizedLinks<ulong> links, HashSet<ulong>
                ↪ intersectWith, HashSet<ulong> usages)
1232            {
1233                _links = links;
1234                _intersectWith = intersectWith;
1235                _usages = usages;
1236                _enter = new HashSet<ulong>(); // защита от зацикливания
1237            }
1238
1239            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1240            public bool Collect(ulong link)
1241            {
1242                if (_enter.Add(link))
1243                {
1244                    if (_intersectWith.Contains(link))
1245                    {
1246                        _usages.Add(link);
1247                    }
1248                    _links.Unsync.Each(link, _links.Constants.Any, Collect);
1249                    _links.Unsync.Each(_links.Constants.Any, link, Collect);
1250                }
1251                return true;
1252            }
1253        }
1254
1255        [MethodImpl(MethodImplOptions.AggressiveInlining)]
1256        private void CloseInnerConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
            ↪ right)
1257        {
1258            TryStepLeftUp(handler, left, right);
1259            TryStepRightUp(handler, right, left);
1260        }
1261
1262        [MethodImpl(MethodImplOptions.AggressiveInlining)]
1263        private void AllCloseConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
            ↪ right)
1264        {
1265            // Direct
1266            if (left == right)
1267            {
1268                handler(new LinkAddress<LinkIndex>(left));
1269            }
1270            var doublet = Links.Unsync.SearchOrDefault(left, right);
1271            if (doublet != Constants.Null)
1272            {
1273                handler(new LinkAddress<LinkIndex>(doublet));
1274            }
1275            // Inner
1276            CloseInnerConnections(handler, left, right);
1277            // Outer
1278            StepLeft(handler, left, right);
1279            StepRight(handler, left, right);
1280            PartialStepRight(handler, left, right);
1281            PartialStepLeft(handler, left, right);
1282        }
1283
1284        [MethodImpl(MethodImplOptions.AggressiveInlining)]
1285        private HashSet<ulong> GetAllPartiallyMatchingSequencesCore(ulong[] sequence,
            ↪ HashSet<ulong> previousMatchings, long startAt)
1286        {
1287            if (startAt >= sequence.Length) // ?
1288            {
1289                return previousMatchings;
1290            }
1291            var secondLinkUsages = new HashSet<ulong>();
1292            AllUsagesCore(sequence[startAt], secondLinkUsages);
1293            secondLinkUsages.Add(sequence[startAt]);
1294            var matchings = new HashSet<ulong>();
1295            var filler = new SetFiller<LinkIndex, LinkIndex>(matchings, Constants.Continue);
```

```
            //for (var i = 0; i < previousMatchings.Count; i++)
            foreach (var secondLinkUsage in secondLinkUsages)
            {
                foreach (var previousMatching in previousMatchings)
                {
                    //AllCloseConnections(matchings.AddAndReturnVoid, previousMatching,
                    ↪  secondLinkUsage);
                    StepRight(filler.AddFirstAndReturnConstant, previousMatching,
                    ↪  secondLinkUsage);
                    TryStepRightUp(filler.AddFirstAndReturnConstant, secondLinkUsage,
                    ↪  previousMatching);
                    //PartialStepRight(matchings.AddAndReturnVoid, secondLinkUsage,
                    ↪  sequence[startAt]); // почему-то эта ошибочная запись приводит к
                    ↪  желаемым результам.
                    PartialStepRight(filler.AddFirstAndReturnConstant, previousMatching,
                    ↪  secondLinkUsage);
                }
            }
            if (matchings.Count == 0)
            {
                return matchings;
            }
            return GetAllPartiallyMatchingSequencesCore(sequence, matchings, startAt + 1); // ??
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static void EnsureEachLinkIsAnyOrZeroOrManyOrExists(SynchronizedLinks<ulong>
        ↪  links, params ulong[] sequence)
        {
            if (sequence == null)
            {
                return;
            }
            for (var i = 0; i < sequence.Length; i++)
            {
                if (sequence[i] != links.Constants.Any && sequence[i] != ZeroOrMany &&
                ↪  !links.Exists(sequence[i]))
                {
                    throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
                    ↪  $"patternSequence[{i}]");
                }
            }
        }

        // Pattern Matching -> Key To Triggers
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> MatchPattern(params ulong[] patternSequence)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                patternSequence = Simplify(patternSequence);
                if (patternSequence.Length > 0)
                {
                    EnsureEachLinkIsAnyOrZeroOrManyOrExists(Links, patternSequence);
                    var uniqueSequenceElements = new HashSet<ulong>();
                    for (var i = 0; i < patternSequence.Length; i++)
                    {
                        if (patternSequence[i] != Constants.Any && patternSequence[i] !=
                        ↪  ZeroOrMany)
                        {
                            uniqueSequenceElements.Add(patternSequence[i]);
                        }
                    }
                    var results = new HashSet<ulong>();
                    foreach (var uniqueSequenceElement in uniqueSequenceElements)
                    {
                        AllUsagesCore(uniqueSequenceElement, results);
                    }
                    var filteredResults = new HashSet<ulong>();
                    var matcher = new PatternMatcher(this, patternSequence, filteredResults);
                    matcher.AddAllPatternMatchedToResults(results);
                    return filteredResults;
                }
                return new HashSet<ulong>();
            });
        }

```

```
        // Найти все возможные связи между указанным списком связей.
        // Находит связи между всеми указанными связями в любом порядке.
        // TODO: решить что делать с повторами (когда одни и те же элементы встречаются
        ↪  несколько раз в последовательности)
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> GetAllConnections(params ulong[] linksToConnect)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                var results = new HashSet<ulong>();
                if (linksToConnect.Length > 0)
                {
                    Links.EnsureLinkExists(linksToConnect);
                    AllUsagesCore(linksToConnect[0], results);
                    for (var i = 1; i < linksToConnect.Length; i++)
                    {
                        var next = new HashSet<ulong>();
                        AllUsagesCore(linksToConnect[i], next);
                        results.IntersectWith(next);
                    }
                }
                return results;
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> GetAllConnections1(params ulong[] linksToConnect)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                var results = new HashSet<ulong>();
                if (linksToConnect.Length > 0)
                {
                    Links.EnsureLinkExists(linksToConnect);
                    var collector1 = new AllUsagesCollector(Links.Unsync, results);
                    collector1.Collect(linksToConnect[0]);
                    var next = new HashSet<ulong>();
                    for (var i = 1; i < linksToConnect.Length; i++)
                    {
                        var collector = new AllUsagesCollector(Links.Unsync, next);
                        collector.Collect(linksToConnect[i]);
                        results.IntersectWith(next);
                        next.Clear();
                    }
                }
                return results;
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> GetAllConnections2(params ulong[] linksToConnect)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                var results = new HashSet<ulong>();
                if (linksToConnect.Length > 0)
                {
                    Links.EnsureLinkExists(linksToConnect);
                    var collector1 = new AllUsagesCollector(Links, results);
                    collector1.Collect(linksToConnect[0]);
                    //AllUsagesCore(linksToConnect[0], results);
                    for (var i = 1; i < linksToConnect.Length; i++)
                    {
                        var next = new HashSet<ulong>();
                        var collector = new AllUsagesIntersectingCollector(Links, results, next);
                        collector.Collect(linksToConnect[i]);
                        //AllUsagesCore(linksToConnect[i], next);
                        //results.IntersectWith(next);
                        results = next;
                    }
                }
                return results;
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public List<ulong> GetAllConnections3(params ulong[] linksToConnect)
        {
```

```
            return _sync.ExecuteReadOperation(() =>
            {
                var results = new BitString((long)Links.Unsync.Count() + 1); // new
                ↪  BitArray((int)_links.Total + 1);
                if (linksToConnect.Length > 0)
                {
                    Links.EnsureLinkExists(linksToConnect);
                    var collector1 = new AllUsagesCollector2(Links.Unsync, results);
                    collector1.Collect(linksToConnect[0]);
                    for (var i = 1; i < linksToConnect.Length; i++)
                    {
                        var next = new BitString((long)Links.Unsync.Count() + 1); //new
                        ↪  BitArray((int)_links.Total + 1);
                        var collector = new AllUsagesCollector2(Links.Unsync, next);
                        collector.Collect(linksToConnect[i]);
                        results = results.And(next);
                    }
                }
                return results.GetSetUInt64Indices();
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static ulong[] Simplify(ulong[] sequence)
        {
            // Считаем новый размер последовательности
            long newLength = 0;
            var zeroOrManyStepped = false;
            for (var i = 0; i < sequence.Length; i++)
            {
                if (sequence[i] == ZeroOrMany)
                {
                    if (zeroOrManyStepped)
                    {
                        continue;
                    }
                    zeroOrManyStepped = true;
                }
                else
                {
                    //if (zeroOrManyStepped) Is it efficient?
                    zeroOrManyStepped = false;
                }
                newLength++;
            }
            // Строим новую последовательность
            zeroOrManyStepped = false;
            var newSequence = new ulong[newLength];
            long j = 0;
            for (var i = 0; i < sequence.Length; i++)
            {
                //var current = zeroOrManyStepped;
                //zeroOrManyStepped = patternSequence[i] == zeroOrMany;
                //if (current && zeroOrManyStepped)
                //    continue;
                //var newZeroOrManyStepped = patternSequence[i] == zeroOrMany;
                //if (zeroOrManyStepped && newZeroOrManyStepped)
                //    continue;
                //zeroOrManyStepped = newZeroOrManyStepped;
                if (sequence[i] == ZeroOrMany)
                {
                    if (zeroOrManyStepped)
                    {
                        continue;
                    }
                    zeroOrManyStepped = true;
                }
                else
                {
                    //if (zeroOrManyStepped) Is it efficient?
                    zeroOrManyStepped = false;
                }
                newSequence[j++] = sequence[i];
            }
            return newSequence;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static void TestSimplify()
```

```
1517            {
1518                var sequence = new ulong[] { ZeroOrMany, ZeroOrMany, 2, 3, 4, ZeroOrMany,
                    ↪  ZeroOrMany, ZeroOrMany, 4, ZeroOrMany, ZeroOrMany, ZeroOrMany };
1519                var simplifiedSequence = Simplify(sequence);
1520            }
1521
1522            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1523            public List<ulong> GetSimilarSequences() => new List<ulong>();
1524
1525            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1526            public void Prediction()
1527            {
1528                //_links
1529                //sequences
1530            }
1531
1532            #region From Triplets
1533
1534            //public static void DeleteSequence(Link sequence)
1535            //{
1536            //}
1537
1538            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1539            public List<ulong> CollectMatchingSequences(ulong[] links)
1540            {
1541                if (links.Length == 1)
1542                {
1543                    throw new InvalidOperationException("Подпоследовательности с одним элементом не
                        ↪  поддерживаются.");
1544                }
1545                var leftBound = 0;
1546                var rightBound = links.Length - 1;
1547                var left = links[leftBound++];
1548                var right = links[rightBound--];
1549                var results = new List<ulong>();
1550                CollectMatchingSequences(left, leftBound, links, right, rightBound, ref results);
1551                return results;
1552            }
1553
1554            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1555            private void CollectMatchingSequences(ulong leftLink, int leftBound, ulong[]
                ↪  middleLinks, ulong rightLink, int rightBound, ref List<ulong> results)
1556            {
1557                var leftLinkTotalReferers = Links.Unsync.Count(leftLink);
1558                var rightLinkTotalReferers = Links.Unsync.Count(rightLink);
1559                if (leftLinkTotalReferers <= rightLinkTotalReferers)
1560                {
1561                    var nextLeftLink = middleLinks[leftBound];
1562                    var elements = GetRightElements(leftLink, nextLeftLink);
1563                    if (leftBound <= rightBound)
1564                    {
1565                        for (var i = elements.Length - 1; i >= 0; i--)
1566                        {
1567                            var element = elements[i];
1568                            if (element != 0)
1569                            {
1570                                CollectMatchingSequences(element, leftBound + 1, middleLinks,
                                    ↪  rightLink, rightBound, ref results);
1571                            }
1572                        }
1573                    }
1574                    else
1575                    {
1576                        for (var i = elements.Length - 1; i >= 0; i--)
1577                        {
1578                            var element = elements[i];
1579                            if (element != 0)
1580                            {
1581                                results.Add(element);
1582                            }
1583                        }
1584                    }
1585                }
1586                else
1587                {
1588                    var nextRightLink = middleLinks[rightBound];
1589                    var elements = GetLeftElements(rightLink, nextRightLink);
1590                    if (leftBound <= rightBound)
```

```
                {
                    for (var i = elements.Length - 1; i >= 0; i--)
                    {
                        var element = elements[i];
                        if (element != 0)
                        {
                            CollectMatchingSequences(leftLink, leftBound, middleLinks,
                            ↪  elements[i], rightBound - 1, ref results);
                        }
                    }
                }
                else
                {
                    for (var i = elements.Length - 1; i >= 0; i--)
                    {
                        var element = elements[i];
                        if (element != 0)
                        {
                            results.Add(element);
                        }
                    }
                }
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ulong[] GetRightElements(ulong startLink, ulong rightLink)
        {
            var result = new ulong[5];
            TryStepRight(startLink, rightLink, result, 0);
            Links.Each(Constants.Any, startLink, couple =>
            {
                if (couple != startLink)
                {
                    if (TryStepRight(couple, rightLink, result, 2))
                    {
                        return false;
                    }
                }
                return true;
            });
            if (Links.GetTarget(Links.GetTarget(startLink)) == rightLink)
            {
                result[4] = startLink;
            }
            return result;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool TryStepRight(ulong startLink, ulong rightLink, ulong[] result, int offset)
        {
            var added = 0;
            Links.Each(startLink, Constants.Any, couple =>
            {
                if (couple != startLink)
                {
                    var coupleTarget = Links.GetTarget(couple);
                    if (coupleTarget == rightLink)
                    {
                        result[offset] = couple;
                        if (++added == 2)
                        {
                            return false;
                        }
                    }
                    else if (Links.GetSource(coupleTarget) == rightLink) // coupleTarget.Linker
                    ↪  == Net.And &&
                    {
                        result[offset + 1] = couple;
                        if (++added == 2)
                        {
                            return false;
                        }
                    }
                }
                return true;
            });
            return added > 0;
```

```
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ulong[] GetLeftElements(ulong startLink, ulong leftLink)
        {
            var result = new ulong[5];
            TryStepLeft(startLink, leftLink, result, 0);
            Links.Each(startLink, Constants.Any, couple =>
            {
                if (couple != startLink)
                {
                    if (TryStepLeft(couple, leftLink, result, 2))
                    {
                        return false;
                    }
                }
                return true;
            });
            if (Links.GetSource(Links.GetSource(leftLink)) == startLink)
            {
                result[4] = leftLink;
            }
            return result;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool TryStepLeft(ulong startLink, ulong leftLink, ulong[] result, int offset)
        {
            var added = 0;
            Links.Each(Constants.Any, startLink, couple =>
            {
                if (couple != startLink)
                {
                    var coupleSource = Links.GetSource(couple);
                    if (coupleSource == leftLink)
                    {
                        result[offset] = couple;
                        if (++added == 2)
                        {
                            return false;
                        }
                    }
                    else if (Links.GetTarget(coupleSource) == leftLink) // coupleSource.Linker
                    ↪  == Net.And &&
                    {
                        result[offset + 1] = couple;
                        if (++added == 2)
                        {
                            return false;
                        }
                    }
                }
                return true;
            });
            return added > 0;
        }

        #endregion

        #region Walkers

        public class PatternMatcher : RightSequenceWalker<ulong>
        {
            private readonly Sequences _sequences;
            private readonly ulong[] _patternSequence;
            private readonly HashSet<LinkIndex> _linksInSequence;
            private readonly HashSet<LinkIndex> _results;

            #region Pattern Match

            enum PatternBlockType
            {
                Undefined,
                Gap,
                Elements
            }

            struct PatternBlock
            {
                public PatternBlockType Type;
```

```
1746                public long Start;
1747                public long Stop;
1748            }
1749
1750            private readonly List<PatternBlock> _pattern;
1751            private int _patternPosition;
1752            private long _sequencePosition;
1753
1754            #endregion
1755
1756            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1757            public PatternMatcher(Sequences sequences, LinkIndex[] patternSequence,
                ↪  HashSet<LinkIndex> results)
1758                : base(sequences.Links.Unsync, new DefaultStack<ulong>())
1759            {
1760                _sequences = sequences;
1761                _patternSequence = patternSequence;
1762                _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
                    ↪  _sequences.Constants.Any && x != ZeroOrMany));
1763                _results = results;
1764                _pattern = CreateDetailedPattern();
1765            }
1766
1767            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1768            protected override bool IsElement(ulong link) => _linksInSequence.Contains(link) ||
                ↪  base.IsElement(link);
1769
1770            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1771            public bool PatternMatch(LinkIndex sequenceToMatch)
1772            {
1773                _patternPosition = 0;
1774                _sequencePosition = 0;
1775                foreach (var part in Walk(sequenceToMatch))
1776                {
1777                    if (!PatternMatchCore(part))
1778                    {
1779                        break;
1780                    }
1781                }
1782                return _patternPosition == _pattern.Count || (_patternPosition == _pattern.Count
                    ↪  - 1 && _pattern[_patternPosition].Start == 0);
1783            }
1784
1785            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1786            private List<PatternBlock> CreateDetailedPattern()
1787            {
1788                var pattern = new List<PatternBlock>();
1789                var patternBlock = new PatternBlock();
1790                for (var i = 0; i < _patternSequence.Length; i++)
1791                {
1792                    if (patternBlock.Type == PatternBlockType.Undefined)
1793                    {
1794                        if (_patternSequence[i] == _sequences.Constants.Any)
1795                        {
1796                            patternBlock.Type = PatternBlockType.Gap;
1797                            patternBlock.Start = 1;
1798                            patternBlock.Stop = 1;
1799                        }
1800                        else if (_patternSequence[i] == ZeroOrMany)
1801                        {
1802                            patternBlock.Type = PatternBlockType.Gap;
1803                            patternBlock.Start = 0;
1804                            patternBlock.Stop = long.MaxValue;
1805                        }
1806                        else
1807                        {
1808                            patternBlock.Type = PatternBlockType.Elements;
1809                            patternBlock.Start = i;
1810                            patternBlock.Stop = i;
1811                        }
1812                    }
1813                    else if (patternBlock.Type == PatternBlockType.Elements)
1814                    {
1815                        if (_patternSequence[i] == _sequences.Constants.Any)
1816                        {
1817                            pattern.Add(patternBlock);
1818                            patternBlock = new PatternBlock
1819                            {
1820                                Type = PatternBlockType.Gap,
1821                                Start = 1,
```

```
                        Stop = 1
                    };
                }
                else if (_patternSequence[i] == ZeroOrMany)
                {
                    pattern.Add(patternBlock);
                    patternBlock = new PatternBlock
                    {
                        Type = PatternBlockType.Gap,
                        Start = 0,
                        Stop = long.MaxValue
                    };
                }
                else
                {
                    patternBlock.Stop = i;
                }
            }
            else // patternBlock.Type == PatternBlockType.Gap
            {
                if (_patternSequence[i] == _sequences.Constants.Any)
                {
                    patternBlock.Start++;
                    if (patternBlock.Stop < patternBlock.Start)
                    {
                        patternBlock.Stop = patternBlock.Start;
                    }
                }
                else if (_patternSequence[i] == ZeroOrMany)
                {
                    patternBlock.Stop = long.MaxValue;
                }
                else
                {
                    pattern.Add(patternBlock);
                    patternBlock = new PatternBlock
                    {
                        Type = PatternBlockType.Elements,
                        Start = i,
                        Stop = i
                    };
                }
            }
        }
        if (patternBlock.Type != PatternBlockType.Undefined)
        {
            pattern.Add(patternBlock);
        }
        return pattern;
    }

    // match: search for regexp anywhere in text
    //int match(char* regexp, char* text)
    //{
    //    do
    //    {
    //    } while (*text++ != '\0');
    //    return 0;
    //}

    // matchhere: search for regexp at beginning of text
    //int matchhere(char* regexp, char* text)
    //{
    //    if (regexp[0] == '\0')
    //        return 1;
    //    if (regexp[1] == '*')
    //        return matchstar(regexp[0], regexp + 2, text);
    //    if (regexp[0] == '$' && regexp[1] == '\0')
    //        return *text == '\0';
    //    if (*text != '\0' && (regexp[0] == '.' || regexp[0] == *text))
    //        return matchhere(regexp + 1, text + 1);
    //    return 0;
    //}

    // matchstar: search for c*regexp at beginning of text
    //int matchstar(int c, char* regexp, char* text)
    //{
    //    do
    //    {    /* a * matches zero or more instances */
```

```
//        if (matchhere(regexp, text))
//            return 1;
//    } while (*text != '\0' && (*text++ == c || c == '.'));
//    return 0;
//}

//private void GetNextPatternElement(out LinkIndex element, out long mininumGap, out long maximumGap)
//{
//    mininumGap = 0;
//    maximumGap = 0;
//    element = 0;
//    for (; _patternPosition < _patternSequence.Length; _patternPosition++)
//    {
//        if (_patternSequence[_patternPosition] == Doublets.Links.Null)
//            mininumGap++;
//        else if (_patternSequence[_patternPosition] == ZeroOrMany)
//            maximumGap = long.MaxValue;
//        else
//            break;
//    }

//    if (maximumGap < mininumGap)
//        maximumGap = mininumGap;
//}

[MethodImpl(MethodImplOptions.AggressiveInlining)]
private bool PatternMatchCore(LinkIndex element)
{
    if (_patternPosition >= _pattern.Count)
    {
        _patternPosition = -2;
        return false;
    }
    var currentPatternBlock = _pattern[_patternPosition];
    if (currentPatternBlock.Type == PatternBlockType.Gap)
    {
        //var currentMatchingBlockLength = (_sequencePosition - _lastMatchedBlockPosition);
        if (_sequencePosition < currentPatternBlock.Start)
        {
            _sequencePosition++;
            return true; // Двигаемся дальше
        }
        // Это последний блок
        if (_pattern.Count == _patternPosition + 1)
        {
            _patternPosition++;
            _sequencePosition = 0;
            return false; // Полное соответствие
        }
        else
        {
            if (_sequencePosition > currentPatternBlock.Stop)
            {
                return false; // Соответствие невозможно
            }
            var nextPatternBlock = _pattern[_patternPosition + 1];
            if (_patternSequence[nextPatternBlock.Start] == element)
            {
                if (nextPatternBlock.Start < nextPatternBlock.Stop)
                {
                    _patternPosition++;
                    _sequencePosition = 1;
                }
                else
                {
                    _patternPosition += 2;
                    _sequencePosition = 0;
                }
            }
        }
    }
    else // currentPatternBlock.Type == PatternBlockType.Elements
    {
        var patternElementPosition = currentPatternBlock.Start + _sequencePosition;
        if (_patternSequence[patternElementPosition] != element)
        {
            return false; // Соответствие невозможно
```

```
                    }
                    if (patternElementPosition == currentPatternBlock.Stop)
                    {
                        _patternPosition++;
                        _sequencePosition = 0;
                    }
                    else
                    {
                        _sequencePosition++;
                    }
                }
                return true;
                //if (_patternSequence[_patternPosition] != element)
                //    return false;
                //else
                //{
                //    _sequencePosition++;
                //    _patternPosition++;
                //    return true;
                //}
                ////////
                //if (_filterPosition == _patternSequence.Length)
                //{
                //    _filterPosition = -2; // Длиннее чем нужно
                //    return false;
                //}
                //if (element != _patternSequence[_filterPosition])
                //{
                //    _filterPosition = -1;
                //    return false; // Начинается иначе
                //}
                //_filterPosition++;
                //if (_filterPosition == (_patternSequence.Length - 1))
                //    return false;
                //if (_filterPosition >= 0)
                //{
                //    if (element == _patternSequence[_filterPosition + 1])
                //        _filterPosition++;
                //    else
                //        return false;
                //}
                //if (_filterPosition < 0)
                //{
                //    if (element == _patternSequence[0])
                //        _filterPosition = 0;
                //}
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public void AddAllPatternMatchedToResults(IEnumerable<ulong> sequencesToMatch)
            {
                foreach (var sequenceToMatch in sequencesToMatch)
                {
                    if (PatternMatch(sequenceToMatch))
                    {
                        _results.Add(sequenceToMatch);
                    }
                }
            }
        }

        #endregion
    }
}
```

1.116 ./csharp/Platform.Data.Doublets/Sequences/Sequences.cs

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Runtime.CompilerServices;
using Platform.Collections;
using Platform.Collections.Lists;
using Platform.Collections.Stacks;
using Platform.Threading.Synchronization;
using Platform.Data.Doublets.Sequences.Walkers;
using LinkIndex = System.UInt64;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

```

```
14  namespace Platform.Data.Doublets.Sequences
15  {
16      /// <summary>
17      /// Представляет коллекцию последовательностей связей.
18      /// </summary>
19      /// <remarks>
20      /// Обязательно реализовать атомарность каждого публичного метода.
21      ///
22      /// TODO:
23      ///
24      /// !!! Повышение вероятности повторного использования групп (подпоследовательностей),
25      /// через естественную группировку по unicode типам, все whitespace вместе, все символы
        ↪  вместе, все числа вместе и т.п.
26      /// + использовать ровно сбалансированный вариант, чтобы уменьшать вложенность (глубину
        ↪  графа)
27      ///
28      /// x*y - найти все связи между, в последовательностях любой формы, если не стоит
        ↪  ограничитель на то, что является последовательностью, а что нет,
29      /// то находятся любые структуры связей, которые содержат эти элементы именно в таком
        ↪  порядке.
30      ///
31      /// Рост последовательности слева и справа.
32      /// Поиск со звёздочкой.
33      /// URL, PURL - реестр используемых во вне ссылок на ресурсы,
34      /// так же проблема может быть решена при реализации дистанционных триггеров.
35      /// Нужны ли уникальные указатели вообще?
36      /// Что если обращение к информации будет происходить через содержимое всегда?
37      ///
38      /// Писать тесты.
39      ///
40      ///
41      /// Можно убрать зависимость от конкретной реализации Links,
42      /// на зависимость от абстрактного элемента, который может быть представлен несколькими
        ↪  способами.
43      ///
44      /// Можно ли как-то сделать один общий интерфейс
45      ///
46      ///
47      /// Блокчейн и/или гит для распределённой записи транзакций.
48      ///
49      /// </remarks>
50      public partial class Sequences : ILinks<LinkIndex> // IList<string>, IList<LinkIndex[]>
        ↪  (после завершения реализации Sequences)
51      {
52          /// <summary>Возвращает значение LinkIndex, обозначающее любое количество
            ↪  связей.</summary>
53          public const LinkIndex ZeroOrMany = LinkIndex.MaxValue;
54
55          public SequencesOptions<LinkIndex> Options { get; }
56          public SynchronizedLinks<LinkIndex> Links { get; }
57          private readonly ISynchronization _sync;
58
59          public LinksConstants<LinkIndex> Constants { get; }
60
61          [MethodImpl(MethodImplOptions.AggressiveInlining)]
62          public Sequences(SynchronizedLinks<LinkIndex> links, SequencesOptions<LinkIndex> options)
63          {
64              Links = links;
65              _sync = links.SyncRoot;
66              Options = options;
67              Options.ValidateOptions();
68              Options.InitOptions(Links);
69              Constants = links.Constants;
70          }
71
72          [MethodImpl(MethodImplOptions.AggressiveInlining)]
73          public Sequences(SynchronizedLinks<LinkIndex> links) : this(links, new
            ↪  SequencesOptions<LinkIndex>()) { }
74
75          [MethodImpl(MethodImplOptions.AggressiveInlining)]
76          public bool IsSequence(LinkIndex sequence)
77          {
78              return _sync.ExecuteReadOperation(() =>
79              {
80                  if (Options.UseSequenceMarker)
81                  {
82                      return Options.MarkedSequenceMatcher.IsMatched(sequence);
83                  }
```

```
                return !Links.Unsync.IsPartialPoint(sequence);
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private LinkIndex GetSequenceByElements(LinkIndex sequence)
        {
            if (Options.UseSequenceMarker)
            {
                return Links.SearchOrDefault(Options.SequenceMarkerLink, sequence);
            }
            return sequence;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private LinkIndex GetSequenceElements(LinkIndex sequence)
        {
            if (Options.UseSequenceMarker)
            {
                var linkContents = new Link<ulong>(Links.GetLink(sequence));
                if (linkContents.Source == Options.SequenceMarkerLink)
                {
                    return linkContents.Target;
                }
                if (linkContents.Target == Options.SequenceMarkerLink)
                {
                    return linkContents.Source;
                }
            }
            return sequence;
        }

        #region Count

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkIndex Count(IList<LinkIndex> restrictions)
        {
            if (restrictions.IsNullOrEmpty())
            {
                return Links.Count(Constants.Any, Options.SequenceMarkerLink, Constants.Any);
            }
            if (restrictions.Count == 1) // Первая связь это адрес
            {
                var sequenceIndex = restrictions[0];
                if (sequenceIndex == Constants.Null)
                {
                    return 0;
                }
                if (sequenceIndex == Constants.Any)
                {
                    return Count(null);
                }
                if (Options.UseSequenceMarker)
                {
                    return Links.Count(Constants.Any, Options.SequenceMarkerLink, sequenceIndex);
                }
                return Links.Exists(sequenceIndex) ? 1UL : 0;
            }
            throw new NotImplementedException();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private LinkIndex CountUsages(params LinkIndex[] restrictions)
        {
            if (restrictions.Length == 0)
            {
                return 0;
            }
            if (restrictions.Length == 1) // Первая связь это адрес
            {
                if (restrictions[0] == Constants.Null)
                {
                    return 0;
                }
                var any = Constants.Any;
                if (Options.UseSequenceMarker)
                {
                    var elementsLink = GetSequenceElements(restrictions[0]);
                    var sequenceLink = GetSequenceByElements(elementsLink);
```

```
                if (sequenceLink != Constants.Null)
                {
                    return Links.Count(any, sequenceLink) + Links.Count(any, elementsLink) -
                    ↪ 1;
                }
                return Links.Count(any, elementsLink);
            }
            return Links.Count(any, restrictions[0]);
        }
        throw new NotImplementedException();
    }

    #endregion

    #region Create

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public LinkIndex Create(IList<LinkIndex> restrictions)
    {
        return _sync.ExecuteWriteOperation(() =>
        {
            if (restrictions.IsNullOrEmpty())
            {
                return Constants.Null;
            }
            Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
            return CreateCore(restrictions);
        });
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private LinkIndex CreateCore(IList<LinkIndex> restrictions)
    {
        LinkIndex[] sequence = restrictions.SkipFirst();
        if (Options.UseIndex)
        {
            Options.Index.Add(sequence);
        }
        var sequenceRoot = default(LinkIndex);
        if (Options.EnforceSingleSequenceVersionOnWriteBasedOnExisting)
        {
            var matches = Each(restrictions);
            if (matches.Count > 0)
            {
                sequenceRoot = matches[0];
            }
        }
        else if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew)
        {
            return CompactCore(sequence);
        }
        if (sequenceRoot == default)
        {
            sequenceRoot = Options.LinksToSequenceConverter.Convert(sequence);
        }
        if (Options.UseSequenceMarker)
        {
            return Links.Unsync.GetOrCreate(Options.SequenceMarkerLink, sequenceRoot);
        }
        return sequenceRoot; // Возвращаем корень последовательности (т.е. сами элементы)
    }

    #endregion

    #region Each

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public List<LinkIndex> Each(IList<LinkIndex> sequence)
    {
        var results = new List<LinkIndex>();
        var filler = new ListFiller<LinkIndex, LinkIndex>(results, Constants.Continue);
        Each(filler.AddFirstAndReturnConstant, sequence);
        return results;
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public LinkIndex Each(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
    ↪ restrictions)
    {
```

```
240             return _sync.ExecuteReadOperation(() =>
241             {
242                 if (restrictions.IsNullOrEmpty())
243                 {
244                     return Constants.Continue;
245                 }
246                 Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
247                 if (restrictions.Count == 1)
248                 {
249                     var link = restrictions[0];
250                     var any = Constants.Any;
251                     if (link == any)
252                     {
253                         if (Options.UseSequenceMarker)
254                         {
255                             return Links.Unsync.Each(handler, new Link<LinkIndex>(any,
                                ↪  Options.SequenceMarkerLink, any));
256                         }
257                         else
258                         {
259                             return Links.Unsync.Each(handler, new Link<LinkIndex>(any, any,
                                ↪  any));
260                         }
261                     }
262                     if (Options.UseSequenceMarker)
263                     {
264                         var sequenceLinkValues = Links.Unsync.GetLink(link);
265                         if (sequenceLinkValues[Constants.SourcePart] ==
                            ↪  Options.SequenceMarkerLink)
266                         {
267                             link = sequenceLinkValues[Constants.TargetPart];
268                         }
269                     }
270                     var sequence = Options.Walker.Walk(link).ToArray().ShiftRight();
271                     sequence[0] = link;
272                     return handler(sequence);
273                 }
274                 else if (restrictions.Count == 2)
275                 {
276                     throw new NotImplementedException();
277                 }
278                 else if (restrictions.Count == 3)
279                 {
280                     return Links.Unsync.Each(handler, restrictions);
281                 }
282                 else
283                 {
284                     var sequence = restrictions.SkipFirst();
285                     if (Options.UseIndex && !Options.Index.MightContain(sequence))
286                     {
287                         return Constants.Break;
288                     }
289                     return EachCore(handler, sequence);
290                 }
291             });
292         }
293 
294         [MethodImpl(MethodImplOptions.AggressiveInlining)]
295         private LinkIndex EachCore(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
            ↪  values)
296         {
297             var matcher = new Matcher(this, values, new HashSet<LinkIndex>(), handler);
298             // TODO: Find out why matcher.HandleFullMatched executed twice for the same sequence
                ↪  Id.
299             Func<IList<LinkIndex>, LinkIndex> innerHandler = Options.UseSequenceMarker ?
                ↪  (Func<IList<LinkIndex>, LinkIndex>)matcher.HandleFullMatchedSequence :
                ↪  matcher.HandleFullMatched;
300             //if (sequence.Length >= 2)
301             if (StepRight(innerHandler, values[0], values[1]) != Constants.Continue)
302             {
303                 return Constants.Break;
304             }
305             var last = values.Count - 2;
306             for (var i = 1; i < last; i++)
307             {
308                 if (PartialStepRight(innerHandler, values[i], values[i + 1]) !=
                    ↪  Constants.Continue)
309                 {
```

```
                    return Constants.Break;
                }
            }
            if (values.Count >= 3)
            {
                if (StepLeft(innerHandler, values[values.Count - 2], values[values.Count - 1])
                ↪  != Constants.Continue)
                {
                    return Constants.Break;
                }
            }
            return Constants.Continue;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private LinkIndex PartialStepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
        ↪  left, LinkIndex right)
        {
            return Links.Unsync.Each(doublet =>
            {
                var doubletIndex = doublet[Constants.IndexPart];
                if (StepRight(handler, doubletIndex, right) != Constants.Continue)
                {
                    return Constants.Break;
                }
                if (left != doubletIndex)
                {
                    return PartialStepRight(handler, doubletIndex, right);
                }
                return Constants.Continue;
            }, new Link<LinkIndex>(Constants.Any, Constants.Any, left));
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private LinkIndex StepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex left,
        ↪  LinkIndex right) => Links.Unsync.Each(rightStep => TryStepRightUp(handler, right,
        ↪  rightStep[Constants.IndexPart]), new Link<LinkIndex>(Constants.Any, left,
        ↪  Constants.Any));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private LinkIndex TryStepRightUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
        ↪  right, LinkIndex stepFrom)
        {
            var upStep = stepFrom;
            var firstSource = Links.Unsync.GetTarget(upStep);
            while (firstSource != right && firstSource != upStep)
            {
                upStep = firstSource;
                firstSource = Links.Unsync.GetSource(upStep);
            }
            if (firstSource == right)
            {
                return handler(new LinkAddress<LinkIndex>(stepFrom));
            }
            return Constants.Continue;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private LinkIndex StepLeft(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex left,
        ↪  LinkIndex right) => Links.Unsync.Each(leftStep => TryStepLeftUp(handler, left,
        ↪  leftStep[Constants.IndexPart]), new Link<LinkIndex>(Constants.Any, Constants.Any,
        ↪  right));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private LinkIndex TryStepLeftUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
        ↪  left, LinkIndex stepFrom)
        {
            var upStep = stepFrom;
            var firstTarget = Links.Unsync.GetSource(upStep);
            while (firstTarget != left && firstTarget != upStep)
            {
                upStep = firstTarget;
                firstTarget = Links.Unsync.GetTarget(upStep);
            }
            if (firstTarget == left)
            {
                return handler(new LinkAddress<LinkIndex>(stepFrom));
            }
```

```
            return Constants.Continue;
        }

        #endregion

        #region Update

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkIndex Update(IList<LinkIndex> restrictions, IList<LinkIndex> substitution)
        {
            var sequence = restrictions.SkipFirst();
            var newSequence = substitution.SkipFirst();
            if (sequence.IsNullOrEmpty() && newSequence.IsNullOrEmpty())
            {
                return Constants.Null;
            }
            if (sequence.IsNullOrEmpty())
            {
                return Create(substitution);
            }
            if (newSequence.IsNullOrEmpty())
            {
                Delete(restrictions);
                return Constants.Null;
            }
            return _sync.ExecuteWriteOperation((Func<ulong>)(() =>
            {
                ILinksExtensions.EnsureLinkIsAnyOrExists<ulong>(Links, (IList<ulong>)sequence);
                Links.EnsureLinkExists(newSequence);
                return UpdateCore(sequence, newSequence);
            }));
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private LinkIndex UpdateCore(IList<LinkIndex> sequence, IList<LinkIndex> newSequence)
        {
            LinkIndex bestVariant;
            if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew &&
            ↪  !sequence.EqualTo(newSequence))
            {
                bestVariant = CompactCore(newSequence);
            }
            else
            {
                bestVariant = CreateCore(newSequence);
            }
            // TODO: Check all options only ones before loop execution
            // Возможно нужно две версии Each, возвращающий фактические последовательности и с
            ↪  маркером,
            // или возможно даже возвращать и тот и тот вариант. С другой стороны все варианты
            ↪  можно получить имея только фактические последовательности.
            foreach (var variant in Each(sequence))
            {
                if (variant != bestVariant)
                {
                    UpdateOneCore(variant, bestVariant);
                }
            }
            return bestVariant;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void UpdateOneCore(LinkIndex sequence, LinkIndex newSequence)
        {
            if (Options.UseGarbageCollection)
            {
                var sequenceElements = GetSequenceElements(sequence);
                var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
                var sequenceLink = GetSequenceByElements(sequenceElements);
                var newSequenceElements = GetSequenceElements(newSequence);
                var newSequenceLink = GetSequenceByElements(newSequenceElements);
                if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
                {
                    if (sequenceLink != Constants.Null)
                    {
                        Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
                    }
                    Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
                }
```

```
                ClearGarbage(sequenceElementsContents.Source);
                ClearGarbage(sequenceElementsContents.Target);
            }
            else
            {
                if (Options.UseSequenceMarker)
                {
                    var sequenceElements = GetSequenceElements(sequence);
                    var sequenceLink = GetSequenceByElements(sequenceElements);
                    var newSequenceElements = GetSequenceElements(newSequence);
                    var newSequenceLink = GetSequenceByElements(newSequenceElements);
                    if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
                    {
                        if (sequenceLink != Constants.Null)
                        {
                            Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
                        }
                        Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
                    }
                }
                else
                {
                    if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
                    {
                        Links.Unsync.MergeAndDelete(sequence, newSequence);
                    }
                }
            }
        }

        #endregion

        #region Delete

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Delete(IList<LinkIndex> restrictions)
        {
            _sync.ExecuteWriteOperation(() =>
            {
                var sequence = restrictions.SkipFirst();
                // TODO: Check all options only ones before loop execution
                foreach (var linkToDelete in Each(sequence))
                {
                    DeleteOneCore(linkToDelete);
                }
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void DeleteOneCore(LinkIndex link)
        {
            if (Options.UseGarbageCollection)
            {
                var sequenceElements = GetSequenceElements(link);
                var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
                var sequenceLink = GetSequenceByElements(sequenceElements);
                if (Options.UseCascadeDelete || CountUsages(link) == 0)
                {
                    if (sequenceLink != Constants.Null)
                    {
                        Links.Unsync.Delete(sequenceLink);
                    }
                    Links.Unsync.Delete(link);
                }
                ClearGarbage(sequenceElementsContents.Source);
                ClearGarbage(sequenceElementsContents.Target);
            }
            else
            {
                if (Options.UseSequenceMarker)
                {
                    var sequenceElements = GetSequenceElements(link);
                    var sequenceLink = GetSequenceByElements(sequenceElements);
                    if (Options.UseCascadeDelete || CountUsages(link) == 0)
                    {
                        if (sequenceLink != Constants.Null)
                        {
                            Links.Unsync.Delete(sequenceLink);
```

```
                    }
                    Links.Unsync.Delete(link);
                }
            }
            else
            {
                if (Options.UseCascadeDelete || CountUsages(link) == 0)
                {
                    Links.Unsync.Delete(link);
                }
            }
        }
    }

    #endregion

    #region Compactification

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public void CompactAll()
    {
        _sync.ExecuteWriteOperation(() =>
        {
            var sequences = Each((LinkAddress<LinkIndex>)Constants.Any);
            for (int i = 0; i < sequences.Count; i++)
            {
                var sequence = this.ToList(sequences[i]);
                Compact(sequence.ShiftRight());
            }
        });
    }

    /// <remarks>
    /// bestVariant можно выбирать по максимальному числу использований,
    /// но балансированный позволяет гарантировать уникальность (если есть возможность,
    /// гарантировать его использование в других местах).
    ///
    /// Получается этот метод должен игнорировать Options.EnforceSingleSequenceVersionOnWrite
    /// </remarks>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public LinkIndex Compact(IList<LinkIndex> sequence)
    {
        return _sync.ExecuteWriteOperation(() =>
        {
            if (sequence.IsNullOrEmpty())
            {
                return Constants.Null;
            }
            Links.EnsureInnerReferenceExists(sequence, nameof(sequence));
            return CompactCore(sequence);
        });
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private LinkIndex CompactCore(IList<LinkIndex> sequence) => UpdateCore(sequence,
    ↪  sequence);

    #endregion

    #region Garbage Collection

    /// <remarks>
    /// TODO: Добавить дополнительный обработчик / событие CanBeDeleted которое можно
    ↪  определить извне или в унаследованном классе
    /// </remarks>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private bool IsGarbage(LinkIndex link) => link != Options.SequenceMarkerLink &&
    ↪  !Links.Unsync.IsPartialPoint(link) && Links.Count(Constants.Any, link) == 0;

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private void ClearGarbage(LinkIndex link)
    {
        if (IsGarbage(link))
        {
            var contents = new Link<ulong>(Links.GetLink(link));
            Links.Unsync.Delete(link);
            ClearGarbage(contents.Source);
            ClearGarbage(contents.Target);
        }
```

```
608         }
609
610         #endregion
611
612         #region Walkers
613
614         [MethodImpl(MethodImplOptions.AggressiveInlining)]
615         public bool EachPart(Func<LinkIndex, bool> handler, LinkIndex sequence)
616         {
617             return _sync.ExecuteReadOperation(() =>
618             {
619                 var links = Links.Unsync;
620                 foreach (var part in Options.Walker.Walk(sequence))
621                 {
622                     if (!handler(part))
623                     {
624                         return false;
625                     }
626                 }
627                 return true;
628             });
629         }
630
631         public class Matcher : RightSequenceWalker<LinkIndex>
632         {
633             private readonly Sequences _sequences;
634             private readonly IList<LinkIndex> _patternSequence;
635             private readonly HashSet<LinkIndex> _linksInSequence;
636             private readonly HashSet<LinkIndex> _results;
637             private readonly Func<IList<LinkIndex>, LinkIndex> _stopableHandler;
638             private readonly HashSet<LinkIndex> _readAsElements;
639             private int _filterPosition;
640
641             [MethodImpl(MethodImplOptions.AggressiveInlining)]
642             public Matcher(Sequences sequences, IList<LinkIndex> patternSequence,
                ↪  HashSet<LinkIndex> results, Func<IList<LinkIndex>, LinkIndex> stopableHandler,
                ↪  HashSet<LinkIndex> readAsElements = null)
643                 : base(sequences.Links.Unsync, new DefaultStack<LinkIndex>())
644             {
645                 _sequences = sequences;
646                 _patternSequence = patternSequence;
647                 _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
                    ↪  _links.Constants.Any && x != ZeroOrMany));
648                 _results = results;
649                 _stopableHandler = stopableHandler;
650                 _readAsElements = readAsElements;
651             }
652
653             [MethodImpl(MethodImplOptions.AggressiveInlining)]
654             protected override bool IsElement(LinkIndex link) => base.IsElement(link) ||
                ↪  (_readAsElements != null && _readAsElements.Contains(link)) ||
                ↪  _linksInSequence.Contains(link);
655
656             [MethodImpl(MethodImplOptions.AggressiveInlining)]
657             public bool FullMatch(LinkIndex sequenceToMatch)
658             {
659                 _filterPosition = 0;
660                 foreach (var part in Walk(sequenceToMatch))
661                 {
662                     if (!FullMatchCore(part))
663                     {
664                         break;
665                     }
666                 }
667                 return _filterPosition == _patternSequence.Count;
668             }
669
670             [MethodImpl(MethodImplOptions.AggressiveInlining)]
671             private bool FullMatchCore(LinkIndex element)
672             {
673                 if (_filterPosition == _patternSequence.Count)
674                 {
675                     _filterPosition = -2; // Длиннее чем нужно
676                     return false;
677                 }
678                 if (_patternSequence[_filterPosition] != _links.Constants.Any
679                  && element != _patternSequence[_filterPosition])
680                 {
681                     _filterPosition = -1;
682                     return false; // Начинается/Продолжается иначе
```

```
            }
            _filterPosition++;
            return true;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void AddFullMatchedToResults(IList<LinkIndex> restrictions)
        {
            var sequenceToMatch = restrictions[_links.Constants.IndexPart];
            if (FullMatch(sequenceToMatch))
            {
                _results.Add(sequenceToMatch);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkIndex HandleFullMatched(IList<LinkIndex> restrictions)
        {
            var sequenceToMatch = restrictions[_links.Constants.IndexPart];
            if (FullMatch(sequenceToMatch) && _results.Add(sequenceToMatch))
            {
                return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
            }
            return _links.Constants.Continue;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkIndex HandleFullMatchedSequence(IList<LinkIndex> restrictions)
        {
            var sequenceToMatch = restrictions[_links.Constants.IndexPart];
            var sequence = _sequences.GetSequenceByElements(sequenceToMatch);
            if (sequence != _links.Constants.Null && FullMatch(sequenceToMatch) &&
            ↪  _results.Add(sequenceToMatch))
            {
                return _stopableHandler(new LinkAddress<LinkIndex>(sequence));
            }
            return _links.Constants.Continue;
        }

        /// <remarks>
        /// TODO: Add support for LinksConstants.Any
        /// </remarks>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool PartialMatch(LinkIndex sequenceToMatch)
        {
            _filterPosition = -1;
            foreach (var part in Walk(sequenceToMatch))
            {
                if (!PartialMatchCore(part))
                {
                    break;
                }
            }
            return _filterPosition == _patternSequence.Count - 1;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool PartialMatchCore(LinkIndex element)
        {
            if (_filterPosition == (_patternSequence.Count - 1))
            {
                return false; // Нашлось
            }
            if (_filterPosition >= 0)
            {
                if (element == _patternSequence[_filterPosition + 1])
                {
                    _filterPosition++;
                }
                else
                {
                    _filterPosition = -1;
                }
            }
            if (_filterPosition < 0)
            {
                if (element == _patternSequence[0])
                {
                    _filterPosition = 0;
```

```
                    }
                }
                return true; // Ищем дальше
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public void AddPartialMatchedToResults(LinkIndex sequenceToMatch)
            {
                if (PartialMatch(sequenceToMatch))
                {
                    _results.Add(sequenceToMatch);
                }
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public LinkIndex HandlePartialMatched(IList<LinkIndex> restrictions)
            {
                var sequenceToMatch = restrictions[_links.Constants.IndexPart];
                if (PartialMatch(sequenceToMatch))
                {
                    return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
                }
                return _links.Constants.Continue;
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public void AddAllPartialMatchedToResults(IEnumerable<LinkIndex> sequencesToMatch)
            {
                foreach (var sequenceToMatch in sequencesToMatch)
                {
                    if (PartialMatch(sequenceToMatch))
                    {
                        _results.Add(sequenceToMatch);
                    }
                }
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public void AddAllPartialMatchedToResultsAndReadAsElements(IEnumerable<LinkIndex>
            ↪  sequencesToMatch)
            {
                foreach (var sequenceToMatch in sequencesToMatch)
                {
                    if (PartialMatch(sequenceToMatch))
                    {
                        _readAsElements.Add(sequenceToMatch);
                        _results.Add(sequenceToMatch);
                    }
                }
            }
        }

        #endregion
    }
}
```

1.117 ./csharp/Platform.Data.Doublets/Sequences/SequencesExtensions.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Lists;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    public static class SequencesExtensions
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static TLink Create<TLink>(this ILinks<TLink> sequences, IList<TLink[]>
        ↪  groupedSequence)
        {
            var finalSequence = new TLink[groupedSequence.Count];
            for (var i = 0; i < finalSequence.Length; i++)
            {
                var part = groupedSequence[i];
                finalSequence[i] = part.Length == 1 ? part[0] :
                ↪  sequences.Create(part.ShiftRight());
            }
            return sequences.Create(finalSequence.ShiftRight());
```

```
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static IList<TLink> ToList<TLink>(this ILinks<TLink> sequences, TLink sequence)
        {
            var list = new List<TLink>();
            var filler = new ListFiller<TLink, TLink>(list, sequences.Constants.Break);
            sequences.Each(filler.AddSkipFirstAndReturnConstant, new
            ↪  LinkAddress<TLink>(sequence));
            return list;
        }
    }
}
```

1.118 ./csharp/Platform.Data.Doublets/Sequences/SequencesOptions.cs

```
using System;
using System.Collections.Generic;
using Platform.Interfaces;
using Platform.Collections.Stacks;
using Platform.Converters;
using Platform.Data.Doublets.Sequences.Frequencies.Cache;
using Platform.Data.Doublets.Sequences.Frequencies.Counters;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Data.Doublets.Sequences.Indexes;
using Platform.Data.Doublets.Sequences.CriterionMatchers;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    public class SequencesOptions<TLink> // TODO: To use type parameter <TLink> the
    ↪  ILinks<TLink> must contain GetConstants function.
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        public TLink SequenceMarkerLink
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool UseCascadeUpdate
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool UseCascadeDelete
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool UseIndex
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        } // TODO: Update Index on sequence update/delete.

        public bool UseSequenceMarker
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool UseCompression
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool UseGarbageCollection
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool EnforceSingleSequenceVersionOnWriteBasedOnExisting
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool EnforceSingleSequenceVersionOnWriteBasedOnNew
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public MarkedSequenceCriterionMatcher<TLink> MarkedSequenceMatcher
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public IConverter<IList<TLink>, TLink> LinksToSequenceConverter
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public ISequenceIndex<TLink> Index
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public ISequenceWalker<TLink> Walker
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool ReadFullSequence
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        // TODO: Реализовать компактификацию при чтении
        //public bool EnforceSingleSequenceVersionOnRead { get; set; }
        //public bool UseRequestMarker { get; set; }
        //public bool StoreRequestResults { get; set; }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void InitOptions(ISynchronizedLinks<TLink> links)
        {
            if (UseSequenceMarker)
            {
                if (_equalityComparer.Equals(SequenceMarkerLink, links.Constants.Null))
                {
```

```
                    SequenceMarkerLink = links.CreatePoint();
                }
                else
                {
                    if (!links.Exists(SequenceMarkerLink))
                    {
                        var link = links.CreatePoint();
                        if (!_equalityComparer.Equals(link, SequenceMarkerLink))
                        {
                            throw new InvalidOperationException("Cannot recreate sequence marker
                            ↪  link.");
                        }
                    }
                }
                if (MarkedSequenceMatcher == null)
                {
                    MarkedSequenceMatcher = new MarkedSequenceCriterionMatcher<TLink>(links,
                    ↪  SequenceMarkerLink);
                }
            }
            var balancedVariantConverter = new BalancedVariantConverter<TLink>(links);
            if (UseCompression)
            {
                if (LinksToSequenceConverter == null)
                {
                    ICounter<TLink, TLink> totalSequenceSymbolFrequencyCounter;
                    if (UseSequenceMarker)
                    {
                        totalSequenceSymbolFrequencyCounter = new
                        ↪  TotalMarkedSequenceSymbolFrequencyCounter<TLink>(links,
                        ↪  MarkedSequenceMatcher);
                    }
                    else
                    {
                        totalSequenceSymbolFrequencyCounter = new
                        ↪  TotalSequenceSymbolFrequencyCounter<TLink>(links);
                    }
                    var doubletFrequenciesCache = new LinkFrequenciesCache<TLink>(links,
                    ↪  totalSequenceSymbolFrequencyCounter);
                    var compressingConverter = new CompressingConverter<TLink>(links,
                    ↪  balancedVariantConverter, doubletFrequenciesCache);
                    LinksToSequenceConverter = compressingConverter;
                }
            }
            else
            {
                if (LinksToSequenceConverter == null)
                {
                    LinksToSequenceConverter = balancedVariantConverter;
                }
            }
            if (UseIndex && Index == null)
            {
                Index = new SequenceIndex<TLink>(links);
            }
            if (Walker == null)
            {
                Walker = new RightSequenceWalker<TLink>(links, new DefaultStack<TLink>());
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void ValidateOptions()
        {
            if (UseGarbageCollection && !UseSequenceMarker)
            {
                throw new NotSupportedException("To use garbage collection UseSequenceMarker
                ↪  option must be on.");
            }
        }
    }
}
```

1.119 ./csharp/Platform.Data.Doublets/Sequences/Walkers/ISequenceWalker.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
```

```

namespace Platform.Data.Doublets.Sequences.Walkers
{
    public interface ISequenceWalker<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        IEnumerable<TLink> Walk(TLink sequence);
    }
}
```

1.120 ./csharp/Platform.Data.Doublets/Sequences/Walkers/LeftSequenceWalker.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Stacks;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Walkers
{
    public class LeftSequenceWalker<TLink> : SequenceWalkerBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LeftSequenceWalker(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
        ↪  isElement) : base(links, stack, isElement) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LeftSequenceWalker(ILinks<TLink> links, IStack<TLink> stack) : base(links, stack,
        ↪  links.IsPartialPoint) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetNextElementAfterPop(TLink element) =>
        ↪  _links.GetSource(element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetNextElementAfterPush(TLink element) =>
        ↪  _links.GetTarget(element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override IEnumerable<TLink> WalkContents(TLink element)
        {
            var links = _links;
            var parts = links.GetLink(element);
            var start = links.Constants.SourcePart;
            for (var i = parts.Count - 1; i >= start; i--)
            {
                var part = parts[i];
                if (IsElement(part))
                {
                    yield return part;
                }
            }
        }
    }
}
```

1.121 ./csharp/Platform.Data.Doublets/Sequences/Walkers/LeveledSequenceWalker.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

//#define USEARRAYPOOL
#if USEARRAYPOOL
using Platform.Collections;
#endif

namespace Platform.Data.Doublets.Sequences.Walkers
{
    public class LeveledSequenceWalker<TLink> : LinksOperatorBase<TLink>, ISequenceWalker<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly Func<TLink, bool> _isElement;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LeveledSequenceWalker(ILinks<TLink> links, Func<TLink, bool> isElement) :
        ↪  base(links) => _isElement = isElement;
```

```
22
23          [MethodImpl(MethodImplOptions.AggressiveInlining)]
24          public LeveledSequenceWalker(ILinks<TLink> links) : base(links) => _isElement =
            ↪  _links.IsPartialPoint;
25
26          [MethodImpl(MethodImplOptions.AggressiveInlining)]
27          public IEnumerable<TLink> Walk(TLink sequence) => ToArray(sequence);
28
29          [MethodImpl(MethodImplOptions.AggressiveInlining)]
30          public TLink[] ToArray(TLink sequence)
31          {
32              var length = 1;
33              var array = new TLink[length];
34              array[0] = sequence;
35              if (_isElement(sequence))
36              {
37                  return array;
38              }
39              bool hasElements;
40              do
41              {
42                  length *= 2;
43  #if USEARRAYPOOL
44                  var nextArray = ArrayPool.Allocate<ulong>(length);
45  #else
46                  var nextArray = new TLink[length];
47  #endif
48                  hasElements = false;
49                  for (var i = 0; i < array.Length; i++)
50                  {
51                      var candidate = array[i];
52                      if (_equalityComparer.Equals(array[i], default))
53                      {
54                          continue;
55                      }
56                      var doubletOffset = i * 2;
57                      if (_isElement(candidate))
58                      {
59                          nextArray[doubletOffset] = candidate;
60                      }
61                      else
62                      {
63                          var links = _links;
64                          var link = links.GetLink(candidate);
65                          var linkSource = links.GetSource(link);
66                          var linkTarget = links.GetTarget(link);
67                          nextArray[doubletOffset] = linkSource;
68                          nextArray[doubletOffset + 1] = linkTarget;
69                          if (!hasElements)
70                          {
71                              hasElements = !(_isElement(linkSource) && _isElement(linkTarget));
72                          }
73                      }
74                  }
75  #if USEARRAYPOOL
76                  if (array.Length > 1)
77                  {
78                      ArrayPool.Free(array);
79                  }
80  #endif
81                  array = nextArray;
82              }
83              while (hasElements);
84              var filledElementsCount = CountFilledElements(array);
85              if (filledElementsCount == array.Length)
86              {
87                  return array;
88              }
89              else
90              {
91                  return CopyFilledElements(array, filledElementsCount);
92              }
93          }
94
95          [MethodImpl(MethodImplOptions.AggressiveInlining)]
96          private static TLink[] CopyFilledElements(TLink[] array, int filledElementsCount)
97          {
98              var finalArray = new TLink[filledElementsCount];
99              for (int i = 0, j = 0; i < array.Length; i++)
```

```
            {
                if (!_equalityComparer.Equals(array[i], default))
                {
                    finalArray[j] = array[i];
                    j++;
                }
            }
#if USEARRAYPOOL
            ArrayPool.Free(array);
#endif
            return finalArray;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static int CountFilledElements(TLink[] array)
        {
            var count = 0;
            for (var i = 0; i < array.Length; i++)
            {
                if (!_equalityComparer.Equals(array[i], default))
                {
                    count++;
                }
            }
            return count;
        }
    }
}
```

1.122 ./csharp/Platform.Data.Doublets/Sequences/Walkers/RightSequenceWalker.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Stacks;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Walkers
{
    public class RightSequenceWalker<TLink> : SequenceWalkerBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public RightSequenceWalker(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
        ↪  isElement) : base(links, stack, isElement) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public RightSequenceWalker(ILinks<TLink> links, IStack<TLink> stack) : base(links,
        ↪  stack, links.IsPartialPoint) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetNextElementAfterPop(TLink element) =>
        ↪  _links.GetTarget(element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetNextElementAfterPush(TLink element) =>
        ↪  _links.GetSource(element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override IEnumerable<TLink> WalkContents(TLink element)
        {
            var parts = _links.GetLink(element);
            for (var i = _links.Constants.SourcePart; i < parts.Count; i++)
            {
                var part = parts[i];
                if (IsElement(part))
                {
                    yield return part;
                }
            }
        }
    }
}
```

1.123 ./csharp/Platform.Data.Doublets/Sequences/Walkers/SequenceWalkerBase.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Stacks;

```

```
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Walkers
{
    public abstract class SequenceWalkerBase<TLink> : LinksOperatorBase<TLink>,
    ↪ ISequenceWalker<TLink>
    {
        private readonly IStack<TLink> _stack;
        private readonly Func<TLink, bool> _isElement;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
        ↪ isElement) : base(links)
        {
            _stack = stack;
            _isElement = isElement;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack) : this(links,
        ↪ stack, links.IsPartialPoint) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public IEnumerable<TLink> Walk(TLink sequence)
        {
            _stack.Clear();
            var element = sequence;
            if (IsElement(element))
            {
                yield return element;
            }
            else
            {
                while (true)
                {
                    if (IsElement(element))
                    {
                        if (_stack.IsEmpty)
                        {
                            break;
                        }
                        element = _stack.Pop();
                        foreach (var output in WalkContents(element))
                        {
                            yield return output;
                        }
                        element = GetNextElementAfterPop(element);
                    }
                    else
                    {
                        _stack.Push(element);
                        element = GetNextElementAfterPush(element);
                    }
                }
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual bool IsElement(TLink elementLink) => _isElement(elementLink);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract TLink GetNextElementAfterPop(TLink element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract TLink GetNextElementAfterPush(TLink element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract IEnumerable<TLink> WalkContents(TLink element);
    }
}
```

1.124 ./csharp/Platform.Data.Doublets/Stacks/Stack.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Stacks;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Stacks
{
```

```
    public class Stack<TLink> : LinksOperatorBase<TLink>, IStack<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly TLink _stack;

        public bool IsEmpty
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get => _equalityComparer.Equals(Peek(), _stack);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public Stack(ILinks<TLink> links, TLink stack) : base(links) => _stack = stack;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private TLink GetStackMarker() => _links.GetSource(_stack);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private TLink GetTop() => _links.GetTarget(_stack);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Peek() => _links.GetTarget(GetTop());

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Pop()
        {
            var element = Peek();
            if (!_equalityComparer.Equals(element, _stack))
            {
                var top = GetTop();
                var previousTop = _links.GetSource(top);
                _links.Update(_stack, GetStackMarker(), previousTop);
                _links.Delete(top);
            }
            return element;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Push(TLink element) => _links.Update(_stack, GetStackMarker(),
        ↪  _links.GetOrCreate(GetTop(), element));
    }
}
```

1.125 ./csharp/Platform.Data.Doublets/Stacks/StackExtensions.cs

```
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Stacks
{
    public static class StackExtensions
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static TLink CreateStack<TLink>(this ILinks<TLink> links, TLink stackMarker)
        {
            var stackPoint = links.CreatePoint();
            var stack = links.Update(stackPoint, stackMarker, stackPoint);
            return stack;
        }
    }
}
```

1.126 ./csharp/Platform.Data.Doublets/SynchronizedLinks.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Data.Doublets;
using Platform.Threading.Synchronization;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets
{
    /// <remarks>
    /// TODO: Autogeneration of synchronized wrapper (decorator).
    /// TODO: Try to unfold code of each method using IL generation for performance improvements.
    /// TODO: Or even to unfold multiple layers of implementations.
```

```
15      /// </remarks>
16      public class SynchronizedLinks<TLinkAddress> : ISynchronizedLinks<TLinkAddress>
17      {
18          public LinksConstants<TLinkAddress> Constants
19          {
20              [MethodImpl(MethodImplOptions.AggressiveInlining)]
21              get;
22          }
23
24          public ISynchronization SyncRoot
25          {
26              [MethodImpl(MethodImplOptions.AggressiveInlining)]
27              get;
28          }
29
30          public ILinks<TLinkAddress> Sync
31          {
32              [MethodImpl(MethodImplOptions.AggressiveInlining)]
33              get;
34          }
35
36          public ILinks<TLinkAddress> Unsync
37          {
38              [MethodImpl(MethodImplOptions.AggressiveInlining)]
39              get;
40          }
41
42          [MethodImpl(MethodImplOptions.AggressiveInlining)]
43          public SynchronizedLinks(ILinks<TLinkAddress> links) : this(new
            ↪  ReaderWriterLockSynchronization(), links) { }
44
45          [MethodImpl(MethodImplOptions.AggressiveInlining)]
46          public SynchronizedLinks(ISynchronization synchronization, ILinks<TLinkAddress> links)
47          {
48              SyncRoot = synchronization;
49              Sync = this;
50              Unsync = links;
51              Constants = links.Constants;
52          }
53
54          [MethodImpl(MethodImplOptions.AggressiveInlining)]
55          public TLinkAddress Count(IList<TLinkAddress> restriction) =>
            ↪  SyncRoot.ExecuteReadOperation(restriction, Unsync.Count);
56
57          [MethodImpl(MethodImplOptions.AggressiveInlining)]
58          public TLinkAddress Each(Func<IList<TLinkAddress>, TLinkAddress> handler,
            ↪  IList<TLinkAddress> restrictions) => SyncRoot.ExecuteReadOperation(handler,
            ↪  restrictions, (handler1, restrictions1) => Unsync.Each(handler1, restrictions1));
59
60          [MethodImpl(MethodImplOptions.AggressiveInlining)]
61          public TLinkAddress Create(IList<TLinkAddress> restrictions) =>
            ↪  SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Create);
62
63          [MethodImpl(MethodImplOptions.AggressiveInlining)]
64          public TLinkAddress Update(IList<TLinkAddress> restrictions, IList<TLinkAddress>
            ↪  substitution) => SyncRoot.ExecuteWriteOperation(restrictions, substitution,
            ↪  Unsync.Update);
65
66          [MethodImpl(MethodImplOptions.AggressiveInlining)]
67          public void Delete(IList<TLinkAddress> restrictions) =>
            ↪  SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Delete);
68
69          //public T Trigger(IList<T> restriction, Func<IList<T>, IList<T>, T> matchedHandler,
            ↪  IList<T> substitution, Func<IList<T>, IList<T>, T> substitutedHandler)
70          //{
71          //    if (restriction != null && substitution != null &&
            ↪  !substitution.EqualTo(restriction))
72          //        return SyncRoot.ExecuteWriteOperation(restriction, matchedHandler,
            ↪  substitution, substitutedHandler, Unsync.Trigger);
73
74          //    return SyncRoot.ExecuteReadOperation(restriction, matchedHandler, substitution,
            ↪  substitutedHandler, Unsync.Trigger);
75          //}
76      }
77  }
```

1.127 ./csharp/Platform.Data.Doublets/UInt64LinksExtensions.cs

```
1   using System;
2   using System.Text;
```

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Singletons;
using Platform.Data.Doublets.Unicode;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets
{
    public static class UInt64LinksExtensions
    {
        public static readonly LinksConstants<ulong> Constants =
        ↪  Default<LinksConstants<ulong>>.Instance;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static void UseUnicode(this ILinks<ulong> links) => UnicodeMap.InitNew(links);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool AnyLinkIsAny(this ILinks<ulong> links, params ulong[] sequence)
        {
            if (sequence == null)
            {
                return false;
            }
            var constants = links.Constants;
            for (var i = 0; i < sequence.Length; i++)
            {
                if (sequence[i] == constants.Any)
                {
                    return true;
                }
            }
            return false;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
        ↪  Func<Link<ulong>, bool> isElement, bool renderIndex = false, bool renderDebug =
        ↪  false)
        {
            var sb = new StringBuilder();
            var visited = new HashSet<ulong>();
            links.AppendStructure(sb, visited, linkIndex, isElement, (innerSb, link) =>
            ↪  innerSb.Append(link.Index), renderIndex, renderDebug);
            return sb.ToString();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
        ↪  Func<Link<ulong>, bool> isElement, Action<StringBuilder, Link<ulong>> appendElement,
        ↪  bool renderIndex = false, bool renderDebug = false)
        {
            var sb = new StringBuilder();
            var visited = new HashSet<ulong>();
            links.AppendStructure(sb, visited, linkIndex, isElement, appendElement, renderIndex,
            ↪  renderDebug);
            return sb.ToString();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static void AppendStructure(this ILinks<ulong> links, StringBuilder sb,
        ↪  HashSet<ulong> visited, ulong linkIndex, Func<Link<ulong>, bool> isElement,
        ↪  Action<StringBuilder, Link<ulong>> appendElement, bool renderIndex = false, bool
        ↪  renderDebug = false)
        {
            if (sb == null)
            {
                throw new ArgumentNullException(nameof(sb));
            }
            if (linkIndex == Constants.Null || linkIndex == Constants.Any || linkIndex ==
            ↪  Constants.Itself)
            {
                return;
            }
            if (links.Exists(linkIndex))
            {
                if (visited.Add(linkIndex))
                {
                    sb.Append('(');
```

```
                    var link = new Link<ulong>(links.GetLink(linkIndex));
                    if (renderIndex)
                    {
                        sb.Append(link.Index);
                        sb.Append(':');
                    }
                    if (link.Source == link.Index)
                    {
                        sb.Append(link.Index);
                    }
                    else
                    {
                        var source = new Link<ulong>(links.GetLink(link.Source));
                        if (isElement(source))
                        {
                            appendElement(sb, source);
                        }
                        else
                        {
                            links.AppendStructure(sb, visited, source.Index, isElement,
                            ↪  appendElement, renderIndex);
                        }
                    }
                    sb.Append(' ');
                    if (link.Target == link.Index)
                    {
                        sb.Append(link.Index);
                    }
                    else
                    {
                        var target = new Link<ulong>(links.GetLink(link.Target));
                        if (isElement(target))
                        {
                            appendElement(sb, target);
                        }
                        else
                        {
                            links.AppendStructure(sb, visited, target.Index, isElement,
                            ↪  appendElement, renderIndex);
                        }
                    }
                    sb.Append(')');
                }
                else
                {
                    if (renderDebug)
                    {
                        sb.Append('*');
                    }
                    sb.Append(linkIndex);
                }
            }
            else
            {
                if (renderDebug)
                {
                    sb.Append('~');
                }
                sb.Append(linkIndex);
            }
        }
    }
}
```

1.128 ./csharp/Platform.Data.Doublets/UInt64LinksTransactionsLayer.cs

```
using System;
using System.Linq;
using System.Collections.Generic;
using System.IO;
using System.Runtime.CompilerServices;
using System.Threading;
using System.Threading.Tasks;
using Platform.Disposables;
using Platform.Timestamps;
using Platform.Unsafe;
using Platform.IO;
using Platform.Data.Doublets.Decorators;
using Platform.Exceptions;

```

```
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets
{
    public class UInt64LinksTransactionsLayer : LinksDisposableDecoratorBase<ulong> //-V3073
    {
        /// <remarks>
        /// Альтернативные варианты хранения трансформации (элемента транзакции):
        ///
        /// private enum TransitionType
        /// {
        ///     Creation,
        ///     UpdateOf,
        ///     UpdateTo,
        ///     Deletion
        /// }
        ///
        /// private struct Transition
        /// {
        ///     public ulong TransactionId;
        ///     public UniqueTimestamp Timestamp;
        ///     public TransactionItemType Type;
        ///     public Link Source;
        ///     public Link Linker;
        ///     public Link Target;
        /// }
        ///
        /// Или
        ///
        /// public struct TransitionHeader
        /// {
        ///     public ulong TransactionIdCombined;
        ///     public ulong TimestampCombined;
        ///
        ///     public ulong TransactionId
        ///     {
        ///         get
        ///         {
        ///             return (ulong) mask &amp;amp; TransactionIdCombined;
        ///         }
        ///     }
        ///
        ///     public UniqueTimestamp Timestamp
        ///     {
        ///         get
        ///         {
        ///             return (UniqueTimestamp)mask &amp;amp; TransactionIdCombined;
        ///         }
        ///     }
        ///
        ///     public TransactionItemType Type
        ///     {
        ///         get
        ///         {
        ///             // Использовать по одному биту из TransactionId и Timestamp,
        ///             // для значения в 2 бита, которое представляет тип операции
        ///             throw new NotImplementedException();
        ///         }
        ///     }
        /// }
        ///
        /// private struct Transition
        /// {
        ///     public TransitionHeader Header;
        ///     public Link Source;
        ///     public Link Linker;
        ///     public Link Target;
        /// }
        ///
        /// </remarks>
        public struct Transition : IEquatable<Transition>
        {
            public static readonly long Size = Structure<Transition>.Size;

            public readonly ulong TransactionId;
            public readonly Link<ulong> Before;
            public readonly Link<ulong> After;
            public readonly Timestamp Timestamp;
```

```
93
94              [MethodImpl(MethodImplOptions.AggressiveInlining)]
95              public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
                ↪  transactionId, Link<ulong> before, Link<ulong> after)
96              {
97                  TransactionId = transactionId;
98                  Before = before;
99                  After = after;
100                 Timestamp = uniqueTimestampFactory.Create();
101             }
102
103             [MethodImpl(MethodImplOptions.AggressiveInlining)]
104             public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
                ↪  transactionId, Link<ulong> before) : this(uniqueTimestampFactory, transactionId,
                ↪  before, default) { }
105
106             [MethodImpl(MethodImplOptions.AggressiveInlining)]
107             public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
                ↪  transactionId) : this(uniqueTimestampFactory, transactionId, default, default) {
                ↪  }
108
109             [MethodImpl(MethodImplOptions.AggressiveInlining)]
110             public override string ToString() => $"{Timestamp} {TransactionId}: {Before} =>
                ↪  {After}";
111
112             [MethodImpl(MethodImplOptions.AggressiveInlining)]
113             public override bool Equals(object obj) => obj is Transition transition ?
                ↪  Equals(transition) : false;
114
115             [MethodImpl(MethodImplOptions.AggressiveInlining)]
116             public override int GetHashCode() => (TransactionId, Before, After,
                ↪  Timestamp).GetHashCode();
117
118             [MethodImpl(MethodImplOptions.AggressiveInlining)]
119             public bool Equals(Transition other) => TransactionId == other.TransactionId &&
                ↪  Before == other.Before && After == other.After && Timestamp == other.Timestamp;
120
121             [MethodImpl(MethodImplOptions.AggressiveInlining)]
122             public static bool operator ==(Transition left, Transition right) =>
                ↪  left.Equals(right);
123
124             [MethodImpl(MethodImplOptions.AggressiveInlining)]
125             public static bool operator !=(Transition left, Transition right) => !(left ==
                ↪  right);
126         }
127
128         /// <remarks>
129         /// Другие варианты реализации транзакций (атомарности):
130         ///     1. Разделение хранения значения связи ((Source Target) или (Source Linker
                ↪  Target)) и индексов.
131         ///     2. Хранение трансформаций/операций в отдельном хранилище Links, но дополнительно
                ↪  потребуется решить вопрос
132         ///        со ссылками на внешние идентификаторы, или как-то иначе решить вопрос с
                ↪  пересечениями идентификаторов.
133         ///
134         /// Где хранить промежуточный список транзакций?
135         ///
136         /// В оперативной памяти:
137         ///  Минусы:
138         ///     1. Может усложнить систему, если она будет функционировать самостоятельно,
139         ///     так как нужно отдельно выделять память под список трансформаций.
140         ///     2. Выделенной оперативной памяти может не хватить, в том случае,
141         ///     если транзакция использует слишком много трансформаций.
142         ///         -> Можно использовать жёсткий диск для слишком длинных транзакций.
143         ///         -> Максимальный размер списка трансформаций можно ограничить / задать
                ↪  константой.
144         ///     3. При подтверждении транзакции (Commit) все трансформации записываются разом
                ↪  создавая задержку.
145         ///
146         /// На жёстком диске:
147         ///  Минусы:
148         ///     1. Длительный отклик, на запись каждой трансформации.
149         ///     2. Лог транзакций дополнительно наполняется отменёнными транзакциями.
150         ///         -> Это может решаться упаковкой/исключением дублирующих операций.
151         ///         -> Также это может решаться тем, что короткие транзакции вообще
152         ///            не будут записываться в случае отката.
153         ///     3. Перед тем как выполнять отмену операций транзакции нужно дождаться пока все
                ↪  операции (трансформации)
```

```
154         ///        будут записаны в лог.
155         ///
156         /// </remarks>
157         public class Transaction : DisposableBase
158         {
159             private readonly Queue<Transition> _transitions;
160             private readonly UInt64LinksTransactionsLayer _layer;
161             public bool IsCommitted { get; private set; }
162             public bool IsReverted { get; private set; }
163 
164             [MethodImpl(MethodImplOptions.AggressiveInlining)]
165             public Transaction(UInt64LinksTransactionsLayer layer)
166             {
167                 _layer = layer;
168                 if (_layer._currentTransactionId != 0)
169                 {
170                     throw new NotSupportedException("Nested transactions not supported.");
171                 }
172                 IsCommitted = false;
173                 IsReverted = false;
174                 _transitions = new Queue<Transition>();
175                 SetCurrentTransaction(layer, this);
176             }
177 
178             [MethodImpl(MethodImplOptions.AggressiveInlining)]
179             public void Commit()
180             {
181                 EnsureTransactionAllowsWriteOperations(this);
182                 while (_transitions.Count > 0)
183                 {
184                     var transition = _transitions.Dequeue();
185                     _layer._transitions.Enqueue(transition);
186                 }
187                 _layer._lastCommitedTransactionId = _layer._currentTransactionId;
188                 IsCommitted = true;
189             }
190 
191             [MethodImpl(MethodImplOptions.AggressiveInlining)]
192             private void Revert()
193             {
194                 EnsureTransactionAllowsWriteOperations(this);
195                 var transitionsToRevert = new Transition[_transitions.Count];
196                 _transitions.CopyTo(transitionsToRevert, 0);
197                 for (var i = transitionsToRevert.Length - 1; i >= 0; i--)
198                 {
199                     _layer.RevertTransition(transitionsToRevert[i]);
200                 }
201                 IsReverted = true;
202             }
203 
204             [MethodImpl(MethodImplOptions.AggressiveInlining)]
205             public static void SetCurrentTransaction(UInt64LinksTransactionsLayer layer,
                ↪  Transaction transaction)
206             {
207                 layer._currentTransactionId = layer._lastCommitedTransactionId + 1;
208                 layer._currentTransactionTransitions = transaction._transitions;
209                 layer._currentTransaction = transaction;
210             }
211 
212             [MethodImpl(MethodImplOptions.AggressiveInlining)]
213             public static void EnsureTransactionAllowsWriteOperations(Transaction transaction)
214             {
215                 if (transaction.IsReverted)
216                 {
217                     throw new InvalidOperationException("Transation is reverted.");
218                 }
219                 if (transaction.IsCommitted)
220                 {
221                     throw new InvalidOperationException("Transation is commited.");
222                 }
223             }
224 
225             [MethodImpl(MethodImplOptions.AggressiveInlining)]
226             protected override void Dispose(bool manual, bool wasDisposed)
227             {
228                 if (!wasDisposed && _layer != null && !_layer.Disposable.IsDisposed)
229                 {
230                     if (!IsCommitted && !IsReverted)
231                     {
```

```
                    Revert();
                }
                _layer.ResetCurrentTransation();
            }
        }
    }

    public static readonly TimeSpan DefaultPushDelay = TimeSpan.FromSeconds(0.1);

    private readonly string _logAddress;
    private readonly FileStream _log;
    private readonly Queue<Transition> _transitions;
    private readonly UniqueTimestampFactory _uniqueTimestampFactory;
    private Task _transitionsPusher;
    private Transition _lastCommitedTransition;
    private ulong _currentTransactionId;
    private Queue<Transition> _currentTransactionTransitions;
    private Transaction _currentTransaction;
    private ulong _lastCommitedTransactionId;

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public UInt64LinksTransactionsLayer(ILinks<ulong> links, string logAddress)
        : base(links)
    {
        if (string.IsNullOrWhiteSpace(logAddress))
        {
            throw new ArgumentNullException(nameof(logAddress));
        }
        // В первой строке файла хранится последняя закоммиченную транзакцию.
        // При запуске это используется для проверки удачного закрытия файла лога.
        // In the first line of the file the last committed transaction is stored.
        // On startup, this is used to check that the log file is successfully closed.
        var lastCommitedTransition = FileHelpers.ReadFirstOrDefault<Transition>(logAddress);
        var lastWrittenTransition = FileHelpers.ReadLastOrDefault<Transition>(logAddress);
        if (!lastCommitedTransition.Equals(lastWrittenTransition))
        {
            Dispose();
            throw new NotSupportedException("Database is damaged, autorecovery is not
            ↪  supported yet.");
        }
        if (lastCommitedTransition == default)
        {
            FileHelpers.WriteFirst(logAddress, lastCommitedTransition);
        }
        _lastCommitedTransition = lastCommitedTransition;
        // TODO: Think about a better way to calculate or store this value
        var allTransitions = FileHelpers.ReadAll<Transition>(logAddress);
        _lastCommitedTransactionId = allTransitions.Length > 0 ? allTransitions.Max(x =>
        ↪  x.TransactionId) : 0;
        _uniqueTimestampFactory = new UniqueTimestampFactory();
        _logAddress = logAddress;
        _log = FileHelpers.Append(logAddress);
        _transitions = new Queue<Transition>();
        _transitionsPusher = new Task(TransitionsPusher);
        _transitionsPusher.Start();
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public IList<ulong> GetLinkValue(ulong link) => _links.GetLink(link);

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public override ulong Create(IList<ulong> restrictions)
    {
        var createdLinkIndex = _links.Create();
        var createdLink = new Link<ulong>(_links.GetLink(createdLinkIndex));
        CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↪  default, createdLink));
        return createdLinkIndex;
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public override ulong Update(IList<ulong> restrictions, IList<ulong> substitution)
    {
        var linkIndex = restrictions[_constants.IndexPart];
        var beforeLink = new Link<ulong>(_links.GetLink(linkIndex));
        linkIndex = _links.Update(restrictions, substitution);
        var afterLink = new Link<ulong>(_links.GetLink(linkIndex));
        CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↪  beforeLink, afterLink));
```

```
307             return linkIndex;
308         }
309 
310         [MethodImpl(MethodImplOptions.AggressiveInlining)]
311         public override void Delete(IList<ulong> restrictions)
312         {
313             var link = restrictions[_constants.IndexPart];
314             var deletedLink = new Link<ulong>(_links.GetLink(link));
315             _links.Delete(link);
316             CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
                ↪  deletedLink, default));
317         }
318 
319         [MethodImpl(MethodImplOptions.AggressiveInlining)]
320         private Queue<Transition> GetCurrentTransitions() => _currentTransactionTransitions ??
                ↪  _transitions;
321 
322         [MethodImpl(MethodImplOptions.AggressiveInlining)]
323         private void CommitTransition(Transition transition)
324         {
325             if (_currentTransaction != null)
326             {
327                 Transaction.EnsureTransactionAllowsWriteOperations(_currentTransaction);
328             }
329             var transitions = GetCurrentTransitions();
330             transitions.Enqueue(transition);
331         }
332 
333         [MethodImpl(MethodImplOptions.AggressiveInlining)]
334         private void RevertTransition(Transition transition)
335         {
336             if (transition.After.IsNull()) // Revert Deletion with Creation
337             {
338                 _links.Create();
339             }
340             else if (transition.Before.IsNull()) // Revert Creation with Deletion
341             {
342                 _links.Delete(transition.After.Index);
343             }
344             else // Revert Update
345             {
346                 _links.Update(new[] { transition.After.Index, transition.Before.Source,
                        ↪  transition.Before.Target });
347             }
348         }
349 
350         [MethodImpl(MethodImplOptions.AggressiveInlining)]
351         private void ResetCurrentTransation()
352         {
353             _currentTransactionId = 0;
354             _currentTransactionTransitions = null;
355             _currentTransaction = null;
356         }
357 
358         [MethodImpl(MethodImplOptions.AggressiveInlining)]
359         private void PushTransitions()
360         {
361             if (_log == null || _transitions == null)
362             {
363                 return;
364             }
365             for (var i = 0; i < _transitions.Count; i++)
366             {
367                 var transition = _transitions.Dequeue();
368 
369                 _log.Write(transition);
370                 _lastCommitedTransition = transition;
371             }
372         }
373 
374         [MethodImpl(MethodImplOptions.AggressiveInlining)]
375         private void TransitionsPusher()
376         {
377             while (!Disposable.IsDisposed && _transitionsPusher != null)
378             {
379                 Thread.Sleep(DefaultPushDelay);
380                 PushTransitions();
381             }
```

```
382         }
383
384         [MethodImpl(MethodImplOptions.AggressiveInlining)]
385         public Transaction BeginTransaction() => new Transaction(this);
386
387         [MethodImpl(MethodImplOptions.AggressiveInlining)]
388         private void DisposeTransitions()
389         {
390             try
391             {
392                 var pusher = _transitionsPusher;
393                 if (pusher != null)
394                 {
395                     _transitionsPusher = null;
396                     pusher.Wait();
397                 }
398                 if (_transitions != null)
399                 {
400                     PushTransitions();
401                 }
402                 _log.DisposeIfPossible();
403                 FileHelpers.WriteFirst(_logAddress, _lastCommitedTransition);
404             }
405             catch (Exception ex)
406             {
407                 ex.Ignore();
408             }
409         }
410
411         #region DisposalBase
412
413         [MethodImpl(MethodImplOptions.AggressiveInlining)]
414         protected override void Dispose(bool manual, bool wasDisposed)
415         {
416             if (!wasDisposed)
417             {
418                 DisposeTransitions();
419             }
420             base.Dispose(manual, wasDisposed);
421         }
422
423         #endregion
424     }
425 }
```

1.129 ./csharp/Platform.Data.Doublets/Unicode/CharToUnicodeSymbolConverter.cs

```
1  using System.Runtime.CompilerServices;
2  using Platform.Converters;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Unicode
7  {
8      public class CharToUnicodeSymbolConverter<TLink> : LinksOperatorBase<TLink>,
       ↪  IConverter<char, TLink>
9      {
10         private static readonly UncheckedConverter<char, TLink> _charToAddressConverter =
           ↪  UncheckedConverter<char, TLink>.Default;
11
12         private readonly IConverter<TLink> _addressToNumberConverter;
13         private readonly TLink _unicodeSymbolMarker;
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         public CharToUnicodeSymbolConverter(ILinks<TLink> links, IConverter<TLink>
           ↪  addressToNumberConverter, TLink unicodeSymbolMarker) : base(links)
17         {
18             _addressToNumberConverter = addressToNumberConverter;
19             _unicodeSymbolMarker = unicodeSymbolMarker;
20         }
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         public TLink Convert(char source)
24         {
25             var unaryNumber =
               ↪  _addressToNumberConverter.Convert(_charToAddressConverter.Convert(source));
26             return _links.GetOrCreate(unaryNumber, _unicodeSymbolMarker);
27         }
28     }
29 }
```

1.130 ./csharp/Platform.Data.Doublets/Unicode/StringToUnicodeSequenceConverter.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;
using Platform.Data.Doublets.Sequences.Indexes;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class StringToUnicodeSequenceConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<string, TLink>
    {
        private readonly IConverter<string, IList<TLink>> _stringToUnicodeSymbolListConverter;
        private readonly IConverter<IList<TLink>, TLink> _unicodeSymbolListToSequenceConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<string,
        ↪ IList<TLink>> stringToUnicodeSymbolListConverter, IConverter<IList<TLink>, TLink>
        ↪ unicodeSymbolListToSequenceConverter) : base(links)
        {
            _stringToUnicodeSymbolListConverter = stringToUnicodeSymbolListConverter;
            _unicodeSymbolListToSequenceConverter = unicodeSymbolListToSequenceConverter;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<string,
        ↪ IList<TLink>> stringToUnicodeSymbolListConverter, ISequenceIndex<TLink> index,
        ↪ IConverter<IList<TLink>, TLink> listToSequenceLinkConverter, TLink
        ↪ unicodeSequenceMarker)
            : this(links, stringToUnicodeSymbolListConverter, new
            ↪ UnicodeSymbolsListToUnicodeSequenceConverter<TLink>(links, index,
            ↪ listToSequenceLinkConverter, unicodeSequenceMarker)) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<char, TLink>
        ↪ charToUnicodeSymbolConverter, ISequenceIndex<TLink> index, IConverter<IList<TLink>,
        ↪ TLink> listToSequenceLinkConverter, TLink unicodeSequenceMarker)
            : this(links, new
            ↪ StringToUnicodeSymbolsListConverter<TLink>(charToUnicodeSymbolConverter), index,
            ↪ listToSequenceLinkConverter, unicodeSequenceMarker) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<char, TLink>
        ↪ charToUnicodeSymbolConverter, IConverter<IList<TLink>, TLink>
        ↪ listToSequenceLinkConverter, TLink unicodeSequenceMarker)
            : this(links, charToUnicodeSymbolConverter, new Unindex<TLink>(),
            ↪ listToSequenceLinkConverter, unicodeSequenceMarker) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<string,
        ↪ IList<TLink>> stringToUnicodeSymbolListConverter, IConverter<IList<TLink>, TLink>
        ↪ listToSequenceLinkConverter, TLink unicodeSequenceMarker)
            : this(links, stringToUnicodeSymbolListConverter, new Unindex<TLink>(),
            ↪ listToSequenceLinkConverter, unicodeSequenceMarker) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(string source)
        {
            var elements = _stringToUnicodeSymbolListConverter.Convert(source);
            return _unicodeSymbolListToSequenceConverter.Convert(elements);
        }
    }
}
```

1.131 ./csharp/Platform.Data.Doublets/Unicode/StringToUnicodeSymbolsListConverter.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class StringToUnicodeSymbolsListConverter<TLink> : IConverter<string, IList<TLink>>
    {
        private readonly IConverter<char, TLink> _charToUnicodeSymbolConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
        public StringToUnicodeSymbolsListConverter(IConverter<char, TLink>
        ↪  charToUnicodeSymbolConverter) => _charToUnicodeSymbolConverter =
        ↪  charToUnicodeSymbolConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public IList<TLink> Convert(string source)
        {
            var elements = new TLink[source.Length];
            for (var i = 0; i < elements.Length; i++)
            {
                elements[i] = _charToUnicodeSymbolConverter.Convert(source[i]);
            }
            return elements;
        }
    }
}
```

1.132 ./csharp/Platform.Data.Doublets/Unicode/UnicodeMap.cs

```
using System;
using System.Collections.Generic;
using System.Globalization;
using System.Runtime.CompilerServices;
using System.Text;
using Platform.Data.Sequences;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class UnicodeMap
    {
        public static readonly ulong FirstCharLink = 1;
        public static readonly ulong LastCharLink = FirstCharLink + char.MaxValue;
        public static readonly ulong MapSize = 1 + char.MaxValue;

        private readonly ILinks<ulong> _links;
        private bool _initialized;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnicodeMap(ILinks<ulong> links) => _links = links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static UnicodeMap InitNew(ILinks<ulong> links)
        {
            var map = new UnicodeMap(links);
            map.Init();
            return map;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Init()
        {
            if (_initialized)
            {
                return;
            }
            _initialized = true;
            var firstLink = _links.CreatePoint();
            if (firstLink != FirstCharLink)
            {
                _links.Delete(firstLink);
            }
            else
            {
                for (var i = FirstCharLink + 1; i <= LastCharLink; i++)
                {
                    // From NIL to It (NIL -> Character) transformation meaning, (or infinite
                    ↪  amount of NIL characters before actual Character)
                    var createdLink = _links.CreatePoint();
                    _links.Update(createdLink, firstLink, createdLink);
                    if (createdLink != i)
                    {
                        throw new InvalidOperationException("Unable to initialize UTF 16
                        ↪  table.");
                    }
                }
            }
        }

        // 0 - null link
```

```
        // 1 - nil character (0 character)
        // ...
        // 65536 (0(1) + 65535 = 65536 possible values)

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static ulong FromCharToLink(char character) => (ulong)character + 1;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static char FromLinkToChar(ulong link) => (char)(link - 1);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool IsCharLink(ulong link) => link <= MapSize;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static string FromLinksToString(IList<ulong> linksList)
        {
            var sb = new StringBuilder();
            for (int i = 0; i < linksList.Count; i++)
            {
                sb.Append(FromLinkToChar(linksList[i]));
            }
            return sb.ToString();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static string FromSequenceLinkToString(ulong link, ILinks<ulong> links)
        {
            var sb = new StringBuilder();
            if (links.Exists(link))
            {
                StopableSequenceWalker.WalkRight(link, links.GetSource, links.GetTarget,
                    x => x <= MapSize || links.GetSource(x) == x || links.GetTarget(x) == x,
                    element =>
                    {
                        sb.Append(FromLinkToChar(element));
                        return true;
                    });
            }
            return sb.ToString();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static ulong[] FromCharsToLinkArray(char[] chars) => FromCharsToLinkArray(chars,
        chars.Length);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static ulong[] FromCharsToLinkArray(char[] chars, int count)
        {
            // char array to ulong array
            var linksSequence = new ulong[count];
            for (var i = 0; i < count; i++)
            {
                linksSequence[i] = FromCharToLink(chars[i]);
            }
            return linksSequence;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static ulong[] FromStringToLinkArray(string sequence)
        {
            // char array to ulong array
            var linksSequence = new ulong[sequence.Length];
            for (var i = 0; i < sequence.Length; i++)
            {
                linksSequence[i] = FromCharToLink(sequence[i]);
            }
            return linksSequence;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static List<ulong[]> FromStringToLinkArrayGroups(string sequence)
        {
            var result = new List<ulong[]>();
            var offset = 0;
            while (offset < sequence.Length)
            {
                var currentCategory = CharUnicodeInfo.GetUnicodeCategory(sequence[offset]);
                var relativeLength = 1;
                var absoluteLength = offset + relativeLength;
```

```
                while (absoluteLength < sequence.Length &&
                       currentCategory ==
                       ↪ CharUnicodeInfo.GetUnicodeCategory(sequence[absoluteLength]))
                {
                    relativeLength++;
                    absoluteLength++;
                }
                // char array to ulong array
                var innerSequence = new ulong[relativeLength];
                var maxLength = offset + relativeLength;
                for (var i = offset; i < maxLength; i++)
                {
                    innerSequence[i - offset] = FromCharToLink(sequence[i]);
                }
                result.Add(innerSequence);
                offset += relativeLength;
            }
            return result;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static List<ulong[]> FromLinkArrayToLinkArrayGroups(ulong[] array)
        {
            var result = new List<ulong[]>();
            var offset = 0;
            while (offset < array.Length)
            {
                var relativeLength = 1;
                if (array[offset] <= LastCharLink)
                {
                    var currentCategory =
                    ↪ CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(array[offset]));
                    var absoluteLength = offset + relativeLength;
                    while (absoluteLength < array.Length &&
                           array[absoluteLength] <= LastCharLink &&
                           currentCategory == CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(
                           ↪ array[absoluteLength])))
                    {
                        relativeLength++;
                        absoluteLength++;
                    }
                }
                else
                {
                    var absoluteLength = offset + relativeLength;
                    while (absoluteLength < array.Length && array[absoluteLength] > LastCharLink)
                    {
                        relativeLength++;
                        absoluteLength++;
                    }
                }
                // copy array
                var innerSequence = new ulong[relativeLength];
                var maxLength = offset + relativeLength;
                for (var i = offset; i < maxLength; i++)
                {
                    innerSequence[i - offset] = array[i];
                }
                result.Add(innerSequence);
                offset += relativeLength;
            }
            return result;
        }
    }
}
```

1.133 ./csharp/Platform.Data.Doublets/Unicode/UnicodeSequenceToStringConverter.cs

```
using System;
using System.Linq;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Converters;
using Platform.Data.Doublets.Sequences.Walkers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class UnicodeSequenceToStringConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<TLink, string>
```

```
    {
        private readonly ICriterionMatcher<TLink> _unicodeSequenceCriterionMatcher;
        private readonly ISequenceWalker<TLink> _sequenceWalker;
        private readonly IConverter<TLink, char> _unicodeSymbolToCharConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnicodeSequenceToStringConverter(ILinks<TLink> links, ICriterionMatcher<TLink>
        ↪ unicodeSequenceCriterionMatcher, ISequenceWalker<TLink> sequenceWalker,
        ↪ IConverter<TLink, char> unicodeSymbolToCharConverter) : base(links)
        {
            _unicodeSequenceCriterionMatcher = unicodeSequenceCriterionMatcher;
            _sequenceWalker = sequenceWalker;
            _unicodeSymbolToCharConverter = unicodeSymbolToCharConverter;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public string Convert(TLink source)
        {
            if (!_unicodeSequenceCriterionMatcher.IsMatched(source))
            {
                throw new ArgumentOutOfRangeException(nameof(source), source, "Specified link is
                ↪ not a unicode sequence.");
            }
            var sequence = _links.GetSource(source);
            var charArray = _sequenceWalker.Walk(sequence).Select(_unicodeSymbolToCharConverter.
            ↪ Convert).ToArray();
            return new string(charArray);
        }
    }
}
```

1.134 ./csharp/Platform.Data.Doublets/Unicode/UnicodeSymbolToCharConverter.cs

```
using System;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class UnicodeSymbolToCharConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<TLink, char>
    {
        private static readonly UncheckedConverter<TLink, char> _addressToCharConverter =
        ↪ UncheckedConverter<TLink, char>.Default;

        private readonly IConverter<TLink> _numberToAddressConverter;
        private readonly ICriterionMatcher<TLink> _unicodeSymbolCriterionMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnicodeSymbolToCharConverter(ILinks<TLink> links, IConverter<TLink>
        ↪ numberToAddressConverter, ICriterionMatcher<TLink> unicodeSymbolCriterionMatcher) :
        ↪ base(links)
        {
            _numberToAddressConverter = numberToAddressConverter;
            _unicodeSymbolCriterionMatcher = unicodeSymbolCriterionMatcher;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public char Convert(TLink source)
        {
            if (!_unicodeSymbolCriterionMatcher.IsMatched(source))
            {
                throw new ArgumentOutOfRangeException(nameof(source), source, "Specified link is
                ↪ not a unicode symbol.");
            }
            return _addressToCharConverter.Convert(_numberToAddressConverter.Convert(_links.GetS
            ↪ ource(source)));
        }
    }
}
```

1.135 ./csharp/Platform.Data.Doublets/Unicode/UnicodeSymbolsListToUnicodeSequenceConverter.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;
using Platform.Data.Doublets.Sequences.Indexes;

```

```
#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class UnicodeSymbolsListToUnicodeSequenceConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<IList<TLink>, TLink>
    {
        private readonly ISequenceIndex<TLink> _index;
        private readonly IConverter<IList<TLink>, TLink> _listToSequenceLinkConverter;
        private readonly TLink _unicodeSequenceMarker;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnicodeSymbolsListToUnicodeSequenceConverter(ILinks<TLink> links,
        ↪ ISequenceIndex<TLink> index, IConverter<IList<TLink>, TLink>
        ↪ listToSequenceLinkConverter, TLink unicodeSequenceMarker) : base(links)
        {
            _index = index;
            _listToSequenceLinkConverter = listToSequenceLinkConverter;
            _unicodeSequenceMarker = unicodeSequenceMarker;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnicodeSymbolsListToUnicodeSequenceConverter(ILinks<TLink> links,
        ↪ IConverter<IList<TLink>, TLink> listToSequenceLinkConverter, TLink
        ↪ unicodeSequenceMarker)
            : this(links, new Unindex<TLink>(), listToSequenceLinkConverter,
            ↪ unicodeSequenceMarker) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(IList<TLink> list)
        {
            _index.Add(list);
            var sequence = _listToSequenceLinkConverter.Convert(list);
            return _links.GetOrCreate(sequence, _unicodeSequenceMarker);
        }
    }
}
```

1.136 ./csharp/Platform.Data.Doublets.Tests/GenericLinksTests.cs

```
using System;
using Xunit;
using Platform.Reflection;
using Platform.Memory;
using Platform.Scopes;
using Platform.Data.Doublets.Memory.United.Generic;

namespace Platform.Data.Doublets.Tests
{
    public unsafe static class GenericLinksTests
    {
        [Fact]
        public static void CRUDTest()
        {
            Using<byte>(links => links.TestCRUDOperations());
            Using<ushort>(links => links.TestCRUDOperations());
            Using<uint>(links => links.TestCRUDOperations());
            Using<ulong>(links => links.TestCRUDOperations());
        }

        [Fact]
        public static void RawNumbersCRUDTest()
        {
            Using<byte>(links => links.TestRawNumbersCRUDOperations());
            Using<ushort>(links => links.TestRawNumbersCRUDOperations());
            Using<uint>(links => links.TestRawNumbersCRUDOperations());
            Using<ulong>(links => links.TestRawNumbersCRUDOperations());
        }

        [Fact]
        public static void MultipleRandomCreationsAndDeletionsTest()
        {
            Using<byte>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Test
            ↪ MultipleRandomCreationsAndDeletions(16)); // Cannot use more because current
            ↪ implementation of tree cuts out 5 bits from the address space.
            Using<ushort>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Te
            ↪ stMultipleRandomCreationsAndDeletions(100));
            Using<uint>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Test
            ↪ MultipleRandomCreationsAndDeletions(100));
```

```
            Using<ulong>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Tes
            ↪  tMultipleRandomCreationsAndDeletions(100));
        }

        private static void Using<TLink>(Action<ILinks<TLink>> action)
        {
            using (var scope = new Scope<Types<HeapResizableDirectMemory,
            ↪  UnitedMemoryLinks<TLink>>>())
            {
                action(scope.Use<ILinks<TLink>>());
            }
        }
    }
}
```

1.137 ./csharp/Platform.Data.Doublets.Tests/ILinksExtensionsTests.cs

```
using Xunit;

namespace Platform.Data.Doublets.Tests
{
    public class ILinksExtensionsTests
    {
        [Fact]
        public void FormatTest()
        {
            using (var scope = new TempLinksTestScope())
            {
                var links = scope.Links;
                var link = links.Create();
                var linkString = links.Format(link);
                Assert.Equal("(1: 1 1)", linkString);
            }
        }
    }
}
```

1.138 ./csharp/Platform.Data.Doublets.Tests/LinksConstantsTests.cs

```
using Xunit;

namespace Platform.Data.Doublets.Tests
{
    public static class LinksConstantsTests
    {
        [Fact]
        public static void ExternalReferencesTest()
        {
            LinksConstants<ulong> constants = new LinksConstants<ulong>((1, long.MaxValue),
            ↪  (long.MaxValue + 1UL, ulong.MaxValue));

            //var minimum = new Hybrid<ulong>(0, isExternal: true);
            var minimum = new Hybrid<ulong>(1, isExternal: true);
            var maximum = new Hybrid<ulong>(long.MaxValue, isExternal: true);

            Assert.True(constants.IsExternalReference(minimum));
            Assert.True(constants.IsExternalReference(maximum));
        }
    }
}
```

1.139 ./csharp/Platform.Data.Doublets.Tests/OptimalVariantSequenceTests.cs

```
using System;
using System.Linq;
using Xunit;
using Platform.Collections.Stacks;
using Platform.Collections.Arrays;
using Platform.Memory;
using Platform.Data.Numbers.Raw;
using Platform.Data.Doublets.Sequences;
using Platform.Data.Doublets.Sequences.Frequencies.Cache;
using Platform.Data.Doublets.Sequences.Frequencies.Counters;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Doublets.PropertyOperators;
using Platform.Data.Doublets.Incrementers;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Data.Doublets.Sequences.Indexes;
using Platform.Data.Doublets.Unicode;
using Platform.Data.Doublets.Numbers.Unary;
using Platform.Data.Doublets.Decorators;
using Platform.Data.Doublets.Memory.United.Specific;
```

```
using Platform.Data.Doublets.Memory;

namespace Platform.Data.Doublets.Tests
{
    public static class OptimalVariantSequenceTests
    {
        private static readonly string _sequenceExample = "зеленела зелёная зелень";
        private static readonly string _loremIpsumExample = @"Lorem ipsum dolor sit amet,
        ↪  consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore
        ↪  magna aliqua.
Facilisi nullam vehicula ipsum a arcu cursus vitae congue mauris.
Et malesuada fames ac turpis egestas sed.
Eget velit aliquet sagittis id consectetur purus.
Dignissim cras tincidunt lobortis feugiat vivamus.
Vitae aliquet nec ullamcorper sit.
Lectus quam id leo in vitae.
Tortor dignissim convallis aenean et tortor at risus viverra adipiscing.
Sed risus ultricies tristique nulla aliquet enim tortor at auctor.
Integer eget aliquet nibh praesent tristique.
Vitae congue eu consequat ac felis donec et odio.
Tristique et egestas quis ipsum suspendisse.
Suspendisse potenti nullam ac tortor vitae purus faucibus ornare.
Nulla facilisi etiam dignissim diam quis enim lobortis scelerisque.
Imperdiet proin fermentum leo vel orci.
In ante metus dictum at tempor commodo.
Nisi lacus sed viverra tellus in.
Quam vulputate dignissim suspendisse in.
Elit scelerisque mauris pellentesque pulvinar pellentesque habitant morbi tristique senectus.
Gravida cum sociis natoque penatibus et magnis dis parturient.
Risus quis varius quam quisque id diam.
Congue nisi vitae suscipit tellus mauris a diam maecenas.
Eget nunc scelerisque viverra mauris in aliquam sem fringilla.
Pharetra vel turpis nunc eget lorem dolor sed viverra.
Mattis pellentesque id nibh tortor id aliquet.
Purus non enim praesent elementum facilisis leo vel.
Etiam sit amet nisl purus in mollis nunc sed.
Tortor at auctor urna nunc id cursus metus aliquam.
Volutpat odio facilisis mauris sit amet.
Turpis egestas pretium aenean pharetra magna ac placerat.
Fermentum dui faucibus in ornare quam viverra orci sagittis eu.
Porttitor leo a diam sollicitudin tempor id eu.
Volutpat sed cras ornare arcu dui.
Ut aliquam purus sit amet luctus venenatis lectus magna.
Aliquet risus feugiat in ante metus dictum at.
Mattis nunc sed blandit libero.
Elit pellentesque habitant morbi tristique senectus et netus.
Nibh sit amet commodo nulla facilisi nullam vehicula ipsum a.
Enim sit amet venenatis urna cursus eget nunc scelerisque viverra.
Amet venenatis urna cursus eget nunc scelerisque viverra mauris in.
Diam donec adipiscing tristique risus nec feugiat.
Pulvinar mattis nunc sed blandit libero volutpat.
Cras fermentum odio eu feugiat pretium nibh ipsum.
In nulla posuere sollicitudin aliquam ultrices sagittis orci a.
Mauris pellentesque pulvinar pellentesque habitant morbi tristique senectus et.
A iaculis at erat pellentesque.
Morbi blandit cursus risus at ultrices mi tempus imperdiet nulla.
Eget lorem dolor sed viverra ipsum nunc.
Leo a diam sollicitudin tempor id eu.
Interdum consectetur libero id faucibus nisl tincidunt eget nullam non.";

        [Fact]
        public static void LinksBasedFrequencyStoredOptimalVariantSequenceTest()
        {
            using (var scope = new TempLinksTestScope(useSequences: false))
            {
                var links = scope.Links;
                var constants = links.Constants;

                links.UseUnicode();

                var sequence = UnicodeMap.FromStringToLinkArray(_sequenceExample);

                var meaningRoot = links.CreatePoint();
                var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
                var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
                var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
                ↪  constants.Itself);

                var unaryNumberToAddressConverter = new
                ↪  UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
                var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
                var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
                ↪  frequencyMarker, unaryOne, unaryNumberIncrementer);
```

```
98                  var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
                    ↪  frequencyPropertyMarker, frequencyMarker);
99                  var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
                    ↪  frequencyPropertyOperator, frequencyIncrementer);
100                 var linkToItsFrequencyNumberConverter = new
                    ↪  LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
                    ↪  unaryNumberToAddressConverter);
101                 var sequenceToItsLocalElementLevelsConverter = new
                    ↪  SequenceToItsLocalElementLevelsConverter<ulong>(links,
                    ↪  linkToItsFrequencyNumberConverter);
102                 var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                    ↪  sequenceToItsLocalElementLevelsConverter);
103
104                 var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
                    ↪  Walker = new LeveledSequenceWalker<ulong>(links) });
105
106                 ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
                    ↪  index, optimalVariantConverter);
107             }
108         }
109
110         [Fact]
111         public static void DictionaryBasedFrequencyStoredOptimalVariantSequenceTest()
112         {
113             using (var scope = new TempLinksTestScope(useSequences: false))
114             {
115                 var links = scope.Links;
116
117                 links.UseUnicode();
118
119                 var sequence = UnicodeMap.FromStringToLinkArray(_sequenceExample);
120
121                 var totalSequenceSymbolFrequencyCounter = new
                    ↪  TotalSequenceSymbolFrequencyCounter<ulong>(links);
122
123                 var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
                    ↪  totalSequenceSymbolFrequencyCounter);
124
125                 var index = new
                    ↪  CachedFrequencyIncrementingSequenceIndex<ulong>(linkFrequenciesCache);
126                 var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFreque
                    ↪  ncyNumberConverter<ulong>(linkFrequenciesCache);
127
128                 var sequenceToItsLocalElementLevelsConverter = new
                    ↪  SequenceToItsLocalElementLevelsConverter<ulong>(links,
                    ↪  linkToItsFrequencyNumberConverter);
129                 var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                    ↪  sequenceToItsLocalElementLevelsConverter);
130
131                 var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
                    ↪  Walker = new LeveledSequenceWalker<ulong>(links) });
132
133                 ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
                    ↪  index, optimalVariantConverter);
134             }
135         }
136
137         private static void ExecuteTest(Sequences.Sequences sequences, ulong[] sequence,
            ↪  SequenceToItsLocalElementLevelsConverter<ulong>
            ↪  sequenceToItsLocalElementLevelsConverter, ISequenceIndex<ulong> index,
            ↪  OptimalVariantConverter<ulong> optimalVariantConverter)
138         {
139             index.Add(sequence);
140
141             var optimalVariant = optimalVariantConverter.Convert(sequence);
142
143             var readSequence1 = sequences.ToList(optimalVariant);
144
145             Assert.True(sequence.SequenceEqual(readSequence1));
146         }
147
148         [Fact]
149         public static void SavedSequencesOptimizationTest()
150         {
151             LinksConstants<ulong> constants = new LinksConstants<ulong>((1, long.MaxValue),
                ↪  (long.MaxValue + 1UL, ulong.MaxValue));
152
153             using (var memory = new HeapResizableDirectMemory())
```

```
154             using (var disposableLinks = new UInt64UnitedMemoryLinks(memory,
                ↪  UInt64UnitedMemoryLinks.DefaultLinksSizeStep, constants, IndexTreeType.Default))
155             {
156                 var links = new UInt64Links(disposableLinks);
157 
158                 var root = links.CreatePoint();
159 
160                 //var numberToAddressConverter = new RawNumberToAddressConverter<ulong>();
161                 var addressToNumberConverter = new AddressToRawNumberConverter<ulong>();
162 
163                 var unicodeSymbolMarker = links.GetOrCreate(root,
                    ↪  addressToNumberConverter.Convert(1));
164                 var unicodeSequenceMarker = links.GetOrCreate(root,
                    ↪  addressToNumberConverter.Convert(2));
165 
166                 var totalSequenceSymbolFrequencyCounter = new
                    ↪  TotalSequenceSymbolFrequencyCounter<ulong>(links);
167                 var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
                    ↪  totalSequenceSymbolFrequencyCounter);
168                 var index = new
                    ↪  CachedFrequencyIncrementingSequenceIndex<ulong>(linkFrequenciesCache);
169                 var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFreque
                    ↪  ncyNumberConverter<ulong>(linkFrequenciesCache);
170                 var sequenceToItsLocalElementLevelsConverter = new
                    ↪  SequenceToItsLocalElementLevelsConverter<ulong>(links,
                    ↪  linkToItsFrequencyNumberConverter);
171                 var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                    ↪  sequenceToItsLocalElementLevelsConverter);
172 
173                 var walker = new RightSequenceWalker<ulong>(links, new DefaultStack<ulong>(),
                    ↪  (link) => constants.IsExternalReference(link) || links.IsPartialPoint(link));
174 
175                 var unicodeSequencesOptions = new SequencesOptions<ulong>()
176                 {
177                     UseSequenceMarker = true,
178                     SequenceMarkerLink = unicodeSequenceMarker,
179                     UseIndex = true,
180                     Index = index,
181                     LinksToSequenceConverter = optimalVariantConverter,
182                     Walker = walker,
183                     UseGarbageCollection = true
184                 };
185 
186                 var unicodeSequences = new Sequences.Sequences(new
                    ↪  SynchronizedLinks<ulong>(links), unicodeSequencesOptions);
187 
188                 // Create some sequences
189                 var strings = _loremIpsumExample.Split(new[] { '\n', '\r' },
                    ↪  StringSplitOptions.RemoveEmptyEntries);
190                 var arrays = strings.Select(x => x.Select(y =>
                    ↪  addressToNumberConverter.Convert(y)).ToArray()).ToArray();
191                 for (int i = 0; i < arrays.Length; i++)
192                 {
193                     unicodeSequences.Create(arrays[i].ShiftRight());
194                 }
195 
196                 var linksCountAfterCreation = links.Count();
197 
198                 // get list of sequences links
199                 // for each sequence link
200                 //   create new sequence version
201                 //   if new sequence is not the same as sequence link
202                 //     delete sequence link
203                 //     collect garbadge
204                 unicodeSequences.CompactAll();
205 
206                 var linksCountAfterCompactification = links.Count();
207 
208                 Assert.True(linksCountAfterCompactification < linksCountAfterCreation);
209             }
210         }
211     }
212 }
```

1.140 ./csharp/Platform.Data.Doublets.Tests/ReadSequenceTests.cs

```
1  using System;
2  using System.Collections.Generic;
3  using System.Diagnostics;
4  using System.Linq;
```

```
using Xunit;
using Platform.Data.Sequences;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Data.Doublets.Sequences;

namespace Platform.Data.Doublets.Tests
{
    public static class ReadSequenceTests
    {
        [Fact]
        public static void ReadSequenceTest()
        {
            const long sequenceLength = 2000;

            using (var scope = new TempLinksTestScope(useSequences: false))
            {
                var links = scope.Links;
                var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong> { Walker = new LeveledSequenceWalker<ulong>(links) });

                var sequence = new ulong[sequenceLength];
                for (var i = 0; i < sequenceLength; i++)
                {
                    sequence[i] = links.Create();
                }

                var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);

                var sw1 = Stopwatch.StartNew();
                var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();

                var sw2 = Stopwatch.StartNew();
                var readSequence1 = sequences.ToList(balancedVariant); sw2.Stop();

                var sw3 = Stopwatch.StartNew();
                var readSequence2 = new List<ulong>();
                SequenceWalker.WalkRight(balancedVariant,
                                         links.GetSource,
                                         links.GetTarget,
                                         links.IsPartialPoint,
                                         readSequence2.Add);
                sw3.Stop();

                Assert.True(sequence.SequenceEqual(readSequence1));

                Assert.True(sequence.SequenceEqual(readSequence2));

                // Assert.True(sw2.Elapsed < sw3.Elapsed);

                Console.WriteLine($"Stack-based walker: {sw3.Elapsed}, Level-based reader: {sw2.Elapsed}");

                for (var i = 0; i < sequenceLength; i++)
                {
                    links.Delete(sequence[i]);
                }
            }
        }
    }
}
```

1.141 ./csharp/Platform.Data.Doublets.Tests/ResizableDirectMemoryLinksTests.cs

```
using System.IO;
using Xunit;
using Platform.Singletons;
using Platform.Memory;
using Platform.Data.Doublets.Memory.United.Specific;

namespace Platform.Data.Doublets.Tests
{
    public static class ResizableDirectMemoryLinksTests
    {
        private static readonly LinksConstants<ulong> _constants = Default<LinksConstants<ulong>>.Instance;

        [Fact]
        public static void BasicFileMappedMemoryTest()
        {
            var tempFilename = Path.GetTempFileName();
```

```
            using (var memoryAdapter = new UInt64UnitedMemoryLinks(tempFilename))
            {
                memoryAdapter.TestBasicMemoryOperations();
            }
            File.Delete(tempFilename);
        }

        [Fact]
        public static void BasicHeapMemoryTest()
        {
            using (var memory = new
            ↪  HeapResizableDirectMemory(UInt64UnitedMemoryLinks.DefaultLinksSizeStep))
            using (var memoryAdapter = new UInt64UnitedMemoryLinks(memory,
            ↪  UInt64UnitedMemoryLinks.DefaultLinksSizeStep))
            {
                memoryAdapter.TestBasicMemoryOperations();
            }
        }

        private static void TestBasicMemoryOperations(this ILinks<ulong> memoryAdapter)
        {
            var link = memoryAdapter.Create();
            memoryAdapter.Delete(link);
        }

        [Fact]
        public static void NonexistentReferencesHeapMemoryTest()
        {
            using (var memory = new
            ↪  HeapResizableDirectMemory(UInt64UnitedMemoryLinks.DefaultLinksSizeStep))
            using (var memoryAdapter = new UInt64UnitedMemoryLinks(memory,
            ↪  UInt64UnitedMemoryLinks.DefaultLinksSizeStep))
            {
                memoryAdapter.TestNonexistentReferences();
            }
        }

        private static void TestNonexistentReferences(this ILinks<ulong> memoryAdapter)
        {
            var link = memoryAdapter.Create();
            memoryAdapter.Update(link, ulong.MaxValue, ulong.MaxValue);
            var resultLink = _constants.Null;
            memoryAdapter.Each(foundLink =>
            {
                resultLink = foundLink[_constants.IndexPart];
                return _constants.Break;
            }, _constants.Any, ulong.MaxValue, ulong.MaxValue);
            Assert.True(resultLink == link);
            Assert.True(memoryAdapter.Count(ulong.MaxValue) == 0);
            memoryAdapter.Delete(link);
        }
    }
}
```

1.142 ./csharp/Platform.Data.Doublets.Tests/ScopeTests.cs

```
using Xunit;
using Platform.Scopes;
using Platform.Memory;
using Platform.Data.Doublets.Decorators;
using Platform.Reflection;
using Platform.Data.Doublets.Memory.United.Generic;
using Platform.Data.Doublets.Memory.United.Specific;

namespace Platform.Data.Doublets.Tests
{
    public static class ScopeTests
    {
        [Fact]
        public static void SingleDependencyTest()
        {
            using (var scope = new Scope())
            {
                scope.IncludeAssemblyOf<IMemory>();
                var instance = scope.Use<IDirectMemory>();
                Assert.IsType<HeapResizableDirectMemory>(instance);
            }
        }

        [Fact]
```

```
25          public static void CascadeDependencyTest()
26          {
27              using (var scope = new Scope())
28              {
29                  scope.Include<TemporaryFileMappedResizableDirectMemory>();
30                  scope.Include<UInt64UnitedMemoryLinks>();
31                  var instance = scope.Use<ILinks<ulong>>();
32                  Assert.IsType<UInt64UnitedMemoryLinks>(instance);
33              }
34          }
35
36          [Fact]
37          public static void FullAutoResolutionTest()
38          {
39              using (var scope = new Scope(autoInclude: true, autoExplore: true))
40              {
41                  var instance = scope.Use<UInt64Links>();
42                  Assert.IsType<UInt64Links>(instance);
43              }
44          }
45
46          [Fact]
47          public static void TypeParametersTest()
48          {
49              using (var scope = new Scope<Types<HeapResizableDirectMemory,
                ↪ UnitedMemoryLinks<ulong>>>())
50              {
51                  var links = scope.Use<ILinks<ulong>>();
52                  Assert.IsType<UnitedMemoryLinks<ulong>>(links);
53              }
54          }
55      }
56  }
```

1.143 ./csharp/Platform.Data.Doublets.Tests/SequencesTests.cs

```
1   using System;
2   using System.Collections.Generic;
3   using System.Diagnostics;
4   using System.Linq;
5   using Xunit;
6   using Platform.Collections;
7   using Platform.Collections.Arrays;
8   using Platform.Random;
9   using Platform.IO;
10  using Platform.Singletons;
11  using Platform.Data.Doublets.Sequences;
12  using Platform.Data.Doublets.Sequences.Frequencies.Cache;
13  using Platform.Data.Doublets.Sequences.Frequencies.Counters;
14  using Platform.Data.Doublets.Sequences.Converters;
15  using Platform.Data.Doublets.Unicode;
16
17  namespace Platform.Data.Doublets.Tests
18  {
19      public static class SequencesTests
20      {
21          private static readonly LinksConstants<ulong> _constants =
            ↪ Default<LinksConstants<ulong>>.Instance;
22
23          static SequencesTests()
24          {
25              // Trigger static constructor to not mess with perfomance measurements
26              _ = BitString.GetBitMaskFromIndex(1);
27          }
28
29          [Fact]
30          public static void CreateAllVariantsTest()
31          {
32              const long sequenceLength = 8;
33
34              using (var scope = new TempLinksTestScope(useSequences: true))
35              {
36                  var links = scope.Links;
37                  var sequences = scope.Sequences;
38
39                  var sequence = new ulong[sequenceLength];
40                  for (var i = 0; i < sequenceLength; i++)
41                  {
42                      sequence[i] = links.Create();
43                  }
44
```

```
            var sw1 = Stopwatch.StartNew();
            var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();

            var sw2 = Stopwatch.StartNew();
            var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();

            Assert.True(results1.Count > results2.Length);
            Assert.True(sw1.Elapsed > sw2.Elapsed);

            for (var i = 0; i < sequenceLength; i++)
            {
                links.Delete(sequence[i]);
            }

            Assert.True(links.Count() == 0);
        }
    }

    //[Fact]
    //public void CUDTest()
    //{
    //    var tempFilename = Path.GetTempFileName();

    //    const long sequenceLength = 8;

    //    const ulong itself = LinksConstants.Itself;

    //    using (var memoryAdapter = new ResizableDirectMemoryLinks(tempFilename,
    ↪  DefaultLinksSizeStep))
    //    using (var links = new Links(memoryAdapter))
    //    {
    //        var sequence = new ulong[sequenceLength];
    //        for (var i = 0; i < sequenceLength; i++)
    //            sequence[i] = links.Create(itself, itself);

    //        SequencesOptions o = new SequencesOptions();

    // TODO: Из числа в bool значения o.UseSequenceMarker = ((value & 1) != 0)
    //        o.

    //        var sequences = new Sequences(links);

    //        var sw1 = Stopwatch.StartNew();
    //        var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();

    //        var sw2 = Stopwatch.StartNew();
    //        var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();

    //        Assert.True(results1.Count > results2.Length);
    //        Assert.True(sw1.Elapsed > sw2.Elapsed);

    //        for (var i = 0; i < sequenceLength; i++)
    //            links.Delete(sequence[i]);
    //    }

    //    File.Delete(tempFilename);
    //}

    [Fact]
    public static void AllVariantsSearchTest()
    {
        const long sequenceLength = 8;

        using (var scope = new TempLinksTestScope(useSequences: true))
        {
            var links = scope.Links;
            var sequences = scope.Sequences;

            var sequence = new ulong[sequenceLength];
            for (var i = 0; i < sequenceLength; i++)
            {
                sequence[i] = links.Create();
            }

            var createResults = sequences.CreateAllVariants2(sequence).Distinct().ToArray();

            //for (int i = 0; i < createResults.Length; i++)
            //    sequences.Create(createResults[i]);

            var sw0 = Stopwatch.StartNew();
```

```
124                 var searchResults0 = sequences.GetAllMatchingSequences0(sequence); sw0.Stop();
125
126                 var sw1 = Stopwatch.StartNew();
127                 var searchResults1 = sequences.GetAllMatchingSequences1(sequence); sw1.Stop();
128
129                 var sw2 = Stopwatch.StartNew();
130                 var searchResults2 = sequences.Each1(sequence); sw2.Stop();
131
132                 var sw3 = Stopwatch.StartNew();
133                 var searchResults3 = sequences.Each(sequence.ShiftRight()); sw3.Stop();
134
135                 var intersection0 = createResults.Intersect(searchResults0).ToList();
136                 Assert.True(intersection0.Count == searchResults0.Count);
137                 Assert.True(intersection0.Count == createResults.Length);
138
139                 var intersection1 = createResults.Intersect(searchResults1).ToList();
140                 Assert.True(intersection1.Count == searchResults1.Count);
141                 Assert.True(intersection1.Count == createResults.Length);
142
143                 var intersection2 = createResults.Intersect(searchResults2).ToList();
144                 Assert.True(intersection2.Count == searchResults2.Count);
145                 Assert.True(intersection2.Count == createResults.Length);
146
147                 var intersection3 = createResults.Intersect(searchResults3).ToList();
148                 Assert.True(intersection3.Count == searchResults3.Count);
149                 Assert.True(intersection3.Count == createResults.Length);
150
151                 for (var i = 0; i < sequenceLength; i++)
152                 {
153                     links.Delete(sequence[i]);
154                 }
155             }
156         }
157
158         [Fact]
159         public static void BalancedVariantSearchTest()
160         {
161             const long sequenceLength = 200;
162
163             using (var scope = new TempLinksTestScope(useSequences: true))
164             {
165                 var links = scope.Links;
166                 var sequences = scope.Sequences;
167
168                 var sequence = new ulong[sequenceLength];
169                 for (var i = 0; i < sequenceLength; i++)
170                 {
171                     sequence[i] = links.Create();
172                 }
173
174                 var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
175
176                 var sw1 = Stopwatch.StartNew();
177                 var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();
178
179                 var sw2 = Stopwatch.StartNew();
180                 var searchResults2 = sequences.GetAllMatchingSequences0(sequence); sw2.Stop();
181
182                 var sw3 = Stopwatch.StartNew();
183                 var searchResults3 = sequences.GetAllMatchingSequences1(sequence); sw3.Stop();
184
185                 // На количестве в 200 элементов это будет занимать вечность
186                 //var sw4 = Stopwatch.StartNew();
187                 //var searchResults4 = sequences.Each(sequence); sw4.Stop();
188
189                 Assert.True(searchResults2.Count == 1 && balancedVariant == searchResults2[0]);
190
191                 Assert.True(searchResults3.Count == 1 && balancedVariant ==
                    ↪ searchResults3.First());
192
193                 //Assert.True(sw1.Elapsed < sw2.Elapsed);
194
195                 for (var i = 0; i < sequenceLength; i++)
196                 {
197                     links.Delete(sequence[i]);
198                 }
199             }
200         }
201
202         [Fact]
```

```
203         public static void AllPartialVariantsSearchTest()
204         {
205             const long sequenceLength = 8;
206
207             using (var scope = new TempLinksTestScope(useSequences: true))
208             {
209                 var links = scope.Links;
210                 var sequences = scope.Sequences;
211
212                 var sequence = new ulong[sequenceLength];
213                 for (var i = 0; i < sequenceLength; i++)
214                 {
215                     sequence[i] = links.Create();
216                 }
217
218                 var createResults = sequences.CreateAllVariants2(sequence);
219
220                 //var createResultsStrings = createResults.Select(x => x + ": " +
                    ↪ sequences.FormatSequence(x)).ToList();
221                 //Global.Trash = createResultsStrings;
222
223                 var partialSequence = new ulong[sequenceLength - 2];
224
225                 Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
226
227                 var sw1 = Stopwatch.StartNew();
228                 var searchResults1 =
                    ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
229
230                 var sw2 = Stopwatch.StartNew();
231                 var searchResults2 =
                    ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
232
233                 //var sw3 = Stopwatch.StartNew();
234                 //var searchResults3 =
                    ↪ sequences.GetAllPartiallyMatchingSequences2(partialSequence); sw3.Stop();
235
236                 var sw4 = Stopwatch.StartNew();
237                 var searchResults4 =
                    ↪ sequences.GetAllPartiallyMatchingSequences3(partialSequence); sw4.Stop();
238
239                 //Global.Trash = searchResults3;
240
241                 //var searchResults1Strings = searchResults1.Select(x => x + ": " +
                    ↪ sequences.FormatSequence(x)).ToList();
242                 //Global.Trash = searchResults1Strings;
243
244                 var intersection1 = createResults.Intersect(searchResults1).ToList();
245                 Assert.True(intersection1.Count == createResults.Length);
246
247                 var intersection2 = createResults.Intersect(searchResults2).ToList();
248                 Assert.True(intersection2.Count == createResults.Length);
249
250                 var intersection4 = createResults.Intersect(searchResults4).ToList();
251                 Assert.True(intersection4.Count == createResults.Length);
252
253                 for (var i = 0; i < sequenceLength; i++)
254                 {
255                     links.Delete(sequence[i]);
256                 }
257             }
258         }
259
260         [Fact]
261         public static void BalancedPartialVariantsSearchTest()
262         {
263             const long sequenceLength = 200;
264
265             using (var scope = new TempLinksTestScope(useSequences: true))
266             {
267                 var links = scope.Links;
268                 var sequences = scope.Sequences;
269
270                 var sequence = new ulong[sequenceLength];
271                 for (var i = 0; i < sequenceLength; i++)
272                 {
273                     sequence[i] = links.Create();
274                 }
275
276                 var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
```

```
277
278                 var balancedVariant = balancedVariantConverter.Convert(sequence);
279
280                 var partialSequence = new ulong[sequenceLength - 2];
281
282                 Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
283
284                 var sw1 = Stopwatch.StartNew();
285                 var searchResults1 =
                    ↪  sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
286
287                 var sw2 = Stopwatch.StartNew();
288                 var searchResults2 =
                    ↪  sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
289
290                 Assert.True(searchResults1.Count == 1 && balancedVariant == searchResults1[0]);
291
292                 Assert.True(searchResults2.Count == 1 && balancedVariant ==
                    ↪  searchResults2.First());
293
294                 for (var i = 0; i < sequenceLength; i++)
295                 {
296                     links.Delete(sequence[i]);
297                 }
298             }
299         }
300
301         [Fact(Skip = "Correct implementation is pending")]
302         public static void PatternMatchTest()
303         {
304             var zeroOrMany = Sequences.Sequences.ZeroOrMany;
305
306             using (var scope = new TempLinksTestScope(useSequences: true))
307             {
308                 var links = scope.Links;
309                 var sequences = scope.Sequences;
310
311                 var e1 = links.Create();
312                 var e2 = links.Create();
313
314                 var sequence = new[]
315                 {
316                     e1, e2, e1, e2 // mama / papa
317                 };
318
319                 var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
320
321                 var balancedVariant = balancedVariantConverter.Convert(sequence);
322
323                 // 1: [1]
324                 // 2: [2]
325                 // 3: [1,2]
326                 // 4: [1,2,1,2]
327
328                 var doublet = links.GetSource(balancedVariant);
329
330                 var matchedSequences1 = sequences.MatchPattern(e2, e1, zeroOrMany);
331
332                 Assert.True(matchedSequences1.Count == 0);
333
334                 var matchedSequences2 = sequences.MatchPattern(zeroOrMany, e2, e1);
335
336                 Assert.True(matchedSequences2.Count == 0);
337
338                 var matchedSequences3 = sequences.MatchPattern(e1, zeroOrMany, e1);
339
340                 Assert.True(matchedSequences3.Count == 0);
341
342                 var matchedSequences4 = sequences.MatchPattern(e1, zeroOrMany, e2);
343
344                 Assert.Contains(doublet, matchedSequences4);
345                 Assert.Contains(balancedVariant, matchedSequences4);
346
347                 for (var i = 0; i < sequence.Length; i++)
348                 {
349                     links.Delete(sequence[i]);
350                 }
351             }
352         }
353
```

```
        [Fact]
        public static void IndexTest()
        {
            using (var scope = new TempLinksTestScope(new SequencesOptions<ulong> { UseIndex =
            ↪  true }, useSequences: true))
            {
                var links = scope.Links;
                var sequences = scope.Sequences;
                var index = sequences.Options.Index;

                var e1 = links.Create();
                var e2 = links.Create();

                var sequence = new[]
                {
                    e1, e2, e1, e2 // mama / papa
                };

                Assert.False(index.MightContain(sequence));

                index.Add(sequence);

                Assert.True(index.MightContain(sequence));
            }
        }

        /// <summary>Imported from https://raw.githubusercontent.com/wiki/Konard/LinksPlatform/%
        ↪  D0%9E-%D1%82%D0%BE%D0%BC%2C-%D0%BA%D0%B0%D0%BA-%D0%B2%D1%81%D1%91-%D0%BD%D0%B0%D1%87
        ↪  %D0%B8%D0%BD%D0%B0%D0%BB%D0%BE%D1%81%D1%8C.md</summary>
        private static readonly string _exampleText =
            @"([english
            ↪  version](https://github.com/Konard/LinksPlatform/wiki/About-the-beginning))

Обозначение пустоты, какое оно? Темнота ли это? Там где отсутствие света, отсутствие фотонов
↪  (носителей света)? Или это то, что полностью отражает свет? Пустой белый лист бумаги? Там
↪  где есть место для нового начала? Разве пустота это не характеристика пространства?
↪  Пространство это то, что можно чем-то наполнить?

[![чёрное пространство, белое
↪  пространство](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/1.png
↪  ""чёрное пространство, белое пространство"")](https://raw.githubusercontent.com/Konard/Links
↪  Platform/master/doc/Intro/1.png)

Что может быть минимальным рисунком, образом, графикой? Может быть это точка? Это ли простейшая
↪  форма? Но есть ли у точки размер? Цвет? Масса? Координаты? Время существования?

[![чёрное пространство, чёрная
↪  точка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/2.png
↪  ""чёрное пространство, чёрная
↪  точка"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/2.png)

А что если повторить? Сделать копию? Создать дубликат? Из одного сделать два? Может это быть
↪  так? Инверсия? Отражение? Сумма?

[![белая точка, чёрная
↪  точка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/3.png ""белая
↪  точка, чёрная
↪  точка"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/3.png)

А что если мы вообразим движение? Нужно ли время? Каким самым коротким будет путь? Что будет
↪  если этот путь зафиксировать? Запомнить след? Как две точки становятся линией? Чертой?
↪  Гранью? Разделителем? Единицей?

[![две белые точки, чёрная вертикальная
↪  линия](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/4.png ""две
↪  белые точки, чёрная вертикальная
↪  линия"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/4.png)

Можно ли замкнуть движение? Может ли это быть кругом? Можно ли замкнуть время? Или остаётся
↪  только спираль? Но что если замкнуть предел? Создать ограничение, разделение? Получится
↪  замкнутая область? Полностью отделённая от всего остального? Но что это всё остальное? Что
↪  можно делить? В каком направлении? Ничего или всё? Пустота или полнота? Начало или конец?
↪  Или может быть это единица и ноль? Дуальность? Противоположность? А что будет с кругом если
↪  у него нет размера? Будет ли круг точкой? Точка состоящая из точек?

[![белая вертикальная линия, чёрный
↪  круг](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/5.png ""белая
↪  вертикальная линия, чёрный
↪  круг"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/5.png)
```

```
402
403 Как ещё можно использовать грань, черту, линию? А что если она может что-то соединять, может
    ↪ тогда её нужно повернуть? Почему то, что перпендикулярно вертикальному горизонтально?
    ↪ Горизонт? Инвертирует ли это смысл? Что такое смысл? Из чего состоит смысл? Существует ли
    ↪ элементарная единица смысла?
404
405 [![белый круг, чёрная горизонтальная
    ↪ линия](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/6.png ""белый
    ↪ круг, чёрная горизонтальная
    ↪ линия"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/6.png)
406
407 Соединять, допустим, а какой смысл в этом есть ещё? Что если помимо смысла ""соединить,
    ↪ связать"", есть ещё и смысл направления ""от начала к концу""? От предка к потомку? От
    ↪ родителя к ребёнку? От общего к частному?
408
409 [![белая горизонтальная линия, чёрная горизонтальная
    ↪ стрелка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/7.png
    ↪ ""белая горизонтальная линия, чёрная горизонтальная
    ↪ стрелка"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/7.png)
410
411 Шаг назад. Возьмём опять отделённую область, которая лишь та же замкнутая линия, что ещё она
    ↪ может представлять собой? Объект? Но в чём его суть? Разве не в том, что у него есть
    ↪ граница, разделяющая внутреннее и внешнее? Допустим связь, стрелка, линия соединяет два
    ↪ объекта, как бы это выглядело?
412
413 [![белая связь, чёрная направленная
    ↪ связь](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/8.png ""белая
    ↪ связь, чёрная направленная
    ↪ связь"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/8.png)
414
415 Допустим у нас есть смысл ""связать"" и смысл ""направления"", много ли это нам даёт? Много ли
    ↪ вариантов интерпретации? А что если уточнить, каким именно образом выполнена связь? Что если
    ↪ можно задать ей чёткий, конкретный смысл? Что это будет? Тип? Глагол? Связка? Действие?
    ↪ Трансформация? Переход из состояния в состояние? Или всё это и есть объект, суть которого в
    ↪ его конечном состоянии, если конечно конец определён направлением?
416
417 [![белая обычная и направленная связи, чёрная типизированная
    ↪ связь](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/9.png ""белая
    ↪ обычная и направленная связи, чёрная типизированная
    ↪ связь"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/9.png)
418
419 А что если всё это время, мы смотрели на суть как бы снаружи? Можно ли взглянуть на это изнутри?
    ↪ Что будет внутри объектов? Объекты ли это? Или это связи? Может ли эта структура описать
    ↪ сама себя? Но что тогда получится, разве это не рекурсия? Может это фрактал?
420
421 [![белая обычная и направленная связи с рекурсивной внутренней структурой, чёрная типизированная
    ↪ связь с рекурсивной внутренней
    ↪ структурой](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/10.png
    ↪ ""белая обычная и направленная связи с рекурсивной внутренней структурой, чёрная
    ↪ типизированная связь с рекурсивной внутренней структурой"")](https://raw.githubusercontent.c
    ↪ om/Konard/LinksPlatform/master/doc/Intro/10.png)
422
423 На один уровень внутрь (вниз)? Или на один уровень во вне (вверх)? Или это можно назвать шагом
    ↪ рекурсии или фрактала?
424
425 [![белая обычная и направленная связи с двойной рекурсивной внутренней структурой, чёрная
    ↪ типизированная связь с двойной рекурсивной внутренней
    ↪ структурой](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/11.png
    ↪ ""белая обычная и направленная связи с двойной рекурсивной внутренней структурой, чёрная
    ↪ типизированная связь с двойной рекурсивной внутренней структурой"")](https://raw.githubuserc
    ↪ ontent.com/Konard/LinksPlatform/master/doc/Intro/11.png)
426
427 Последовательность? Массив? Список? Множество? Объект? Таблица? Элементы? Цвета? Символы? Буквы?
    ↪ Слово? Цифры? Число? Алфавит? Дерево? Сеть? Граф? Гиперграф?
428
429 [![белая обычная и направленная связи со структурой из 8 цветных элементов последовательности,
    ↪ чёрная типизированная связь со структурой из 8 цветных элементов последовательности](https:/
    ↪ /raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/12.png ""белая обычная и
    ↪ направленная связи со структурой из 8 цветных элементов последовательности, чёрная
    ↪ типизированная связь со структурой из 8 цветных элементов последовательности"")](https://raw
    ↪ .githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/12.png)
430
431 ...
432
433 [![анимация](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro-anima
    ↪ tion-500.gif
    ↪ ""анимация"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro
    ↪ -animation-500.gif)";
434
```

```
435         private static readonly string _exampleLoremIpsumText =
436             @"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor
                ↪  incididunt ut labore et dolore magna aliqua.
437 Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo
    ↪  consequat.";
438 
439         [Fact]
440         public static void CompressionTest()
441         {
442             using (var scope = new TempLinksTestScope(useSequences: true))
443             {
444                 var links = scope.Links;
445                 var sequences = scope.Sequences;
446 
447                 var e1 = links.Create();
448                 var e2 = links.Create();
449 
450                 var sequence = new[]
451                 {
452                     e1, e2, e1, e2 // mama / papa / template [(m/p), a] { [1] [2] [1] [2] }
453                 };
454 
455                 var balancedVariantConverter = new BalancedVariantConverter<ulong>(links.Unsync);
456                 var totalSequenceSymbolFrequencyCounter = new
                    ↪  TotalSequenceSymbolFrequencyCounter<ulong>(links.Unsync);
457                 var doubletFrequenciesCache = new LinkFrequenciesCache<ulong>(links.Unsync,
                    ↪  totalSequenceSymbolFrequencyCounter);
458                 var compressingConverter = new CompressingConverter<ulong>(links.Unsync,
                    ↪  balancedVariantConverter, doubletFrequenciesCache);
459 
460                 var compressedVariant = compressingConverter.Convert(sequence);
461 
462                 // 1: [1]       (1->1) point
463                 // 2: [2]       (2->2) point
464                 // 3: [1,2]     (1->2) doublet
465                 // 4: [1,2,1,2] (3->3) doublet
466 
467                 Assert.True(links.GetSource(links.GetSource(compressedVariant)) == sequence[0]);
468                 Assert.True(links.GetTarget(links.GetSource(compressedVariant)) == sequence[1]);
469                 Assert.True(links.GetSource(links.GetTarget(compressedVariant)) == sequence[2]);
470                 Assert.True(links.GetTarget(links.GetTarget(compressedVariant)) == sequence[3]);
471 
472                 var source = _constants.SourcePart;
473                 var target = _constants.TargetPart;
474 
475                 Assert.True(links.GetByKeys(compressedVariant, source, source) == sequence[0]);
476                 Assert.True(links.GetByKeys(compressedVariant, source, target) == sequence[1]);
477                 Assert.True(links.GetByKeys(compressedVariant, target, source) == sequence[2]);
478                 Assert.True(links.GetByKeys(compressedVariant, target, target) == sequence[3]);
479 
480                 // 4 - length of sequence
481                 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 0)
                    ↪  == sequence[0]);
482                 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 1)
                    ↪  == sequence[1]);
483                 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 2)
                    ↪  == sequence[2]);
484                 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 3)
                    ↪  == sequence[3]);
485             }
486         }
487 
488         [Fact]
489         public static void CompressionEfficiencyTest()
490         {
491             var strings = _exampleLoremIpsumText.Split(new[] { '\n', '\r' },
                ↪  StringSplitOptions.RemoveEmptyEntries);
492             var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
493             var totalCharacters = arrays.Select(x => x.Length).Sum();
494 
495             using (var scope1 = new TempLinksTestScope(useSequences: true))
496             using (var scope2 = new TempLinksTestScope(useSequences: true))
497             using (var scope3 = new TempLinksTestScope(useSequences: true))
498             {
499                 scope1.Links.Unsync.UseUnicode();
500                 scope2.Links.Unsync.UseUnicode();
501                 scope3.Links.Unsync.UseUnicode();
502 
```

```
503                 var balancedVariantConverter1 = new
                    ↪  BalancedVariantConverter<ulong>(scope1.Links.Unsync);
504                 var totalSequenceSymbolFrequencyCounter = new
                    ↪  TotalSequenceSymbolFrequencyCounter<ulong>(scope1.Links.Unsync);
505                 var linkFrequenciesCache1 = new LinkFrequenciesCache<ulong>(scope1.Links.Unsync,
                    ↪  totalSequenceSymbolFrequencyCounter);
506                 var compressor1 = new CompressingConverter<ulong>(scope1.Links.Unsync,
                    ↪  balancedVariantConverter1, linkFrequenciesCache1,
                    ↪  doInitialFrequenciesIncrement: false);
507
508                 //var compressor2 = scope2.Sequences;
509                 var compressor3 = scope3.Sequences;
510
511                 var constants = Default<LinksConstants<ulong>>.Instance;
512
513                 var sequences = compressor3;
514                 //var meaningRoot = links.CreatePoint();
515                 //var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
516                 //var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
517                 //var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
                    ↪  constants.Itself);
518
519                 //var unaryNumberToAddressConverter = new
                    ↪  UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
520                 //var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links,
                    ↪  unaryOne);
521                 //var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
                    ↪  frequencyMarker, unaryOne, unaryNumberIncrementer);
522                 //var frequencyPropertyOperator = new FrequencyPropertyOperator<ulong>(links,
                    ↪  frequencyPropertyMarker, frequencyMarker);
523                 //var linkFrequencyIncrementer = new LinkFrequencyIncrementer<ulong>(links,
                    ↪  frequencyPropertyOperator, frequencyIncrementer);
524                 //var linkToItsFrequencyNumberConverter = new
                    ↪  LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
                    ↪  unaryNumberToAddressConverter);
525
526                 var linkFrequenciesCache3 = new LinkFrequenciesCache<ulong>(scope3.Links.Unsync,
                    ↪  totalSequenceSymbolFrequencyCounter);
527
528                 var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFreque
                    ↪  ncyNumberConverter<ulong>(linkFrequenciesCache3);
529
530                 var sequenceToItsLocalElementLevelsConverter = new
                    ↪  SequenceToItsLocalElementLevelsConverter<ulong>(scope3.Links.Unsync,
                    ↪  linkToItsFrequencyNumberConverter);
531                 var optimalVariantConverter = new
                    ↪  OptimalVariantConverter<ulong>(scope3.Links.Unsync,
                    ↪  sequenceToItsLocalElementLevelsConverter);
532
533                 var compressed1 = new ulong[arrays.Length];
534                 var compressed2 = new ulong[arrays.Length];
535                 var compressed3 = new ulong[arrays.Length];
536
537                 var START = 0;
538                 var END = arrays.Length;
539
540                 //for (int i = START; i < END; i++)
541                 //    linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
542
543                 var initialCount1 = scope2.Links.Unsync.Count();
544
545                 var sw1 = Stopwatch.StartNew();
546
547                 for (int i = START; i < END; i++)
548                 {
549                     linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
550                     compressed1[i] = compressor1.Convert(arrays[i]);
551                 }
552
553                 var elapsed1 = sw1.Elapsed;
554
555                 var balancedVariantConverter2 = new
                    ↪  BalancedVariantConverter<ulong>(scope2.Links.Unsync);
556
557                 var initialCount2 = scope2.Links.Unsync.Count();
558
559                 var sw2 = Stopwatch.StartNew();
560
```

```
                for (int i = START; i < END; i++)
                {
                    compressed2[i] = balancedVariantConverter2.Convert(arrays[i]);
                }

                var elapsed2 = sw2.Elapsed;

                for (int i = START; i < END; i++)
                {
                    linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
                }

                var initialCount3 = scope3.Links.Unsync.Count();

                var sw3 = Stopwatch.StartNew();

                for (int i = START; i < END; i++)
                {
                    //linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
                    compressed3[i] = optimalVariantConverter.Convert(arrays[i]);
                }

                var elapsed3 = sw3.Elapsed;

                Console.WriteLine($"Compressor: {elapsed1}, Balanced variant: {elapsed2},
                ↪  Optimal variant: {elapsed3}");

                // Assert.True(elapsed1 > elapsed2);

                // Checks
                for (int i = START; i < END; i++)
                {
                    var sequence1 = compressed1[i];
                    var sequence2 = compressed2[i];
                    var sequence3 = compressed3[i];

                    var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
                    ↪  scope1.Links.Unsync);

                    var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
                    ↪  scope2.Links.Unsync);

                    var decompress3 = UnicodeMap.FromSequenceLinkToString(sequence3,
                    ↪  scope3.Links.Unsync);

                    var structure1 = scope1.Links.Unsync.FormatStructure(sequence1, link =>
                    ↪  link.IsPartialPoint());
                    var structure2 = scope2.Links.Unsync.FormatStructure(sequence2, link =>
                    ↪  link.IsPartialPoint());
                    var structure3 = scope3.Links.Unsync.FormatStructure(sequence3, link =>
                    ↪  link.IsPartialPoint());

                    //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
                    ↪  arrays[i].Length > 3)
                    //    Assert.False(structure1 == structure2);
                    //if (sequence3 != Constants.Null && sequence2 != Constants.Null &&
                    ↪  arrays[i].Length > 3)
                    //    Assert.False(structure3 == structure2);

                    Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
                    Assert.True(strings[i] == decompress3 && decompress3 == decompress2);
                }

                Assert.True((int)(scope1.Links.Unsync.Count() - initialCount1) <
                ↪  totalCharacters);
                Assert.True((int)(scope2.Links.Unsync.Count() - initialCount2) <
                ↪  totalCharacters);
                Assert.True((int)(scope3.Links.Unsync.Count() - initialCount3) <
                ↪  totalCharacters);

                Console.WriteLine($"{(double)(scope1.Links.Unsync.Count() - initialCount1) /
                ↪  totalCharacters} | {(double)(scope2.Links.Unsync.Count() - initialCount2) /
                ↪  totalCharacters} | {(double)(scope3.Links.Unsync.Count() - initialCount3) /
                ↪  totalCharacters}");

                Assert.True(scope1.Links.Unsync.Count() - initialCount1 <
                ↪  scope2.Links.Unsync.Count() - initialCount2);
```

```
622                 Assert.True(scope3.Links.Unsync.Count() - initialCount3 <
                    ↪  scope2.Links.Unsync.Count() - initialCount2);
623
624                 var duplicateProvider1 = new
                    ↪  DuplicateSegmentsProvider<ulong>(scope1.Links.Unsync, scope1.Sequences);
625                 var duplicateProvider2 = new
                    ↪  DuplicateSegmentsProvider<ulong>(scope2.Links.Unsync, scope2.Sequences);
626                 var duplicateProvider3 = new
                    ↪  DuplicateSegmentsProvider<ulong>(scope3.Links.Unsync, scope3.Sequences);
627
628                 var duplicateCounter1 = new DuplicateSegmentsCounter<ulong>(duplicateProvider1);
629                 var duplicateCounter2 = new DuplicateSegmentsCounter<ulong>(duplicateProvider2);
630                 var duplicateCounter3 = new DuplicateSegmentsCounter<ulong>(duplicateProvider3);
631
632                 var duplicates1 = duplicateCounter1.Count();
633
634                 ConsoleHelpers.Debug("------");
635
636                 var duplicates2 = duplicateCounter2.Count();
637
638                 ConsoleHelpers.Debug("------");
639
640                 var duplicates3 = duplicateCounter3.Count();
641
642                 Console.WriteLine($"{duplicates1} | {duplicates2} | {duplicates3}");
643
644                 linkFrequenciesCache1.ValidateFrequencies();
645                 linkFrequenciesCache3.ValidateFrequencies();
646             }
647         }
648
649         [Fact]
650         public static void CompressionStabilityTest()
651         {
652             // TODO: Fix bug (do a separate test)
653             //const ulong minNumbers = 0;
654             //const ulong maxNumbers = 1000;
655
656             const ulong minNumbers = 10000;
657             const ulong maxNumbers = 12500;
658
659             var strings = new List<string>();
660
661             for (ulong i = minNumbers; i < maxNumbers; i++)
662             {
663                 strings.Add(i.ToString());
664             }
665
666             var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
667             var totalCharacters = arrays.Select(x => x.Length).Sum();
668
669             using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
                    ↪  SequencesOptions<ulong> { UseCompression = true,
                    ↪  EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
670             using (var scope2 = new TempLinksTestScope(useSequences: true))
671             {
672                 scope1.Links.UseUnicode();
673                 scope2.Links.UseUnicode();
674
675                 //var compressor1 = new Compressor(scope1.Links.Unsync, scope1.Sequences);
676                 var compressor1 = scope1.Sequences;
677                 var compressor2 = scope2.Sequences;
678
679                 var compressed1 = new ulong[arrays.Length];
680                 var compressed2 = new ulong[arrays.Length];
681
682                 var sw1 = Stopwatch.StartNew();
683
684                 var START = 0;
685                 var END = arrays.Length;
686
687                 // Collisions proved (cannot be solved by max doublet comparison, no stable rule)
688                 // Stability issue starts at 10001 or 11000
689                 //for (int i = START; i < END; i++)
690                 //{
691                 //    var first = compressor1.Compress(arrays[i]);
692                 //    var second = compressor1.Compress(arrays[i]);
693
694                 //    if (first == second)
695                 //        compressed1[i] = first;
```

```
//    else
//    {
//        // TODO: Find a solution for this case
//    }
//}

for (int i = START; i < END; i++)
{
    var first = compressor1.Create(arrays[i].ShiftRight());
    var second = compressor1.Create(arrays[i].ShiftRight());

    if (first == second)
    {
        compressed1[i] = first;
    }
    else
    {
        // TODO: Find a solution for this case
    }
}

var elapsed1 = sw1.Elapsed;

var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);

var sw2 = Stopwatch.StartNew();

for (int i = START; i < END; i++)
{
    var first = balancedVariantConverter.Convert(arrays[i]);
    var second = balancedVariantConverter.Convert(arrays[i]);

    if (first == second)
    {
        compressed2[i] = first;
    }
}

var elapsed2 = sw2.Elapsed;

Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
↪  {elapsed2}");

Assert.True(elapsed1 > elapsed2);

// Checks
for (int i = START; i < END; i++)
{
    var sequence1 = compressed1[i];
    var sequence2 = compressed2[i];

    if (sequence1 != _constants.Null && sequence2 != _constants.Null)
    {
        var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
        ↪  scope1.Links);

        var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
        ↪  scope2.Links);

        //var structure1 = scope1.Links.FormatStructure(sequence1, link =>
        ↪  link.IsPartialPoint());
        //var structure2 = scope2.Links.FormatStructure(sequence2, link =>
        ↪  link.IsPartialPoint());

        //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
        ↪  arrays[i].Length > 3)
        //    Assert.False(structure1 == structure2);

        Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
    }
}

Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);

Debug.WriteLine($"{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
↪  totalCharacters} | {(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
↪  totalCharacters}");

```

```
767                 Assert.True(scope1.Links.Count() <= scope2.Links.Count());
768
769                 //compressor1.ValidateFrequencies();
770             }
771         }
772
773         [Fact]
774         public static void RundomNumbersCompressionQualityTest()
775         {
776             const ulong N = 500;
777
778             //const ulong minNumbers = 10000;
779             //const ulong maxNumbers = 20000;
780
781             //var strings = new List<string>();
782
783             //for (ulong i = 0; i < N; i++)
784             //    strings.Add(RandomHelpers.DefaultFactory.NextUInt64(minNumbers,
                ↪ maxNumbers).ToString());
785
786             var strings = new List<string>();
787
788             for (ulong i = 0; i < N; i++)
789             {
790                 strings.Add(RandomHelpers.Default.NextUInt64().ToString());
791             }
792
793             strings = strings.Distinct().ToList();
794
795             var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
796             var totalCharacters = arrays.Select(x => x.Length).Sum();
797
798             using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
                ↪ SequencesOptions<ulong> { UseCompression = true,
                ↪ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
799             using (var scope2 = new TempLinksTestScope(useSequences: true))
800             {
801                 scope1.Links.UseUnicode();
802                 scope2.Links.UseUnicode();
803
804                 var compressor1 = scope1.Sequences;
805                 var compressor2 = scope2.Sequences;
806
807                 var compressed1 = new ulong[arrays.Length];
808                 var compressed2 = new ulong[arrays.Length];
809
810                 var sw1 = Stopwatch.StartNew();
811
812                 var START = 0;
813                 var END = arrays.Length;
814
815                 for (int i = START; i < END; i++)
816                 {
817                     compressed1[i] = compressor1.Create(arrays[i].ShiftRight());
818                 }
819
820                 var elapsed1 = sw1.Elapsed;
821
822                 var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
823
824                 var sw2 = Stopwatch.StartNew();
825
826                 for (int i = START; i < END; i++)
827                 {
828                     compressed2[i] = balancedVariantConverter.Convert(arrays[i]);
829                 }
830
831                 var elapsed2 = sw2.Elapsed;
832
833                 Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
                    ↪ {elapsed2}");
834
835                 Assert.True(elapsed1 > elapsed2);
836
837                 // Checks
838                 for (int i = START; i < END; i++)
839                 {
840                     var sequence1 = compressed1[i];
841                     var sequence2 = compressed2[i];
842
```

```
                    if (sequence1 != _constants.Null && sequence2 != _constants.Null)
                    {
                        var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
                        ↪  scope1.Links);

                        var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
                        ↪  scope2.Links);

                        Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
                    }
                }

                Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
                Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);

                Debug.WriteLine($"{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
                ↪  totalCharacters} | {(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
                ↪  totalCharacters}");

                // Can be worse than balanced variant
                //Assert.True(scope1.Links.Count() <= scope2.Links.Count());

                //compressor1.ValidateFrequencies();
            }
        }

        [Fact]
        public static void AllTreeBreakDownAtSequencesCreationBugTest()
        {
            // Made out of AllPossibleConnectionsTest test.

            //const long sequenceLength = 5; //100% bug
            const long sequenceLength = 4; //100% bug
            //const long sequenceLength = 3; //100% _no_bug (ok)

            using (var scope = new TempLinksTestScope(useSequences: true))
            {
                var links = scope.Links;
                var sequences = scope.Sequences;

                var sequence = new ulong[sequenceLength];
                for (var i = 0; i < sequenceLength; i++)
                {
                    sequence[i] = links.Create();
                }

                var createResults = sequences.CreateAllVariants2(sequence);

                Global.Trash = createResults;

                for (var i = 0; i < sequenceLength; i++)
                {
                    links.Delete(sequence[i]);
                }
            }
        }

        [Fact]
        public static void AllPossibleConnectionsTest()
        {
            const long sequenceLength = 5;

            using (var scope = new TempLinksTestScope(useSequences: true))
            {
                var links = scope.Links;
                var sequences = scope.Sequences;

                var sequence = new ulong[sequenceLength];
                for (var i = 0; i < sequenceLength; i++)
                {
                    sequence[i] = links.Create();
                }

                var createResults = sequences.CreateAllVariants2(sequence);
                var reverseResults = sequences.CreateAllVariants2(sequence.Reverse().ToArray());

                for (var i = 0; i < 1; i++)
                {
                    var sw1 = Stopwatch.StartNew();
```

```
                    var searchResults1 = sequences.GetAllConnections(sequence); sw1.Stop();

                    var sw2 = Stopwatch.StartNew();
                    var searchResults2 = sequences.GetAllConnections1(sequence); sw2.Stop();

                    var sw3 = Stopwatch.StartNew();
                    var searchResults3 = sequences.GetAllConnections2(sequence); sw3.Stop();

                    var sw4 = Stopwatch.StartNew();
                    var searchResults4 = sequences.GetAllConnections3(sequence); sw4.Stop();

                    Global.Trash = searchResults3;
                    Global.Trash = searchResults4; //-V3008

                    var intersection1 = createResults.Intersect(searchResults1).ToList();
                    Assert.True(intersection1.Count == createResults.Length);

                    var intersection2 = reverseResults.Intersect(searchResults1).ToList();
                    Assert.True(intersection2.Count == reverseResults.Length);

                    var intersection0 = searchResults1.Intersect(searchResults2).ToList();
                    Assert.True(intersection0.Count == searchResults2.Count);

                    var intersection3 = searchResults2.Intersect(searchResults3).ToList();
                    Assert.True(intersection3.Count == searchResults3.Count);

                    var intersection4 = searchResults3.Intersect(searchResults4).ToList();
                    Assert.True(intersection4.Count == searchResults4.Count);
                }

                for (var i = 0; i < sequenceLength; i++)
                {
                    links.Delete(sequence[i]);
                }
            }
        }

        [Fact(Skip = "Correct implementation is pending")]
        public static void CalculateAllUsagesTest()
        {
            const long sequenceLength = 3;

            using (var scope = new TempLinksTestScope(useSequences: true))
            {
                var links = scope.Links;
                var sequences = scope.Sequences;

                var sequence = new ulong[sequenceLength];
                for (var i = 0; i < sequenceLength; i++)
                {
                    sequence[i] = links.Create();
                }

                var createResults = sequences.CreateAllVariants2(sequence);

                //var reverseResults =
                ↪  sequences.CreateAllVariants2(sequence.Reverse().ToArray());

                for (var i = 0; i < 1; i++)
                {
                    var linksTotalUsages1 = new ulong[links.Count() + 1];

                    sequences.CalculateAllUsages(linksTotalUsages1);

                    var linksTotalUsages2 = new ulong[links.Count() + 1];

                    sequences.CalculateAllUsages2(linksTotalUsages2);

                    var intersection1 = linksTotalUsages1.Intersect(linksTotalUsages2).ToList();
                    Assert.True(intersection1.Count == linksTotalUsages2.Length);
                }

                for (var i = 0; i < sequenceLength; i++)
                {
                    links.Delete(sequence[i]);
                }
            }
        }
    }
}
```

1.144 ./csharp/Platform.Data.Doublets.Tests/SplitMemoryGenericLinksTests.cs

```
using System;
using Xunit;
using Platform.Memory;
using Platform.Data.Doublets.Memory.Split.Generic;

namespace Platform.Data.Doublets.Tests
{
    public unsafe static class SplitMemoryGenericLinksTests
    {
        [Fact]
        public static void CRUDTest()
        {
            Using<byte>(links => links.TestCRUDOperations());
            Using<ushort>(links => links.TestCRUDOperations());
            Using<uint>(links => links.TestCRUDOperations());
            Using<ulong>(links => links.TestCRUDOperations());
        }

        [Fact]
        public static void RawNumbersCRUDTest()
        {
            UsingWithExternalReferences<byte>(links => links.TestRawNumbersCRUDOperations());
            UsingWithExternalReferences<ushort>(links => links.TestRawNumbersCRUDOperations());
            UsingWithExternalReferences<uint>(links => links.TestRawNumbersCRUDOperations());
            UsingWithExternalReferences<ulong>(links => links.TestRawNumbersCRUDOperations());
        }

        [Fact]
        public static void MultipleRandomCreationsAndDeletionsTest()
        {
            Using<byte>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().TestMultipleRandomCreationsAndDeletions(16)); // Cannot use more because current implementation of tree cuts out 5 bits from the address space.
            Using<ushort>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().TestMultipleRandomCreationsAndDeletions(100));
            Using<uint>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().TestMultipleRandomCreationsAndDeletions(100));
            Using<ulong>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().TestMultipleRandomCreationsAndDeletions(100));
        }

        private static void Using<TLink>(Action<ILinks<TLink>> action)
        {
            using (var dataMemory = new HeapResizableDirectMemory())
            using (var indexMemory = new HeapResizableDirectMemory())
            using (var memory = new SplitMemoryLinks<TLink>(dataMemory, indexMemory))
            {
                action(memory);
            }
        }

        private static void UsingWithExternalReferences<TLink>(Action<ILinks<TLink>> action)
        {
            var contants = new LinksConstants<TLink>(enableExternalReferencesSupport: true);
            using (var dataMemory = new HeapResizableDirectMemory())
            using (var indexMemory = new HeapResizableDirectMemory())
            using (var memory = new SplitMemoryLinks<TLink>(dataMemory, indexMemory, SplitMemoryLinks<TLink>.DefaultLinksSizeStep, contants))
            {
                action(memory);
            }
        }
    }
}
```

1.145 ./csharp/Platform.Data.Doublets.Tests/SplitMemoryUInt32LinksTests.cs

```
using System;
using Xunit;
using Platform.Memory;
using Platform.Data.Doublets.Memory.Split.Specific;
using TLink = System.UInt32;

namespace Platform.Data.Doublets.Tests
{
    public unsafe static class SplitMemoryUInt32LinksTests
    {
        [Fact]
        public static void CRUDTest()
```

```
        {
            Using(links => links.TestCRUDOperations());
        }

        [Fact]
        public static void RawNumbersCRUDTest()
        {
            UsingWithExternalReferences(links => links.TestRawNumbersCRUDOperations());
        }

        [Fact]
        public static void MultipleRandomCreationsAndDeletionsTest()
        {
            Using(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().TestMultip
            ↪  leRandomCreationsAndDeletions(100));
        }

        private static void Using(Action<ILinks<TLink>> action)
        {
            using (var dataMemory = new HeapResizableDirectMemory())
            using (var indexMemory = new HeapResizableDirectMemory())
            using (var memory = new UInt32SplitMemoryLinks(dataMemory, indexMemory))
            {
                action(memory);
            }
        }

        private static void UsingWithExternalReferences(Action<ILinks<TLink>> action)
        {
            var contants = new LinksConstants<TLink>(enableExternalReferencesSupport: true);
            using (var dataMemory = new HeapResizableDirectMemory())
            using (var indexMemory = new HeapResizableDirectMemory())
            using (var memory = new UInt32SplitMemoryLinks(dataMemory, indexMemory,
            ↪  UInt32SplitMemoryLinks.DefaultLinksSizeStep, contants))
            {
                action(memory);
            }
        }
    }
}
```

1.146 ./csharp/Platform.Data.Doublets.Tests/SplitMemoryUInt64LinksTests.cs

```
using System;
using Xunit;
using Platform.Memory;
using Platform.Data.Doublets.Memory.Split.Specific;
using TLink = System.UInt64;

namespace Platform.Data.Doublets.Tests
{
    public unsafe static class SplitMemoryUInt64LinksTests
    {
        [Fact]
        public static void CRUDTest()
        {
            Using(links => links.TestCRUDOperations());
        }

        [Fact]
        public static void RawNumbersCRUDTest()
        {
            UsingWithExternalReferences(links => links.TestRawNumbersCRUDOperations());
        }

        [Fact]
        public static void MultipleRandomCreationsAndDeletionsTest()
        {
            Using(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().TestMultip
            ↪  leRandomCreationsAndDeletions(100));
        }

        private static void Using(Action<ILinks<TLink>> action)
        {
            using (var dataMemory = new HeapResizableDirectMemory())
            using (var indexMemory = new HeapResizableDirectMemory())
            using (var memory = new UInt64SplitMemoryLinks(dataMemory, indexMemory))
            {
                action(memory);
            }
```

```
        }

        private static void UsingWithExternalReferences(Action<ILinks<TLink>> action)
        {
            var contants = new LinksConstants<TLink>(enableExternalReferencesSupport: true);
            using (var dataMemory = new HeapResizableDirectMemory())
            using (var indexMemory = new HeapResizableDirectMemory())
            using (var memory = new UInt64SplitMemoryLinks(dataMemory, indexMemory,
            ↪  UInt64SplitMemoryLinks.DefaultLinksSizeStep, contants))
            {
                action(memory);
            }
        }
    }
}
```

1.147 ./csharp/Platform.Data.Doublets.Tests/TempLinksTestScope.cs

```
using System.IO;
using Platform.Disposables;
using Platform.Data.Doublets.Sequences;
using Platform.Data.Doublets.Decorators;
using Platform.Data.Doublets.Memory.United.Specific;

namespace Platform.Data.Doublets.Tests
{
    public class TempLinksTestScope : DisposableBase
    {
        public ILinks<ulong> MemoryAdapter { get; }
        public SynchronizedLinks<ulong> Links { get; }
        public Sequences.Sequences Sequences { get; }
        public string TempFilename { get; }
        public string TempTransactionLogFilename { get; }
        private readonly bool _deleteFiles;

        public TempLinksTestScope(bool deleteFiles = true, bool useSequences = false, bool
        ↪  useLog = false) : this(new SequencesOptions<ulong>(), deleteFiles, useSequences,
        ↪  useLog) { }

        public TempLinksTestScope(SequencesOptions<ulong> sequencesOptions, bool deleteFiles =
        ↪  true, bool useSequences = false, bool useLog = false)
        {
            _deleteFiles = deleteFiles;
            TempFilename = Path.GetTempFileName();
            TempTransactionLogFilename = Path.GetTempFileName();
            var coreMemoryAdapter = new UInt64UnitedMemoryLinks(TempFilename);
            MemoryAdapter = useLog ? (ILinks<ulong>)new
            ↪  UInt64LinksTransactionsLayer(coreMemoryAdapter, TempTransactionLogFilename) :
            ↪  coreMemoryAdapter;
            Links = new SynchronizedLinks<ulong>(new UInt64Links(MemoryAdapter));
            if (useSequences)
            {
                Sequences = new Sequences.Sequences(Links, sequencesOptions);
            }
        }

        protected override void Dispose(bool manual, bool wasDisposed)
        {
            if (!wasDisposed)
            {
                Links.Unsync.DisposeIfPossible();
                if (_deleteFiles)
                {
                    DeleteFiles();
                }
            }
        }

        public void DeleteFiles()
        {
            File.Delete(TempFilename);
            File.Delete(TempTransactionLogFilename);
        }
    }
}
```

1.148 ./csharp/Platform.Data.Doublets.Tests/TestExtensions.cs

```
using System.Collections.Generic;
using Xunit;
```

```
using Platform.Ranges;
using Platform.Numbers;
using Platform.Random;
using Platform.Setters;
using Platform.Converters;

namespace Platform.Data.Doublets.Tests
{
    public static class TestExtensions
    {
        public static void TestCRUDOperations<T>(this ILinks<T> links)
        {
            var constants = links.Constants;

            var equalityComparer = EqualityComparer<T>.Default;

            var zero = default(T);
            var one = Arithmetic.Increment(zero);

            // Create Link
            Assert.True(equalityComparer.Equals(links.Count(), zero));

            var setter = new Setter<T>(constants.Null);
            links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);

            Assert.True(equalityComparer.Equals(setter.Result, constants.Null));

            var linkAddress = links.Create();

            var link = new Link<T>(links.GetLink(linkAddress));

            Assert.True(link.Count == 3);
            Assert.True(equalityComparer.Equals(link.Index, linkAddress));
            Assert.True(equalityComparer.Equals(link.Source, constants.Null));
            Assert.True(equalityComparer.Equals(link.Target, constants.Null));

            Assert.True(equalityComparer.Equals(links.Count(), one));

            // Get first link
            setter = new Setter<T>(constants.Null);
            links.Each(constants.Any, constants.Any, setter.SetAndReturnFalse);

            Assert.True(equalityComparer.Equals(setter.Result, linkAddress));

            // Update link to reference itself
            links.Update(linkAddress, linkAddress, linkAddress);

            link = new Link<T>(links.GetLink(linkAddress));

            Assert.True(equalityComparer.Equals(link.Source, linkAddress));
            Assert.True(equalityComparer.Equals(link.Target, linkAddress));

            // Update link to reference null (prepare for delete)
            var updated = links.Update(linkAddress, constants.Null, constants.Null);

            Assert.True(equalityComparer.Equals(updated, linkAddress));

            link = new Link<T>(links.GetLink(linkAddress));

            Assert.True(equalityComparer.Equals(link.Source, constants.Null));
            Assert.True(equalityComparer.Equals(link.Target, constants.Null));

            // Delete link
            links.Delete(linkAddress);

            Assert.True(equalityComparer.Equals(links.Count(), zero));

            setter = new Setter<T>(constants.Null);
            links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);

            Assert.True(equalityComparer.Equals(setter.Result, constants.Null));
        }

        public static void TestRawNumbersCRUDOperations<T>(this ILinks<T> links)
        {
            // Constants
            var constants = links.Constants;
            var equalityComparer = EqualityComparer<T>.Default;

            var zero = default(T);
            var one = Arithmetic.Increment(zero);
```

```
            var two = Arithmetic.Increment(one);

            var h106E = new Hybrid<T>(106L, isExternal: true);
            var h107E = new Hybrid<T>(-char.ConvertFromUtf32(107)[0]);
            var h108E = new Hybrid<T>(-108L);

            Assert.Equal(106L, h106E.AbsoluteValue);
            Assert.Equal(107L, h107E.AbsoluteValue);
            Assert.Equal(108L, h108E.AbsoluteValue);

            // Create Link (External -> External)
            var linkAddress1 = links.Create();

            links.Update(linkAddress1, h106E, h108E);

            var link1 = new Link<T>(links.GetLink(linkAddress1));

            Assert.True(equalityComparer.Equals(link1.Source, h106E));
            Assert.True(equalityComparer.Equals(link1.Target, h108E));

            // Create Link (Internal -> External)
            var linkAddress2 = links.Create();

            links.Update(linkAddress2, linkAddress1, h108E);

            var link2 = new Link<T>(links.GetLink(linkAddress2));

            Assert.True(equalityComparer.Equals(link2.Source, linkAddress1));
            Assert.True(equalityComparer.Equals(link2.Target, h108E));

            // Create Link (Internal -> Internal)
            var linkAddress3 = links.Create();

            links.Update(linkAddress3, linkAddress1, linkAddress2);

            var link3 = new Link<T>(links.GetLink(linkAddress3));

            Assert.True(equalityComparer.Equals(link3.Source, linkAddress1));
            Assert.True(equalityComparer.Equals(link3.Target, linkAddress2));

            // Search for created link
            var setter1 = new Setter<T>(constants.Null);
            links.Each(h106E, h108E, setter1.SetAndReturnFalse);

            Assert.True(equalityComparer.Equals(setter1.Result, linkAddress1));

            // Search for nonexistent link
            var setter2 = new Setter<T>(constants.Null);
            links.Each(h106E, h107E, setter2.SetAndReturnFalse);

            Assert.True(equalityComparer.Equals(setter2.Result, constants.Null));

            // Update link to reference null (prepare for delete)
            var updated = links.Update(linkAddress3, constants.Null, constants.Null);

            Assert.True(equalityComparer.Equals(updated, linkAddress3));

            link3 = new Link<T>(links.GetLink(linkAddress3));

            Assert.True(equalityComparer.Equals(link3.Source, constants.Null));
            Assert.True(equalityComparer.Equals(link3.Target, constants.Null));

            // Delete link
            links.Delete(linkAddress3);

            Assert.True(equalityComparer.Equals(links.Count(), two));

            var setter3 = new Setter<T>(constants.Null);
            links.Each(constants.Any, constants.Any, setter3.SetAndReturnTrue);

            Assert.True(equalityComparer.Equals(setter3.Result, linkAddress2));
        }

        public static void TestMultipleRandomCreationsAndDeletions<TLink>(this ILinks<TLink>
        ↪  links, int maximumOperationsPerCycle)
        {
            var comparer = Comparer<TLink>.Default;
            var addressToUInt64Converter = CheckedConverter<TLink, ulong>.Default;
            var uInt64ToAddressConverter = CheckedConverter<ulong, TLink>.Default;
            for (var N = 1; N < maximumOperationsPerCycle; N++)
```

```
163             {
164                 var random = new System.Random(N);
165                 var created = 0UL;
166                 var deleted = 0UL;
167                 for (var i = 0; i < N; i++)
168                 {
169                     var linksCount = addressToUInt64Converter.Convert(links.Count());
170                     var createPoint = random.NextBoolean();
171                     if (linksCount > 2 && createPoint)
172                     {
173                         var linksAddressRange = new Range<ulong>(1, linksCount);
174                         TLink source = uInt64ToAddressConverter.Convert(random.NextUInt64(linksA
                            ↪ ddressRange));
175                         TLink target = uInt64ToAddressConverter.Convert(random.NextUInt64(linksA
                            ↪ ddressRange));
                            ↪ //-V3086
176                         var resultLink = links.GetOrCreate(source, target);
177                         if (comparer.Compare(resultLink,
                            ↪ uInt64ToAddressConverter.Convert(linksCount)) > 0)
178                         {
179                             created++;
180                         }
181                     }
182                     else
183                     {
184                         links.Create();
185                         created++;
186                     }
187                 }
188                 Assert.True(created == addressToUInt64Converter.Convert(links.Count()));
189                 for (var i = 0; i < N; i++)
190                 {
191                     TLink link = uInt64ToAddressConverter.Convert((ulong)i + 1UL);
192                     if (links.Exists(link))
193                     {
194                         links.Delete(link);
195                         deleted++;
196                     }
197                 }
198                 Assert.True(addressToUInt64Converter.Convert(links.Count()) == 0L);
199             }
200         }
201     }
202 }
```

1.149 ./csharp/Platform.Data.Doublets.Tests/UInt64LinksTests.cs

```
1  using System;
2  using System.Collections.Generic;
3  using System.Diagnostics;
4  using System.IO;
5  using System.Text;
6  using System.Threading;
7  using System.Threading.Tasks;
8  using Xunit;
9  using Platform.Disposables;
10 using Platform.Ranges;
11 using Platform.Random;
12 using Platform.Timestamps;
13 using Platform.Reflection;
14 using Platform.Singletons;
15 using Platform.Scopes;
16 using Platform.Counters;
17 using Platform.Diagnostics;
18 using Platform.IO;
19 using Platform.Memory;
20 using Platform.Data.Doublets.Decorators;
21 using Platform.Data.Doublets.Memory.United.Specific;
22
23 namespace Platform.Data.Doublets.Tests
24 {
25     public static class UInt64LinksTests
26     {
27         private static readonly LinksConstants<ulong> _constants =
            ↪ Default<LinksConstants<ulong>>.Instance;
28
29         private const long Iterations = 10 * 1024;
30
31         #region Concept
32
33         [Fact]
```

```
34          public static void MultipleCreateAndDeleteTest()
35          {
36              using (var scope = new Scope<Types<HeapResizableDirectMemory,
                ↪  UInt64UnitedMemoryLinks>>())
37              {
38                  new UInt64Links(scope.Use<ILinks<ulong>>()).TestMultipleRandomCreationsAndDeleti⌋
                    ↪  ons(100);
39              }
40          }
41
42          [Fact]
43          public static void CascadeUpdateTest()
44          {
45              var itself = _constants.Itself;
46              using (var scope = new TempLinksTestScope(useLog: true))
47              {
48                  var links = scope.Links;
49
50                  var l1 = links.Create();
51                  var l2 = links.Create();
52
53                  l2 = links.Update(l2, l2, l1, l2);
54
55                  links.CreateAndUpdate(l2, itself);
56                  links.CreateAndUpdate(l2, itself);
57
58                  l2 = links.Update(l2, l1);
59
60                  links.Delete(l2);
61
62                  Global.Trash = links.Count();
63
64                  links.Unsync.DisposeIfPossible(); // Close links to access log
65
66                  Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scop⌋
                    ↪  e.TempTransactionLogFilename);
67              }
68          }
69
70          [Fact]
71          public static void BasicTransactionLogTest()
72          {
73              using (var scope = new TempLinksTestScope(useLog: true))
74              {
75                  var links = scope.Links;
76                  var l1 = links.Create();
77                  var l2 = links.Create();
78
79                  Global.Trash = links.Update(l2, l2, l1, l2);
80
81                  links.Delete(l1);
82
83                  links.Unsync.DisposeIfPossible(); // Close links to access log
84
85                  Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scop⌋
                    ↪  e.TempTransactionLogFilename);
86              }
87          }
88
89          [Fact]
90          public static void TransactionAutoRevertedTest()
91          {
92              // Auto Reverted (Because no commit at transaction)
93              using (var scope = new TempLinksTestScope(useLog: true))
94              {
95                  var links = scope.Links;
96                  var transactionsLayer = (UInt64LinksTransactionsLayer)scope.MemoryAdapter;
97                  using (var transaction = transactionsLayer.BeginTransaction())
98                  {
99                      var l1 = links.Create();
100                     var l2 = links.Create();
101
102                     links.Update(l2, l2, l1, l2);
103                 }
104
105                 Assert.Equal(0UL, links.Count());
106
107                 links.Unsync.DisposeIfPossible();
108
```

```
109                 var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(s
                    ↪  cope.TempTransactionLogFilename);
110                 Assert.Single(transitions);
111             }
112         }
113 
114         [Fact]
115         public static void TransactionUserCodeErrorNoDataSavedTest()
116         {
117             // User Code Error (Autoreverted), no data saved
118             var itself = _constants.Itself;
119 
120             TempLinksTestScope lastScope = null;
121             try
122             {
123                 using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
                    ↪  useLog: true))
124                 {
125                     var links = scope.Links;
126                     var transactionsLayer = (UInt64LinksTransactionsLayer)((LinksDisposableDecor
                        ↪  atorBase<ulong>)links.Unsync).Links;
127                     using (var transaction = transactionsLayer.BeginTransaction())
128                     {
129                         var l1 = links.CreateAndUpdate(itself, itself);
130                         var l2 = links.CreateAndUpdate(itself, itself);
131 
132                         l2 = links.Update(l2, l2, l1, l2);
133 
134                         links.CreateAndUpdate(l2, itself);
135                         links.CreateAndUpdate(l2, itself);
136 
137                         //Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transi
                            ↪  tion>(scope.TempTransactionLogFilename);
138 
139                         l2 = links.Update(l2, l1);
140 
141                         links.Delete(l2);
142 
143                         ExceptionThrower();
144 
145                         transaction.Commit();
146                     }
147 
148                     Global.Trash = links.Count();
149                 }
150             }
151             catch
152             {
153                 Assert.False(lastScope == null);
154 
155                 var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(l
                    ↪  astScope.TempTransactionLogFilename);
156 
157                 Assert.True(transitions.Length == 1 && transitions[0].Before.IsNull() &&
                    ↪  transitions[0].After.IsNull());
158 
159                 lastScope.DeleteFiles();
160             }
161         }
162 
163         [Fact]
164         public static void TransactionUserCodeErrorSomeDataSavedTest()
165         {
166             // User Code Error (Autoreverted), some data saved
167             var itself = _constants.Itself;
168 
169             TempLinksTestScope lastScope = null;
170             try
171             {
172                 ulong l1;
173                 ulong l2;
174 
175                 using (var scope = new TempLinksTestScope(useLog: true))
176                 {
177                     var links = scope.Links;
178                     l1 = links.CreateAndUpdate(itself, itself);
179                     l2 = links.CreateAndUpdate(itself, itself);
180 
181                     l2 = links.Update(l2, l2, l1, l2);
182 
```

```
                    links.CreateAndUpdate(l2, itself);
                    links.CreateAndUpdate(l2, itself);

                    links.Unsync.DisposeIfPossible();

                    Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(
                    ↪ scope.TempTransactionLogFilename);
                }

                using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
                ↪ useLog: true))
                {
                    var links = scope.Links;
                    var transactionsLayer = (UInt64LinksTransactionsLayer)links.Unsync;
                    using (var transaction = transactionsLayer.BeginTransaction())
                    {
                        l2 = links.Update(l2, l1);

                        links.Delete(l2);

                        ExceptionThrower();

                        transaction.Commit();
                    }

                    Global.Trash = links.Count();
                }
            }
            catch
            {
                Assert.False(lastScope == null);

                Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(last
                ↪ Scope.TempTransactionLogFilename);

                lastScope.DeleteFiles();
            }
        }

        [Fact]
        public static void TransactionCommit()
        {
            var itself = _constants.Itself;

            var tempDatabaseFilename = Path.GetTempFileName();
            var tempTransactionLogFilename = Path.GetTempFileName();

            // Commit
            using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
            ↪ UInt64UnitedMemoryLinks(tempDatabaseFilename), tempTransactionLogFilename))
            using (var links = new UInt64Links(memoryAdapter))
            {
                using (var transaction = memoryAdapter.BeginTransaction())
                {
                    var l1 = links.CreateAndUpdate(itself, itself);
                    var l2 = links.CreateAndUpdate(itself, itself);

                    Global.Trash = links.Update(l2, l2, l1, l2);

                    links.Delete(l1);

                    transaction.Commit();
                }

                Global.Trash = links.Count();
            }

            Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
            ↪ sactionLogFilename);
        }

        [Fact]
        public static void TransactionDamage()
        {
            var itself = _constants.Itself;

            var tempDatabaseFilename = Path.GetTempFileName();
            var tempTransactionLogFilename = Path.GetTempFileName();

```

```
257             // Commit
258             using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
                ↪ UInt64UnitedMemoryLinks(tempDatabaseFilename), tempTransactionLogFilename))
259             using (var links = new UInt64Links(memoryAdapter))
260             {
261                 using (var transaction = memoryAdapter.BeginTransaction())
262                 {
263                     var l1 = links.CreateAndUpdate(itself, itself);
264                     var l2 = links.CreateAndUpdate(itself, itself);
265 
266                     Global.Trash = links.Update(l2, l2, l1, l2);
267 
268                     links.Delete(l1);
269 
270                     transaction.Commit();
271                 }
272 
273                 Global.Trash = links.Count();
274             }
275 
276             Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
                ↪ sactionLogFilename);
277 
278             // Damage database
279 
280             FileHelpers.WriteFirst(tempTransactionLogFilename, new
                ↪ UInt64LinksTransactionsLayer.Transition(new UniqueTimestampFactory(), 555));
281 
282             // Try load damaged database
283             try
284             {
285                 // TODO: Fix
286                 using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
                    ↪ UInt64UnitedMemoryLinks(tempDatabaseFilename), tempTransactionLogFilename))
287                 using (var links = new UInt64Links(memoryAdapter))
288                 {
289                     Global.Trash = links.Count();
290                 }
291             }
292             catch (NotSupportedException ex)
293             {
294                 Assert.True(ex.Message == "Database is damaged, autorecovery is not supported
                    ↪ yet.");
295             }
296 
297             Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
                ↪ sactionLogFilename);
298 
299             File.Delete(tempDatabaseFilename);
300             File.Delete(tempTransactionLogFilename);
301         }
302 
303         [Fact]
304         public static void Bug1Test()
305         {
306             var tempDatabaseFilename = Path.GetTempFileName();
307             var tempTransactionLogFilename = Path.GetTempFileName();
308 
309             var itself = _constants.Itself;
310 
311             // User Code Error (Autoreverted), some data saved
312             try
313             {
314                 ulong l1;
315                 ulong l2;
316 
317                 using (var memory = new UInt64UnitedMemoryLinks(tempDatabaseFilename))
318                 using (var memoryAdapter = new UInt64LinksTransactionsLayer(memory,
                    ↪ tempTransactionLogFilename))
319                 using (var links = new UInt64Links(memoryAdapter))
320                 {
321                     l1 = links.CreateAndUpdate(itself, itself);
322                     l2 = links.CreateAndUpdate(itself, itself);
323 
324                     l2 = links.Update(l2, l2, l1, l2);
325 
326                     links.CreateAndUpdate(l2, itself);
327                     links.CreateAndUpdate(l2, itself);
328                 }
```

```
329
330                 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
                    ↪ TransactionLogFilename);
331
332                 using (var memory = new UInt64UnitedMemoryLinks(tempDatabaseFilename))
333                 using (var memoryAdapter = new UInt64LinksTransactionsLayer(memory,
                    ↪ tempTransactionLogFilename))
334                 using (var links = new UInt64Links(memoryAdapter))
335                 {
336                     using (var transaction = memoryAdapter.BeginTransaction())
337                     {
338                         l2 = links.Update(l2, l1);
339
340                         links.Delete(l2);
341
342                         ExceptionThrower();
343
344                         transaction.Commit();
345                     }
346
347                     Global.Trash = links.Count();
348                 }
349             }
350             catch
351             {
352                 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
                    ↪ TransactionLogFilename);
353             }
354
355             File.Delete(tempDatabaseFilename);
356             File.Delete(tempTransactionLogFilename);
357         }
358
359         private static void ExceptionThrower() => throw new InvalidOperationException();
360
361         [Fact]
362         public static void PathsTest()
363         {
364             var source = _constants.SourcePart;
365             var target = _constants.TargetPart;
366
367             using (var scope = new TempLinksTestScope())
368             {
369                 var links = scope.Links;
370                 var l1 = links.CreatePoint();
371                 var l2 = links.CreatePoint();
372
373                 var r1 = links.GetByKeys(l1, source, target, source);
374                 var r2 = links.CheckPathExistance(l2, l2, l2, l2);
375             }
376         }
377
378         [Fact]
379         public static void RecursiveStringFormattingTest()
380         {
381             using (var scope = new TempLinksTestScope(useSequences: true))
382             {
383                 var links = scope.Links;
384                 var sequences = scope.Sequences; // TODO: Auto use sequences on Sequences getter.
385
386                 var a = links.CreatePoint();
387                 var b = links.CreatePoint();
388                 var c = links.CreatePoint();
389
390                 var ab = links.GetOrCreate(a, b);
391                 var cb = links.GetOrCreate(c, b);
392                 var ac = links.GetOrCreate(a, c);
393
394                 a = links.Update(a, c, b);
395                 b = links.Update(b, a, c);
396                 c = links.Update(c, a, b);
397
398                 Debug.WriteLine(links.FormatStructure(ab, link => link.IsFullPoint(), true));
399                 Debug.WriteLine(links.FormatStructure(cb, link => link.IsFullPoint(), true));
400                 Debug.WriteLine(links.FormatStructure(ac, link => link.IsFullPoint(), true));
401
402                 Assert.True(links.FormatStructure(cb, link => link.IsFullPoint(), true) ==
                    ↪ "(5:(4:5 (6:5 4)) 6)");
```

```
403                 Assert.True(links.FormatStructure(ac, link => link.IsFullPoint(), true) ==
                    ↪  "(6:(5:(4:5 6) 6) 4)");
404                 Assert.True(links.FormatStructure(ab, link => link.IsFullPoint(), true) ==
                    ↪  "(4:(5:4 (6:5 4)) 6)");
405
406                 // TODO: Think how to build balanced syntax tree while formatting structure (eg.
                    ↪  "(4:(5:4 6) (6:5 4)") instead of "(4:(5:4 (6:5 4)) 6)"
407
408                 Assert.True(sequences.SafeFormatSequence(cb, DefaultFormatter, false) ==
                    ↪  "{{5}{5}{4}{6}}");
409                 Assert.True(sequences.SafeFormatSequence(ac, DefaultFormatter, false) ==
                    ↪  "{{5}{6}{6}{4}}");
410                 Assert.True(sequences.SafeFormatSequence(ab, DefaultFormatter, false) ==
                    ↪  "{{4}{5}{4}{6}}");
411             }
412         }
413
414         private static void DefaultFormatter(StringBuilder sb, ulong link)
415         {
416             sb.Append(link.ToString());
417         }
418
419         #endregion
420
421         #region Performance
422
423         /*
424         public static void RunAllPerformanceTests()
425         {
426             try
427             {
428                 links.TestLinksInSteps();
429             }
430             catch (Exception ex)
431             {
432                 ex.WriteToConsole();
433             }
434
435             return;
436
437             try
438             {
439                 //ThreadPool.SetMaxThreads(2, 2);
440
441                 // Запускаем все тесты дважды, чтобы первоначальная инициализация не повлияла на
    ↪  результат
442                 // Также это дополнительно помогает в отладке
443                 // Увеличивает вероятность попадания информации в кэши
444                 for (var i = 0; i < 10; i++)
445                 {
446                     //0 - 10 ГБ
447                     //Каждые 100 МБ срез цифр
448
449                     //links.TestGetSourceFunction();
450                     //links.TestGetSourceFunctionInParallel();
451                     //links.TestGetTargetFunction();
452                     //links.TestGetTargetFunctionInParallel();
453                     links.Create64BillionLinks();
454
455                     links.TestRandomSearchFixed();
456                     //links.Create64BillionLinksInParallel();
457                     links.TestEachFunction();
458                     //links.TestForeach();
459                     //links.TestParallelForeach();
460                 }
461
462                 links.TestDeletionOfAllLinks();
463
464             }
465             catch (Exception ex)
466             {
467                 ex.WriteToConsole();
468             }
469         }*/
470
471         /*
472         public static void TestLinksInSteps()
473         {
474             const long gibibyte = 1024 * 1024 * 1024;
```

```
475             const long mebibyte = 1024 * 1024;
476 
477             var totalLinksToCreate = gibibyte /
    ↪  Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
478             var linksStep = 102 * mebibyte /
    ↪  Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
479 
480             var creationMeasurements = new List<TimeSpan>();
481             var searchMeasuremets = new List<TimeSpan>();
482             var deletionMeasurements = new List<TimeSpan>();
483 
484             GetBaseRandomLoopOverhead(linksStep);
485             GetBaseRandomLoopOverhead(linksStep);
486 
487             var stepLoopOverhead = GetBaseRandomLoopOverhead(linksStep);
488 
489             ConsoleHelpers.Debug("Step loop overhead: {0}.", stepLoopOverhead);
490 
491             var loops = totalLinksToCreate / linksStep;
492 
493             for (int i = 0; i < loops; i++)
494             {
495                 creationMeasurements.Add(Measure(() => links.RunRandomCreations(linksStep)));
496                 searchMeasuremets.Add(Measure(() => links.RunRandomSearches(linksStep)));
497 
498                 Console.Write("\rC + S {0}/{1}", i + 1, loops);
499             }
500 
501             ConsoleHelpers.Debug();
502 
503             for (int i = 0; i < loops; i++)
504             {
505                 deletionMeasurements.Add(Measure(() => links.RunRandomDeletions(linksStep)));
506 
507                 Console.Write("\rD {0}/{1}", i + 1, loops);
508             }
509 
510             ConsoleHelpers.Debug();
511 
512             ConsoleHelpers.Debug("C S D");
513 
514             for (int i = 0; i < loops; i++)
515             {
516                 ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i],
    ↪  searchMeasuremets[i], deletionMeasurements[i]);
517             }
518 
519             ConsoleHelpers.Debug("C S D (no overhead)");
520 
521             for (int i = 0; i < loops; i++)
522             {
523                 ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i] - stepLoopOverhead,
    ↪  searchMeasuremets[i] - stepLoopOverhead, deletionMeasurements[i] - stepLoopOverhead);
524             }
525 
526             ConsoleHelpers.Debug("All tests done. Total links left in database: {0}.",
    ↪  links.Total);
527         }
528 
529         private static void CreatePoints(this Platform.Links.Data.Core.Doublets.Links links, long
    ↪  amountToCreate)
530         {
531             for (long i = 0; i < amountToCreate; i++)
532                 links.Create(0, 0);
533         }
534 
535          private static TimeSpan GetBaseRandomLoopOverhead(long loops)
536          {
537              return Measure(() =>
538              {
539                  ulong maxValue = RandomHelpers.DefaultFactory.NextUInt64();
540                  ulong result = 0;
541                  for (long i = 0; i < loops; i++)
542                  {
543                      var source = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
544                      var target = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
545 
546                      result += maxValue + source + target;
547                  }
```

```
548                 Global.Trash = result;
549             });
550         }
551          */
552 
553         [Fact(Skip = "performance test")]
554         public static void GetSourceTest()
555         {
556             using (var scope = new TempLinksTestScope())
557             {
558                 var links = scope.Links;
559                 ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations.",
                    ↪  Iterations);
560 
561                 ulong counter = 0;
562 
563                 //var firstLink = links.First();
564                 // Создаём одну связь, из которой будет производить считывание
565                 var firstLink = links.Create();
566 
567                 var sw = Stopwatch.StartNew();
568 
569                 // Тестируем саму функцию
570                 for (ulong i = 0; i < Iterations; i++)
571                 {
572                     counter += links.GetSource(firstLink);
573                 }
574 
575                 var elapsedTime = sw.Elapsed;
576 
577                 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
578 
579                 // Удаляем связь, из которой производилось считывание
580                 links.Delete(firstLink);
581 
582                 ConsoleHelpers.Debug(
583                     "{0} Iterations of GetSource function done in {1} ({2} Iterations per
                        ↪  second), counter result: {3}",
584                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
585             }
586         }
587 
588         [Fact(Skip = "performance test")]
589         public static void GetSourceInParallel()
590         {
591             using (var scope = new TempLinksTestScope())
592             {
593                 var links = scope.Links;
594                 ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations in
                    ↪  parallel.", Iterations);
595 
596                 long counter = 0;
597 
598                 //var firstLink = links.First();
599                 var firstLink = links.Create();
600 
601                 var sw = Stopwatch.StartNew();
602 
603                 // Тестируем саму функцию
604                 Parallel.For(0, Iterations, x =>
605                 {
606                     Interlocked.Add(ref counter, (long)links.GetSource(firstLink));
607                     //Interlocked.Increment(ref counter);
608                 });
609 
610                 var elapsedTime = sw.Elapsed;
611 
612                 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
613 
614                 links.Delete(firstLink);
615 
616                 ConsoleHelpers.Debug(
617                     "{0} Iterations of GetSource function done in {1} ({2} Iterations per
                        ↪  second), counter result: {3}",
618                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
619             }
620         }
621 
622         [Fact(Skip = "performance test")]
```

```
623         public static void TestGetTarget()
624         {
625             using (var scope = new TempLinksTestScope())
626             {
627                 var links = scope.Links;
628                 ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations.",
                    ↪  Iterations);
629 
630                 ulong counter = 0;
631 
632                 //var firstLink = links.First();
633                 var firstLink = links.Create();
634 
635                 var sw = Stopwatch.StartNew();
636 
637                 for (ulong i = 0; i < Iterations; i++)
638                 {
639                     counter += links.GetTarget(firstLink);
640                 }
641 
642                 var elapsedTime = sw.Elapsed;
643 
644                 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
645 
646                 links.Delete(firstLink);
647 
648                 ConsoleHelpers.Debug(
649                     "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
                        ↪  second), counter result: {3}",
650                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
651             }
652         }
653 
654         [Fact(Skip = "performance test")]
655         public static void TestGetTargetInParallel()
656         {
657             using (var scope = new TempLinksTestScope())
658             {
659                 var links = scope.Links;
660                 ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations in
                    ↪  parallel.", Iterations);
661 
662                 long counter = 0;
663 
664                 //var firstLink = links.First();
665                 var firstLink = links.Create();
666 
667                 var sw = Stopwatch.StartNew();
668 
669                 Parallel.For(0, Iterations, x =>
670                 {
671                     Interlocked.Add(ref counter, (long)links.GetTarget(firstLink));
672                     //Interlocked.Increment(ref counter);
673                 });
674 
675                 var elapsedTime = sw.Elapsed;
676 
677                 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
678 
679                 links.Delete(firstLink);
680 
681                 ConsoleHelpers.Debug(
682                     "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
                        ↪  second), counter result: {3}",
683                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
684             }
685         }
686 
687         // TODO: Заполнить базу данных перед тестом
688         /*
689         [Fact]
690         public void TestRandomSearchFixed()
691         {
692             var tempFilename = Path.GetTempFileName();
693 
694             using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
    ↪  DefaultLinksSizeStep))
695             {
696                 long iterations = 64 * 1024 * 1024 /
    ↪  Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
```

```
697
698                 ulong counter = 0;
699                 var maxLink = links.Total;
700
701                 ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.", iterations);
702
703                 var sw = Stopwatch.StartNew();
704
705                 for (var i = iterations; i > 0; i--)
706                 {
707                     var source =
    ↪  RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
708                     var target =
    ↪  RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
709
710                     counter += links.Search(source, target);
711                 }
712
713                 var elapsedTime = sw.Elapsed;
714
715                 var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
716
717                 ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
    ↪  Iterations per second), c: {3}", iterations, elapsedTime, (long)iterationsPerSecond,
    ↪  counter);
718             }
719
720             File.Delete(tempFilename);
721         }*/
722
723         [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
724         public static void TestRandomSearchAll()
725         {
726             using (var scope = new TempLinksTestScope())
727             {
728                 var links = scope.Links;
729                 ulong counter = 0;
730
731                 var maxLink = links.Count();
732
733                 var iterations = links.Count();
734
735                 ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.",
                    ↪  links.Count());
736
737                 var sw = Stopwatch.StartNew();
738
739                 for (var i = iterations; i > 0; i--)
740                 {
741                     var linksAddressRange = new
                        ↪  Range<ulong>(_constants.InternalReferencesRange.Minimum, maxLink);
742
743                     var source = RandomHelpers.Default.NextUInt64(linksAddressRange);
744                     var target = RandomHelpers.Default.NextUInt64(linksAddressRange);
745
746                     counter += links.SearchOrDefault(source, target);
747                 }
748
749                 var elapsedTime = sw.Elapsed;
750
751                 var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
752
753                 ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
                    ↪  Iterations per second), c: {3}",
754                      iterations, elapsedTime, (long)iterationsPerSecond, counter);
755             }
756         }
757
758         [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
759         public static void TestEach()
760         {
761             using (var scope = new TempLinksTestScope())
762             {
763                 var links = scope.Links;
764
765                 var counter = new Counter<IList<ulong>, ulong>(links.Constants.Continue);
766
767                 ConsoleHelpers.Debug("Testing Each function.");
768
769                 var sw = Stopwatch.StartNew();
```

```
770
771                 links.Each(counter.IncrementAndReturnTrue);
772
773                 var elapsedTime = sw.Elapsed;
774
775                 var linksPerSecond = counter.Count / elapsedTime.TotalSeconds;
776
777                 ConsoleHelpers.Debug("{0} Iterations of Each's handler function done in {1} ({2}
                    ↪  links per second)",
778                     counter, elapsedTime, (long)linksPerSecond);
779             }
780         }
781
782         /*
783         [Fact]
784         public static void TestForeach()
785         {
786             var tempFilename = Path.GetTempFileName();
787
788             using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
    ↪  DefaultLinksSizeStep))
789             {
790                 ulong counter = 0;
791
792                 ConsoleHelpers.Debug("Testing foreach through links.");
793
794                 var sw = Stopwatch.StartNew();
795
796                 //foreach (var link in links)
797                 //{
798                 //    counter++;
799                 //}
800
801                 var elapsedTime = sw.Elapsed;
802
803                 var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
804
805                 ConsoleHelpers.Debug("{0} Iterations of Foreach's handler block done in {1} ({2}
    ↪  links per second)", counter, elapsedTime, (long)linksPerSecond);
806             }
807
808             File.Delete(tempFilename);
809         }
810         */
811
812         /*
813         [Fact]
814         public static void TestParallelForeach()
815         {
816             var tempFilename = Path.GetTempFileName();
817
818             using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
    ↪  DefaultLinksSizeStep))
819             {
820
821                 long counter = 0;
822
823                 ConsoleHelpers.Debug("Testing parallel foreach through links.");
824
825                 var sw = Stopwatch.StartNew();
826
827                 //Parallel.ForEach((IEnumerable<ulong>)links, x =>
828                 //{
829                 //    Interlocked.Increment(ref counter);
830                 //});
831
832                 var elapsedTime = sw.Elapsed;
833
834                 var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
835
836                 ConsoleHelpers.Debug("{0} Iterations of Parallel Foreach's handler block done in
    ↪  {1} ({2} links per second)", counter, elapsedTime, (long)linksPerSecond);
837             }
838
839             File.Delete(tempFilename);
840         }
841         */
842
843         [Fact(Skip = "performance test")]
844         public static void Create64BillionLinks()
```

```
845         {
846             using (var scope = new TempLinksTestScope())
847             {
848                 var links = scope.Links;
849                 var linksBeforeTest = links.Count();
850 
851                 long linksToCreate = 64 * 1024 * 1024 / UInt64UnitedMemoryLinks.LinkSizeInBytes;
852 
853                 ConsoleHelpers.Debug("Creating {0} links.", linksToCreate);
854 
855                 var elapsedTime = Performance.Measure(() =>
856                 {
857                     for (long i = 0; i < linksToCreate; i++)
858                     {
859                         links.Create();
860                     }
861                 });
862 
863                 var linksCreated = links.Count() - linksBeforeTest;
864                 var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
865 
866                 ConsoleHelpers.Debug("Current links count: {0}.", links.Count());
867 
868                 ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
                    ↪  linksCreated, elapsedTime,
869                     (long)linksPerSecond);
870             }
871         }
872 
873         [Fact(Skip = "performance test")]
874         public static void Create64BillionLinksInParallel()
875         {
876             using (var scope = new TempLinksTestScope())
877             {
878                 var links = scope.Links;
879                 var linksBeforeTest = links.Count();
880 
881                 var sw = Stopwatch.StartNew();
882 
883                 long linksToCreate = 64 * 1024 * 1024 / UInt64UnitedMemoryLinks.LinkSizeInBytes;
884 
885                 ConsoleHelpers.Debug("Creating {0} links in parallel.", linksToCreate);
886 
887                 Parallel.For(0, linksToCreate, x => links.Create());
888 
889                 var elapsedTime = sw.Elapsed;
890 
891                 var linksCreated = links.Count() - linksBeforeTest;
892                 var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
893 
894                 ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
                    ↪  linksCreated, elapsedTime,
895                     (long)linksPerSecond);
896             }
897         }
898 
899         [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
900         public static void TestDeletionOfAllLinks()
901         {
902             using (var scope = new TempLinksTestScope())
903             {
904                 var links = scope.Links;
905                 var linksBeforeTest = links.Count();
906 
907                 ConsoleHelpers.Debug("Deleting all links");
908 
909                 var elapsedTime = Performance.Measure(links.DeleteAll);
910 
911                 var linksDeleted = linksBeforeTest - links.Count();
912                 var linksPerSecond = linksDeleted / elapsedTime.TotalSeconds;
913 
914                 ConsoleHelpers.Debug("{0} links deleted in {1} ({2} links per second)",
                    ↪  linksDeleted, elapsedTime,
915                     (long)linksPerSecond);
916             }
917         }
918 
919         #endregion
920     }
921 }
```

1.150 ./csharp/Platform.Data.Doublets.Tests/UnaryNumberConvertersTests.cs

```
using Xunit;
using Platform.Random;
using Platform.Data.Doublets.Numbers.Unary;

namespace Platform.Data.Doublets.Tests
{
    public static class UnaryNumberConvertersTests
    {
        [Fact]
        public static void ConvertersTest()
        {
            using (var scope = new TempLinksTestScope())
            {
                const int N = 10;
                var links = scope.Links;
                var meaningRoot = links.CreatePoint();
                var one = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
                var powerOf2ToUnaryNumberConverter = new
                ↪  PowerOf2ToUnaryNumberConverter<ulong>(links, one);
                var toUnaryNumberConverter = new AddressToUnaryNumberConverter<ulong>(links,
                ↪  powerOf2ToUnaryNumberConverter);
                var random = new System.Random(0);
                ulong[] numbers = new ulong[N];
                ulong[] unaryNumbers = new ulong[N];
                for (int i = 0; i < N; i++)
                {
                    numbers[i] = random.NextUInt64();
                    unaryNumbers[i] = toUnaryNumberConverter.Convert(numbers[i]);
                }
                var fromUnaryNumberConverterUsingOrOperation = new
                ↪  UnaryNumberToAddressOrOperationConverter<ulong>(links,
                ↪  powerOf2ToUnaryNumberConverter);
                var fromUnaryNumberConverterUsingAddOperation = new
                ↪  UnaryNumberToAddressAddOperationConverter<ulong>(links, one);
                for (int i = 0; i < N; i++)
                {
                    Assert.Equal(numbers[i],
                    ↪  fromUnaryNumberConverterUsingOrOperation.Convert(unaryNumbers[i]));
                    Assert.Equal(numbers[i],
                    ↪  fromUnaryNumberConverterUsingAddOperation.Convert(unaryNumbers[i]));
                }
            }
        }
    }
}
```

1.151 ./csharp/Platform.Data.Doublets.Tests/UnicodeConvertersTests.cs

```
using Xunit;
using Platform.Converters;
using Platform.Memory;
using Platform.Reflection;
using Platform.Scopes;
using Platform.Data.Numbers.Raw;
using Platform.Data.Doublets.Incrementers;
using Platform.Data.Doublets.Numbers.Unary;
using Platform.Data.Doublets.PropertyOperators;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Doublets.Sequences.Indexes;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Data.Doublets.Unicode;
using Platform.Data.Doublets.Memory.United.Generic;
using Platform.Data.Doublets.CriterionMatchers;

namespace Platform.Data.Doublets.Tests
{
    public static class UnicodeConvertersTests
    {
        [Fact]
        public static void CharAndUnaryNumberUnicodeSymbolConvertersTest()
        {
            using (var scope = new TempLinksTestScope())
            {
                var links = scope.Links;
                var meaningRoot = links.CreatePoint();
                var one = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
                var powerOf2ToUnaryNumberConverter = new
                ↪  PowerOf2ToUnaryNumberConverter<ulong>(links, one);
                var addressToUnaryNumberConverter = new
                ↪  AddressToUnaryNumberConverter<ulong>(links, powerOf2ToUnaryNumberConverter);
```

```
31                  var unaryNumberToAddressConverter = new
                    ↪  UnaryNumberToAddressOrOperationConverter<ulong>(links,
                    ↪  powerOf2ToUnaryNumberConverter);
32                  TestCharAndUnicodeSymbolConverters(links, meaningRoot,
                    ↪  addressToUnaryNumberConverter, unaryNumberToAddressConverter);
33              }
34          }
35
36          [Fact]
37          public static void CharAndRawNumberUnicodeSymbolConvertersTest()
38          {
39              using (var scope = new Scope<Types<HeapResizableDirectMemory,
                ↪  UnitedMemoryLinks<ulong>>>())
40              {
41                  var links = scope.Use<ILinks<ulong>>();
42                  var meaningRoot = links.CreatePoint();
43                  var addressToRawNumberConverter = new AddressToRawNumberConverter<ulong>();
44                  var rawNumberToAddressConverter = new RawNumberToAddressConverter<ulong>();
45                  TestCharAndUnicodeSymbolConverters(links, meaningRoot,
                    ↪  addressToRawNumberConverter, rawNumberToAddressConverter);
46              }
47          }
48
49          private static void TestCharAndUnicodeSymbolConverters(ILinks<ulong> links, ulong
            ↪  meaningRoot, IConverter<ulong> addressToNumberConverter, IConverter<ulong>
            ↪  numberToAddressConverter)
50          {
51              var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
52              var charToUnicodeSymbolConverter = new CharToUnicodeSymbolConverter<ulong>(links,
                ↪  addressToNumberConverter, unicodeSymbolMarker);
53              var originalCharacter = 'H';
54              var characterLink = charToUnicodeSymbolConverter.Convert(originalCharacter);
55              var unicodeSymbolCriterionMatcher = new TargetMatcher<ulong>(links,
                ↪  unicodeSymbolMarker);
56              var unicodeSymbolToCharConverter = new UnicodeSymbolToCharConverter<ulong>(links,
                ↪  numberToAddressConverter, unicodeSymbolCriterionMatcher);
57              var resultingCharacter = unicodeSymbolToCharConverter.Convert(characterLink);
58              Assert.Equal(originalCharacter, resultingCharacter);
59          }
60
61          [Fact]
62          public static void StringAndUnicodeSequenceConvertersTest()
63          {
64              using (var scope = new TempLinksTestScope())
65              {
66                  var links = scope.Links;
67
68                  var itself = links.Constants.Itself;
69
70                  var meaningRoot = links.CreatePoint();
71                  var unaryOne = links.CreateAndUpdate(meaningRoot, itself);
72                  var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, itself);
73                  var unicodeSequenceMarker = links.CreateAndUpdate(meaningRoot, itself);
74                  var frequencyMarker = links.CreateAndUpdate(meaningRoot, itself);
75                  var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot, itself);
76
77                  var powerOf2ToUnaryNumberConverter = new
                    ↪  PowerOf2ToUnaryNumberConverter<ulong>(links, unaryOne);
78                  var addressToUnaryNumberConverter = new
                    ↪  AddressToUnaryNumberConverter<ulong>(links, powerOf2ToUnaryNumberConverter);
79                  var charToUnicodeSymbolConverter = new
                    ↪  CharToUnicodeSymbolConverter<ulong>(links, addressToUnaryNumberConverter,
                    ↪  unicodeSymbolMarker);
80
81                  var unaryNumberToAddressConverter = new
                    ↪  UnaryNumberToAddressOrOperationConverter<ulong>(links,
                    ↪  powerOf2ToUnaryNumberConverter);
82                  var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
83                  var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
                    ↪  frequencyMarker, unaryOne, unaryNumberIncrementer);
84                  var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
                    ↪  frequencyPropertyMarker, frequencyMarker);
85                  var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
                    ↪  frequencyPropertyOperator, frequencyIncrementer);
86                  var linkToItsFrequencyNumberConverter = new
                    ↪  LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
                    ↪  unaryNumberToAddressConverter);
```

```
87                  var sequenceToItsLocalElementLevelsConverter = new
                    ↪  SequenceToItsLocalElementLevelsConverter<ulong>(links,
                    ↪  linkToItsFrequencyNumberConverter);
88                  var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                    ↪  sequenceToItsLocalElementLevelsConverter);
89
90                  var stringToUnicodeSequenceConverter = new
                    ↪  StringToUnicodeSequenceConverter<ulong>(links, charToUnicodeSymbolConverter,
                    ↪  index, optimalVariantConverter, unicodeSequenceMarker);
91
92                  var originalString = "Hello";
93
94                  var unicodeSequenceLink =
                    ↪  stringToUnicodeSequenceConverter.Convert(originalString);
95
96                  var unicodeSymbolCriterionMatcher = new TargetMatcher<ulong>(links,
                    ↪  unicodeSymbolMarker);
97                  var unicodeSymbolToCharConverter = new
                    ↪  UnicodeSymbolToCharConverter<ulong>(links, unaryNumberToAddressConverter,
                    ↪  unicodeSymbolCriterionMatcher);
98
99                  var unicodeSequenceCriterionMatcher = new TargetMatcher<ulong>(links,
                    ↪  unicodeSequenceMarker);
100
101                 var sequenceWalker = new LeveledSequenceWalker<ulong>(links,
                    ↪  unicodeSymbolCriterionMatcher.IsMatched);
102
103                 var unicodeSequenceToStringConverter = new
                    ↪  UnicodeSequenceToStringConverter<ulong>(links,
                    ↪  unicodeSequenceCriterionMatcher, sequenceWalker,
                    ↪  unicodeSymbolToCharConverter);
104
105                 var resultingString =
                    ↪  unicodeSequenceToStringConverter.Convert(unicodeSequenceLink);
106
107                 Assert.Equal(originalString, resultingString);
108             }
109         }
110     }
111 }
```

1.152 ./csharp/Platform.Data.Doublets.Tests/UnitedMemoryUInt32LinksTests.cs

```
1  using System;
2  using Xunit;
3  using Platform.Reflection;
4  using Platform.Memory;
5  using Platform.Scopes;
6  using Platform.Data.Doublets.Memory.United.Specific;
7  using TLink = System.UInt32;
8
9  namespace Platform.Data.Doublets.Tests
10 {
11     public unsafe static class UnitedMemoryUInt32LinksTests
12     {
13         [Fact]
14         public static void CRUDTest()
15         {
16             Using(links => links.TestCRUDOperations());
17         }
18
19         [Fact]
20         public static void RawNumbersCRUDTest()
21         {
22             Using(links => links.TestRawNumbersCRUDOperations());
23         }
24
25         [Fact]
26         public static void MultipleRandomCreationsAndDeletionsTest()
27         {
28             Using(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().TestMultip
                   ↪  leRandomCreationsAndDeletions(100));
29         }
30
31         private static void Using(Action<ILinks<TLink>> action)
32         {
33             using (var scope = new Scope<Types<HeapResizableDirectMemory,
                   ↪  UInt32UnitedMemoryLinks>>())
34             {
35                 action(scope.Use<ILinks<TLink>>());
```

```
            }
        }
    }
}
```

1.153 ./csharp/Platform.Data.Doublets.Tests/UnitedMemoryUInt64LinksTests.cs

```
using System;
using Xunit;
using Platform.Reflection;
using Platform.Memory;
using Platform.Scopes;
using Platform.Data.Doublets.Memory.United.Specific;
using TLink = System.UInt64;

namespace Platform.Data.Doublets.Tests
{
    public unsafe static class UnitedMemoryUInt64LinksTests
    {
        [Fact]
        public static void CRUDTest()
        {
            Using(links => links.TestCRUDOperations());
        }

        [Fact]
        public static void RawNumbersCRUDTest()
        {
            Using(links => links.TestRawNumbersCRUDOperations());
        }

        [Fact]
        public static void MultipleRandomCreationsAndDeletionsTest()
        {
            Using(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().TestMultip
            ↪ leRandomCreationsAndDeletions(100));
        }

        private static void Using(Action<ILinks<TLink>> action)
        {
            using (var scope = new Scope<Types<HeapResizableDirectMemory,
            ↪ UInt64UnitedMemoryLinks>>())
            {
                action(scope.Use<ILinks<TLink>>());
            }
        }
    }
}
```

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