## 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, memoryReservationStep);
        }

        [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, long memoryReservationStep)
84          {
85              if (dataMemory.ReservedCapacity < memoryReservationStep)
86              {
87                  dataMemory.ReservedCapacity = memoryReservationStep;
88              }
89              if (indexMemory.ReservedCapacity < memoryReservationStep)
90              {
91                  indexMemory.ReservedCapacity = memoryReservationStep;
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/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)]
        protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref AsRef<LinksHeader<TLink>>(Header);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref AsRef<RawLink<TLink>>(Links + (RawLink<TLink>.SizeInBytes * _addressToInt64Converter.Convert(link)));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
        {
            ref var link = ref GetLinkReference(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 GetLinkReference(first);
            ref var secondLink = ref GetLinkReference(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 GetLinkReference(first);
            ref var secondLink = ref GetLinkReference(second);
            return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
            ↪  secondLink.Source, secondLink.Target);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual TLink GetSizeValue(TLink value) => Bit<TLink>.PartialRead(value, 5,
        ↪  -5);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual void SetSizeValue(ref TLink storedValue, TLink size) => storedValue =
        ↪  Bit<TLink>.PartialWrite(storedValue, size, 5, -5);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual bool GetLeftIsChildValue(TLink value)
        {
            unchecked
            {
                return _addressToBoolConverter.Convert(Bit<TLink>.PartialRead(value, 4, 1));
                //return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 4, 1), default);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual void SetLeftIsChildValue(ref TLink storedValue, bool value)
        {
            unchecked
            {
                var previousValue = storedValue;
                var modified = Bit<TLink>.PartialWrite(previousValue,
                ↪  _boolToAddressConverter.Convert(value), 4, 1);
                storedValue = modified;
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual bool GetRightIsChildValue(TLink value)
        {
            unchecked
            {
                return _addressToBoolConverter.Convert(Bit<TLink>.PartialRead(value, 3, 1));
                //return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 3, 1), default);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual void SetRightIsChildValue(ref TLink storedValue, bool value)
        {
            unchecked
            {
                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>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Search(TLink source, TLink target)
        {
            var root = GetTreeRoot();
            while (!EqualToZero(root))
            {
                ref var rootLink = ref GetLinkReference(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 link, Func<IList<TLink>, TLink> handler)
    {
        var root = GetTreeRoot();
        if (EqualToZero(root))
        {
            return Continue;
        }
        TLink first = Zero, current = root;
        while (!EqualToZero(current))
        {
            var @base = GetBasePartValue(current);
            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);
        }
    }
}
```

## 1.42 ./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();

        [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 RawLink<TLink> GetLinkReference(TLink link) => ref AsRef<RawLink<TLink>>(Links + (RawLink<TLink>.SizeInBytes * _addressToInt64Converter.Convert(link)));

        [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
```

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

## 1.43 ./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;
        }
    }
}
```

## 1.44 ./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;
        }
    }
}
```

## 1.45 ./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;

        [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) =>
        ↪  GetSizeValue(GetLinkReference(node).SizeAsTarget);

        [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  }
```

## 1.46 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksTargetsSizeBalancedTreeMethods.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.Generic
6   {
7       public unsafe class LinksTargetsSizeBalancedTreeMethods<TLink> :
        ↪  LinksSizeBalancedTreeMethodsBase<TLink>
8       {
9           [MethodImpl(MethodImplOptions.AggressiveInlining)]
10          public LinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
            ↪  byte* header) : base(constants, links, header) { }
11
12          [MethodImpl(MethodImplOptions.AggressiveInlining)]
13          protected override ref TLink GetLeftReference(TLink node) => ref
            ↪  GetLinkReference(node).LeftAsTarget;
14
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;
```

```

        [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;
        }
    }
}
```

## 1.47 ./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

namespace Platform.Data.Doublets.Memory.United.Generic
{
    public unsafe class UnitedMemoryLinks<TLink> : UnitedMemoryLinksBase<TLink>
    {
        private readonly Func<ILinksTreeMethods<TLink>> _createSourceTreeMethods;
        private readonly Func<ILinksTreeMethods<TLink>> _createTargetTreeMethods;
        private byte* _header;
        private byte* _links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnitedMemoryLinks(string address) : this(address, DefaultLinksSizeStep) { }

        /// <summary>
        /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
        ↪  минимальным шагом расширения базы данных.
        /// </summary>
        /// <param name="address">Полный пусть к файлу базы данных.</param>
        /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
        ↪  байтах.</param>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnitedMemoryLinks(string address, long memoryReservationStep) : this(new
        ↪  FileMappedResizableDirectMemory(address, memoryReservationStep),
        ↪  memoryReservationStep) { }

```

```
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  }
```

## 1.48 ./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                     {
```

```
                        return GetZero();
                    }
                    if (AreEqual(source, any) && AreEqual(target, any))
                    {
                        return GetOne();
                    }
                    ref var storedLinkValue = ref GetLinkReference(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)
            {
                for (var link = GetOne(); LessOrEqualThan(link,
                ↪  GetHeaderReference().AllocatedLinks); link = Increment(link))
                {
                    if (Exists(link) && AreEqual(handler(GetLinkStruct(link)), @break))
                    {
                        return @break;
                    }
                }
                return @break;
            }
            var @continue = constants.Continue;
            var any = constants.Any;
            var index = restrictions[constants.IndexPart];
            if (restrictions.Count == 1)
            {
                if (AreEqual(index, any))
                {
                    return Each(handler, Array.Empty<TLink>());
                }
                if (!Exists(index))
                {
                    return @continue;
                }
                return handler(GetLinkStruct(index));
            }
            if (restrictions.Count == 2)
            {
                var value = restrictions[1];
                if (AreEqual(index, any))
                {
                    if (AreEqual(value, any))
                    {
                        return Each(handler, Array.Empty<TLink>());
                    }
```

```
                    if (AreEqual(Each(handler, new Link<TLink>(index, value, any)), @break))
                    {
                        return @break;
                    }
                    return Each(handler, new Link<TLink>(index, any, value));
                }
                else
                {
                    if (!Exists(index))
                    {
                        return @continue;
                    }
                    if (AreEqual(value, any))
                    {
                        return handler(GetLinkStruct(index));
                    }
                    ref var storedLinkValue = ref GetLinkReference(index);
                    if (AreEqual(storedLinkValue.Source, value) ||
                        AreEqual(storedLinkValue.Target, value))
                    {
                        return handler(GetLinkStruct(index));
                    }
                    return @continue;
                }
            }
            if (restrictions.Count == 3)
            {
                var source = restrictions[constants.SourcePart];
                var target = restrictions[constants.TargetPart];
                if (AreEqual(index, any))
                {
                    if (AreEqual(source, any) && AreEqual(target, any))
                    {
                        return Each(handler, Array.Empty<TLink>());
                    }
                    else if (AreEqual(source, any))
                    {
                        return TargetsTreeMethods.EachUsage(target, handler);
                    }
                    else if (AreEqual(target, any))
                    {
                        return SourcesTreeMethods.EachUsage(source, handler);
                    }
                    else //if(source != Any && target != Any)
                    {
                        var link = SourcesTreeMethods.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 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;
```

```
317                     }
318                     if (AreEqual(storedLinkValue.Source, value) ||
319                         AreEqual(storedLinkValue.Target, value))
320                     {
321                         return handler(GetLinkStruct(index));
322                     }
323                     return @continue;
324                 }
325             }
326             throw new NotSupportedException("Другие размеры и способы ограничений не
                ↪  поддерживаются.");
327         }
328 
329         /// <remarks>
330         /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
                ↪  в другом месте (но не в менеджере памяти, а в логике Links)
331         /// </remarks>
332         [MethodImpl(MethodImplOptions.AggressiveInlining)]
333         public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
334         {
335             var constants = Constants;
336             var @null = constants.Null;
337             var linkIndex = restrictions[constants.IndexPart];
338             ref var link = ref GetLinkReference(linkIndex);
339             ref var header = ref GetHeaderReference();
340             ref var firstAsSource = ref header.RootAsSource;
341             ref var firstAsTarget = ref header.RootAsTarget;
342             // Будет корректно работать только в том случае, если пространство выделенной связи
                ↪  предварительно заполнено нулями
343             if (!AreEqual(link.Source, @null))
344             {
345                 SourcesTreeMethods.Detach(ref firstAsSource, linkIndex);
346             }
347             if (!AreEqual(link.Target, @null))
348             {
349                 TargetsTreeMethods.Detach(ref firstAsTarget, linkIndex);
350             }
351             link.Source = substitution[constants.SourcePart];
352             link.Target = substitution[constants.TargetPart];
353             if (!AreEqual(link.Source, @null))
354             {
355                 SourcesTreeMethods.Attach(ref firstAsSource, linkIndex);
356             }
357             if (!AreEqual(link.Target, @null))
358             {
359                 TargetsTreeMethods.Attach(ref firstAsTarget, linkIndex);
360             }
361             return linkIndex;
362         }
363 
364         /// <remarks>
365         /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
                ↪  пространство
366         /// </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                 }
```

```
                header.AllocatedLinks = Increment(header.AllocatedLinks);
                _memory.UsedCapacity += LinkSizeInBytes;
                freeLink = header.AllocatedLinks;
            }
            return freeLink;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual void Delete(IList<TLink> restrictions)
        {
            ref var header = ref GetHeaderReference();
            var link = restrictions[Constants.IndexPart];
            if (LessThan(link, header.AllocatedLinks))
            {
                UnusedLinksListMethods.AttachAsFirst(link);
            }
            else if (AreEqual(link, header.AllocatedLinks))
            {
                header.AllocatedLinks = Decrement(header.AllocatedLinks);
                _memory.UsedCapacity -= LinkSizeInBytes;
                // Убираем все связи, находящиеся в списке свободных в конце файла, до тех пор, пока не дойдём до первой существующей связи
                // Позволяет оптимизировать количество выделенных связей (AllocatedLinks)
                while (GreaterThan(header.AllocatedLinks, GetZero()) && IsUnusedLink(header.AllocatedLinks))
                {
                    UnusedLinksListMethods.Detach(header.AllocatedLinks);
                    header.AllocatedLinks = Decrement(header.AllocatedLinks);
                    _memory.UsedCapacity -= LinkSizeInBytes;
                }
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public IList<TLink> GetLinkStruct(TLink linkIndex)
        {
            ref var link = ref GetLinkReference(linkIndex);
            return new Link<TLink>(linkIndex, link.Source, link.Target);
        }

        /// <remarks>
        /// TODO: Возможно это должно быть событием, вызываемым из IMemory, в том случае, если адрес реально поменялся
        ///
        /// Указатель this.links может быть в том же месте,
        /// так как 0-я связь не используется и имеет такой же размер как Header,
        /// поэтому header размещается в том же месте, что и 0-я связь
        /// </remarks>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract void SetPointers(IResizableDirectMemory memory);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual void ResetPointers()
        {
            SourcesTreeMethods = null;
            TargetsTreeMethods = null;
            UnusedLinksListMethods = null;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract ref LinksHeader<TLink> GetHeaderReference();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract ref RawLink<TLink> GetLinkReference(TLink linkIndex);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual bool Exists(TLink link)
            => GreaterOrEqualThan(link, Constants.InternalReferencesRange.Minimum)
            && LessOrEqualThan(link, GetHeaderReference().AllocatedLinks)
            && !IsUnusedLink(link);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual bool IsUnusedLink(TLink linkIndex)
        {
            if (!AreEqual(GetHeaderReference().FirstFreeLink, linkIndex)) // May be this check is not needed
            {
                ref var link = ref GetLinkReference(linkIndex);
                return AreEqual(link.SizeAsSource, default) && !AreEqual(link.Source, default);
```

```
            }
            else
            {
                return true;
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual TLink GetOne() => _one;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual TLink GetZero() => default;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual bool AreEqual(TLink first, TLink second) =>
        ↪ _equalityComparer.Equals(first, second);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual bool LessThan(TLink first, TLink second) => _comparer.Compare(first,
        ↪ second) < 0;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual bool LessOrEqualThan(TLink first, TLink second) =>
        ↪ _comparer.Compare(first, second) <= 0;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual bool GreaterThan(TLink first, TLink second) =>
        ↪ _comparer.Compare(first, second) > 0;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual bool GreaterOrEqualThan(TLink first, TLink second) =>
        ↪ _comparer.Compare(first, second) >= 0;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual long ConvertToInt64(TLink value) =>
        ↪ _addressToInt64Converter.Convert(value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual TLink ConvertToAddress(long value) =>
        ↪ _int64ToAddressConverter.Convert(value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual TLink Add(TLink first, TLink second) => Arithmetic<TLink>.Add(first,
        ↪ second);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual TLink Subtract(TLink first, TLink second) =>
        ↪ Arithmetic<TLink>.Subtract(first, second);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual TLink Increment(TLink link) => Arithmetic<TLink>.Increment(link);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual TLink Decrement(TLink link) => Arithmetic<TLink>.Decrement(link);

        #region Disposable

        protected override bool AllowMultipleDisposeCalls
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get => true;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void Dispose(bool manual, bool wasDisposed)
        {
            if (!wasDisposed)
            {
                ResetPointers();
                _memory.DisposeIfPossible();
            }
        }

        #endregion
    }
}
```

## 1.49 ./csharp/Platform.Data.Doublets/Memory/United/Generic/UnusedLinksListMethods.cs

```
using System.Runtime.CompilerServices;
using Platform.Collections.Methods.Lists;
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 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 RawLink<TLink> GetLinkReference(TLink link) => ref
        ↪  AsRef<RawLink<TLink>>(_links + (RawLink<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) => GetLinkReference(element).Source;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetNext(TLink element) => GetLinkReference(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) =>
        ↪  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;
    }
}
```

## 1.50 ./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);
    }
}
```

## 1.51 ./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;

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

## 1.52 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt32LinksSourcesSizeBalancedTreeMethods.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 UInt32LinksSourcesSizeBalancedTreeMethods :
    ↪  UInt32LinksSizeBalancedTreeMethodsBase
    {
        public UInt32LinksSourcesSizeBalancedTreeMethods(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].LeftAsSource;

        [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  }
```

## 1.53 ./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
6   {
7       public unsafe class UInt32LinksTargetsSizeBalancedTreeMethods :
        ↪  UInt32LinksSizeBalancedTreeMethodsBase
8       {
9           public UInt32LinksTargetsSizeBalancedTreeMethods(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].LeftAsTarget;
13
14          [MethodImpl(MethodImplOptions.AggressiveInlining)]
15          protected override ref uint GetRightReference(uint node) => ref
            ↪  Links[node].RightAsTarget;
16
17          [MethodImpl(MethodImplOptions.AggressiveInlining)]
18          protected override uint GetLeft(uint node) => Links[node].LeftAsTarget;
19
20          [MethodImpl(MethodImplOptions.AggressiveInlining)]
21          protected override uint GetRight(uint node) => Links[node].RightAsTarget;
22
23          [MethodImpl(MethodImplOptions.AggressiveInlining)]
24          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;
        }
    }
}
```

## 1.54 ./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>
    /// </summary>
    public unsafe class UInt32UnitedMemoryLinks : UnitedMemoryLinksBase<uint>
    {
        private readonly Func<ILinksTreeMethods<uint>> _createSourceTreeMethods;
        private readonly Func<ILinksTreeMethods<uint>> _createTargetTreeMethods;
        private LinksHeader<uint>* _header;
        private RawLink<uint>* _links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt32UnitedMemoryLinks(string address) : this(address, DefaultLinksSizeStep) { }

        /// <summary>
        /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
        ↪  минимальным шагом расширения базы данных.
        /// </summary>
        /// <param name="address">Полный пусть к файлу базы данных.</param>
        /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
        ↪  байтах.</param>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        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
80          [MethodImpl(MethodImplOptions.AggressiveInlining)]
81          protected override bool GreaterThan(uint first, uint second) => first > second;
82
83          [MethodImpl(MethodImplOptions.AggressiveInlining)]
84          protected override bool GreaterOrEqualThan(uint first, uint second) => first >= second;
85
86          [MethodImpl(MethodImplOptions.AggressiveInlining)]
87          protected override uint GetZero() => 0U;
88
89          [MethodImpl(MethodImplOptions.AggressiveInlining)]
90          protected override uint GetOne() => 1U;
91
92          [MethodImpl(MethodImplOptions.AggressiveInlining)]
93          protected override long ConvertToInt64(uint value) => (long)value;
94
95          [MethodImpl(MethodImplOptions.AggressiveInlining)]
96          protected override uint ConvertToAddress(long value) => (uint)value;
97
98          [MethodImpl(MethodImplOptions.AggressiveInlining)]
99          protected override uint Add(uint first, uint second) => first + second;
100
101         [MethodImpl(MethodImplOptions.AggressiveInlining)]
102         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;
    }
}
```

## 1.55 ./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;
    }
}
```

## 1.56 ./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)
        {
            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)]
```

```
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;
90
91          [MethodImpl(MethodImplOptions.AggressiveInlining)]
92          protected override void SetLeftIsChildValue(ref ulong storedValue, bool value) =>
            ↪  storedValue = storedValue & 4294967279UL | (As<bool, byte>(ref value) & 1UL) << 4;
93
94          [MethodImpl(MethodImplOptions.AggressiveInlining)]
95          protected override bool GetRightIsChildValue(ulong value) => (value & 8UL) >> 3 == 1UL;
96
97          [MethodImpl(MethodImplOptions.AggressiveInlining)]
98          protected override void SetRightIsChildValue(ref ulong storedValue, bool value) =>
            ↪  storedValue = storedValue & 4294967287UL | (As<bool, byte>(ref value) & 1UL) << 3;
99
100         [MethodImpl(MethodImplOptions.AggressiveInlining)]
101         protected override sbyte GetBalanceValue(ulong value) => unchecked((sbyte)(value & 7UL |
            ↪  0xF8UL * ((value & 4UL) >> 2))); // if negative, then continue ones to the end of
            ↪  sbyte
102
103         [MethodImpl(MethodImplOptions.AggressiveInlining)]
104         protected override void SetBalanceValue(ref ulong storedValue, sbyte value) =>
            ↪  storedValue = unchecked(storedValue & 4294967288UL | (ulong)((byte)value >> 5 & 4 |
            ↪  value & 3) & 7UL);
105
106         [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
107         protected override ref LinksHeader<ulong> GetHeaderReference() => ref *Header;
108
109         [MethodImpl(MethodImplOptions.AggressiveInlining)]
110         protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref Links[link];
111     }
112 }
```

## 1.57 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksSizeBalancedTreeMethodsBase.cs

```
1  using System.Runtime.CompilerServices;
2  using Platform.Data.Doublets.Memory.United.Generic;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Memory.United.Specific
7  {
8      public unsafe abstract class UInt64LinksSizeBalancedTreeMethodsBase :
       ↪  LinksSizeBalancedTreeMethodsBase<ulong>
9      {
10         protected new readonly RawLink<ulong>* Links;
11         protected new readonly LinksHeader<ulong>* Header;
12
13         protected UInt64LinksSizeBalancedTreeMethodsBase(LinksConstants<ulong> constants,
           ↪  RawLink<ulong>* links, LinksHeader<ulong>* header)
14             : base(constants, (byte*)links, (byte*)header)
15         {
16             Links = links;
17             Header = header;
18         }
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         protected override ulong GetZero() => 0UL;
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected override bool EqualToZero(ulong value) => value == 0UL;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         protected override bool AreEqual(ulong first, ulong second) => first == second;
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         protected override bool GreaterThanZero(ulong value) => value > 0UL;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override bool GreaterThan(ulong first, ulong second) => first > second;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
37
38         [MethodImpl(MethodImplOptions.AggressiveInlining)]
39         protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
           ↪  always true for ulong
40
41         [MethodImpl(MethodImplOptions.AggressiveInlining)]
42         protected override bool LessOrEqualThanZero(ulong value) => value == 0UL; // value is
           ↪  always >= 0 for ulong
43
44         [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         {
```

```
            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(ulong first, ulong 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<ulong> GetHeaderReference() => ref *Header;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref Links[link];
    }
}
```

## 1.58 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksSourcesAvlBalancedTreeMethods.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 UInt64LinksSourcesAvlBalancedTreeMethods :
    ↪  UInt64LinksAvlBalancedTreeMethodsBase
    {
        public UInt64LinksSourcesAvlBalancedTreeMethods(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) => 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)]
```

```
45          protected override bool GetRightIsChild(ulong node) =>
            ↪  GetRightIsChildValue(Links[node].SizeAsSource);
46
47          //[MethodImpl(MethodImplOptions.AggressiveInlining)]
48          //protected override bool GetRightIsChild(ulong node) => IsChild(node, GetRight(node));
49
50          [MethodImpl(MethodImplOptions.AggressiveInlining)]
51          protected override void SetRightIsChild(ulong node, bool value) =>
            ↪  SetRightIsChildValue(ref Links[node].SizeAsSource, value);
52
53          [MethodImpl(MethodImplOptions.AggressiveInlining)]
54          protected override sbyte GetBalance(ulong node) =>
            ↪  GetBalanceValue(Links[node].SizeAsSource);
55
56          [MethodImpl(MethodImplOptions.AggressiveInlining)]
57          protected override void SetBalance(ulong node, sbyte value) => SetBalanceValue(ref
            ↪  Links[node].SizeAsSource, value);
58
59          [MethodImpl(MethodImplOptions.AggressiveInlining)]
60          protected override ulong GetTreeRoot() => Header->RootAsSource;
61
62          [MethodImpl(MethodImplOptions.AggressiveInlining)]
63          protected override ulong GetBasePartValue(ulong link) => Links[link].Source;
64
65          [MethodImpl(MethodImplOptions.AggressiveInlining)]
66          protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
            ↪  ulong secondSource, ulong secondTarget)
67              => firstSource < secondSource || (firstSource == secondSource && firstTarget <
                ↪  secondTarget);
68
69          [MethodImpl(MethodImplOptions.AggressiveInlining)]
70          protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
            ↪  ulong secondSource, ulong secondTarget)
71              => firstSource > secondSource || (firstSource == secondSource && firstTarget >
                ↪  secondTarget);
72
73          [MethodImpl(MethodImplOptions.AggressiveInlining)]
74          protected override void ClearNode(ulong node)
75          {
76              ref var link = ref Links[node];
77              link.LeftAsSource = 0UL;
78              link.RightAsSource = 0UL;
79              link.SizeAsSource = 0UL;
80          }
81      }
82  }
```

## 1.59 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksSourcesSizeBalancedTreeMethods.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 UInt64LinksSourcesSizeBalancedTreeMethods :
        ↪  UInt64LinksSizeBalancedTreeMethodsBase
8       {
9           public UInt64LinksSourcesSizeBalancedTreeMethods(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) => 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 = OUL;
            link.RightAsSource = OUL;
            link.SizeAsSource = OUL;
        }
    }
}
```

## 1.60 ./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)]
        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) => GetSizeValue(Links[node].SizeAsTarget);

```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSize(ulong node, ulong size) => SetSizeValue(ref
        ↪  Links[node].SizeAsTarget, size);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GetLeftIsChild(ulong node) =>
        ↪  GetLeftIsChildValue(Links[node].SizeAsTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeftIsChild(ulong node, bool value) =>
        ↪  SetLeftIsChildValue(ref Links[node].SizeAsTarget, value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GetRightIsChild(ulong node) =>
        ↪  GetRightIsChildValue(Links[node].SizeAsTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRightIsChild(ulong node, bool value) =>
        ↪  SetRightIsChildValue(ref Links[node].SizeAsTarget, value);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override sbyte GetBalance(ulong node) =>
        ↪  GetBalanceValue(Links[node].SizeAsTarget);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetBalance(ulong node, sbyte value) => SetBalanceValue(ref
        ↪  Links[node].SizeAsTarget, value);

        [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;
        }
    }
}
```

## 1.61 ./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 = OUL;
            link.RightAsTarget = OUL;
            link.SizeAsTarget = OUL;
        }
    }
}
```

## 1.62 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64UnitedMemoryLinks.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="ulong"
    ↪  />.</para>
    /// <para>Представляет низкоуровневую реализация прямого доступа к памяти с переменным
    ↪  размером, для организации хранения связей с адресами представленными в виде <see
    ↪  cref="ulong"/>.</para>
    /// </summary>
    public unsafe class UInt64UnitedMemoryLinks : UnitedMemoryLinksBase<ulong>
    {
        private readonly Func<ILinksTreeMethods<ulong>> _createSourceTreeMethods;
        private readonly Func<ILinksTreeMethods<ulong>> _createTargetTreeMethods;
        private LinksHeader<ulong>* _header;
        private RawLink<ulong>* _links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UInt64UnitedMemoryLinks(string address) : this(address, DefaultLinksSizeStep) { }

```

```
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
65          [MethodImpl(MethodImplOptions.AggressiveInlining)]
66          protected override void ResetPointers()
67          {
68              base.ResetPointers();
69              _links = null;
70              _header = null;
71          }
72
73          [MethodImpl(MethodImplOptions.AggressiveInlining)]
74          protected override ref LinksHeader<ulong> GetHeaderReference() => ref *_header;
75
76          [MethodImpl(MethodImplOptions.AggressiveInlining)]
77          protected override ref RawLink<ulong> GetLinkReference(ulong linkIndex) => ref
            ↪ _links[linkIndex];
78
79          [MethodImpl(MethodImplOptions.AggressiveInlining)]
80          protected override bool AreEqual(ulong first, ulong second) => first == second;
81
82          [MethodImpl(MethodImplOptions.AggressiveInlining)]
83          protected override bool LessThan(ulong first, ulong second) => first < second;
84
85          [MethodImpl(MethodImplOptions.AggressiveInlining)]
86          protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
87
88          [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
89          protected override bool GreaterThan(ulong first, ulong second) => first > second;
90
91          [MethodImpl(MethodImplOptions.AggressiveInlining)]
92          protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
93
94          [MethodImpl(MethodImplOptions.AggressiveInlining)]
95          protected override ulong GetZero() => 0UL;
96
97          [MethodImpl(MethodImplOptions.AggressiveInlining)]
98          protected override ulong GetOne() => 1UL;
99
100         [MethodImpl(MethodImplOptions.AggressiveInlining)]
101         protected override long ConvertToInt64(ulong value) => (long)value;
102
103         [MethodImpl(MethodImplOptions.AggressiveInlining)]
104         protected override ulong ConvertToAddress(long value) => (ulong)value;
105
106         [MethodImpl(MethodImplOptions.AggressiveInlining)]
107         protected override ulong Add(ulong first, ulong second) => first + second;
108
109         [MethodImpl(MethodImplOptions.AggressiveInlining)]
110         protected override ulong Subtract(ulong first, ulong second) => first - second;
111
112         [MethodImpl(MethodImplOptions.AggressiveInlining)]
113         protected override ulong Increment(ulong link) => ++link;
114
115         [MethodImpl(MethodImplOptions.AggressiveInlining)]
116         protected override ulong Decrement(ulong link) => --link;
117     }
118 }
```

## 1.63 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64UnusedLinksListMethods.cs

```
1  using System.Runtime.CompilerServices;
2  using Platform.Data.Doublets.Memory.United.Generic;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Memory.United.Specific
7  {
8      public unsafe class UInt64UnusedLinksListMethods : UnusedLinksListMethods<ulong>
9      {
10         private readonly RawLink<ulong>* _links;
11         private readonly LinksHeader<ulong>* _header;
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public UInt64UnusedLinksListMethods(RawLink<ulong>* links, LinksHeader<ulong>* header)
15             : base((byte*)links, (byte*)header)
16         {
17             _links = links;
18             _header = header;
19         }
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref _links[link];
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected override ref LinksHeader<ulong> GetHeaderReference() => ref *_header;
26     }
27 }
```

## 1.64 ./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;
```

```

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public AddressToUnaryNumberConverter(ILinks<TLink> links, IConverter<int, TLink>
        ↪  powerOf2ToUnaryNumberConverter) : base(links) => _powerOf2ToUnaryNumberConverter =
        ↪  powerOf2ToUnaryNumberConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(TLink number)
        {
            var links = _links;
            var nullConstant = links.Constants.Null;
            var target = nullConstant;
            for (var i = 0; !_equalityComparer.Equals(number, _zero) && i <
            ↪  NumericType<TLink>.BitsSize; i++)
            {
                if (_equalityComparer.Equals(Bit.And(number, _one), _one))
                {
                    target = _equalityComparer.Equals(target, nullConstant)
                        ? _powerOf2ToUnaryNumberConverter.Convert(i)
                        : links.GetOrCreate(_powerOf2ToUnaryNumberConverter.Convert(i), target);
                }
                number = Bit.ShiftRight(number, 1);
            }
            return target;
        }
    }
}
```

## 1.65 ./csharp/Platform.Data.Doublets/Numbers/Unary/LinkToItsFrequencyNumberConveter.cs

```
using System;
using System.Collections.Generic;
using Platform.Interfaces;
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 LinkToItsFrequencyNumberConveter<TLink> : LinksOperatorBase<TLink>,
    ↪  IConverter<Doublet<TLink>, TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly IProperty<TLink, TLink> _frequencyPropertyOperator;
        private readonly IConverter<TLink> _unaryNumberToAddressConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkToItsFrequencyNumberConveter(
            ILinks<TLink> links,
            IProperty<TLink, TLink> frequencyPropertyOperator,
            IConverter<TLink> unaryNumberToAddressConverter)
            : base(links)
        {
            _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);
        }
    }
}
```

## 1.66 ./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;
        }
    }
}
```

## 1.67 ./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);
    }
}
```

## 1.68 ./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));
    }
}
```

## 1.69 ./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);
        }
    }
}
```

## 1.70 ./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);
            }
        }
    }
}
```

## 1.71 ./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];
            }
        }
    }
}
```

## 1.72 ./csharp/Platform.Data.Doublets/Sequences/Converters/CompressingConverter.cs

```
using System;
using System.Collections.Generic;
```

```
3  using System.Runtime.CompilerServices;
4  using Platform.Collections;
5  using Platform.Converters;
6  using Platform.Singletons;
7  using Platform.Numbers;
8  using Platform.Data.Doublets.Sequences.Frequencies.Cache;
9
10 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
11
12 namespace Platform.Data.Doublets.Sequences.Converters
13 {
14     /// <remarks>
15     /// TODO: Возможно будет лучше если алгоритм будет выполняться полностью изолированно от
       ↪  Links на этапе сжатия.
16     ///     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.
17     ///     Как только список/словарь пар был выявлен можно разом выполнить создание всех этих
       ↪  пар, а так же разом выполнить замену.
18     /// </remarks>
19     public class CompressingConverter<TLink> : LinksListToSequenceConverterBase<TLink>
20     {
21         private static readonly LinksConstants<TLink> _constants =
           ↪  Default<LinksConstants<TLink>>.Instance;
22         private static readonly EqualityComparer<TLink> _equalityComparer =
           ↪  EqualityComparer<TLink>.Default;
23         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
24
25         private static readonly TLink _zero = default;
26         private static readonly TLink _one = Arithmetic.Increment(_zero);
27
28         private readonly IConverter<IList<TLink>, TLink> _baseConverter;
29         private readonly LinkFrequenciesCache<TLink> _doubletFrequenciesCache;
30         private readonly TLink _minFrequencyToCompress;
31         private readonly bool _doInitialFrequenciesIncrement;
32         private Doublet<TLink> _maxDoublet;
33         private LinkFrequency<TLink> _maxDoubletData;
34
35         private struct HalfDoublet
36         {
37             public TLink Element;
38             public LinkFrequency<TLink> DoubletData;
39
40             [MethodImpl(MethodImplOptions.AggressiveInlining)]
41             public HalfDoublet(TLink element, LinkFrequency<TLink> doubletData)
42             {
43                 Element = element;
44                 DoubletData = doubletData;
45             }
46
47             public override string ToString() => $"{Element}: ({DoubletData})";
48         }
49
50         [MethodImpl(MethodImplOptions.AggressiveInlining)]
51         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
```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Convert(IList<TLink> source) =>
        ↪  _baseConverter.Convert(Compress(source));

        /// <remarks>
        /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte_pair_encoding .
        /// Faster version (doublets' frequencies dictionary is not recreated).
        /// </remarks>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private IList<TLink> Compress(IList<TLink> sequence)
        {
            if (sequence.IsNullOrEmpty())
            {
                return null;
            }
            if (sequence.Count == 1)
            {
                return sequence;
            }
            if (sequence.Count == 2)
            {
                return new[] { _links.GetOrCreate(sequence[0], sequence[1]) };
            }
            // TODO: arraypool with min size (to improve cache locality) or stackallow with Sigil
            var copy = new HalfDoublet[sequence.Count];
            Doublet<TLink> doublet = default;
            for (var i = 1; i < sequence.Count; i++)
            {
                doublet = new Doublet<TLink>(sequence[i - 1], sequence[i]);
                LinkFrequency<TLink> data;
                if (_doInitialFrequenciesIncrement)
                {
                    data = _doubletFrequenciesCache.IncrementFrequency(ref doublet);
                }
                else
                {
                    data = _doubletFrequenciesCache.GetFrequency(ref doublet);
                    if (data == null)
                    {
                        throw new NotSupportedException("If you ask not to increment
                        ↪  frequencies, it is expected that all frequencies for the sequence
                        ↪  are prepared.");
                    }
                }
                copy[i - 1].Element = sequence[i - 1];
                copy[i - 1].DoubletData = data;
                UpdateMaxDoublet(ref doublet, data);
            }
            copy[sequence.Count - 1].Element = sequence[sequence.Count - 1];
            copy[sequence.Count - 1].DoubletData = new LinkFrequency<TLink>();
            if (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
            {
                var newLength = ReplaceDoublets(copy);
                sequence = new TLink[newLength];
                for (int i = 0; i < newLength; i++)
                {
                    sequence[i] = copy[i].Element;
                }
            }
            return sequence;
        }

        /// <remarks>
        /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte_pair_encoding
        /// </remarks>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private int ReplaceDoublets(HalfDoublet[] copy)
        {
            var oldLength = copy.Length;
            var newLength = copy.Length;
            while (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
            {
                var maxDoubletSource = _maxDoublet.Source;
                var maxDoubletTarget = _maxDoublet.Target;
                if (_equalityComparer.Equals(_maxDoubletData.Link, _constants.Null))
                {
                    _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 }
```

## 1.73 ./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 }
```

## 1.74 ./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];
```

```
            }
            if (length == 2)
            {
                return _links.GetOrCreate(sequence[0], sequence[1]);
            }
            sequence = sequence.ToArray();
            var levels = _sequenceToItsLocalElementLevelsConverter.Convert(sequence);
            while (length > 2)
            {
                var levelRepeat = 1;
                var currentLevel = levels[0];
                var previousLevel = levels[0];
                var skipOnce = false;
                var w = 0;
                for (var i = 1; i < length; i++)
                {
                    if (_equalityComparer.Equals(currentLevel, levels[i]))
                    {
                        levelRepeat++;
                        skipOnce = false;
                        if (levelRepeat == 2)
                        {
                            sequence[w] = _links.GetOrCreate(sequence[i - 1], sequence[i]);
                            var newLevel = i >= length - 1 ?
                                GetPreviousLowerThanCurrentOrCurrent(previousLevel,
                                ↪ currentLevel) :
                                i < 2 ?
                                GetNextLowerThanCurrentOrCurrent(currentLevel, levels[i + 1]) :
                                GetGreatestNeigbourLowerThanCurrentOrCurrent(previousLevel,
                                ↪ currentLevel, levels[i + 1]);
                            levels[w] = newLevel;
                            previousLevel = currentLevel;
                            w++;
                            levelRepeat = 0;
                            skipOnce = true;
                        }
                        else if (i == length - 1)
                        {
                            sequence[w] = sequence[i];
                            levels[w] = levels[i];
                            w++;
                        }
                    }
                    else
                    {
                        currentLevel = levels[i];
                        levelRepeat = 1;
                        if (skipOnce)
                        {
                            skipOnce = false;
                        }
                        else
                        {
                            sequence[w] = sequence[i - 1];
                            levels[w] = levels[i - 1];
                            previousLevel = levels[w];
                            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;
        }
```

```
114
115         [MethodImpl(MethodImplOptions.AggressiveInlining)]
116         private static TLink GetNextLowerThanCurrentOrCurrent(TLink current, TLink next) =>
            ↪ _comparer.Compare(next, current) < 0 ? next : current;
117
118         [MethodImpl(MethodImplOptions.AggressiveInlining)]
119         private static TLink GetPreviousLowerThanCurrentOrCurrent(TLink previous, TLink current)
            ↪ => _comparer.Compare(previous, current) < 0 ? previous : current;
120     }
121 }
```

### 1.75 ./csharp/Platform.Data.Doublets/Sequences/Converters/SequenceToItsLocalElementLevelsConverter.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 class SequenceToItsLocalElementLevelsConverter<TLink> : LinksOperatorBase<TLink>,
       ↪ IConverter<IList<TLink>>
10     {
11         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
12
13         private readonly IConverter<Doublet<TLink>, TLink> _linkToItsFrequencyToNumberConveter;
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         public SequenceToItsLocalElementLevelsConverter(ILinks<TLink> links,
           ↪ IConverter<Doublet<TLink>, TLink> linkToItsFrequencyToNumberConveter) : base(links)
           ↪ => _linkToItsFrequencyToNumberConveter = linkToItsFrequencyToNumberConveter;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         public IList<TLink> Convert(IList<TLink> sequence)
20         {
21             var levels = new TLink[sequence.Count];
22             levels[0] = GetFrequencyNumber(sequence[0], sequence[1]);
23             for (var i = 1; i < sequence.Count - 1; i++)
24             {
25                 var previous = GetFrequencyNumber(sequence[i - 1], sequence[i]);
26                 var next = GetFrequencyNumber(sequence[i], sequence[i + 1]);
27                 levels[i] = _comparer.Compare(previous, next) > 0 ? previous : next;
28             }
29             levels[levels.Length - 1] = GetFrequencyNumber(sequence[sequence.Count - 2],
               ↪ sequence[sequence.Count - 1]);
30             return levels;
31         }
32
33         [MethodImpl(MethodImplOptions.AggressiveInlining)]
34         public TLink GetFrequencyNumber(TLink source, TLink target) =>
           ↪ _linkToItsFrequencyToNumberConveter.Convert(new Doublet<TLink>(source, target));
35     }
36 }
```

### 1.76 ./csharp/Platform.Data.Doublets/Sequences/CriterionMatchers/DefaultSequenceElementCriterionMatcher.cs

```
1  using System.Runtime.CompilerServices;
2  using Platform.Interfaces;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Sequences.CriterionMatchers
7  {
8      public class DefaultSequenceElementCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
       ↪ ICriterionMatcher<TLink>
9      {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public DefaultSequenceElementCriterionMatcher(ILinks<TLink> links) : base(links) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public bool IsMatched(TLink argument) => _links.IsPartialPoint(argument);
15     }
16 }
```

### 1.77 ./csharp/Platform.Data.Doublets/Sequences/CriterionMatchers/MarkedSequenceCriterionMatcher.cs

```
1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Interfaces;
4
5  #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);
    }
}
```

## 1.78 ./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);
        }
    }
}
```

## 1.79 ./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);
    }
}
```

## 1.80 ./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;
        private static readonly UncheckedConverter<ulong, TLink> _uInt64ToAddressConverter =
        ↪  UncheckedConverter<ulong, TLink>.Default;

        private readonly ILinks<TLink> _links;
        private readonly ILinks<TLink> _sequences;
        private HashSet<KeyValuePair<IList<TLink>, IList<TLink>>> _groups;
        private BitString _visited;

        private class ItemEquilityComparer : IEqualityComparer<KeyValuePair<IList<TLink>,
        ↪  IList<TLink>>>
        {
            private readonly IListEqualityComparer<TLink> _listComparer;

            public ItemEquilityComparer() => _listComparer =
            ↪  Default<IListEqualityComparer<TLink>>.Instance;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            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);

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
            public int GetHashCode(KeyValuePair<IList<TLink>, IList<TLink>> pair) =>
            ↪  (_listComparer.GetHashCode(pair.Key),
            ↪  _listComparer.GetHashCode(pair.Value)).GetHashCode();
        }

        private class ItemComparer : IComparer<KeyValuePair<IList<TLink>, IList<TLink>>>
        {
            private readonly IListComparer<TLink> _listComparer;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public ItemComparer() => _listComparer = Default<IListComparer<TLink>>.Instance;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public int Compare(KeyValuePair<IList<TLink>, IList<TLink>> left,
            ↪  KeyValuePair<IList<TLink>, IList<TLink>> right)
            {
                var intermediateResult = _listComparer.Compare(left.Key, right.Key);
                if (intermediateResult == 0)
                {
                    intermediateResult = _listComparer.Compare(left.Value, right.Value);
                }
                return intermediateResult;
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DuplicateSegmentsProvider(ILinks<TLink> links, ILinks<TLink> sequences)
            : base(minimumStringSegmentLength: 2)
        {
            _links = links;
            _sequences = sequences;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public IList<KeyValuePair<IList<TLink>, IList<TLink>>> Get()
        {
            _groups = new HashSet<KeyValuePair<IList<TLink>,
            ↪  IList<TLink>>>(Default<ItemEquilityComparer>.Instance);
            var links = _links;
            var count = links.Count();
            _visited = new BitString(_addressToInt64Converter.Convert(count) + 1L);
            links.Each(link =>
            {
                var linkIndex = links.GetIndex(link);
                var linkBitIndex = _addressToInt64Converter.Convert(linkIndex);
                var constants = links.Constants;
                if (!_visited.Get(linkBitIndex))
                {
                    var sequenceElements = new List<TLink>();
                    var filler = new ListFiller<TLink, TLink>(sequenceElements, constants.Break);
                    _sequences.Each(filler.AddSkipFirstAndReturnConstant, new
                    ↪  LinkAddress<TLink>(linkIndex));
                    if (sequenceElements.Count > 2)
                    {
                        WalkAll(sequenceElements);
                    }
                }
                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);
```

```
112             if (duplicates.Count > 1)
113             {
114                 _groups.Add(new KeyValuePair<IList<TLink>, IList<TLink>>(segment.ToArray(),
                    ↪ duplicates));
115             }
116         }
117 
118         [MethodImpl(MethodImplOptions.AggressiveInlining)]
119         private List<TLink> CollectDuplicatesForSegment(Segment<TLink> segment)
120         {
121             var duplicates = new List<TLink>();
122             var readAsElement = new HashSet<TLink>();
123             var restrictions = segment.ShiftRight();
124             var constants = _links.Constants;
125             restrictions[0] = constants.Any;
126             _sequences.Each(sequence =>
127             {
128                 var sequenceIndex = sequence[constants.IndexPart];
129                 duplicates.Add(sequenceIndex);
130                 readAsElement.Add(sequenceIndex);
131                 return constants.Continue;
132             }, restrictions);
133             if (duplicates.Any(x => _visited.Get(_addressToInt64Converter.Convert(x))))
134             {
135                 return new List<TLink>();
136             }
137             foreach (var duplicate in duplicates)
138             {
139                 var duplicateBitIndex = _addressToInt64Converter.Convert(duplicate);
140                 _visited.Set(duplicateBitIndex);
141             }
142             if (_sequences is Sequences sequencesExperiments)
143             {
144                 var partiallyMatched = sequencesExperiments.GetAllPartiallyMatchingSequences4((H
                    ↪ ashSet<ulong>)(object)readAsElement,
                    ↪ (IList<ulong>)segment);
145                 foreach (var partiallyMatchedSequence in partiallyMatched)
146                 {
147                     var sequenceIndex =
                        ↪ _uInt64ToAddressConverter.Convert(partiallyMatchedSequence);
148                     duplicates.Add(sequenceIndex);
149                 }
150             }
151             duplicates.Sort();
152             return duplicates;
153         }
154 
155         [MethodImpl(MethodImplOptions.AggressiveInlining)]
156         private void PrintDuplicates(KeyValuePair<IList<TLink>, IList<TLink>> duplicatesItem)
157         {
158             if (!(_links is ILinks<ulong> ulongLinks))
159             {
160                 return;
161             }
162             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 }
```

## 1.81 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Cache/LinkFrequenciesCache.cs

```
1  using System;
2  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.Cache
{
    /// <remarks>
    /// Can be used to operate with many CompressingConverters (to keep global frequencies data between them).
    /// TODO: Extract interface to implement frequencies storage inside Links storage
    /// </remarks>
    public class LinkFrequenciesCache<TLink> : LinksOperatorBase<TLink>
    {
        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 Dictionary<Doublet<TLink>, LinkFrequency<TLink>> _doubletsCache;
        private readonly ICounter<TLink, TLink> _frequencyCounter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkFrequenciesCache(ILinks<TLink> links, ICounter<TLink, TLink> frequencyCounter)
            : base(links)
        {
            _doubletsCache = new Dictionary<Doublet<TLink>, LinkFrequency<TLink>>(4096, DoubletComparer<TLink>.Default);
            _frequencyCounter = frequencyCounter;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkFrequency<TLink> GetFrequency(TLink source, TLink target)
        {
            var doublet = new Doublet<TLink>(source, target);
            return GetFrequency(ref doublet);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkFrequency<TLink> GetFrequency(ref Doublet<TLink> doublet)
        {
            _doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data);
            return data;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void IncrementFrequencies(IList<TLink> sequence)
        {
            for (var i = 1; i < sequence.Count; i++)
            {
                IncrementFrequency(sequence[i - 1], sequence[i]);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkFrequency<TLink> IncrementFrequency(TLink source, TLink target)
        {
            var doublet = new Doublet<TLink>(source, target);
            return IncrementFrequency(ref doublet);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void PrintFrequencies(IList<TLink> sequence)
        {
            for (var i = 1; i < sequence.Count; i++)
            {
                PrintFrequency(sequence[i - 1], sequence[i]);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void PrintFrequency(TLink source, TLink target)
        {
            var number = GetFrequency(source, target).Frequency;
            Console.WriteLine("({0},{1}) - {2}", source, target, number);
        }
```

```

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkFrequency<TLink> IncrementFrequency(ref Doublet<TLink> doublet)
        {
            if (_doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data))
            {
                data.IncrementFrequency();
            }
            else
            {
                var link = _links.SearchOrDefault(doublet.Source, doublet.Target);
                data = new LinkFrequency<TLink>(_one, link);
                if (!_equalityComparer.Equals(link, default))
                {
                    data.Frequency = Arithmetic.Add(data.Frequency,
                    ↪  _frequencyCounter.Count(link));
                }
                _doubletsCache.Add(doublet, data);
            }
            return data;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void ValidateFrequencies()
        {
            foreach (var entry in _doubletsCache)
            {
                var value = entry.Value;
                var linkIndex = value.Link;
                if (!_equalityComparer.Equals(linkIndex, default))
                {
                    var frequency = value.Frequency;
                    var count = _frequencyCounter.Count(linkIndex);
                    // TODO: Why `frequency` always greater than `count` by 1?
                    if (((_comparer.Compare(frequency, count) > 0) &&
                    ↪  (_comparer.Compare(Arithmetic.Subtract(frequency, count), _one) > 0))
                     || ((_comparer.Compare(count, frequency) > 0) &&
                     ↪  (_comparer.Compare(Arithmetic.Subtract(count, frequency), _one) > 0)))
                    {
                        throw new InvalidOperationException("Frequencies validation failed.");
                    }
                }
                //else
                //{
                //    if (value.Frequency > 0)
                //    {
                //        var frequency = value.Frequency;
                //        linkIndex = _createLink(entry.Key.Source, entry.Key.Target);
                //        var count = _countLinkFrequency(linkIndex);

                //        if ((frequency > count && frequency - count > 1) || (count > frequency
                ↪  && count - frequency > 1))
                //            throw new InvalidOperationException("Frequencies validation
                ↪  failed.");
                //    }
                //}
            }
        }
    }
}
```

## 1.82 ./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}";
    }
}
```

## 1.83 ./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;
    }
}
```

## 1.84 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/MarkedSequenceSymbolFrequencyOneOf

```
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();
        }
    }
}
```

## 1.85 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/SequenceSymbolFrequencyOneOffCounte

```
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;
        }
    }
}
```

## 1.86 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalMarkedSequenceSymbolFrequencyC

```
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();
    }
}
```

### 1.87 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalMarkedSequenceSymbolFrequencyC

```
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());
        }
    }
}
```

### 1.88 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalSequenceSymbolFrequencyCounter.

```
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();
    }
}
```

### 1.89 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalSequenceSymbolFrequencyOneOffC

```
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;
```

```
27          }
28
29          [MethodImpl(MethodImplOptions.AggressiveInlining)]
30          public TLink Count()
31          {
32              if (_comparer.Compare(_total, default) > 0 || _visits.Count > 0)
33              {
34                  return _total;
35              }
36              CountCore(_symbol);
37              return _total;
38          }
39
40          [MethodImpl(MethodImplOptions.AggressiveInlining)]
41          private void CountCore(TLink link)
42          {
43              var any = _links.Constants.Any;
44              if (_equalityComparer.Equals(_links.Count(any, link), default))
45              {
46                  CountSequenceSymbolFrequency(link);
47              }
48              else
49              {
50                  _links.Each(EachElementHandler, any, link);
51              }
52          }
53
54          [MethodImpl(MethodImplOptions.AggressiveInlining)]
55          protected virtual void CountSequenceSymbolFrequency(TLink link)
56          {
57              var symbolFrequencyCounter = new SequenceSymbolFrequencyOneOffCounter<TLink>(_links,
                ↪  link, _symbol);
58              _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
59          }
60
61          [MethodImpl(MethodImplOptions.AggressiveInlining)]
62          private TLink EachElementHandler(IList<TLink> doublet)
63          {
64              var constants = _links.Constants;
65              var doubletIndex = doublet[constants.IndexPart];
66              if (_visits.Add(doubletIndex))
67              {
68                  CountCore(doubletIndex);
69              }
70              return constants.Continue;
71          }
72      }
73  }
```

## 1.90 ./csharp/Platform.Data.Doublets/Sequences/HeightProviders/CachedSequenceHeightProvider.cs

```
1   using System.Collections.Generic;
2   using System.Runtime.CompilerServices;
3   using Platform.Interfaces;
4   using Platform.Converters;
5
6   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8   namespace Platform.Data.Doublets.Sequences.HeightProviders
9   {
10      public class CachedSequenceHeightProvider<TLink> : ISequenceHeightProvider<TLink>
11      {
12          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪  EqualityComparer<TLink>.Default;
13
14          private readonly TLink _heightPropertyMarker;
15          private readonly ISequenceHeightProvider<TLink> _baseHeightProvider;
16          private readonly IConverter<TLink> _addressToUnaryNumberConverter;
17          private readonly IConverter<TLink> _unaryNumberToAddressConverter;
18          private readonly IProperties<TLink, TLink, TLink> _propertyOperator;
19
20          [MethodImpl(MethodImplOptions.AggressiveInlining)]
21          public CachedSequenceHeightProvider(
22              ISequenceHeightProvider<TLink> baseHeightProvider,
23              IConverter<TLink> addressToUnaryNumberConverter,
24              IConverter<TLink> unaryNumberToAddressConverter,
25              TLink heightPropertyMarker,
26              IProperties<TLink, TLink, TLink> propertyOperator)
27          {
28              _heightPropertyMarker = heightPropertyMarker;
29              _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;
        }
    }
}
```

## 1.91 ./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;
        }
    }
}
```

## 1.92 ./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>
    {
    }
}
```

## 1.93 ./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);
        }
    }
}
```

## 1.94 ./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;
```

```
15          private readonly IIncrementer<TLink> _frequencyIncrementer;
16
17          [MethodImpl(MethodImplOptions.AggressiveInlining)]
18          public FrequencyIncrementingSequenceIndex(ILinks<TLink> links, IProperty<TLink, TLink>
            ↪  frequencyPropertyOperator, IIncrementer<TLink> frequencyIncrementer)
19              : base(links)
20          {
21              _frequencyPropertyOperator = frequencyPropertyOperator;
22              _frequencyIncrementer = frequencyIncrementer;
23          }
24
25          [MethodImpl(MethodImplOptions.AggressiveInlining)]
26          public override bool Add(IList<TLink> sequence)
27          {
28              var indexed = true;
29              var i = sequence.Count;
30              while (--i >= 1 && (indexed = IsIndexedWithIncrement(sequence[i - 1], sequence[i])))
                ↪  { }
31              for (; i >= 1; i--)
32              {
33                  Increment(_links.GetOrCreate(sequence[i - 1], sequence[i]));
34              }
35              return indexed;
36          }
37
38          [MethodImpl(MethodImplOptions.AggressiveInlining)]
39          private bool IsIndexedWithIncrement(TLink source, TLink target)
40          {
41              var link = _links.SearchOrDefault(source, target);
42              var indexed = !_equalityComparer.Equals(link, default);
43              if (indexed)
44              {
45                  Increment(link);
46              }
47              return indexed;
48          }
49
50          [MethodImpl(MethodImplOptions.AggressiveInlining)]
51          private void Increment(TLink link)
52          {
53              var previousFrequency = _frequencyPropertyOperator.Get(link);
54              var frequency = _frequencyIncrementer.Increment(previousFrequency);
55              _frequencyPropertyOperator.Set(link, frequency);
56          }
57      }
58  }
```

## 1.95 ./csharp/Platform.Data.Doublets/Sequences/Indexes/ISequenceIndex.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.Sequences.Indexes
7   {
8       public interface ISequenceIndex<TLink>
9       {
10          /// <summary>
11          /// Индексирует последовательность глобально, и возвращает значение,
12          /// определяющие была ли запрошенная последовательность проиндексирована ранее.
13          /// </summary>
14          /// <param name="sequence">Последовательность для индексации.</param>
15          [MethodImpl(MethodImplOptions.AggressiveInlining)]
16          bool Add(IList<TLink> sequence);
17
18          [MethodImpl(MethodImplOptions.AggressiveInlining)]
19          bool MightContain(IList<TLink> sequence);
20      }
21  }
```

## 1.96 ./csharp/Platform.Data.Doublets/Sequences/Indexes/SequenceIndex.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.Sequences.Indexes
7   {
8       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;
        }
    }
}
```

## 1.97 ./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)]
```

```
41          public bool MightContain(IList<TLink> sequence)
42          {
43              var links = _links.Unsync;
44              return _links.SyncRoot.ExecuteReadOperation(() =>
45              {
46                  var indexed = true;
47                  var i = sequence.Count;
48                  while (--i >= 1 && (indexed =
                        ↪  !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
                        ↪  sequence[i]), default))) { }
49                  return indexed;
50              });
51          }
52      }
53  }
```

## 1.98 ./csharp/Platform.Data.Doublets/Sequences/Indexes/Unindex.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.Sequences.Indexes
7   {
8       public class Unindex<TLink> : ISequenceIndex<TLink>
9       {
10          [MethodImpl(MethodImplOptions.AggressiveInlining)]
11          public virtual bool Add(IList<TLink> sequence) => false;
12
13          [MethodImpl(MethodImplOptions.AggressiveInlining)]
14          public virtual bool MightContain(IList<TLink> sequence) => true;
15      }
16  }
```

## 1.99 ./csharp/Platform.Data.Doublets/Sequences/Sequences.Experiments.cs

```
1   using System;
2   using System.Collections.Generic;
3   using System.Runtime.CompilerServices;
4   using System.Linq;
5   using System.Text;
6   using Platform.Collections;
7   using Platform.Collections.Sets;
8   using Platform.Collections.Stacks;
9   using Platform.Data.Exceptions;
10  using Platform.Data.Sequences;
11  using Platform.Data.Doublets.Sequences.Frequencies.Counters;
12  using Platform.Data.Doublets.Sequences.Walkers;
13  using LinkIndex = System.UInt64;
14  using Stack = System.Collections.Generic.Stack<ulong>;
15
16  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
17
18  namespace Platform.Data.Doublets.Sequences
19  {
20      partial class Sequences
21      {
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
```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private ulong[] CreateAllVariants2Core(ulong[] sequence, long startAt, long stopAt)
        {
#if DEBUG
            if ((stopAt - startAt) < 0)
            {
                throw new ArgumentOutOfRangeException(nameof(startAt), "startAt должен быть меньше или равен stopAt");
            }
#endif
            if ((stopAt - startAt) == 0)
            {
                return new[] { sequence[startAt] };
            }
            if ((stopAt - startAt) == 1)
            {
                return new[] { Links.Unsync.GetOrCreate(sequence[startAt], sequence[stopAt]) };
            }
            var variants = new ulong[(ulong)Platform.Numbers.Math.Catalan(stopAt - startAt)];
            var last = 0;
            for (var splitter = startAt; splitter < stopAt; splitter++)
            {
                var left = CreateAllVariants2Core(sequence, startAt, splitter);
                var right = CreateAllVariants2Core(sequence, splitter + 1, stopAt);
                for (var i = 0; i < left.Length; i++)
                {
                    for (var j = 0; j < right.Length; j++)
                    {
                        var variant = Links.Unsync.GetOrCreate(left[i], right[j]);
                        if (variant == Constants.Null)
                        {
                            throw new NotImplementedException("Creation cancellation is not implemented.");
                        }
                        variants[last++] = variant;
                    }
                }
            }
            return variants;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public List<ulong> CreateAllVariants1(params ulong[] sequence)
        {
            return _sync.ExecuteWriteOperation(() =>
            {
                if (sequence.IsNullOrEmpty())
                {
                    return new List<ulong>();
                }
                Links.Unsync.EnsureLinkExists(sequence);
                if (sequence.Length == 1)
                {
                    return new List<ulong> { sequence[0] };
                }
                var results = new List<ulong>((int)Platform.Numbers.Math.Catalan(sequence.Length));
                return CreateAllVariants1Core(sequence, results);
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private List<ulong> CreateAllVariants1Core(ulong[] sequence, List<ulong> results)
        {
            if (sequence.Length == 2)
            {
                var link = Links.Unsync.GetOrCreate(sequence[0], sequence[1]);
                if (link == Constants.Null)
                {
                    throw new NotImplementedException("Creation cancellation is not implemented.");
                }
                results.Add(link);
                return results;
            }
            var innerSequenceLength = sequence.Length - 1;
            var innerSequence = new ulong[innerSequenceLength];
            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                     {
173                         continue;
174                     }
175                     var linkIndex = li;
176                     ulong[] innerSequence = null;
177                     Links.Unsync.Each(doublet =>
178                     {
179                         if (innerSequence == null)
180                         {
181                             innerSequence = new ulong[innerSequenceLength];
182                             for (var isi = 0; isi < linkIndex; isi++)
183                             {
184                                 innerSequence[isi] = sequence[isi];
185                             }
186                             for (var isi = linkIndex + 1; isi < innerSequenceLength; isi++)
187                             {
188                                 innerSequence[isi] = sequence[isi + 1];
189                             }
190                         }
191                         innerSequence[linkIndex] = doublet[Constants.IndexPart];
192                         Each1(handler, innerSequence);
193                         return Constants.Continue;
194                     }, Constants.Any, left, right);
195                 }
196             }
```

```
197         }
198
199         [MethodImpl(MethodImplOptions.AggressiveInlining)]
200         public HashSet<ulong> EachPart(params ulong[] sequence)
201         {
202             var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
203             EachPartCore(link =>
204             {
205                 var linkIndex = link[Constants.IndexPart];
206                 if (!visitedLinks.Contains(linkIndex))
207                 {
208                     visitedLinks.Add(linkIndex); // изучить почему случаются повторы
209                 }
210                 return Constants.Continue;
211             }, sequence);
212             return visitedLinks;
213         }
214
215         [MethodImpl(MethodImplOptions.AggressiveInlining)]
216         public void EachPart(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[] sequence)
217         {
218             var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
219             EachPartCore(link =>
220             {
221                 var linkIndex = link[Constants.IndexPart];
222                 if (!visitedLinks.Contains(linkIndex))
223                 {
224                     visitedLinks.Add(linkIndex); // изучить почему случаются повторы
225                     return handler(new LinkAddress<LinkIndex>(linkIndex));
226                 }
227                 return Constants.Continue;
228             }, sequence);
229         }
230
231         [MethodImpl(MethodImplOptions.AggressiveInlining)]
232         private void EachPartCore(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[]
        ↪  sequence)
233         {
234             if (sequence.IsNullOrEmpty())
235             {
236                 return;
237             }
238             Links.EnsureLinkIsAnyOrExists(sequence);
239             if (sequence.Length == 1)
240             {
241                 var link = sequence[0];
242                 if (link > 0)
243                 {
244                     handler(new LinkAddress<LinkIndex>(link));
245                 }
246                 else
247                 {
248                     Links.Each(Constants.Any, Constants.Any, handler);
249                 }
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                     }
```

```
                    return true;
                });
                //          ._x o_.
                //           |___|
                PartialStepRight(x => handler(x), sequence[0], sequence[1]);
            }
            else
            {
                throw new NotImplementedException();
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void PartialStepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
        {
            Links.Unsync.Each(Constants.Any, left, doublet =>
            {
                StepRight(handler, doublet, right);
                if (left != doublet)
                {
                    PartialStepRight(handler, doublet, right);
                }
                return true;
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void StepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
        {
            Links.Unsync.Each(left, Constants.Any, rightStep =>
            {
                TryStepRightUp(handler, right, rightStep);
                return true;
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void TryStepRightUp(Action<IList<LinkIndex>> handler, ulong right, ulong
        ↪  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)
            {
                handler(new LinkAddress<LinkIndex>(stepFrom));
            }
        }

        // 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)]
```

```
352         private void TryStepLeftUp(Action<IList<LinkIndex>> handler, ulong left, ulong stepFrom)
353         {
354             var upStep = stepFrom;
355             var firstTarget = Links.Unsync.GetSource(upStep);
356             while (firstTarget != left && firstTarget != upStep)
357             {
358                 upStep = firstTarget;
359                 firstTarget = Links.Unsync.GetTarget(upStep);
360             }
361             if (firstTarget == left)
362             {
363                 handler(new LinkAddress<LinkIndex>(stepFrom));
364             }
365         }
366 
367         [MethodImpl(MethodImplOptions.AggressiveInlining)]
368         private bool StartsWith(ulong sequence, ulong link)
369         {
370             var upStep = sequence;
371             var firstSource = Links.Unsync.GetSource(upStep);
372             while (firstSource != link && firstSource != upStep)
373             {
374                 upStep = firstSource;
375                 firstSource = Links.Unsync.GetSource(upStep);
376             }
377             return firstSource == link;
378         }
379 
380         [MethodImpl(MethodImplOptions.AggressiveInlining)]
381         private bool EndsWith(ulong sequence, ulong link)
382         {
383             var upStep = sequence;
384             var lastTarget = Links.Unsync.GetTarget(upStep);
385             while (lastTarget != link && lastTarget != upStep)
386             {
387                 upStep = lastTarget;
388                 lastTarget = Links.Unsync.GetTarget(upStep);
389             }
390             return lastTarget == link;
391         }
392 
393         [MethodImpl(MethodImplOptions.AggressiveInlining)]
394         public List<ulong> GetAllMatchingSequences0(params ulong[] sequence)
395         {
396             return _sync.ExecuteReadOperation(() =>
397             {
398                 var results = new List<ulong>();
399                 if (sequence.Length > 0)
400                 {
401                     Links.EnsureLinkExists(sequence);
402                     var firstElement = sequence[0];
403                     if (sequence.Length == 1)
404                     {
405                         results.Add(firstElement);
406                         return results;
407                     }
408                     if (sequence.Length == 2)
409                     {
410                         var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
411                         if (doublet != Constants.Null)
412                         {
413                             results.Add(doublet);
414                         }
415                         return results;
416                     }
417                     var linksInSequence = new HashSet<ulong>(sequence);
418                     void handler(IList<LinkIndex> result)
419                     {
420                         var resultIndex = result[Links.Constants.IndexPart];
421                         var filterPosition = 0;
422                         StopableSequenceWalker.WalkRight(resultIndex, Links.Unsync.GetSource,
                            ↪  Links.Unsync.GetTarget,
423                             x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
                                ↪  x =>
424                             {
425                                 if (filterPosition == sequence.Length)
426                                 {
427                                     filterPosition = -2; // Длиннее чем нужно
428                                     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;
            });
        }
```

```
504
505         public const int MaxSequenceFormatSize = 200;
506
507         [MethodImpl(MethodImplOptions.AggressiveInlining)]
508         public string FormatSequence(LinkIndex sequenceLink, params LinkIndex[] knownElements)
            ↪  => FormatSequence(sequenceLink, (sb, x) => sb.Append(x), true, knownElements);
509
510         [MethodImpl(MethodImplOptions.AggressiveInlining)]
511         public string FormatSequence(LinkIndex sequenceLink, Action<StringBuilder, LinkIndex>
            ↪  elementToString, bool insertComma, params LinkIndex[] knownElements) =>
            ↪  Links.SyncRoot.ExecuteReadOperation(() => FormatSequence(Links.Unsync, sequenceLink,
            ↪  elementToString, insertComma, knownElements));
512
513         [MethodImpl(MethodImplOptions.AggressiveInlining)]
514         private string FormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
            ↪  Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
            ↪  LinkIndex[] knownElements)
515         {
516             var linksInSequence = new HashSet<ulong>(knownElements);
517             //var entered = new HashSet<ulong>();
518             var sb = new StringBuilder();
519             sb.Append('{');
520             if (links.Exists(sequenceLink))
521             {
522                 StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
523                     x => linksInSequence.Contains(x) || links.IsPartialPoint(x), element => //
                        ↪  entered.AddAndReturnVoid, x => { }, entered.DoNotContains
524                     {
525                         if (insertComma && sb.Length > 1)
526                         {
527                             sb.Append(',');
528                         }
529                         //if (entered.Contains(element))
530                         //{
531                         //    sb.Append('{');
532                         //    elementToString(sb, element);
533                         //    sb.Append('}');
534                         //}
535                         //else
536                         elementToString(sb, element);
537                         if (sb.Length < MaxSequenceFormatSize)
538                         {
539                             return true;
540                         }
541                         sb.Append(insertComma ? ", ..." : "...");
542                         return false;
543                     });
544             }
545             sb.Append('}');
546             return sb.ToString();
547         }
548
549         [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 =>
```

```
                    {
                        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)]
        public List<ulong> GetAllPartiallyMatchingSequences0(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 List<ulong>();
                    var linksInSequence = new HashSet<ulong>(sequence);
                    foreach (var result in results)
                    {
                        var filterPosition = -1;
                        StopableSequenceWalker.WalkRight(result, Links.Unsync.GetSource,
                        ↪  Links.Unsync.GetTarget,
                            x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
                            ↪  x =>
                            {
                                if (filterPosition == (sequence.Length - 1))
                                {
                                    return false;
                                }
                                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;
        });
    }

    //public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
    //{
    //    return Sync.ExecuteReadOperation(() =>
    //    {
    //        if (sequence.Length > 0)
    //        {
    //            _links.EnsureEachLinkIsAnyOrExists(sequence);

    //            var firstResults = new HashSet<ulong>();
    //            var lastResults = new HashSet<ulong>();

    //            var first = sequence.First(x => x != LinksConstants.Any);
    //            var last = sequence.Last(x => x != LinksConstants.Any);

    //            AllUsagesCore(first, firstResults);
    //            AllUsagesCore(last, lastResults);

    //            firstResults.IntersectWith(lastResults);

    //            //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(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                         //    }
772                         //    else
773                         //    {
774                         //        results.IntersectWith(nextResults);
775                         //        nextResults.Clear();
776                         //    }
777                         //}
778                         var collector1 = new AllUsagesCollector1(Links.Unsync, results);
779                         collector1.Collect(Links.Unsync.GetLink(sequence[0]));
780                         var next = new HashSet<ulong>();
781                         for (var i = 1; i < sequence.Count; i++)
782                         {
783                             var collector = new AllUsagesCollector1(Links.Unsync, next);
784                             collector.Collect(Links.Unsync.GetLink(sequence[i]));
785 
786                             results.IntersectWith(next);
787                             next.Clear();
788                         }
789                         var filteredResults = new HashSet<ulong>();
790                         var matcher = new Matcher(this, sequence, filteredResults, null,
                            ↪  readAsElements);
791                         matcher.AddAllPartialMatchedToResultsAndReadAsElements(results.OrderBy(x =>
                            ↪  x)); // OrderBy is a Hack
792                         return filteredResults;
793                     }
794                     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;
```

```
867                     //////    if (matches.Count == 2)
868                     //////    {
869                     //////        var merged = new List<ulong>();
870                     //////        for (var j = 0; j < matches[0].Count; j++)
871                     //////            for (var k = 0; k < matches[1].Count; k++)
872                     //////                CloseInnerConnections(merged.Add, matches[0][j],
                        ↪  matches[1][k]);
873                     //////        if (merged.Count > 0)
874                     //////            matches = new List<List<ulong>> { merged };
875                     //////        else
876                     //////            return new List<ulong>();
877                     //////    }
878                     //////}
879                     //////if (matches.Count > 0)
880                     //////{
881                     //////    var usages = new HashSet<ulong>();
882                     //////    for (int i = 0; i < sequence.Length; i++)
883                     //////    {
884                     //////        AllUsagesCore(sequence[i], usages);
885                     //////    }
886                     //////    //for (int i = 0; i < matches[0].Count; i++)
887                     //////    //    AllUsagesCore(matches[0][i], usages);
888                     //////    //usages.UnionWith(matches[0]);
889                     //////    return usages.ToList();
890                     //////}
891                     var firstLinkUsages = new HashSet<ulong>();
892                     AllUsagesCore(sequence[0], firstLinkUsages);
893                     firstLinkUsages.Add(sequence[0]);
894                     //var previousMatchings = firstLinkUsages.ToList(); //new List<ulong>() {
                        ↪  sequence[0] }; // or all sequences, containing this element?
895                     //return GetAllPartiallyMatchingSequencesCore(sequence, firstLinkUsages,
                        ↪  1).ToList();
896                     var results = new HashSet<ulong>();
897                     foreach (var match in GetAllPartiallyMatchingSequencesCore(sequence,
                        ↪  firstLinkUsages, 1))
898                     {
899                         AllUsagesCore(match, results);
900                     }
901                     return results.ToList();
902                 }
903                 return new List<ulong>();
904             });
905         }
906 
907         /// <remarks>
908         /// TODO: Может потробоваться ограничение на уровень глубины рекурсии
909         /// </remarks>
910         [MethodImpl(MethodImplOptions.AggressiveInlining)]
911         public HashSet<ulong> AllUsages(ulong link)
912         {
913             return _sync.ExecuteReadOperation(() =>
914             {
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);
```

```
            calculator.Calculate();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void CalculateAllUsages2(ulong[] totals)
        {
            var calculator = new AllUsagesCalculator2(Links, totals);
            calculator.Calculate();
        }

        private class AllUsagesCalculator
        {
            private readonly SynchronizedLinks<ulong> _links;
            private readonly ulong[] _totals;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public AllUsagesCalculator(SynchronizedLinks<ulong> links, ulong[] totals)
            {
                _links = links;
                _totals = totals;
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
            ↪  CalculateCore);

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            private bool CalculateCore(ulong link)
            {
                if (_totals[link] == 0)
                {
                    var total = 1UL;
                    _totals[link] = total;
                    var visitedChildren = new HashSet<ulong>();
                    bool linkCalculator(ulong child)
                    {
                        if (link != child && visitedChildren.Add(child))
                        {
                            total += _totals[child] == 0 ? 1 : _totals[child];
                        }
                        return true;
                    }
                    _links.Unsync.Each(link, _links.Constants.Any, linkCalculator);
                    _links.Unsync.Each(_links.Constants.Any, link, linkCalculator);
                    _totals[link] = total;
                }
                return true;
            }
        }

        private class AllUsagesCalculator2
        {
            private readonly SynchronizedLinks<ulong> _links;
            private readonly ulong[] _totals;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public AllUsagesCalculator2(SynchronizedLinks<ulong> links, ulong[] totals)
            {
                _links = links;
                _totals = totals;
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
            ↪  CalculateCore);

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            private bool IsElement(ulong link)
            {
                //_linksInSequence.Contains(link) ||
                return _links.Unsync.GetTarget(link) == link || _links.Unsync.GetSource(link) ==
                ↪  link;
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            private bool CalculateCore(ulong link)
            {
                // TODO: Проработать защиту от зацикливания
                // Основано на SequenceWalker.WalkLeft
```

```
            Func<ulong, ulong> getSource = _links.Unsync.GetSource;
            Func<ulong, ulong> getTarget = _links.Unsync.GetTarget;
            Func<ulong, bool> isElement = IsElement;
            void visitLeaf(ulong parent)
            {
                if (link != parent)
                {
                    _totals[parent]++;
                }
            }
            void visitNode(ulong parent)
            {
                if (link != parent)
                {
                    _totals[parent]++;
                }
            }
            var stack = new Stack();
            var element = link;
            if (isElement(element))
            {
                visitLeaf(element);
            }
            else
            {
                while (true)
                {
                    if (isElement(element))
                    {
                        if (stack.Count == 0)
                        {
                            break;
                        }
                        element = stack.Pop();
                        var source = getSource(element);
                        var target = getTarget(element);
                        // Обработка элемента
                        if (isElement(target))
                        {
                            visitLeaf(target);
                        }
                        if (isElement(source))
                        {
                            visitLeaf(source);
                        }
                        element = source;
                    }
                    else
                    {
                        stack.Push(element);
                        visitNode(element);
                        element = getTarget(element);
                    }
                }
            }
            _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);
```

```
1168                 }
1169                 return true;
1170             }
1171         }
1172 
1173         private class AllUsagesCollector1
1174         {
1175             private readonly ILinks<ulong> _links;
1176             private readonly HashSet<ulong> _usages;
1177             private readonly ulong _continue;
1178 
1179             [MethodImpl(MethodImplOptions.AggressiveInlining)]
1180             public AllUsagesCollector1(ILinks<ulong> links, HashSet<ulong> usages)
1181             {
1182                 _links = links;
1183                 _usages = usages;
1184                 _continue = _links.Constants.Continue;
1185             }
1186 
1187             [MethodImpl(MethodImplOptions.AggressiveInlining)]
1188             public ulong Collect(IList<ulong> link)
1189             {
1190                 var linkIndex = _links.GetIndex(link);
1191                 if (_usages.Add(linkIndex))
1192                 {
1193                     _links.Each(Collect, _links.Constants.Any, linkIndex);
1194                 }
1195                 return _continue;
1196             }
1197         }
1198 
1199         private class AllUsagesCollector2
1200         {
1201             private readonly ILinks<ulong> _links;
1202             private readonly BitString _usages;
1203 
1204             [MethodImpl(MethodImplOptions.AggressiveInlining)]
1205             public AllUsagesCollector2(ILinks<ulong> links, BitString usages)
1206             {
1207                 _links = links;
1208                 _usages = usages;
1209             }
1210 
1211             [MethodImpl(MethodImplOptions.AggressiveInlining)]
1212             public bool Collect(ulong link)
1213             {
1214                 if (_usages.Add((long)link))
1215                 {
1216                     _links.Each(link, _links.Constants.Any, Collect);
1217                     _links.Each(_links.Constants.Any, link, Collect);
1218                 }
1219                 return true;
1220             }
1221         }
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);
```

```
                }
                _links.Unsync.Each(link, _links.Constants.Any, Collect);
                _links.Unsync.Each(_links.Constants.Any, link, Collect);
            }
            return true;
        }
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private void CloseInnerConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
    ↪  right)
    {
        TryStepLeftUp(handler, left, right);
        TryStepRightUp(handler, right, left);
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private void AllCloseConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
    ↪  right)
    {
        // Direct
        if (left == right)
        {
            handler(new LinkAddress<LinkIndex>(left));
        }
        var doublet = Links.Unsync.SearchOrDefault(left, right);
        if (doublet != Constants.Null)
        {
            handler(new LinkAddress<LinkIndex>(doublet));
        }
        // Inner
        CloseInnerConnections(handler, left, right);
        // Outer
        StepLeft(handler, left, right);
        StepRight(handler, left, right);
        PartialStepRight(handler, left, right);
        PartialStepLeft(handler, left, right);
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private HashSet<ulong> GetAllPartiallyMatchingSequencesCore(ulong[] sequence,
    ↪  HashSet<ulong> previousMatchings, long startAt)
    {
        if (startAt >= sequence.Length) // ?
        {
            return previousMatchings;
        }
        var secondLinkUsages = new HashSet<ulong>();
        AllUsagesCore(sequence[startAt], secondLinkUsages);
        secondLinkUsages.Add(sequence[startAt]);
        var matchings = new HashSet<ulong>();
        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)]
```

```
1388            public HashSet<ulong> GetAllConnections1(params ulong[] linksToConnect)
1389            {
1390                return _sync.ExecuteReadOperation(() =>
1391                {
1392                    var results = new HashSet<ulong>();
1393                    if (linksToConnect.Length > 0)
1394                    {
1395                        Links.EnsureLinkExists(linksToConnect);
1396                        var collector1 = new AllUsagesCollector(Links.Unsync, results);
1397                        collector1.Collect(linksToConnect[0]);
1398                        var next = new HashSet<ulong>();
1399                        for (var i = 1; i < linksToConnect.Length; i++)
1400                        {
1401                            var collector = new AllUsagesCollector(Links.Unsync, next);
1402                            collector.Collect(linksToConnect[i]);
1403                            results.IntersectWith(next);
1404                            next.Clear();
1405                        }
1406                    }
1407                    return results;
1408                });
1409            }
1410
1411            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1412            public HashSet<ulong> GetAllConnections2(params ulong[] linksToConnect)
1413            {
1414                return _sync.ExecuteReadOperation(() =>
1415                {
1416                    var results = new HashSet<ulong>();
1417                    if (linksToConnect.Length > 0)
1418                    {
1419                        Links.EnsureLinkExists(linksToConnect);
1420                        var collector1 = new AllUsagesCollector(Links, results);
1421                        collector1.Collect(linksToConnect[0]);
1422                        //AllUsagesCore(linksToConnect[0], results);
1423                        for (var i = 1; i < linksToConnect.Length; i++)
1424                        {
1425                            var next = new HashSet<ulong>();
1426                            var collector = new AllUsagesIntersectingCollector(Links, results, next);
1427                            collector.Collect(linksToConnect[i]);
1428                            //AllUsagesCore(linksToConnect[i], next);
1429                            //results.IntersectWith(next);
1430                            results = next;
1431                        }
1432                    }
1433                    return results;
1434                });
1435            }
1436
1437            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1438            public List<ulong> GetAllConnections3(params ulong[] linksToConnect)
1439            {
1440                return _sync.ExecuteReadOperation(() =>
1441                {
1442                    var results = new BitString((long)Links.Unsync.Count() + 1); // new
                        ↪  BitArray((int)_links.Total + 1);
1443                    if (linksToConnect.Length > 0)
1444                    {
1445                        Links.EnsureLinkExists(linksToConnect);
1446                        var collector1 = new AllUsagesCollector2(Links.Unsync, results);
1447                        collector1.Collect(linksToConnect[0]);
1448                        for (var i = 1; i < linksToConnect.Length; i++)
1449                        {
1450                            var next = new BitString((long)Links.Unsync.Count() + 1); //new
                                ↪  BitArray((int)_links.Total + 1);
1451                            var collector = new AllUsagesCollector2(Links.Unsync, next);
1452                            collector.Collect(linksToConnect[i]);
1453                            results = results.And(next);
1454                        }
1455                    }
1456                    return results.GetSetUInt64Indices();
1457                });
1458            }
1459
1460            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1461            private static ulong[] Simplify(ulong[] sequence)
1462            {
1463                // 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()
        {
            var sequence = new ulong[] { ZeroOrMany, ZeroOrMany, 2, 3, 4, ZeroOrMany,
            ↪  ZeroOrMany, ZeroOrMany, 4, ZeroOrMany, ZeroOrMany, ZeroOrMany };
            var simplifiedSequence = Simplify(sequence);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public List<ulong> GetSimilarSequences() => new List<ulong>();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Prediction()
        {
            //_links
            //sequences
        }

        #region From Triplets

        //public static void DeleteSequence(Link sequence)
        //{
        //}

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public List<ulong> CollectMatchingSequences(ulong[] links)
        {
            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)
1591                    {
1592                        for (var i = elements.Length - 1; i >= 0; i--)
1593                        {
1594                            var element = elements[i];
1595                            if (element != 0)
1596                            {
1597                                CollectMatchingSequences(leftLink, leftBound, middleLinks,
                                    ↪  elements[i], rightBound - 1, ref results);
1598                            }
1599                        }
1600                    }
1601                    else
1602                    {
1603                        for (var i = elements.Length - 1; i >= 0; i--)
1604                        {
1605                            var element = elements[i];
1606                            if (element != 0)
1607                            {
1608                                results.Add(element);
1609                            }
1610                        }
1611                    }
1612                }
1613            }
1614
1615            [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
1616            public ulong[] GetRightElements(ulong startLink, ulong rightLink)
1617            {
1618                var result = new ulong[5];
1619                TryStepRight(startLink, rightLink, result, 0);
1620                Links.Each(Constants.Any, startLink, couple =>
1621                {
1622                    if (couple != startLink)
1623                    {
1624                        if (TryStepRight(couple, rightLink, result, 2))
1625                        {
1626                            return false;
1627                        }
1628                    }
1629                    return true;
1630                });
1631                if (Links.GetTarget(Links.GetTarget(startLink)) == rightLink)
1632                {
1633                    result[4] = startLink;
1634                }
1635                return result;
1636            }
1637
1638            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1639            public bool TryStepRight(ulong startLink, ulong rightLink, ulong[] result, int offset)
1640            {
1641                var added = 0;
1642                Links.Each(startLink, Constants.Any, couple =>
1643                {
1644                    if (couple != startLink)
1645                    {
1646                        var coupleTarget = Links.GetTarget(couple);
1647                        if (coupleTarget == rightLink)
1648                        {
1649                            result[offset] = couple;
1650                            if (++added == 2)
1651                            {
1652                                return false;
1653                            }
1654                        }
1655                        else if (Links.GetSource(coupleTarget) == rightLink) // coupleTarget.Linker
                             ↪  == Net.And &&
1656                        {
1657                            result[offset + 1] = couple;
1658                            if (++added == 2)
1659                            {
1660                                return false;
1661                            }
1662                        }
1663                    }
1664                    return true;
1665                });
1666                return added > 0;
1667            }
1668
1669            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1670            public ulong[] GetLeftElements(ulong startLink, ulong leftLink)
1671            {
1672                var result = new ulong[5];
1673                TryStepLeft(startLink, leftLink, result, 0);
1674                Links.Each(startLink, Constants.Any, couple =>
1675                {
1676                    if (couple != startLink)
1677                    {
1678                        if (TryStepLeft(couple, leftLink, result, 2))
1679                        {
1680                            return false;
1681                        }
1682                    }
1683                    return true;
1684                });
1685                if (Links.GetSource(Links.GetSource(leftLink)) == startLink)
1686                {
1687                    result[4] = leftLink;
1688                }
1689                return result;
1690            }
1691
1692            [MethodImpl(MethodImplOptions.AggressiveInlining)]
1693            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;
                public long Start;
                public long Stop;
            }

            private readonly List<PatternBlock> _pattern;
            private int _patternPosition;
            private long _sequencePosition;

            #endregion

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public PatternMatcher(Sequences sequences, LinkIndex[] patternSequence, HashSet<LinkIndex> results)
                : base(sequences.Links.Unsync, new DefaultStack<ulong>())
            {
                _sequences = sequences;
                _patternSequence = patternSequence;
                _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x != _sequences.Constants.Any && x != ZeroOrMany));
                _results = results;
                _pattern = CreateDetailedPattern();
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            protected override bool IsElement(ulong link) => _linksInSequence.Contains(link) || base.IsElement(link);

            [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,
1822                                Stop = 1
1823                            };
1824                        }
1825                        else if (_patternSequence[i] == ZeroOrMany)
1826                        {
1827                            pattern.Add(patternBlock);
1828                            patternBlock = new PatternBlock
1829                            {
1830                                Type = PatternBlockType.Gap,
1831                                Start = 0,
1832                                Stop = long.MaxValue
1833                            };
1834                        }
1835                        else
1836                        {
1837                            patternBlock.Stop = i;
1838                        }
1839                    }
1840                    else // patternBlock.Type == PatternBlockType.Gap
1841                    {
1842                        if (_patternSequence[i] == _sequences.Constants.Any)
1843                        {
1844                            patternBlock.Start++;
1845                            if (patternBlock.Stop < patternBlock.Start)
1846                            {
1847                                patternBlock.Stop = patternBlock.Start;
1848                            }
1849                        }
```

```
                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
    }
}
```

## 1.100 ./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

namespace Platform.Data.Doublets.Sequences
{
    /// <summary>
    /// Представляет коллекцию последовательностей связей.
    /// </summary>
    /// <remarks>
    /// Обязательно реализовать атомарность каждого публичного метода.
    ///
    /// TODO:
    ///
    /// !!! Повышение вероятности повторного использования групп (подпоследовательностей),
    /// через естественную группировку по unicode типам, все whitespace вместе, все символы вместе, все числа вместе и т.п.
    /// + использовать ровно сбалансированный вариант, чтобы уменьшать вложенность (глубину графа)
    ///
    /// x*y - найти все связи между, в последовательностях любой формы, если не стоит ограничитель на то, что является последовательностью, а что нет,
    /// то находятся любые структуры связей, которые содержат эти элементы именно в таком порядке.
    ///
    /// Рост последовательности слева и справа.
    /// Поиск со звёздочкой.
    /// URL, PURL - реестр используемых во вне ссылок на ресурсы,
    /// так же проблема может быть решена при реализации дистанционных триггеров.
    /// Нужны ли уникальные указатели вообще?
    /// Что если обращение к информации будет происходить через содержимое всегда?
    ///
```

```
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                  }
84                  return !Links.Unsync.IsPartialPoint(sequence);
85              });
86          }
87
88          [MethodImpl(MethodImplOptions.AggressiveInlining)]
89          private LinkIndex GetSequenceByElements(LinkIndex sequence)
90          {
91              if (Options.UseSequenceMarker)
92              {
93                  return Links.SearchOrDefault(Options.SequenceMarkerLink, sequence);
94              }
95              return sequence;
96          }
97
98          [MethodImpl(MethodImplOptions.AggressiveInlining)]
99          private LinkIndex GetSequenceElements(LinkIndex sequence)
100         {
101             if (Options.UseSequenceMarker)
102             {
103                 var linkContents = new Link<ulong>(Links.GetLink(sequence));
104                 if (linkContents.Source == Options.SequenceMarkerLink)
105                 {
106                     return linkContents.Target;
107                 }
108                 if (linkContents.Target == Options.SequenceMarkerLink)
109                 {
110                     return linkContents.Source;
111                 }
112             }
```

```
113             return sequence;
114         }
115 
116         #region Count
117 
118         [MethodImpl(MethodImplOptions.AggressiveInlining)]
119         public LinkIndex Count(IList<LinkIndex> restrictions)
120         {
121             if (restrictions.IsNullOrEmpty())
122             {
123                 return Links.Count(Constants.Any, Options.SequenceMarkerLink, Constants.Any);
124             }
125             if (restrictions.Count == 1) // Первая связь это адрес
126             {
127                 var sequenceIndex = restrictions[0];
128                 if (sequenceIndex == Constants.Null)
129                 {
130                     return 0;
131                 }
132                 if (sequenceIndex == Constants.Any)
133                 {
134                     return Count(null);
135                 }
136                 if (Options.UseSequenceMarker)
137                 {
138                     return Links.Count(Constants.Any, Options.SequenceMarkerLink, sequenceIndex);
139                 }
140                 return Links.Exists(sequenceIndex) ? 1UL : 0;
141             }
142             throw new NotImplementedException();
143         }
144 
145         [MethodImpl(MethodImplOptions.AggressiveInlining)]
146         private LinkIndex CountUsages(params LinkIndex[] restrictions)
147         {
148             if (restrictions.Length == 0)
149             {
150                 return 0;
151             }
152             if (restrictions.Length == 1) // Первая связь это адрес
153             {
154                 if (restrictions[0] == Constants.Null)
155                 {
156                     return 0;
157                 }
158                 var any = Constants.Any;
159                 if (Options.UseSequenceMarker)
160                 {
161                     var elementsLink = GetSequenceElements(restrictions[0]);
162                     var sequenceLink = GetSequenceByElements(elementsLink);
163                     if (sequenceLink != Constants.Null)
164                     {
165                         return Links.Count(any, sequenceLink) + Links.Count(any, elementsLink) -
                            ↪ 1;
166                     }
167                     return Links.Count(any, elementsLink);
168                 }
169                 return Links.Count(any, restrictions[0]);
170             }
171             throw new NotImplementedException();
172         }
173 
174         #endregion
175 
176         #region Create
177 
178         [MethodImpl(MethodImplOptions.AggressiveInlining)]
179         public LinkIndex Create(IList<LinkIndex> restrictions)
180         {
181             return _sync.ExecuteWriteOperation(() =>
182             {
183                 if (restrictions.IsNullOrEmpty())
184                 {
185                     return Constants.Null;
186                 }
187                 Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
188                 return CreateCore(restrictions);
189             });
190         }
```

```
191
192         [MethodImpl(MethodImplOptions.AggressiveInlining)]
193         private LinkIndex CreateCore(IList<LinkIndex> restrictions)
194         {
195             LinkIndex[] sequence = restrictions.SkipFirst();
196             if (Options.UseIndex)
197             {
198                 Options.Index.Add(sequence);
199             }
200             var sequenceRoot = default(LinkIndex);
201             if (Options.EnforceSingleSequenceVersionOnWriteBasedOnExisting)
202             {
203                 var matches = Each(restrictions);
204                 if (matches.Count > 0)
205                 {
206                     sequenceRoot = matches[0];
207                 }
208             }
209             else if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew)
210             {
211                 return CompactCore(sequence);
212             }
213             if (sequenceRoot == default)
214             {
215                 sequenceRoot = Options.LinksToSequenceConverter.Convert(sequence);
216             }
217             if (Options.UseSequenceMarker)
218             {
219                 return Links.Unsync.GetOrCreate(Options.SequenceMarkerLink, sequenceRoot);
220             }
221             return sequenceRoot; // Возвращаем корень последовательности (т.е. сами элементы)
222         }
223
224         #endregion
225
226         #region Each
227
228         [MethodImpl(MethodImplOptions.AggressiveInlining)]
229         public List<LinkIndex> Each(IList<LinkIndex> sequence)
230         {
231             var results = new List<LinkIndex>();
232             var filler = new ListFiller<LinkIndex, LinkIndex>(results, Constants.Continue);
233             Each(filler.AddFirstAndReturnConstant, sequence);
234             return results;
235         }
236
237         [MethodImpl(MethodImplOptions.AggressiveInlining)]
238         public LinkIndex Each(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
        ↪  restrictions)
239         {
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);
```

```
                    if (sequenceLinkValues[Constants.SourcePart] ==
                    ↪  Options.SequenceMarkerLink)
                    {
                        link = sequenceLinkValues[Constants.TargetPart];
                    }
                }
                var sequence = Options.Walker.Walk(link).ToArray().ShiftRight();
                sequence[0] = link;
                return handler(sequence);
            }
            else if (restrictions.Count == 2)
            {
                throw new NotImplementedException();
            }
            else if (restrictions.Count == 3)
            {
                return Links.Unsync.Each(handler, restrictions);
            }
            else
            {
                var sequence = restrictions.SkipFirst();
                if (Options.UseIndex && !Options.Index.MightContain(sequence))
                {
                    return Constants.Break;
                }
                return EachCore(handler, sequence);
            }
        });
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private LinkIndex EachCore(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
    ↪  values)
    {
        var matcher = new Matcher(this, values, new HashSet<LinkIndex>(), handler);
        // TODO: Find out why matcher.HandleFullMatched executed twice for the same sequence
        ↪  Id.
        Func<IList<LinkIndex>, LinkIndex> innerHandler = Options.UseSequenceMarker ?
        ↪  (Func<IList<LinkIndex>, LinkIndex>)matcher.HandleFullMatchedSequence :
        ↪  matcher.HandleFullMatched;
        //if (sequence.Length >= 2)
        if (StepRight(innerHandler, values[0], values[1]) != Constants.Continue)
        {
            return Constants.Break;
        }
        var last = values.Count - 2;
        for (var i = 1; i < last; i++)
        {
            if (PartialStepRight(innerHandler, values[i], values[i + 1]) !=
            ↪  Constants.Continue)
            {
                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);
```

```
406                 Links.EnsureLinkExists(newSequence);
407                 return UpdateCore(sequence, newSequence);
408             }));
409         }
410 
411         [MethodImpl(MethodImplOptions.AggressiveInlining)]
412         private LinkIndex UpdateCore(IList<LinkIndex> sequence, IList<LinkIndex> newSequence)
413         {
414             LinkIndex bestVariant;
415             if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew &&
                ↪  !sequence.EqualTo(newSequence))
416             {
417                 bestVariant = CompactCore(newSequence);
418             }
419             else
420             {
421                 bestVariant = CreateCore(newSequence);
422             }
423             // TODO: Check all options only ones before loop execution
424             // Возможно нужно две версии Each, возвращающий фактические последовательности и с
                ↪  маркером,
425             // или возможно даже возвращать и тот и тот вариант. С другой стороны все варианты
                ↪  можно получить имея только фактические последовательности.
426             foreach (var variant in Each(sequence))
427             {
428                 if (variant != bestVariant)
429                 {
430                     UpdateOneCore(variant, bestVariant);
431                 }
432             }
433             return bestVariant;
434         }
435 
436         [MethodImpl(MethodImplOptions.AggressiveInlining)]
437         private void UpdateOneCore(LinkIndex sequence, LinkIndex newSequence)
438         {
439             if (Options.UseGarbageCollection)
440             {
441                 var sequenceElements = GetSequenceElements(sequence);
442                 var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
443                 var sequenceLink = GetSequenceByElements(sequenceElements);
444                 var newSequenceElements = GetSequenceElements(newSequence);
445                 var newSequenceLink = GetSequenceByElements(newSequenceElements);
446                 if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
447                 {
448                     if (sequenceLink != Constants.Null)
449                     {
450                         Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
451                     }
452                     Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
453                 }
454                 ClearGarbage(sequenceElementsContents.Source);
455                 ClearGarbage(sequenceElementsContents.Target);
456             }
457             else
458             {
459                 if (Options.UseSequenceMarker)
460                 {
461                     var sequenceElements = GetSequenceElements(sequence);
462                     var sequenceLink = GetSequenceByElements(sequenceElements);
463                     var newSequenceElements = GetSequenceElements(newSequence);
464                     var newSequenceLink = GetSequenceByElements(newSequenceElements);
465                     if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
466                     {
467                         if (sequenceLink != Constants.Null)
468                         {
469                             Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
470                         }
471                         Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
472                     }
473                 }
474                 else
475                 {
476                     if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
477                     {
478                         Links.Unsync.MergeAndDelete(sequence, newSequence);
479                     }
480                 }
```

```
            }
        }

        #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());
```

```
560                 }
561             });
562         }
563 
564         /// <remarks>
565         /// bestVariant можно выбирать по максимальному числу использований,
566         /// но балансированный позволяет гарантировать уникальность (если есть возможность,
567         /// гарантировать его использование в других местах).
568         ///
569         /// Получается этот метод должен игнорировать Options.EnforceSingleSequenceVersionOnWrite
570         /// </remarks>
571         [MethodImpl(MethodImplOptions.AggressiveInlining)]
572         public LinkIndex Compact(IList<LinkIndex> sequence)
573         {
574             return _sync.ExecuteWriteOperation(() =>
575             {
576                 if (sequence.IsNullOrEmpty())
577                 {
578                     return Constants.Null;
579                 }
580                 Links.EnsureInnerReferenceExists(sequence, nameof(sequence));
581                 return CompactCore(sequence);
582             });
583         }
584 
585         [MethodImpl(MethodImplOptions.AggressiveInlining)]
586         private LinkIndex CompactCore(IList<LinkIndex> sequence) => UpdateCore(sequence,
        ↪  sequence);
587 
588         #endregion
589 
590         #region Garbage Collection
591 
592         /// <remarks>
593         /// TODO: Добавить дополнительный обработчик / событие CanBeDeleted которое можно
        ↪  определить извне или в унаследованном классе
594         /// </remarks>
595         [MethodImpl(MethodImplOptions.AggressiveInlining)]
596         private bool IsGarbage(LinkIndex link) => link != Options.SequenceMarkerLink &&
        ↪  !Links.Unsync.IsPartialPoint(link) && Links.Count(Constants.Any, link) == 0;
597 
598         [MethodImpl(MethodImplOptions.AggressiveInlining)]
599         private void ClearGarbage(LinkIndex link)
600         {
601             if (IsGarbage(link))
602             {
603                 var contents = new Link<ulong>(Links.GetLink(link));
604                 Links.Unsync.Delete(link);
605                 ClearGarbage(contents.Source);
606                 ClearGarbage(contents.Target);
607             }
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
683                 }
684                 _filterPosition++;
685                 return true;
686             }
687 
688             [MethodImpl(MethodImplOptions.AggressiveInlining)]
689             public void AddFullMatchedToResults(IList<LinkIndex> restrictions)
690             {
691                 var sequenceToMatch = restrictions[_links.Constants.IndexPart];
692                 if (FullMatch(sequenceToMatch))
693                 {
694                     _results.Add(sequenceToMatch);
695                 }
696             }
697 
698             [MethodImpl(MethodImplOptions.AggressiveInlining)]
699             public LinkIndex HandleFullMatched(IList<LinkIndex> restrictions)
700             {
701                 var sequenceToMatch = restrictions[_links.Constants.IndexPart];
702                 if (FullMatch(sequenceToMatch) && _results.Add(sequenceToMatch))
703                 {
704                     return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
705                 }
706                 return _links.Constants.Continue;
707             }
708 
709             [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
710             public LinkIndex HandleFullMatchedSequence(IList<LinkIndex> restrictions)
711             {
712                 var sequenceToMatch = restrictions[_links.Constants.IndexPart];
713                 var sequence = _sequences.GetSequenceByElements(sequenceToMatch);
714                 if (sequence != _links.Constants.Null && FullMatch(sequenceToMatch) &&
                    ↪ _results.Add(sequenceToMatch))
715                 {
716                     return _stopableHandler(new LinkAddress<LinkIndex>(sequence));
717                 }
718                 return _links.Constants.Continue;
719             }
720
721             /// <remarks>
722             /// TODO: Add support for LinksConstants.Any
723             /// </remarks>
724             [MethodImpl(MethodImplOptions.AggressiveInlining)]
725             public bool PartialMatch(LinkIndex sequenceToMatch)
726             {
727                 _filterPosition = -1;
728                 foreach (var part in Walk(sequenceToMatch))
729                 {
730                     if (!PartialMatchCore(part))
731                     {
732                         break;
733                     }
734                 }
735                 return _filterPosition == _patternSequence.Count - 1;
736             }
737
738             [MethodImpl(MethodImplOptions.AggressiveInlining)]
739             private bool PartialMatchCore(LinkIndex element)
740             {
741                 if (_filterPosition == (_patternSequence.Count - 1))
742                 {
743                     return false; // Нашлось
744                 }
745                 if (_filterPosition >= 0)
746                 {
747                     if (element == _patternSequence[_filterPosition + 1])
748                     {
749                         _filterPosition++;
750                     }
751                     else
752                     {
753                         _filterPosition = -1;
754                     }
755                 }
756                 if (_filterPosition < 0)
757                 {
758                     if (element == _patternSequence[0])
759                     {
760                         _filterPosition = 0;
761                     }
762                 }
763                 return true; // Ищем дальше
764             }
765
766             [MethodImpl(MethodImplOptions.AggressiveInlining)]
767             public void AddPartialMatchedToResults(LinkIndex sequenceToMatch)
768             {
769                 if (PartialMatch(sequenceToMatch))
770                 {
771                     _results.Add(sequenceToMatch);
772                 }
773             }
774
775             [MethodImpl(MethodImplOptions.AggressiveInlining)]
776             public LinkIndex HandlePartialMatched(IList<LinkIndex> restrictions)
777             {
778                 var sequenceToMatch = restrictions[_links.Constants.IndexPart];
779                 if (PartialMatch(sequenceToMatch))
780                 {
781                     return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
782                 }
783                 return _links.Constants.Continue;
784             }
785
786             [MethodImpl(MethodImplOptions.AggressiveInlining)]
787             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
    }
}
```

## 1.101 ./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;
        }
    }
}
```

## 1.102 ./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;
```

```
13
14  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
15
16  namespace Platform.Data.Doublets.Sequences
17  {
18      public class SequencesOptions<TLink> // TODO: To use type parameter <TLink> the
        ↪  ILinks<TLink> must contain GetConstants function.
19      {
20          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪  EqualityComparer<TLink>.Default;
21
22          public TLink SequenceMarkerLink
23          {
24              [MethodImpl(MethodImplOptions.AggressiveInlining)]
25              get;
26              [MethodImpl(MethodImplOptions.AggressiveInlining)]
27              set;
28          }
29
30          public bool UseCascadeUpdate
31          {
32              [MethodImpl(MethodImplOptions.AggressiveInlining)]
33              get;
34              [MethodImpl(MethodImplOptions.AggressiveInlining)]
35              set;
36          }
37
38          public bool UseCascadeDelete
39          {
40              [MethodImpl(MethodImplOptions.AggressiveInlining)]
41              get;
42              [MethodImpl(MethodImplOptions.AggressiveInlining)]
43              set;
44          }
45
46          public bool UseIndex
47          {
48              [MethodImpl(MethodImplOptions.AggressiveInlining)]
49              get;
50              [MethodImpl(MethodImplOptions.AggressiveInlining)]
51              set;
52          } // TODO: Update Index on sequence update/delete.
53
54          public bool UseSequenceMarker
55          {
56              [MethodImpl(MethodImplOptions.AggressiveInlining)]
57              get;
58              [MethodImpl(MethodImplOptions.AggressiveInlining)]
59              set;
60          }
61
62          public bool UseCompression
63          {
64              [MethodImpl(MethodImplOptions.AggressiveInlining)]
65              get;
66              [MethodImpl(MethodImplOptions.AggressiveInlining)]
67              set;
68          }
69
70          public bool UseGarbageCollection
71          {
72              [MethodImpl(MethodImplOptions.AggressiveInlining)]
73              get;
74              [MethodImpl(MethodImplOptions.AggressiveInlining)]
75              set;
76          }
77
78          public bool EnforceSingleSequenceVersionOnWriteBasedOnExisting
79          {
80              [MethodImpl(MethodImplOptions.AggressiveInlining)]
81              get;
82              [MethodImpl(MethodImplOptions.AggressiveInlining)]
83              set;
84          }
85
86          public bool EnforceSingleSequenceVersionOnWriteBasedOnNew
87          {
88              [MethodImpl(MethodImplOptions.AggressiveInlining)]
89              get;
90              [MethodImpl(MethodImplOptions.AggressiveInlining)]
91              set;
```

```
92          }
93
94          public MarkedSequenceCriterionMatcher<TLink> MarkedSequenceMatcher
95          {
96              [MethodImpl(MethodImplOptions.AggressiveInlining)]
97              get;
98              [MethodImpl(MethodImplOptions.AggressiveInlining)]
99              set;
100         }
101
102         public IConverter<IList<TLink>, TLink> LinksToSequenceConverter
103         {
104             [MethodImpl(MethodImplOptions.AggressiveInlining)]
105             get;
106             [MethodImpl(MethodImplOptions.AggressiveInlining)]
107             set;
108         }
109
110         public ISequenceIndex<TLink> Index
111         {
112             [MethodImpl(MethodImplOptions.AggressiveInlining)]
113             get;
114             [MethodImpl(MethodImplOptions.AggressiveInlining)]
115             set;
116         }
117
118         public ISequenceWalker<TLink> Walker
119         {
120             [MethodImpl(MethodImplOptions.AggressiveInlining)]
121             get;
122             [MethodImpl(MethodImplOptions.AggressiveInlining)]
123             set;
124         }
125
126         public bool ReadFullSequence
127         {
128             [MethodImpl(MethodImplOptions.AggressiveInlining)]
129             get;
130             [MethodImpl(MethodImplOptions.AggressiveInlining)]
131             set;
132         }
133
134         // TODO: Реализовать компактификацию при чтении
135         //public bool EnforceSingleSequenceVersionOnRead { get; set; }
136         //public bool UseRequestMarker { get; set; }
137         //public bool StoreRequestResults { get; set; }
138
139         [MethodImpl(MethodImplOptions.AggressiveInlining)]
140         public void InitOptions(ISynchronizedLinks<TLink> links)
141         {
142             if (UseSequenceMarker)
143             {
144                 if (_equalityComparer.Equals(SequenceMarkerLink, links.Constants.Null))
145                 {
146                     SequenceMarkerLink = links.CreatePoint();
147                 }
148                 else
149                 {
150                     if (!links.Exists(SequenceMarkerLink))
151                     {
152                         var link = links.CreatePoint();
153                         if (!_equalityComparer.Equals(link, SequenceMarkerLink))
154                         {
155                             throw new InvalidOperationException("Cannot recreate sequence marker
                                ↪  link.");
156                         }
157                     }
158                 }
159                 if (MarkedSequenceMatcher == null)
160                 {
161                     MarkedSequenceMatcher = new MarkedSequenceCriterionMatcher<TLink>(links,
                        ↪  SequenceMarkerLink);
162                 }
163             }
164             var balancedVariantConverter = new BalancedVariantConverter<TLink>(links);
165             if (UseCompression)
166             {
167                 if (LinksToSequenceConverter == null)
168                 {
```

```
                    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.");
            }
        }
    }
}
```

### 1.103 ./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);
    }
}
```

### 1.104 ./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;
                }
            }
        }
    }
}
```

### 1.105 ./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;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LeveledSequenceWalker(ILinks<TLink> links) : base(links) => _isElement =
        ↪  _links.IsPartialPoint;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public IEnumerable<TLink> Walk(TLink sequence) => ToArray(sequence);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink[] ToArray(TLink sequence)
        {
            var length = 1;
            var array = new TLink[length];
            array[0] = sequence;
            if (_isElement(sequence))
            {
                return array;
            }
            bool hasElements;
            do
            {
                length *= 2;
#if USEARRAYPOOL
                var nextArray = ArrayPool.Allocate<ulong>(length);
#else
                var nextArray = new TLink[length];
```

```
#endif
                hasElements = false;
                for (var i = 0; i < array.Length; i++)
                {
                    var candidate = array[i];
                    if (_equalityComparer.Equals(array[i], default))
                    {
                        continue;
                    }
                    var doubletOffset = i * 2;
                    if (_isElement(candidate))
                    {
                        nextArray[doubletOffset] = candidate;
                    }
                    else
                    {
                        var links = _links;
                        var link = links.GetLink(candidate);
                        var linkSource = links.GetSource(link);
                        var linkTarget = links.GetTarget(link);
                        nextArray[doubletOffset] = linkSource;
                        nextArray[doubletOffset + 1] = linkTarget;
                        if (!hasElements)
                        {
                            hasElements = !(_isElement(linkSource) && _isElement(linkTarget));
                        }
                    }
                }
#if USEARRAYPOOL
                if (array.Length > 1)
                {
                    ArrayPool.Free(array);
                }
#endif
                array = nextArray;
            }
            while (hasElements);
            var filledElementsCount = CountFilledElements(array);
            if (filledElementsCount == array.Length)
            {
                return array;
            }
            else
            {
                return CopyFilledElements(array, filledElementsCount);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static TLink[] CopyFilledElements(TLink[] array, int filledElementsCount)
        {
            var finalArray = new TLink[filledElementsCount];
            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;
        }
```

```
    }
}
```

### 1.106 ./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;
                }
            }
        }
    }
}
```

### 1.107 ./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);
    }
}
```

## 1.108 ./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)]
```

```
34          public TLink Pop()
35          {
36              var element = Peek();
37              if (!_equalityComparer.Equals(element, _stack))
38              {
39                  var top = GetTop();
40                  var previousTop = _links.GetSource(top);
41                  _links.Update(_stack, GetStackMarker(), previousTop);
42                  _links.Delete(top);
43              }
44              return element;
45          }
46
47          [MethodImpl(MethodImplOptions.AggressiveInlining)]
48          public void Push(TLink element) => _links.Update(_stack, GetStackMarker(),
            ↪  _links.GetOrCreate(GetTop(), element));
49      }
50  }
```

### 1.109 ./csharp/Platform.Data.Doublets/Stacks/StackExtensions.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.Stacks
6   {
7       public static class StackExtensions
8       {
9           [MethodImpl(MethodImplOptions.AggressiveInlining)]
10          public static TLink CreateStack<TLink>(this ILinks<TLink> links, TLink stackMarker)
11          {
12              var stackPoint = links.CreatePoint();
13              var stack = links.Update(stackPoint, stackMarker, stackPoint);
14              return stack;
15          }
16      }
17  }
```

### 1.110 ./csharp/Platform.Data.Doublets/SynchronizedLinks.cs

```
1   using System;
2   using System.Collections.Generic;
3   using System.Runtime.CompilerServices;
4   using Platform.Data.Doublets;
5   using Platform.Threading.Synchronization;
6
7   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9   namespace Platform.Data.Doublets
10  {
11      /// <remarks>
12      /// TODO: Autogeneration of synchronized wrapper (decorator).
13      /// TODO: Try to unfold code of each method using IL generation for performance improvements.
14      /// 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
```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SynchronizedLinks(ILinks<TLinkAddress> links) : this(new
        ↪  ReaderWriterLockSynchronization(), links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SynchronizedLinks(ISynchronization synchronization, ILinks<TLinkAddress> links)
        {
            SyncRoot = synchronization;
            Sync = this;
            Unsync = links;
            Constants = links.Constants;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLinkAddress Count(IList<TLinkAddress> restriction) =>
        ↪  SyncRoot.ExecuteReadOperation(restriction, Unsync.Count);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLinkAddress Each(Func<IList<TLinkAddress>, TLinkAddress> handler,
        ↪  IList<TLinkAddress> restrictions) => SyncRoot.ExecuteReadOperation(handler,
        ↪  restrictions, (handler1, restrictions1) => Unsync.Each(handler1, restrictions1));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLinkAddress Create(IList<TLinkAddress> restrictions) =>
        ↪  SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Create);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLinkAddress Update(IList<TLinkAddress> restrictions, IList<TLinkAddress>
        ↪  substitution) => SyncRoot.ExecuteWriteOperation(restrictions, substitution,
        ↪  Unsync.Update);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Delete(IList<TLinkAddress> restrictions) =>
        ↪  SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Delete);

        //public T Trigger(IList<T> restriction, Func<IList<T>, IList<T>, T> matchedHandler,
        ↪  IList<T> substitution, Func<IList<T>, IList<T>, T> substitutedHandler)
        //{
        //    if (restriction != null && substitution != null &&
        ↪  !substitution.EqualTo(restriction))
        //        return SyncRoot.ExecuteWriteOperation(restriction, matchedHandler,
        ↪  substitution, substitutedHandler, Unsync.Trigger);

        //    return SyncRoot.ExecuteReadOperation(restriction, matchedHandler, substitution,
        ↪  substitutedHandler, Unsync.Trigger);
        //}
    }
}
```

## 1.111 ./csharp/Platform.Data.Doublets/UInt64LinksExtensions.cs

```
using System;
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++)
            {
```

```
29                  if (sequence[i] == constants.Any)
30                  {
31                      return true;
32                  }
33              }
34              return false;
35          }
36
37          [MethodImpl(MethodImplOptions.AggressiveInlining)]
38          public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
            ↪  Func<Link<ulong>, bool> isElement, bool renderIndex = false, bool renderDebug =
            ↪  false)
39          {
40              var sb = new StringBuilder();
41              var visited = new HashSet<ulong>();
42              links.AppendStructure(sb, visited, linkIndex, isElement, (innerSb, link) =>
                ↪  innerSb.Append(link.Index), renderIndex, renderDebug);
43              return sb.ToString();
44          }
45
46          [MethodImpl(MethodImplOptions.AggressiveInlining)]
47          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)
48          {
49              var sb = new StringBuilder();
50              var visited = new HashSet<ulong>();
51              links.AppendStructure(sb, visited, linkIndex, isElement, appendElement, renderIndex,
                ↪  renderDebug);
52              return sb.ToString();
53          }
54
55          [MethodImpl(MethodImplOptions.AggressiveInlining)]
56          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)
57          {
58              if (sb == null)
59              {
60                  throw new ArgumentNullException(nameof(sb));
61              }
62              if (linkIndex == Constants.Null || linkIndex == Constants.Any || linkIndex ==
                ↪  Constants.Itself)
63              {
64                  return;
65              }
66              if (links.Exists(linkIndex))
67              {
68                  if (visited.Add(linkIndex))
69                  {
70                      sb.Append('(');
71                      var link = new Link<ulong>(links.GetLink(linkIndex));
72                      if (renderIndex)
73                      {
74                          sb.Append(link.Index);
75                          sb.Append(':');
76                      }
77                      if (link.Source == link.Index)
78                      {
79                          sb.Append(link.Index);
80                      }
81                      else
82                      {
83                          var source = new Link<ulong>(links.GetLink(link.Source));
84                          if (isElement(source))
85                          {
86                              appendElement(sb, source);
87                          }
88                          else
89                          {
90                              links.AppendStructure(sb, visited, source.Index, isElement,
                                ↪  appendElement, renderIndex);
91                          }
92                      }
93                      sb.Append(' ');
94                      if (link.Target == link.Index)
95                      {
```

```
                        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);
            }
        }
    }
}
```

## 1.112 ./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;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
            ↪  transactionId, Link<ulong> before, Link<ulong> after)
            {
                TransactionId = transactionId;
                Before = before;
                After = after;
                Timestamp = uniqueTimestampFactory.Create();
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
            ↪  transactionId, Link<ulong> before) : this(uniqueTimestampFactory, transactionId,
            ↪  before, default) { }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
            ↪  transactionId) : this(uniqueTimestampFactory, transactionId, default, default) {
            ↪  }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public override string ToString() => $"{Timestamp} {TransactionId}: {Before} =>
            ↪  {After}";

            [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                     {
232                         Revert();
233                     }
234                     _layer.ResetCurrentTransation();
235                 }
236             }
237         }
238 
239         public static readonly TimeSpan DefaultPushDelay = TimeSpan.FromSeconds(0.1);
240 
241         private readonly string _logAddress;
242         private readonly FileStream _log;
243         private readonly Queue<Transition> _transitions;
244         private readonly UniqueTimestampFactory _uniqueTimestampFactory;
245         private Task _transitionsPusher;
246         private Transition _lastCommitedTransition;
247         private ulong _currentTransactionId;
248         private Queue<Transition> _currentTransactionTransitions;
249         private Transaction _currentTransaction;
250         private ulong _lastCommitedTransactionId;
251 
252         [MethodImpl(MethodImplOptions.AggressiveInlining)]
253         public UInt64LinksTransactionsLayer(ILinks<ulong> links, string logAddress)
254             : base(links)
255         {
256             if (string.IsNullOrWhiteSpace(logAddress))
257             {
```

```
258                 throw new ArgumentNullException(nameof(logAddress));
259             }
260             // В первой строке файла хранится последняя закоммиченную транзакцию.
261             // При запуске это используется для проверки удачного закрытия файла лога.
262             // In the first line of the file the last committed transaction is stored.
263             // On startup, this is used to check that the log file is successfully closed.
264             var lastCommitedTransition = FileHelpers.ReadFirstOrDefault<Transition>(logAddress);
265             var lastWrittenTransition = FileHelpers.ReadLastOrDefault<Transition>(logAddress);
266             if (!lastCommitedTransition.Equals(lastWrittenTransition))
267             {
268                 Dispose();
269                 throw new NotSupportedException("Database is damaged, autorecovery is not
                    ↪  supported yet.");
270             }
271             if (lastCommitedTransition == default)
272             {
273                 FileHelpers.WriteFirst(logAddress, lastCommitedTransition);
274             }
275             _lastCommitedTransition = lastCommitedTransition;
276             // TODO: Think about a better way to calculate or store this value
277             var allTransitions = FileHelpers.ReadAll<Transition>(logAddress);
278             _lastCommitedTransactionId = allTransitions.Length > 0 ? allTransitions.Max(x =>
                ↪  x.TransactionId) : 0;
279             _uniqueTimestampFactory = new UniqueTimestampFactory();
280             _logAddress = logAddress;
281             _log = FileHelpers.Append(logAddress);
282             _transitions = new Queue<Transition>();
283             _transitionsPusher = new Task(TransitionsPusher);
284             _transitionsPusher.Start();
285         }
286
287         [MethodImpl(MethodImplOptions.AggressiveInlining)]
288         public IList<ulong> GetLinkValue(ulong link) => _links.GetLink(link);
289
290         [MethodImpl(MethodImplOptions.AggressiveInlining)]
291         public override ulong Create(IList<ulong> restrictions)
292         {
293             var createdLinkIndex = _links.Create();
294             var createdLink = new Link<ulong>(_links.GetLink(createdLinkIndex));
295             CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
                ↪  default, createdLink));
296             return createdLinkIndex;
297         }
298
299         [MethodImpl(MethodImplOptions.AggressiveInlining)]
300         public override ulong Update(IList<ulong> restrictions, IList<ulong> substitution)
301         {
302             var linkIndex = restrictions[_constants.IndexPart];
303             var beforeLink = new Link<ulong>(_links.GetLink(linkIndex));
304             linkIndex = _links.Update(restrictions, substitution);
305             var afterLink = new Link<ulong>(_links.GetLink(linkIndex));
306             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();
```

```
            }
        }

        #region DisposalBase

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void Dispose(bool manual, bool wasDisposed)
        {
            if (!wasDisposed)
            {
                DisposeTransitions();
            }
            base.Dispose(manual, wasDisposed);
        }

        #endregion
    }
}
```

## 1.113 ./csharp/Platform.Data.Doublets/Unicode/CharToUnicodeSymbolConverter.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.Unicode
{
    public class CharToUnicodeSymbolConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<char, TLink>
    {
        private static readonly UncheckedConverter<char, TLink> _charToAddressConverter =
        ↪ UncheckedConverter<char, TLink>.Default;

        private readonly IConverter<TLink> _addressToNumberConverter;
        private readonly TLink _unicodeSymbolMarker;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public CharToUnicodeSymbolConverter(ILinks<TLink> links, IConverter<TLink>
        ↪ addressToNumberConverter, TLink unicodeSymbolMarker) : base(links)
        {
            _addressToNumberConverter = addressToNumberConverter;
            _unicodeSymbolMarker = unicodeSymbolMarker;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(char source)
        {
            var unaryNumber =
            ↪ _addressToNumberConverter.Convert(_charToAddressConverter.Convert(source));
            return _links.GetOrCreate(unaryNumber, _unicodeSymbolMarker);
        }
    }
}
```

## 1.114 ./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)]
```

```
23          public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<string,
            ↪  IList<TLink>> stringToUnicodeSymbolListConverter, ISequenceIndex<TLink> index,
            ↪  IConverter<IList<TLink>, TLink> listToSequenceLinkConverter, TLink
            ↪  unicodeSequenceMarker)
24              : this(links, stringToUnicodeSymbolListConverter, new
                ↪  UnicodeSymbolsListToUnicodeSequenceConverter<TLink>(links, index,
                ↪  listToSequenceLinkConverter, unicodeSequenceMarker)) { }
25
26          [MethodImpl(MethodImplOptions.AggressiveInlining)]
27          public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<char, TLink>
            ↪  charToUnicodeSymbolConverter, ISequenceIndex<TLink> index, IConverter<IList<TLink>,
            ↪  TLink> listToSequenceLinkConverter, TLink unicodeSequenceMarker)
28              : this(links, new
                ↪  StringToUnicodeSymbolsListConverter<TLink>(charToUnicodeSymbolConverter), index,
                ↪  listToSequenceLinkConverter, unicodeSequenceMarker) { }
29
30          [MethodImpl(MethodImplOptions.AggressiveInlining)]
31          public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<char, TLink>
            ↪  charToUnicodeSymbolConverter, IConverter<IList<TLink>, TLink>
            ↪  listToSequenceLinkConverter, TLink unicodeSequenceMarker)
32              : this(links, charToUnicodeSymbolConverter, new Unindex<TLink>(),
                ↪  listToSequenceLinkConverter, unicodeSequenceMarker) { }
33
34          [MethodImpl(MethodImplOptions.AggressiveInlining)]
35          public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<string,
            ↪  IList<TLink>> stringToUnicodeSymbolListConverter, IConverter<IList<TLink>, TLink>
            ↪  listToSequenceLinkConverter, TLink unicodeSequenceMarker)
36              : this(links, stringToUnicodeSymbolListConverter, new Unindex<TLink>(),
                ↪  listToSequenceLinkConverter, unicodeSequenceMarker) { }
37
38          [MethodImpl(MethodImplOptions.AggressiveInlining)]
39          public TLink Convert(string source)
40          {
41              var elements = _stringToUnicodeSymbolListConverter.Convert(source);
42              return _unicodeSymbolListToSequenceConverter.Convert(elements);
43          }
44      }
45  }
```

### 1.115 ./csharp/Platform.Data.Doublets/Unicode/StringToUnicodeSymbolsListConverter.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.Unicode
8   {
9       public class StringToUnicodeSymbolsListConverter<TLink> : IConverter<string, IList<TLink>>
10      {
11          private readonly IConverter<char, TLink> _charToUnicodeSymbolConverter;
12
13          [MethodImpl(MethodImplOptions.AggressiveInlining)]
14          public StringToUnicodeSymbolsListConverter(IConverter<char, TLink>
            ↪  charToUnicodeSymbolConverter) => _charToUnicodeSymbolConverter =
            ↪  charToUnicodeSymbolConverter;
15
16          [MethodImpl(MethodImplOptions.AggressiveInlining)]
17          public IList<TLink> Convert(string source)
18          {
19              var elements = new TLink[source.Length];
20              for (var i = 0; i < elements.Length; i++)
21              {
22                  elements[i] = _charToUnicodeSymbolConverter.Convert(source[i]);
23              }
24              return elements;
25          }
26      }
27  }
```

### 1.116 ./csharp/Platform.Data.Doublets/Unicode/UnicodeMap.cs

```
1   using System;
2   using System.Collections.Generic;
3   using System.Globalization;
4   using System.Runtime.CompilerServices;
5   using System.Text;
6   using Platform.Data.Sequences;
7
8   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
```

```
9
10  namespace Platform.Data.Doublets.Unicode
11  {
12      public class UnicodeMap
13      {
14          public static readonly ulong FirstCharLink = 1;
15          public static readonly ulong LastCharLink = FirstCharLink + char.MaxValue;
16          public static readonly ulong MapSize = 1 + char.MaxValue;
17
18          private readonly ILinks<ulong> _links;
19          private bool _initialized;
20
21          [MethodImpl(MethodImplOptions.AggressiveInlining)]
22          public UnicodeMap(ILinks<ulong> links) => _links = links;
23
24          [MethodImpl(MethodImplOptions.AggressiveInlining)]
25          public static UnicodeMap InitNew(ILinks<ulong> links)
26          {
27              var map = new UnicodeMap(links);
28              map.Init();
29              return map;
30          }
31
32          [MethodImpl(MethodImplOptions.AggressiveInlining)]
33          public void Init()
34          {
35              if (_initialized)
36              {
37                  return;
38              }
39              _initialized = true;
40              var firstLink = _links.CreatePoint();
41              if (firstLink != FirstCharLink)
42              {
43                  _links.Delete(firstLink);
44              }
45              else
46              {
47                  for (var i = FirstCharLink + 1; i <= LastCharLink; i++)
48                  {
49                      // From NIL to It (NIL -> Character) transformation meaning, (or infinite
                        ↪  amount of NIL characters before actual Character)
50                      var createdLink = _links.CreatePoint();
51                      _links.Update(createdLink, firstLink, createdLink);
52                      if (createdLink != i)
53                      {
54                          throw new InvalidOperationException("Unable to initialize UTF 16
                            ↪  table.");
55                      }
56                  }
57              }
58          }
59
60          // 0 - null link
61          // 1 - nil character (0 character)
62          // ...
63          // 65536 (0(1) + 65535 = 65536 possible values)
64
65          [MethodImpl(MethodImplOptions.AggressiveInlining)]
66          public static ulong FromCharToLink(char character) => (ulong)character + 1;
67
68          [MethodImpl(MethodImplOptions.AggressiveInlining)]
69          public static char FromLinkToChar(ulong link) => (char)(link - 1);
70
71          [MethodImpl(MethodImplOptions.AggressiveInlining)]
72          public static bool IsCharLink(ulong link) => link <= MapSize;
73
74          [MethodImpl(MethodImplOptions.AggressiveInlining)]
75          public static string FromLinksToString(IList<ulong> linksList)
76          {
77              var sb = new StringBuilder();
78              for (int i = 0; i < linksList.Count; i++)
79              {
80                  sb.Append(FromLinkToChar(linksList[i]));
81              }
82              return sb.ToString();
83          }
84
85          [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
86          public static string FromSequenceLinkToString(ulong link, ILinks<ulong> links)
87          {
88              var sb = new StringBuilder();
89              if (links.Exists(link))
90              {
91                  StopableSequenceWalker.WalkRight(link, links.GetSource, links.GetTarget,
92                      x => x <= MapSize || links.GetSource(x) == x || links.GetTarget(x) == x,
                        ↪  element =>
93                      {
94                          sb.Append(FromLinkToChar(element));
95                          return true;
96                      });
97              }
98              return sb.ToString();
99          }
100
101         [MethodImpl(MethodImplOptions.AggressiveInlining)]
102         public static ulong[] FromCharsToLinkArray(char[] chars) => FromCharsToLinkArray(chars,
            ↪  chars.Length);
103
104         [MethodImpl(MethodImplOptions.AggressiveInlining)]
105         public static ulong[] FromCharsToLinkArray(char[] chars, int count)
106         {
107             // char array to ulong array
108             var linksSequence = new ulong[count];
109             for (var i = 0; i < count; i++)
110             {
111                 linksSequence[i] = FromCharToLink(chars[i]);
112             }
113             return linksSequence;
114         }
115
116         [MethodImpl(MethodImplOptions.AggressiveInlining)]
117         public static ulong[] FromStringToLinkArray(string sequence)
118         {
119             // char array to ulong array
120             var linksSequence = new ulong[sequence.Length];
121             for (var i = 0; i < sequence.Length; i++)
122             {
123                 linksSequence[i] = FromCharToLink(sequence[i]);
124             }
125             return linksSequence;
126         }
127
128         [MethodImpl(MethodImplOptions.AggressiveInlining)]
129         public static List<ulong[]> FromStringToLinkArrayGroups(string sequence)
130         {
131             var result = new List<ulong[]>();
132             var offset = 0;
133             while (offset < sequence.Length)
134             {
135                 var currentCategory = CharUnicodeInfo.GetUnicodeCategory(sequence[offset]);
136                 var relativeLength = 1;
137                 var absoluteLength = offset + relativeLength;
138                 while (absoluteLength < sequence.Length &&
139                        currentCategory ==
                           ↪  CharUnicodeInfo.GetUnicodeCategory(sequence[absoluteLength]))
140                 {
141                     relativeLength++;
142                     absoluteLength++;
143                 }
144                 // char array to ulong array
145                 var innerSequence = new ulong[relativeLength];
146                 var maxLength = offset + relativeLength;
147                 for (var i = offset; i < maxLength; i++)
148                 {
149                     innerSequence[i - offset] = FromCharToLink(sequence[i]);
150                 }
151                 result.Add(innerSequence);
152                 offset += relativeLength;
153             }
154             return result;
155         }
156
157         [MethodImpl(MethodImplOptions.AggressiveInlining)]
158         public static List<ulong[]> FromLinkArrayToLinkArrayGroups(ulong[] array)
159         {
160             var result = new List<ulong[]>();
161             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;
        }
    }
}
```

### 1.117 ./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);
        }
    }
}
```

## 1.118 ./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.GetSource(source)));
        }
    }
}
```

## 1.119 ./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);
        }
    }
}
```

## 1.120 ./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>>());
            }
        }
    }
}
```

## 1.121 ./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);
            }
        }
    }
}
```

### 1.122 ./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));
        }
    }
}
```

### 1.123 ./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);
                var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
                ↪  frequencyPropertyMarker, frequencyMarker);
                var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
                ↪  frequencyPropertyOperator, frequencyIncrementer);
                var linkToItsFrequencyNumberConverter = new
                ↪  LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
                ↪  unaryNumberToAddressConverter);
                var sequenceToItsLocalElementLevelsConverter = new
                ↪  SequenceToItsLocalElementLevelsConverter<ulong>(links,
                ↪  linkToItsFrequencyNumberConverter);
                var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                ↪  sequenceToItsLocalElementLevelsConverter);

                var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
                ↪  Walker = new LeveledSequenceWalker<ulong>(links) });

                ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
                ↪  index, optimalVariantConverter);
            }
        }

        [Fact]
        public static void DictionaryBasedFrequencyStoredOptimalVariantSequenceTest()
        {
            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);
```

```
                var sequenceToItsLocalElementLevelsConverter = new
                ↪  SequenceToItsLocalElementLevelsConverter<ulong>(links,
                ↪  linkToItsFrequencyNumberConverter);
                var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                ↪  sequenceToItsLocalElementLevelsConverter);

                var walker = new RightSequenceWalker<ulong>(links, new DefaultStack<ulong>(),
                ↪  (link) => constants.IsExternalReference(link) || links.IsPartialPoint(link));

                var unicodeSequencesOptions = new SequencesOptions<ulong>()
                {
                    UseSequenceMarker = true,
                    SequenceMarkerLink = unicodeSequenceMarker,
                    UseIndex = true,
                    Index = index,
                    LinksToSequenceConverter = optimalVariantConverter,
                    Walker = walker,
                    UseGarbageCollection = true
                };

                var unicodeSequences = new Sequences.Sequences(new
                ↪  SynchronizedLinks<ulong>(links), unicodeSequencesOptions);

                // Create some sequences
                var strings = _loremIpsumExample.Split(new[] { '\n', '\r' },
                ↪  StringSplitOptions.RemoveEmptyEntries);
                var arrays = strings.Select(x => x.Select(y =>
                ↪  addressToNumberConverter.Convert(y)).ToArray()).ToArray();
                for (int i = 0; i < arrays.Length; i++)
                {
                    unicodeSequences.Create(arrays[i].ShiftRight());
                }

                var linksCountAfterCreation = links.Count();

                // get list of sequences links
                // for each sequence link
                //   create new sequence version
                //   if new sequence is not the same as sequence link
                //     delete sequence link
                //     collect garbadge
                unicodeSequences.CompactAll();

                var linksCountAfterCompactification = links.Count();

                Assert.True(linksCountAfterCompactification < linksCountAfterCreation);
            }
        }
    }
}
```

### 1.124 ./csharp/Platform.Data.Doublets.Tests/ReadSequenceTests.cs

```
using System;
using System.Collections.Generic;
using System.Diagnostics;
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]);
                }
            }
        }
    }
}
```

### 1.125 ./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);
        }
    }
}
```

### 1.126 ./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]
        public static void CascadeDependencyTest()
        {
            using (var scope = new Scope())
            {
                scope.Include<TemporaryFileMappedResizableDirectMemory>();
                scope.Include<UInt64UnitedMemoryLinks>();
                var instance = scope.Use<ILinks<ulong>>();
                Assert.IsType<UInt64UnitedMemoryLinks>(instance);
            }
        }

        [Fact]
        public static void FullAutoResolutionTest()
        {
            using (var scope = new Scope(autoInclude: true, autoExplore: true))
            {
                var instance = scope.Use<UInt64Links>();
                Assert.IsType<UInt64Links>(instance);
            }
        }

        [Fact]
        public static void TypeParametersTest()
```

```
        {
            using (var scope = new Scope<Types<HeapResizableDirectMemory,
            ↪  UnitedMemoryLinks<ulong>>>())
            {
                var links = scope.Use<ILinks<ulong>>();
                Assert.IsType<UnitedMemoryLinks<ulong>>(links);
            }
        }
    }
}
```

### 1.127 ./csharp/Platform.Data.Doublets.Tests/SequencesTests.cs

```
using System;
using System.Collections.Generic;
using System.Diagnostics;
using System.Linq;
using Xunit;
using Platform.Collections;
using Platform.Collections.Arrays;
using Platform.Random;
using Platform.IO;
using Platform.Singletons;
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.Unicode;

namespace Platform.Data.Doublets.Tests
{
    public static class SequencesTests
    {
        private static readonly LinksConstants<ulong> _constants =
        ↪  Default<LinksConstants<ulong>>.Instance;

        static SequencesTests()
        {
            // Trigger static constructor to not mess with perfomance measurements
            _ = BitString.GetBitMaskFromIndex(1);
        }

        [Fact]
        public static void CreateAllVariantsTest()
        {
            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 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();

```

```
68          //    const long sequenceLength = 8;
69
70          //    const ulong itself = LinksConstants.Itself;
71
72          //    using (var memoryAdapter = new ResizableDirectMemoryLinks(tempFilename,
            ↪  DefaultLinksSizeStep))
73          //    using (var links = new Links(memoryAdapter))
74          //    {
75          //        var sequence = new ulong[sequenceLength];
76          //        for (var i = 0; i < sequenceLength; i++)
77          //            sequence[i] = links.Create(itself, itself);
78
79          //        SequencesOptions o = new SequencesOptions();
80
81          // TODO: Из числа в bool значения o.UseSequenceMarker = ((value & 1) != 0)
82          //        o.
83
84          //        var sequences = new Sequences(links);
85
86          //        var sw1 = Stopwatch.StartNew();
87          //        var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
88
89          //        var sw2 = Stopwatch.StartNew();
90          //        var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();
91
92          //        Assert.True(results1.Count > results2.Length);
93          //        Assert.True(sw1.Elapsed > sw2.Elapsed);
94
95          //        for (var i = 0; i < sequenceLength; i++)
96          //            links.Delete(sequence[i]);
97          //    }
98
99          //    File.Delete(tempFilename);
100         //}
101
102         [Fact]
103         public static void AllVariantsSearchTest()
104         {
105             const long sequenceLength = 8;
106
107             using (var scope = new TempLinksTestScope(useSequences: true))
108             {
109                 var links = scope.Links;
110                 var sequences = scope.Sequences;
111
112                 var sequence = new ulong[sequenceLength];
113                 for (var i = 0; i < sequenceLength; i++)
114                 {
115                     sequence[i] = links.Create();
116                 }
117
118                 var createResults = sequences.CreateAllVariants2(sequence).Distinct().ToArray();
119
120                 //for (int i = 0; i < createResults.Length; i++)
121                 //    sequences.Create(createResults[i]);
122
123                 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
```

```
            var intersection3 = createResults.Intersect(searchResults3).ToList();
            Assert.True(intersection3.Count == searchResults3.Count);
            Assert.True(intersection3.Count == createResults.Length);

            for (var i = 0; i < sequenceLength; i++)
            {
                links.Delete(sequence[i]);
            }
        }
    }

    [Fact]
    public static void BalancedVariantSearchTest()
    {
        const long sequenceLength = 200;

        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 balancedVariantConverter = new BalancedVariantConverter<ulong>(links);

            var sw1 = Stopwatch.StartNew();
            var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();

            var sw2 = Stopwatch.StartNew();
            var searchResults2 = sequences.GetAllMatchingSequences0(sequence); sw2.Stop();

            var sw3 = Stopwatch.StartNew();
            var searchResults3 = sequences.GetAllMatchingSequences1(sequence); sw3.Stop();

            // На количестве в 200 элементов это будет занимать вечность
            //var sw4 = Stopwatch.StartNew();
            //var searchResults4 = sequences.Each(sequence); sw4.Stop();

            Assert.True(searchResults2.Count == 1 && balancedVariant == searchResults2[0]);

            Assert.True(searchResults3.Count == 1 && balancedVariant ==
            ↪  searchResults3.First());

            //Assert.True(sw1.Elapsed < sw2.Elapsed);

            for (var i = 0; i < sequenceLength; i++)
            {
                links.Delete(sequence[i]);
            }
        }
    }

    [Fact]
    public static void AllPartialVariantsSearchTest()
    {
        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);

            //var createResultsStrings = createResults.Select(x => x + ": " +
            ↪  sequences.FormatSequence(x)).ToList();
            //Global.Trash = createResultsStrings;

            var partialSequence = new ulong[sequenceLength - 2];

```

```
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                 {
```

```
                links.Delete(sequence[i]);
            }
        }
    }

    [Fact(Skip = "Correct implementation is pending")]
    public static void PatternMatchTest()
    {
        var zeroOrMany = Sequences.Sequences.ZeroOrMany;

        using (var scope = new TempLinksTestScope(useSequences: true))
        {
            var links = scope.Links;
            var sequences = scope.Sequences;

            var e1 = links.Create();
            var e2 = links.Create();

            var sequence = new[]
            {
                e1, e2, e1, e2 // mama / papa
            };

            var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);

            var balancedVariant = balancedVariantConverter.Convert(sequence);

            // 1: [1]
            // 2: [2]
            // 3: [1,2]
            // 4: [1,2,1,2]

            var doublet = links.GetSource(balancedVariant);

            var matchedSequences1 = sequences.MatchPattern(e2, e1, zeroOrMany);

            Assert.True(matchedSequences1.Count == 0);

            var matchedSequences2 = sequences.MatchPattern(zeroOrMany, e2, e1);

            Assert.True(matchedSequences2.Count == 0);

            var matchedSequences3 = sequences.MatchPattern(e1, zeroOrMany, e1);

            Assert.True(matchedSequences3.Count == 0);

            var matchedSequences4 = sequences.MatchPattern(e1, zeroOrMany, e2);

            Assert.Contains(doublet, matchedSequences4);
            Assert.Contains(balancedVariant, matchedSequences4);

            for (var i = 0; i < sequence.Length; i++)
            {
                links.Delete(sequence[i]);
            }
        }
    }

    [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/LinksPlatform/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)

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?

[![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)

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?

[![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)
```

```
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?

[![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)

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?

[![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)

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?

[![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.com/Konard/LinksPlatform/master/doc/Intro/10.png)

На один уровень внутрь (вниз)? Или на один уровень во вне (вверх)? Или это можно назвать шагом рекурсии или фрактала?

[![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.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/11.png)

Последовательность? Массив? Список? Множество? Объект? Таблица? Элементы? Цвета? Символы? Буквы? Слово? Цифры? Число? Алфавит? Дерево? Сеть? Граф? Гиперграф?

[![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)

...

[![анимация](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro-animation-500.gif ""анимация"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro-animation-500.gif)";

        private static readonly string _exampleLoremIpsumText =
            @"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore magna aliqua.
Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo consequat.";

        [Fact]
        public static void CompressionTest()
        {
            using (var scope = new TempLinksTestScope(useSequences: true))
            {
                var links = scope.Links;
                var sequences = scope.Sequences;

                var e1 = links.Create();
                var e2 = links.Create();

                var sequence = new[]
                {
                    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
561                 for (int i = START; i < END; i++)
562                 {
563                     compressed2[i] = balancedVariantConverter2.Convert(arrays[i]);
564                 }
565
566                 var elapsed2 = sw2.Elapsed;
567
568                 for (int i = START; i < END; i++)
569                 {
570                     linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
571                 }
572
573                 var initialCount3 = scope3.Links.Unsync.Count();
574
575                 var sw3 = Stopwatch.StartNew();
576
577                 for (int i = START; i < END; i++)
578                 {
579                     //linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
580                     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);
                Assert.True(scope3.Links.Unsync.Count() - initialCount3 <
                ↪  scope2.Links.Unsync.Count() - initialCount2);

                var duplicateProvider1 = new
                ↪  DuplicateSegmentsProvider<ulong>(scope1.Links.Unsync, scope1.Sequences);
                var duplicateProvider2 = new
                ↪  DuplicateSegmentsProvider<ulong>(scope2.Links.Unsync, scope2.Sequences);
                var duplicateProvider3 = new
                ↪  DuplicateSegmentsProvider<ulong>(scope3.Links.Unsync, scope3.Sequences);

                var duplicateCounter1 = new DuplicateSegmentsCounter<ulong>(duplicateProvider1);
                var duplicateCounter2 = new DuplicateSegmentsCounter<ulong>(duplicateProvider2);
                var duplicateCounter3 = new DuplicateSegmentsCounter<ulong>(duplicateProvider3);

                var duplicates1 = duplicateCounter1.Count();

                ConsoleHelpers.Debug("------");

                var duplicates2 = duplicateCounter2.Count();

                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;
696                 //    else
697                 //    {
698                 //        // TODO: Find a solution for this case
699                 //    }
700                 //}
701
702                 for (int i = START; i < END; i++)
703                 {
704                     var first = compressor1.Create(arrays[i].ShiftRight());
705                     var second = compressor1.Create(arrays[i].ShiftRight());
706
707                     if (first == second)
708                     {
709                         compressed1[i] = first;
710                     }
711                     else
712                     {
713                         // TODO: Find a solution for this case
714                     }
715                 }
```

```
716
717                 var elapsed1 = sw1.Elapsed;
718
719                 var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
720
721                 var sw2 = Stopwatch.StartNew();
722
723                 for (int i = START; i < END; i++)
724                 {
725                     var first = balancedVariantConverter.Convert(arrays[i]);
726                     var second = balancedVariantConverter.Convert(arrays[i]);
727
728                     if (first == second)
729                     {
730                         compressed2[i] = first;
731                     }
732                 }
733
734                 var elapsed2 = sw2.Elapsed;
735
736                 Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
                    {elapsed2}");
737
738                 Assert.True(elapsed1 > elapsed2);
739
740                 // Checks
741                 for (int i = START; i < END; i++)
742                 {
743                     var sequence1 = compressed1[i];
744                     var sequence2 = compressed2[i];
745
746                     if (sequence1 != _constants.Null && sequence2 != _constants.Null)
747                     {
748                         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
                            scope1.Links);
749
750                         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
                            scope2.Links);
751
752                         //var structure1 = scope1.Links.FormatStructure(sequence1, link =>
                            link.IsPartialPoint());
753                         //var structure2 = scope2.Links.FormatStructure(sequence2, link =>
                            link.IsPartialPoint());
754
755                         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
                            arrays[i].Length > 3)
756                         //    Assert.False(structure1 == structure2);
757
758                         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
759                     }
760                 }
761
762                 Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
763                 Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
764
765                 Debug.WriteLine($"{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
                    totalCharacters} | {(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
                    totalCharacters}");
766
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
```

```
            var strings = new List<string>();

            for (ulong i = 0; i < N; i++)
            {
                strings.Add(RandomHelpers.Default.NextUInt64().ToString());
            }

            strings = strings.Distinct().ToList();

            var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
            var totalCharacters = arrays.Select(x => x.Length).Sum();

            using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
            ↪  SequencesOptions<ulong> { UseCompression = true,
            ↪  EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
            using (var scope2 = new TempLinksTestScope(useSequences: true))
            {
                scope1.Links.UseUnicode();
                scope2.Links.UseUnicode();

                var compressor1 = scope1.Sequences;
                var compressor2 = scope2.Sequences;

                var compressed1 = new ulong[arrays.Length];
                var compressed2 = new ulong[arrays.Length];

                var sw1 = Stopwatch.StartNew();

                var START = 0;
                var END = arrays.Length;

                for (int i = START; i < END; i++)
                {
                    compressed1[i] = compressor1.Create(arrays[i].ShiftRight());
                }

                var elapsed1 = sw1.Elapsed;

                var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);

                var sw2 = Stopwatch.StartNew();

                for (int i = START; i < END; i++)
                {
                    compressed2[i] = balancedVariantConverter.Convert(arrays[i]);
                }

                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);

                        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]);
                }
            }
        }
    }
}
```

### 1.128 ./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());
        }

```

```
19          [Fact]
20          public static void RawNumbersCRUDTest()
21          {
22              UsingWithExternalReferences<byte>(links => links.TestRawNumbersCRUDOperations());
23              UsingWithExternalReferences<ushort>(links => links.TestRawNumbersCRUDOperations());
24              UsingWithExternalReferences<uint>(links => links.TestRawNumbersCRUDOperations());
25              UsingWithExternalReferences<ulong>(links => links.TestRawNumbersCRUDOperations());
26          }
27
28          [Fact]
29          public static void MultipleRandomCreationsAndDeletionsTest()
30          {
31              Using<byte>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Test
                ↪ MultipleRandomCreationsAndDeletions(16)); // Cannot use more because current
                ↪ implementation of tree cuts out 5 bits from the address space.
32              Using<ushort>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Te
                ↪ stMultipleRandomCreationsAndDeletions(100));
33              Using<uint>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Test
                ↪ MultipleRandomCreationsAndDeletions(100));
34              Using<ulong>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Tes
                ↪ tMultipleRandomCreationsAndDeletions(100));
35          }
36
37          private static void Using<TLink>(Action<ILinks<TLink>> action)
38          {
39              using (var dataMemory = new HeapResizableDirectMemory())
40              using (var indexMemory = new HeapResizableDirectMemory())
41              using (var memory = new SplitMemoryLinks<TLink>(dataMemory, indexMemory))
42              {
43                  action(memory);
44              }
45          }
46
47          private static void UsingWithExternalReferences<TLink>(Action<ILinks<TLink>> action)
48          {
49              var contants = new LinksConstants<TLink>(enableExternalReferencesSupport: true);
50              using (var dataMemory = new HeapResizableDirectMemory())
51              using (var indexMemory = new HeapResizableDirectMemory())
52              using (var memory = new SplitMemoryLinks<TLink>(dataMemory, indexMemory,
                ↪ SplitMemoryLinks<TLink>.DefaultLinksSizeStep, contants))
53              {
54                  action(memory);
55              }
56          }
57      }
58  }
```

## 1.129 ./csharp/Platform.Data.Doublets.Tests/TempLinksTestScope.cs

```
1   using System.IO;
2   using Platform.Disposables;
3   using Platform.Data.Doublets.Sequences;
4   using Platform.Data.Doublets.Decorators;
5   using Platform.Data.Doublets.Memory.United.Specific;
6
7   namespace Platform.Data.Doublets.Tests
8   {
9       public class TempLinksTestScope : DisposableBase
10      {
11          public ILinks<ulong> MemoryAdapter { get; }
12          public SynchronizedLinks<ulong> Links { get; }
13          public Sequences.Sequences Sequences { get; }
14          public string TempFilename { get; }
15          public string TempTransactionLogFilename { get; }
16          private readonly bool _deleteFiles;
17
18          public TempLinksTestScope(bool deleteFiles = true, bool useSequences = false, bool
                ↪ useLog = false) : this(new SequencesOptions<ulong>(), deleteFiles, useSequences,
                ↪ useLog) { }
19
20          public TempLinksTestScope(SequencesOptions<ulong> sequencesOptions, bool deleteFiles =
                ↪ true, bool useSequences = false, bool useLog = false)
21          {
22              _deleteFiles = deleteFiles;
23              TempFilename = Path.GetTempFileName();
24              TempTransactionLogFilename = Path.GetTempFileName();
25              var coreMemoryAdapter = new UInt64UnitedMemoryLinks(TempFilename);
26              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);
        }
    }
}
```

### 1.130 ./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);
```

```
133
134             Assert.True(equalityComparer.Equals(setter2.Result, constants.Null));
135
136             // Update link to reference null (prepare for delete)
137             var updated = links.Update(linkAddress3, constants.Null, constants.Null);
138
139             Assert.True(equalityComparer.Equals(updated, linkAddress3));
140
141             link3 = new Link<T>(links.GetLink(linkAddress3));
142
143             Assert.True(equalityComparer.Equals(link3.Source, constants.Null));
144             Assert.True(equalityComparer.Equals(link3.Target, constants.Null));
145
146             // Delete link
147             links.Delete(linkAddress3);
148
149             Assert.True(equalityComparer.Equals(links.Count(), two));
150
151             var setter3 = new Setter<T>(constants.Null);
152             links.Each(constants.Any, constants.Any, setter3.SetAndReturnTrue);
153
154             Assert.True(equalityComparer.Equals(setter3.Result, linkAddress2));
155         }
156
157         public static void TestMultipleRandomCreationsAndDeletions<TLink>(this ILinks<TLink>
            ↪ links, int maximumOperationsPerCycle)
158         {
159             var comparer = Comparer<TLink>.Default;
160             var addressToUInt64Converter = CheckedConverter<TLink, ulong>.Default;
161             var uInt64ToAddressConverter = CheckedConverter<ulong, TLink>.Default;
162             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 }
```

## 1.131 ./csharp/Platform.Data.Doublets.Tests/UInt64LinksTests.cs

```
1 using System;
2 using System.Collections.Generic;
```

```
using System.Diagnostics;
using System.IO;
using System.Text;
using System.Threading;
using System.Threading.Tasks;
using Xunit;
using Platform.Disposables;
using Platform.Ranges;
using Platform.Random;
using Platform.Timestamps;
using Platform.Reflection;
using Platform.Singletons;
using Platform.Scopes;
using Platform.Counters;
using Platform.Diagnostics;
using Platform.IO;
using Platform.Memory;
using Platform.Data.Doublets.Decorators;
using Platform.Data.Doublets.Memory.United.Specific;

namespace Platform.Data.Doublets.Tests
{
    public static class UInt64LinksTests
    {
        private static readonly LinksConstants<ulong> _constants =
        ↪ Default<LinksConstants<ulong>>.Instance;

        private const long Iterations = 10 * 1024;

        #region Concept

        [Fact]
        public static void MultipleCreateAndDeleteTest()
        {
            using (var scope = new Scope<Types<HeapResizableDirectMemory,
            ↪ UInt64UnitedMemoryLinks>>())
            {
                new UInt64Links(scope.Use<ILinks<ulong>>()).TestMultipleRandomCreationsAndDeleti⌋
                ↪ ons(100);
            }
        }

        [Fact]
        public static void CascadeUpdateTest()
        {
            var itself = _constants.Itself;
            using (var scope = new TempLinksTestScope(useLog: true))
            {
                var links = scope.Links;

                var l1 = links.Create();
                var l2 = links.Create();

                l2 = links.Update(l2, l2, l1, l2);

                links.CreateAndUpdate(l2, itself);
                links.CreateAndUpdate(l2, itself);

                l2 = links.Update(l2, l1);

                links.Delete(l2);

                Global.Trash = links.Count();

                links.Unsync.DisposeIfPossible(); // Close links to access log

                Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scop⌋
                ↪ e.TempTransactionLogFilename);
            }
        }

        [Fact]
        public static void BasicTransactionLogTest()
        {
            using (var scope = new TempLinksTestScope(useLog: true))
            {
                var links = scope.Links;
                var l1 = links.Create();
                var l2 = links.Create();

                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
183                     links.CreateAndUpdate(l2, itself);
184                     links.CreateAndUpdate(l2, itself);
185
186                     links.Unsync.DisposeIfPossible();
187
188                     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(
                        ↪  scope.TempTransactionLogFilename);
189                 }
190
191                 using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
                    ↪  useLog: true))
192                 {
193                     var links = scope.Links;
194                     var transactionsLayer = (UInt64LinksTransactionsLayer)links.Unsync;
195                     using (var transaction = transactionsLayer.BeginTransaction())
196                     {
197                         l2 = links.Update(l2, l1);
198
199                         links.Delete(l2);
200
201                         ExceptionThrower();
202
203                         transaction.Commit();
204                     }
205
206                     Global.Trash = links.Count();
207                 }
208             }
209             catch
210             {
211                 Assert.False(lastScope == null);
212
213                 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(last
                    ↪  Scope.TempTransactionLogFilename);
214
215                 lastScope.DeleteFiles();
216             }
217         }
218
219         [Fact]
220         public static void TransactionCommit()
221         {
222             var itself = _constants.Itself;
223
224             var tempDatabaseFilename = Path.GetTempFileName();
225             var tempTransactionLogFilename = Path.GetTempFileName();
226
227             // Commit
```

```
228             using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
                ↪ UInt64UnitedMemoryLinks(tempDatabaseFilename), tempTransactionLogFilename))
229             using (var links = new UInt64Links(memoryAdapter))
230             {
231                 using (var transaction = memoryAdapter.BeginTransaction())
232                 {
233                     var l1 = links.CreateAndUpdate(itself, itself);
234                     var l2 = links.CreateAndUpdate(itself, itself);
235
236                     Global.Trash = links.Update(l2, l2, l1, l2);
237
238                     links.Delete(l1);
239
240                     transaction.Commit();
241                 }
242
243                 Global.Trash = links.Count();
244             }
245
246             Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
                ↪ sactionLogFilename);
247         }
248
249         [Fact]
250         public static void TransactionDamage()
251         {
252             var itself = _constants.Itself;
253
254             var tempDatabaseFilename = Path.GetTempFileName();
255             var tempTransactionLogFilename = Path.GetTempFileName();
256
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
```

```
            File.Delete(tempDatabaseFilename);
            File.Delete(tempTransactionLogFilename);
        }

        [Fact]
        public static void Bug1Test()
        {
            var tempDatabaseFilename = Path.GetTempFileName();
            var tempTransactionLogFilename = Path.GetTempFileName();

            var itself = _constants.Itself;

            // User Code Error (Autoreverted), some data saved
            try
            {
                ulong l1;
                ulong l2;

                using (var memory = new UInt64UnitedMemoryLinks(tempDatabaseFilename))
                using (var memoryAdapter = new UInt64LinksTransactionsLayer(memory,
                ↪  tempTransactionLogFilename))
                using (var links = new UInt64Links(memoryAdapter))
                {
                    l1 = links.CreateAndUpdate(itself, itself);
                    l2 = links.CreateAndUpdate(itself, itself);

                    l2 = links.Update(l2, l2, l1, l2);

                    links.CreateAndUpdate(l2, itself);
                    links.CreateAndUpdate(l2, itself);
                }

                Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp⌋
                ↪  TransactionLogFilename);

                using (var memory = new UInt64UnitedMemoryLinks(tempDatabaseFilename))
                using (var memoryAdapter = new UInt64LinksTransactionsLayer(memory,
                ↪  tempTransactionLogFilename))
                using (var links = new UInt64Links(memoryAdapter))
                {
                    using (var transaction = memoryAdapter.BeginTransaction())
                    {
                        l2 = links.Update(l2, l1);

                        links.Delete(l2);

                        ExceptionThrower();

                        transaction.Commit();
                    }

                    Global.Trash = links.Count();
                }
            }
            catch
            {
                Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp⌋
                ↪  TransactionLogFilename);
            }

            File.Delete(tempDatabaseFilename);
            File.Delete(tempTransactionLogFilename);
        }

        private static void ExceptionThrower() => throw new InvalidOperationException();

        [Fact]
        public static void PathsTest()
        {
            var source = _constants.SourcePart;
            var target = _constants.TargetPart;

            using (var scope = new TempLinksTestScope())
            {
                var links = scope.Links;
                var l1 = links.CreatePoint();
                var l2 = links.CreatePoint();

                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++)
```

```
                {
                    //0 - 10 ГБ
                    //Каждые 100 МБ срез цифр

                    //links.TestGetSourceFunction();
                    //links.TestGetSourceFunctionInParallel();
                    //links.TestGetTargetFunction();
                    //links.TestGetTargetFunctionInParallel();
                    links.Create64BillionLinks();

                    links.TestRandomSearchFixed();
                    //links.Create64BillionLinksInParallel();
                    links.TestEachFunction();
                    //links.TestForeach();
                    //links.TestParallelForeach();
                }

                links.TestDeletionOfAllLinks();

            }
            catch (Exception ex)
            {
                ex.WriteToConsole();
            }
        }*/

         /*
        public static void TestLinksInSteps()
        {
            const long gibibyte = 1024 * 1024 * 1024;
            const long mebibyte = 1024 * 1024;

            var totalLinksToCreate = gibibyte /
↪   Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
            var linksStep = 102 * mebibyte /
↪   Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;

            var creationMeasurements = new List<TimeSpan>();
            var searchMeasuremets = new List<TimeSpan>();
            var deletionMeasurements = new List<TimeSpan>();

            GetBaseRandomLoopOverhead(linksStep);
            GetBaseRandomLoopOverhead(linksStep);

            var stepLoopOverhead = GetBaseRandomLoopOverhead(linksStep);

            ConsoleHelpers.Debug("Step loop overhead: {0}.", stepLoopOverhead);

            var loops = totalLinksToCreate / linksStep;

            for (int i = 0; i < loops; i++)
            {
                creationMeasurements.Add(Measure(() => links.RunRandomCreations(linksStep)));
                searchMeasuremets.Add(Measure(() => links.RunRandomSearches(linksStep)));

                Console.Write("\rC + S {0}/{1}", i + 1, loops);
            }

            ConsoleHelpers.Debug();

            for (int i = 0; i < loops; i++)
            {
                deletionMeasurements.Add(Measure(() => links.RunRandomDeletions(linksStep)));

                Console.Write("\rD {0}/{1}", i + 1, loops);
            }

            ConsoleHelpers.Debug();

            ConsoleHelpers.Debug("C S D");

            for (int i = 0; i < loops; i++)
            {
                ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i],
↪   searchMeasuremets[i], deletionMeasurements[i]);
            }

            ConsoleHelpers.Debug("C S D (no overhead)");

```

```
            for (int i = 0; i < loops; i++)
            {
                ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i] - stepLoopOverhead,
    ↪  searchMeasuremets[i] - stepLoopOverhead, deletionMeasurements[i] - stepLoopOverhead);
            }

            ConsoleHelpers.Debug("All tests done. Total links left in database: {0}.",
    ↪  links.Total);
        }

        private static void CreatePoints(this Platform.Links.Data.Core.Doublets.Links links, long
    ↪  amountToCreate)
        {
            for (long i = 0; i < amountToCreate; i++)
                links.Create(0, 0);
        }

         private static TimeSpan GetBaseRandomLoopOverhead(long loops)
         {
             return Measure(() =>
             {
                 ulong maxValue = RandomHelpers.DefaultFactory.NextUInt64();
                 ulong result = 0;
                 for (long i = 0; i < loops; i++)
                 {
                     var source = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
                     var target = RandomHelpers.DefaultFactory.NextUInt64(maxValue);

                     result += maxValue + source + target;
                 }
                 Global.Trash = result;
             });
         }
          */

         [Fact(Skip = "performance test")]
         public static void GetSourceTest()
         {
             using (var scope = new TempLinksTestScope())
             {
                 var links = scope.Links;
                 ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations.",
                     ↪  Iterations);

                 ulong counter = 0;

                 //var firstLink = links.First();
                 // Создаём одну связь, из которой будет производить считывание
                 var firstLink = links.Create();

                 var sw = Stopwatch.StartNew();

                 // Тестируем саму функцию
                 for (ulong i = 0; i < Iterations; i++)
                 {
                     counter += links.GetSource(firstLink);
                 }

                 var elapsedTime = sw.Elapsed;

                 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;

                 // Удаляем связь, из которой производилось считывание
                 links.Delete(firstLink);

                 ConsoleHelpers.Debug(
                     "{0} Iterations of GetSource function done in {1} ({2} Iterations per
                         ↪  second), counter result: {3}",
                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
             }
         }

         [Fact(Skip = "performance test")]
         public static void GetSourceInParallel()
         {
             using (var scope = new TempLinksTestScope())
             {
                 var links = scope.Links;
```

```
            ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations in parallel.", Iterations);

            long counter = 0;

            //var firstLink = links.First();
            var firstLink = links.Create();

            var sw = Stopwatch.StartNew();

            // Тестируем саму функцию
            Parallel.For(0, Iterations, x =>
            {
                Interlocked.Add(ref counter, (long)links.GetSource(firstLink));
                //Interlocked.Increment(ref counter);
            });

            var elapsedTime = sw.Elapsed;

            var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;

            links.Delete(firstLink);

            ConsoleHelpers.Debug(
                "{0} Iterations of GetSource function done in {1} ({2} Iterations per second), counter result: {3}",
                Iterations, elapsedTime, (long)iterationsPerSecond, counter);
        }
    }

    [Fact(Skip = "performance test")]
    public static void TestGetTarget()
    {
        using (var scope = new TempLinksTestScope())
        {
            var links = scope.Links;
            ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations.", Iterations);

            ulong counter = 0;

            //var firstLink = links.First();
            var firstLink = links.Create();

            var sw = Stopwatch.StartNew();

            for (ulong i = 0; i < Iterations; i++)
            {
                counter += links.GetTarget(firstLink);
            }

            var elapsedTime = sw.Elapsed;

            var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;

            links.Delete(firstLink);

            ConsoleHelpers.Debug(
                "{0} Iterations of GetTarget function done in {1} ({2} Iterations per second), counter result: {3}",
                Iterations, elapsedTime, (long)iterationsPerSecond, counter);
        }
    }

    [Fact(Skip = "performance test")]
    public static void TestGetTargetInParallel()
    {
        using (var scope = new TempLinksTestScope())
        {
            var links = scope.Links;
            ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations in parallel.", Iterations);

            long counter = 0;

            //var firstLink = links.First();
            var firstLink = links.Create();

            var sw = Stopwatch.StartNew();

```

```
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()
```

```
        {
            var tempFilename = Path.GetTempFileName();

            using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename, DefaultLinksSizeStep))
            {

                long counter = 0;

                ConsoleHelpers.Debug("Testing parallel foreach through links.");

                var sw = Stopwatch.StartNew();

                //Parallel.ForEach((IEnumerable<ulong>)links, x =>
                //{
                //    Interlocked.Increment(ref counter);
                //});

                var elapsedTime = sw.Elapsed;

                var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;

                ConsoleHelpers.Debug("{0} Iterations of Parallel Foreach's handler block done in {1} ({2} links per second)", counter, elapsedTime, (long)linksPerSecond);
            }

            File.Delete(tempFilename);
        }
        */

        [Fact(Skip = "performance test")]
        public static void Create64BillionLinks()
        {
            using (var scope = new TempLinksTestScope())
            {
                var links = scope.Links;
                var linksBeforeTest = links.Count();

                long linksToCreate = 64 * 1024 * 1024 / UInt64UnitedMemoryLinks.LinkSizeInBytes;

                ConsoleHelpers.Debug("Creating {0} links.", linksToCreate);

                var elapsedTime = Performance.Measure(() =>
                {
                    for (long i = 0; i < linksToCreate; i++)
                    {
                        links.Create();
                    }
                });

                var linksCreated = links.Count() - linksBeforeTest;
                var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;

                ConsoleHelpers.Debug("Current links count: {0}.", links.Count());

                ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
                    linksCreated, elapsedTime,
                    (long)linksPerSecond);
            }
        }

        [Fact(Skip = "performance test")]
        public static void Create64BillionLinksInParallel()
        {
            using (var scope = new TempLinksTestScope())
            {
                var links = scope.Links;
                var linksBeforeTest = links.Count();

                var sw = Stopwatch.StartNew();

                long linksToCreate = 64 * 1024 * 1024 / UInt64UnitedMemoryLinks.LinkSizeInBytes;

                ConsoleHelpers.Debug("Creating {0} links in parallel.", linksToCreate);

                Parallel.For(0, linksToCreate, x => links.Create());

                var elapsedTime = sw.Elapsed;

                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 }
```

## 1.132 ./csharp/Platform.Data.Doublets.Tests/UnaryNumberConvertersTests.cs

```
1  using Xunit;
2  using Platform.Random;
3  using Platform.Data.Doublets.Numbers.Unary;
4
5  namespace Platform.Data.Doublets.Tests
6  {
7      public static class UnaryNumberConvertersTests
8      {
9          [Fact]
10         public static void ConvertersTest()
11         {
12             using (var scope = new TempLinksTestScope())
13             {
14                 const int N = 10;
15                 var links = scope.Links;
16                 var meaningRoot = links.CreatePoint();
17                 var one = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
18                 var powerOf2ToUnaryNumberConverter = new
                    ↪ PowerOf2ToUnaryNumberConverter<ulong>(links, one);
19                 var toUnaryNumberConverter = new AddressToUnaryNumberConverter<ulong>(links,
                    ↪ powerOf2ToUnaryNumberConverter);
20                 var random = new System.Random(0);
21                 ulong[] numbers = new ulong[N];
22                 ulong[] unaryNumbers = new ulong[N];
23                 for (int i = 0; i < N; i++)
24                 {
25                     numbers[i] = random.NextUInt64();
26                     unaryNumbers[i] = toUnaryNumberConverter.Convert(numbers[i]);
27                 }
28                 var fromUnaryNumberConverterUsingOrOperation = new
                    ↪ UnaryNumberToAddressOrOperationConverter<ulong>(links,
                    ↪ powerOf2ToUnaryNumberConverter);
29                 var fromUnaryNumberConverterUsingAddOperation = new
                    ↪ UnaryNumberToAddressAddOperationConverter<ulong>(links, one);
30                 for (int i = 0; i < N; i++)
31                 {
32                     Assert.Equal(numbers[i],
                        ↪ fromUnaryNumberConverterUsingOrOperation.Convert(unaryNumbers[i]));
33                     Assert.Equal(numbers[i],
                        ↪ fromUnaryNumberConverterUsingAddOperation.Convert(unaryNumbers[i]));
34                 }
35             }
36         }
37     }
38 }
```

## 1.133 ./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);
                var unaryNumberToAddressConverter = new
                ↪  UnaryNumberToAddressOrOperationConverter<ulong>(links,
                ↪  powerOf2ToUnaryNumberConverter);
                TestCharAndUnicodeSymbolConverters(links, meaningRoot,
                ↪  addressToUnaryNumberConverter, unaryNumberToAddressConverter);
            }
        }

        [Fact]
        public static void CharAndRawNumberUnicodeSymbolConvertersTest()
        {
            using (var scope = new Scope<Types<HeapResizableDirectMemory,
            ↪  UnitedMemoryLinks<ulong>>>())
            {
                var links = scope.Use<ILinks<ulong>>();
                var meaningRoot = links.CreatePoint();
                var addressToRawNumberConverter = new AddressToRawNumberConverter<ulong>();
                var rawNumberToAddressConverter = new RawNumberToAddressConverter<ulong>();
                TestCharAndUnicodeSymbolConverters(links, meaningRoot,
                ↪  addressToRawNumberConverter, rawNumberToAddressConverter);
            }
        }

        private static void TestCharAndUnicodeSymbolConverters(ILinks<ulong> links, ulong
        ↪  meaningRoot, IConverter<ulong> addressToNumberConverter, IConverter<ulong>
        ↪  numberToAddressConverter)
        {
            var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
            var charToUnicodeSymbolConverter = new CharToUnicodeSymbolConverter<ulong>(links,
            ↪  addressToNumberConverter, unicodeSymbolMarker);
            var originalCharacter = 'H';
            var characterLink = charToUnicodeSymbolConverter.Convert(originalCharacter);
            var unicodeSymbolCriterionMatcher = new TargetMatcher<ulong>(links,
            ↪  unicodeSymbolMarker);
            var unicodeSymbolToCharConverter = new UnicodeSymbolToCharConverter<ulong>(links,
            ↪  numberToAddressConverter, unicodeSymbolCriterionMatcher);
            var resultingCharacter = unicodeSymbolToCharConverter.Convert(characterLink);
            Assert.Equal(originalCharacter, resultingCharacter);
        }

        [Fact]
        public static void StringAndUnicodeSequenceConvertersTest()
        {
            using (var scope = new TempLinksTestScope())
            {
                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 }
```

Index