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

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

using System.Runtime.CompilerServices;

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);
        }
    }
}
```

./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);
        }
    }
}
```

./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>
    {
        private ILinks<TLink> _facade;

        public LinksConstants<TLink> Constants { get; }

        public ILinks<TLink> Facade
        {
            get => _facade;
            set
            {
                _facade = value;
                if (Links is LinksDecoratorBase<TLink> decorator)
                {
                    decorator.Facade = value;
                }
                else if (Links is LinksDisposableDecoratorBase<TLink> disposableDecorator)
                {
```

```
                    disposableDecorator.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);
    }
}
```

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

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

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

namespace Platform.Data.Doublets.Decorators
{
    public abstract class LinksDisposableDecoratorBase<TLink> : DisposableBase, ILinks<TLink>
    {
        private ILinks<TLink> _facade;

        public LinksConstants<TLink> Constants { get; }

        public ILinks<TLink> Links { get; }

        public ILinks<TLink> Facade
        {
            get => _facade;
            set
            {
                _facade = value;
                if (Links is LinksDecoratorBase<TLink> decorator)
                {
                    decorator.Facade = value;
                }
                else if (Links is LinksDisposableDecoratorBase<TLink> disposableDecorator)
                {
                    disposableDecorator.Facade = value;
                }
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected LinksDisposableDecoratorBase(ILinks<TLink> links)
        {
            Links = 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);

        protected override bool AllowMultipleDisposeCalls => true;

        protected override void Dispose(bool manual, bool wasDisposed)
        {
            if (!wasDisposed)
            {
                Links.DisposeIfPossible();
            }
        }
    }
}
```

./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)
        {
            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)
            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];
            Links.EnsureLinkExists(link, nameof(link));
            Links.Delete(link);
        }
    }
}
```

./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;
            var indexPartConstant = constants.IndexPart;
            var sourcePartConstant = constants.SourcePart;
            var targetPartConstant = constants.TargetPart;
            var restrictionsCount = restrictions.Count;
            if (!_equalityComparer.Equals(constants.Any, itselfConstant)
             && (((restrictionsCount > indexPartConstant) &&
              ↪  _equalityComparer.Equals(restrictions[indexPartConstant], itselfConstant))
             || ((restrictionsCount > sourcePartConstant) &&
              ↪  _equalityComparer.Equals(restrictions[sourcePartConstant], itselfConstant))
             || ((restrictionsCount > targetPartConstant) &&
              ↪  _equalityComparer.Equals(restrictions[targetPartConstant], 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));
    }
}
```

./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;
            Links.EnsureCreated(substitution[constants.SourcePart],
             ↪  substitution[constants.TargetPart]);
            return Links.Update(restrictions, substitution);
        }
    }
}
```

./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)]
        public override TLink Create(IList<TLink> restrictions)
```

```
        {
            var link = Links.Create();
            return Links.Update(link, link, link);
        }

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

./Platform.Data.Doublets/Decorators/LinksUniquenessResolver.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 LinksUniquenessResolver<TLink> : LinksDecoratorBase<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
        {
            var newLinkAddress = Links.SearchOrDefault(substitution[Constants.SourcePart],
            ↪  substitution[Constants.TargetPart]);
            if (_equalityComparer.Equals(newLinkAddress, default))
            {
                return Links.Update(restrictions, substitution);
            }
            return ResolveAddressChangeConflict(restrictions[Constants.IndexPart],
            ↪  newLinkAddress);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual TLink ResolveAddressChangeConflict(TLink oldLinkAddress, TLink
        ↪  newLinkAddress)
        {
            if (!_equalityComparer.Equals(oldLinkAddress, newLinkAddress) &&
            ↪  Links.Exists(oldLinkAddress))
            {
                Facade.Delete(oldLinkAddress);
            }
            return newLinkAddress;
        }
    }
}
```

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
        {
            Links.EnsureDoesNotExists(substitution[Constants.SourcePart],
            ↪  substitution[Constants.TargetPart]);
            return Links.Update(restrictions, substitution);
        }
    }
}
```

./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)
        {
            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];
            Links.EnsureNoUsages(link);
            Links.Delete(link);
        }
    }
}
```

./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];
            Links.EnforceResetValues(linkIndex);
            Links.Delete(linkIndex);
        }
    }
}
```

./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>
    /// Представляет объект для работы с базой данных (файлом) в формате Links (массива связей).
    /// </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)
    ///     + меньше объём БД
    ///     - больше сложность
    ///
    /// 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
    /// Желательно реализовать поддержку переключения между деревьями и битовыми индексами
    ↪  (битовыми строками) - вариант матрицы (выстраеваемой лениво).
```

```
23      ///
24      /// Решить отключать ли проверки при компиляции под Release. Т.е. исключения будут
        ↪  выбрасываться только при #if DEBUG
25      /// </remarks>
26      public class UInt64Links : LinksDisposableDecoratorBase<ulong>
27      {
28          [MethodImpl(MethodImplOptions.AggressiveInlining)]
29          public UInt64Links(ILinks<ulong> links) : base(links) { }
30
31          [MethodImpl(MethodImplOptions.AggressiveInlining)]
32          public override ulong Create(IList<ulong> restrictions) => Links.CreatePoint();
33
34          public override ulong Update(IList<ulong> restrictions, IList<ulong> substitution)
35          {
36              var constants = Constants;
37              var indexPartConstant = constants.IndexPart;
38              var updatedLink = restrictions[indexPartConstant];
39              var sourcePartConstant = constants.SourcePart;
40              var newSource = substitution[sourcePartConstant];
41              var targetPartConstant = constants.TargetPart;
42              var newTarget = substitution[targetPartConstant];
43              var nullConstant = constants.Null;
44              var existedLink = nullConstant;
45              var itselfConstant = constants.Itself;
46              if (newSource != itselfConstant && newTarget != itselfConstant)
47              {
48                  existedLink = Links.SearchOrDefault(newSource, newTarget);
49              }
50              if (existedLink == nullConstant)
51              {
52                  var before = Links.GetLink(updatedLink);
53                  if (before[sourcePartConstant] != newSource || before[targetPartConstant] !=
                    ↪  newTarget)
54                  {
55                      Links.Update(updatedLink, newSource == itselfConstant ? updatedLink :
                        ↪  newSource,
56                                                newTarget == itselfConstant ? updatedLink :
                                                  ↪  newTarget);
57                  }
58                  return updatedLink;
59              }
60              else
61              {
62                  return Facade.MergeAndDelete(updatedLink, existedLink);
63              }
64          }
65
66          [MethodImpl(MethodImplOptions.AggressiveInlining)]
67          public override void Delete(IList<ulong> restrictions)
68          {
69              var linkIndex = restrictions[Constants.IndexPart];
70              Links.EnforceResetValues(linkIndex);
71              Facade.DeleteAllUsages(linkIndex);
72              Links.Delete(linkIndex);
73          }
74      }
75  }
```

./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.Arrays;
6   using Platform.Collections.Lists;
7   using Platform.Data.Universal;
8
9   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
10
11  namespace Platform.Data.Doublets.Decorators
12  {
13      /// <remarks>
14      /// What does empty pattern (for condition or substitution) mean? Nothing or Everything?
15      /// 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).
16      ///
17      /// 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.)
```

```
18      /// </remarks>
19      internal class UniLinks<TLink> : LinksDecoratorBase<TLink>, IUniLinks<TLink>
20      {
21          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪ EqualityComparer<TLink>.Default;
22
23          public UniLinks(ILinks<TLink> links) : base(links) { }
24
25          private struct Transition
26          {
27              public IList<TLink> Before;
28              public IList<TLink> After;
29
30              public Transition(IList<TLink> before, IList<TLink> after)
31              {
32                  Before = before;
33                  After = after;
34              }
35          }
36
37          //public static readonly TLink NullConstant = Use<LinksConstants<TLink>>.Single.Null;
38          //public static readonly IReadOnlyList<TLink> NullLink = new
            ↪ ReadOnlyCollection<TLink>(new List<TLink> { NullConstant, NullConstant, NullConstant
            ↪ });
39
40          // TODO: Подумать о том, как реализовать древовидный Restriction и Substitution
            ↪ (Links-Expression)
41          public TLink Trigger(IList<TLink> restriction, Func<IList<TLink>, IList<TLink>, TLink>
            ↪ matchedHandler, IList<TLink> substitution, Func<IList<TLink>, IList<TLink>, TLink>
            ↪ substitutedHandler)
42          {
43              ////List<Transition> transitions = null;
44              ////if (!restriction.IsNullOrEmpty())
45              ////{
46              ////    // Есть причина делать проход (чтение)
47              ////    if (matchedHandler != null)
48              ////    {
49              ////        if (!substitution.IsNullOrEmpty())
50              ////        {
51              ////            // restriction => { 0, 0, 0 } | { 0 } // Create
52              ////            // substitution => { itself, 0, 0 } | { itself, itself, itself } //
                ↪ Create / Update
53              ////            // substitution => { 0, 0, 0 } | { 0 } // Delete
54              ////            transitions = new List<Transition>();
55              ////            if (Equals(substitution[Constants.IndexPart], Constants.Null))
56              ////            {
57              ////                // If index is Null, that means we always ignore every other
                ↪ value (they are also Null by definition)
58              ////                var matchDecision = matchedHandler(, NullLink);
59              ////                if (Equals(matchDecision, Constants.Break))
60              ////                    return false;
61              ////                if (!Equals(matchDecision, Constants.Skip))
62              ////                    transitions.Add(new Transition(matchedLink, newValue));
63              ////            }
64              ////            else
65              ////            {
66              ////                Func<T, bool> handler;
67              ////                handler = link =>
68              ////                {
69              ////                    var matchedLink = Memory.GetLinkValue(link);
70              ////                    var newValue = Memory.GetLinkValue(link);
71              ////                    newValue[Constants.IndexPart] = Constants.Itself;
72              ////                    newValue[Constants.SourcePart] =
                ↪ Equals(substitution[Constants.SourcePart], Constants.Itself) ?
                ↪ matchedLink[Constants.IndexPart] : substitution[Constants.SourcePart];
73              ////                    newValue[Constants.TargetPart] =
                ↪ Equals(substitution[Constants.TargetPart], Constants.Itself) ?
                ↪ matchedLink[Constants.IndexPart] : substitution[Constants.TargetPart];
74              ////                    var matchDecision = matchedHandler(matchedLink, newValue);
75              ////                    if (Equals(matchDecision, Constants.Break))
76              ////                        return false;
77              ////                    if (!Equals(matchDecision, Constants.Skip))
78              ////                        transitions.Add(new Transition(matchedLink, newValue));
79              ////                    return true;
80              ////                };
81              ////                if (!Memory.Each(handler, restriction))
82              ////                    return Constants.Break;
83              ////            }
```

```
////        }
////        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)
//    {
//        matchedLinks = new List<IList<T>>();
//        Func<T, bool> handler = link =>
//        {
//            var matchedLink = Memory.GetLinkValue(link);
//            var matchDecision = matchedHandler(matchedLink);
//            if (Equals(matchDecision, Constants.Break))
//                return false;
//            if (!Equals(matchDecision, Constants.Skip))
//                matchedLinks.Add(matchedLink);
//            return true;
```

```
161             //        };
162             //        if (!Memory.Each(handler, restriction))
163             //            return Constants.Break;
164             //    }
165             //    if (!matchedLinks.IsNullOrEmpty())
166             //    {
167             //        var totalMatchedLinks = matchedLinks.Count;
168             //        for (var i = 0; i < totalMatchedLinks; i++)
169             //        {
170             //            var matchedLink = matchedLinks[i];
171             //            if (substitutedHandler != null)
172             //            {
173             //                var newValue = new List<T>(); // TODO: Prepare value to update here
174             //                // TODO: Decide is it actually needed to use Before and After
                ↪  substitution handling.
175             //                var substitutedDecision = substitutedHandler(matchedLink,
                ↪  newValue);
176             //                if (Equals(substitutedDecision, Constants.Break))
177             //                    return Constants.Break;
178             //                if (Equals(substitutedDecision, Constants.Continue))
179             //                {
180             //                    // Actual update here
181             //                    Memory.SetLinkValue(newValue);
182             //                }
183             //                if (Equals(substitutedDecision, Constants.Skip))
184             //                {
185             //                    // Cancel the update. TODO: decide use separate Cancel
                ↪  constant or Skip is enough?
186             //                }
187             //            }
188             //        }
189             //    }
190             //}
191             return Constants.Continue;
192         }
193
194         public TLink Trigger(IList<TLink> patternOrCondition, Func<IList<TLink>, TLink>
            ↪  matchHandler, IList<TLink> substitution, Func<IList<TLink>, IList<TLink>, TLink>
            ↪  substitutionHandler)
195         {
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 = ArrayPool<TLink>.Empty;
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 = ArrayPool<TLink>.Empty;
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);
296                     }
297                     return Constants.Continue;
298                 }
299                 else
300                 {
301                     throw new NotSupportedException();
302                 }
303             }
304         }
305 
306         /// <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>>>();
            Trigger(condition, AlwaysContinue, substitution, (before, after) =>
            {
                var change = new[] { before, after };
                changes.Add(change);
                return Constants.Continue;
            });
            return changes;
        }

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

./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();
    }
}
```

./Platform.Data.Doublets/Doublet.cs

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

#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 T Source { get; set; }
        public T Target { get; set; }

        public Doublet(T source, T target)
        {
            Source = source;
            Target = target;
        }

        public override string ToString() => $"{Source}->{Target}";

        public bool Equals(Doublet<T> other) => _equalityComparer.Equals(Source, other.Source)
        ↪  && _equalityComparer.Equals(Target, other.Target);

        public override bool Equals(object obj) => obj is Doublet<T> doublet ?
        ↪  base.Equals(doublet) : false;
```

```

        public override int GetHashCode() => (Source, Target).GetHashCode();
    }
}
```

./Platform.Data.Doublets/Hybrid.cs

```
using System;
using System.Reflection;
using System.Reflection.Emit;
using Platform.Reflection;
using Platform.Converters;
using Platform.Exceptions;

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

namespace Platform.Data.Doublets
{
    public class Hybrid<T>
    {
        private static readonly Func<object, T> _absAndConvert;
        private static readonly Func<object, T> _absAndNegateAndConvert;

        static Hybrid()
        {
            _absAndConvert = DelegateHelpers.Compile<Func<object, T>>(emiter =>
            {
                Ensure.Always.IsUnsignedInteger<T>();
                emiter.LoadArgument(0);
                var signedVersion = NumericType<T>.SignedVersion;
                var signedVersionField =
                ↪  typeof(NumericType<T>).GetTypeInfo().GetField("SignedVersion",
                ↪  BindingFlags.Static | BindingFlags.Public);
                //emiter.LoadField(signedVersionField);
                emiter.Emit(OpCodes.Ldsfld, signedVersionField);
                var changeTypeMethod = typeof(Convert).GetTypeInfo().GetMethod("ChangeType",
                ↪  Types<object, Type>.Array);
                emiter.Call(changeTypeMethod);
                emiter.UnboxValue(signedVersion);
                var absMethod = typeof(Math).GetTypeInfo().GetMethod("Abs", new[] {
                ↪  signedVersion });
                emiter.Call(absMethod);
                var unsignedMethod = typeof(To).GetTypeInfo().GetMethod("Unsigned", new[] {
                ↪  signedVersion });
                emiter.Call(unsignedMethod);
                emiter.Return();
            });
            _absAndNegateAndConvert = DelegateHelpers.Compile<Func<object, T>>(emiter =>
            {
                Ensure.Always.IsUnsignedInteger<T>();
                emiter.LoadArgument(0);
                var signedVersion = NumericType<T>.SignedVersion;
                var signedVersionField =
                ↪  typeof(NumericType<T>).GetTypeInfo().GetField("SignedVersion",
                ↪  BindingFlags.Static | BindingFlags.Public);
                //emiter.LoadField(signedVersionField);
                emiter.Emit(OpCodes.Ldsfld, signedVersionField);
                var changeTypeMethod = typeof(Convert).GetTypeInfo().GetMethod("ChangeType",
                ↪  Types<object, Type>.Array);
                emiter.Call(changeTypeMethod);
                emiter.UnboxValue(signedVersion);
                var absMethod = typeof(Math).GetTypeInfo().GetMethod("Abs", new[] {
                ↪  signedVersion });
                emiter.Call(absMethod);
                var negateMethod = typeof(Platform.Numbers.Math).GetTypeInfo().GetMethod("Negate
                ↪  ").MakeGenericMethod(signedVersion);
                emiter.Call(negateMethod);
                var unsignedMethod = typeof(To).GetTypeInfo().GetMethod("Unsigned", new[] {
                ↪  signedVersion });
                emiter.Call(unsignedMethod);
                emiter.Return();
            });
        }

        public readonly T Value;
        public bool IsNothing => Convert.ToInt64(To.Signed(Value)) == 0;
        public bool IsInternal => Convert.ToInt64(To.Signed(Value)) > 0;
        public bool IsExternal => Convert.ToInt64(To.Signed(Value)) < 0;
        public long AbsoluteValue =>
        ↪  Platform.Numbers.Math.Abs(Convert.ToInt64(To.Signed(Value)));
```

```
62
63          public Hybrid(T value)
64          {
65              Ensure.OnDebug.IsUnsignedInteger<T>();
66              Value = value;
67          }
68
69          public Hybrid(object value) => Value = To.UnsignedAs<T>(Convert.ChangeType(value,
            ↪  NumericType<T>.SignedVersion));
70
71          public Hybrid(object value, bool isExternal)
72          {
73              //var signedType = Type<T>.SignedVersion;
74              //var signedValue = Convert.ChangeType(value, signedType);
75              //var abs = typeof(Platform.Numbers.Math).GetTypeInfo().GetMethod("Abs").MakeGeneric
                ↪  Method(signedType);
76              //var negate = typeof(Platform.Numbers.Math).GetTypeInfo().GetMethod("Negate").MakeG
                ↪  enericMethod(signedType);
77              //var absoluteValue = abs.Invoke(null, new[] { signedValue });
78              //var resultValue = isExternal ? negate.Invoke(null, new[] { absoluteValue }) :
                ↪  absoluteValue;
79              //Value = To.UnsignedAs<T>(resultValue);
80              if (isExternal)
81              {
82                  Value = _absAndNegateAndConvert(value);
83              }
84              else
85              {
86                  Value = _absAndConvert(value);
87              }
88          }
89
90          public static implicit operator Hybrid<T>(T integer) => new Hybrid<T>(integer);
91
92          public static explicit operator Hybrid<T>(ulong integer) => new Hybrid<T>(integer);
93
94          public static explicit operator Hybrid<T>(long integer) => new Hybrid<T>(integer);
95
96          public static explicit operator Hybrid<T>(uint integer) => new Hybrid<T>(integer);
97
98          public static explicit operator Hybrid<T>(int integer) => new Hybrid<T>(integer);
99
100         public static explicit operator Hybrid<T>(ushort integer) => new Hybrid<T>(integer);
101
102         public static explicit operator Hybrid<T>(short integer) => new Hybrid<T>(integer);
103
104         public static explicit operator Hybrid<T>(byte integer) => new Hybrid<T>(integer);
105
106         public static explicit operator Hybrid<T>(sbyte integer) => new Hybrid<T>(integer);
107
108         public static implicit operator T(Hybrid<T> hybrid) => hybrid.Value;
109
110         public static explicit operator ulong(Hybrid<T> hybrid) =>
            ↪  Convert.ToUInt64(hybrid.Value);
111
112         public static explicit operator long(Hybrid<T> hybrid) => hybrid.AbsoluteValue;
113
114         public static explicit operator uint(Hybrid<T> hybrid) => Convert.ToUInt32(hybrid.Value);
115
116         public static explicit operator int(Hybrid<T> hybrid) =>
            ↪  Convert.ToInt32(hybrid.AbsoluteValue);
117
118         public static explicit operator ushort(Hybrid<T> hybrid) =>
            ↪  Convert.ToUInt16(hybrid.Value);
119
120         public static explicit operator short(Hybrid<T> hybrid) =>
            ↪  Convert.ToInt16(hybrid.AbsoluteValue);
121
122         public static explicit operator byte(Hybrid<T> hybrid) => Convert.ToByte(hybrid.Value);
123
124         public static explicit operator sbyte(Hybrid<T> hybrid) =>
            ↪  Convert.ToSByte(hybrid.AbsoluteValue);
125
126         public override string ToString() => IsNothing ? default(T) == null ? "Nothing" :
            ↪  default(T).ToString() : IsExternal ? $"<{AbsoluteValue}>" : Value.ToString();
127     }
128 }
```

./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>>
    {
    }
}
```

./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.Numbers;
using Platform.Random;
using Platform.Setters;
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
    {
        public static void RunRandomCreations<TLink>(this ILinks<TLink> links, long
        ↪  amountOfCreations)
        {
            for (long i = 0; i < amountOfCreations; i++)
            {
                var linksAddressRange = new Range<ulong>(0, (Integer<TLink>)links.Count());
                Integer<TLink> source = RandomHelpers.Default.NextUInt64(linksAddressRange);
                Integer<TLink> target = RandomHelpers.Default.NextUInt64(linksAddressRange);
                links.CreateAndUpdate(source, target);
            }
        }

        public static void RunRandomSearches<TLink>(this ILinks<TLink> links, long
        ↪  amountOfSearches)
        {
            for (long i = 0; i < amountOfSearches; i++)
            {
                var linkAddressRange = new Range<ulong>(1, (Integer<TLink>)links.Count());
                Integer<TLink> source = RandomHelpers.Default.NextUInt64(linkAddressRange);
                Integer<TLink> target = RandomHelpers.Default.NextUInt64(linkAddressRange);
                links.SearchOrDefault(source, target);
            }
        }

        public static void RunRandomDeletions<TLink>(this ILinks<TLink> links, long
        ↪  amountOfDeletions)
        {
            var min = (ulong)amountOfDeletions > (Integer<TLink>)links.Count() ? 1 :
            ↪  (Integer<TLink>)links.Count() - (ulong)amountOfDeletions;
            for (long i = 0; i < amountOfDeletions; i++)
            {
                var linksAddressRange = new Range<ulong>(min, (Integer<TLink>)links.Count());
                Integer<TLink> link = RandomHelpers.Default.NextUInt64(linksAddressRange);
                links.Delete(link);
                if ((Integer<TLink>)links.Count() < min)
                {
                    break;
                }
            }
        }

        public static void Delete<TLink>(this ILinks<TLink> links, TLink linkToDelete) =>
        ↪  links.Delete(new LinkAddress<TLink>(linkToDelete));

        /// <remarks>
        /// TODO: Возможно есть очень простой способ это сделать.
        /// (Например просто удалить файл, или изменить его размер таким образом,
```

```
62          /// чтобы удалился весь контент)
63          /// Например через _header->AllocatedLinks в ResizableDirectMemoryLinks
64          /// </remarks>
65          public static void DeleteAll<TLink>(this ILinks<TLink> links)
66          {
67              var equalityComparer = EqualityComparer<TLink>.Default;
68              var comparer = Comparer<TLink>.Default;
69              for (var i = links.Count(); comparer.Compare(i, default) > 0; i =
                ↪ Arithmetic.Decrement(i))
70              {
71                  links.Delete(i);
72                  if (!equalityComparer.Equals(links.Count(), Arithmetic.Decrement(i)))
73                  {
74                      i = links.Count();
75                  }
76              }
77          }
78
79          public static TLink First<TLink>(this ILinks<TLink> links)
80          {
81              TLink firstLink = default;
82              var equalityComparer = EqualityComparer<TLink>.Default;
83              if (equalityComparer.Equals(links.Count(), default))
84              {
85                  throw new InvalidOperationException("В хранилище нет связей.");
86              }
87              links.Each(links.Constants.Any, links.Constants.Any, link =>
88              {
89                  firstLink = link[links.Constants.IndexPart];
90                  return links.Constants.Break;
91              });
92              if (equalityComparer.Equals(firstLink, default))
93              {
94                  throw new InvalidOperationException("В процессе поиска по хранилищу не было
                    ↪ найдено связей.");
95              }
96              return firstLink;
97          }
98
99          #region Paths
100
101         /// <remarks>
102         /// TODO: Как так? Как то что ниже может быть корректно?
103         /// Скорее всего практически не применимо
104         /// Предполагалось, что можно было конвертировать формируемый в проходе через
            ↪ SequenceWalker
105         /// Stack в конкретный путь из Source, Target до связи, но это не всегда так.
106         /// TODO: Возможно нужен метод, который именно выбрасывает исключения (EnsurePathExists)
107         /// </remarks>
108         public static bool CheckPathExistance<TLink>(this ILinks<TLink> links, params TLink[]
            ↪ path)
109         {
110             var current = path[0];
111             //EnsureLinkExists(current, "path");
112             if (!links.Exists(current))
113             {
114                 return false;
115             }
116             var equalityComparer = EqualityComparer<TLink>.Default;
117             var constants = links.Constants;
118             for (var i = 1; i < path.Length; i++)
119             {
120                 var next = path[i];
121                 var values = links.GetLink(current);
122                 var source = values[constants.SourcePart];
123                 var target = values[constants.TargetPart];
124                 if (equalityComparer.Equals(source, target) && equalityComparer.Equals(source,
                    ↪ next))
125                 {
126                     //throw new InvalidOperationException(string.Format("Невозможно выбрать
                        ↪ путь, так как и Source и Target совпадают с элементом пути {0}.", next));
127                     return false;
128                 }
129                 if (!equalityComparer.Equals(next, source) && !equalityComparer.Equals(next,
                    ↪ target))
130                 {
131                     //throw new InvalidOperationException(string.Format("Невозможно продолжить
                        ↪ путь через элемент пути {0}", next));
```

```
                return false;
            }
            current = next;
        }
        return true;
    }

    /// <remarks>
    /// Может потребовать дополнительного стека для PathElement's при использовании SequenceWalker.
    /// </remarks>
    public static TLink GetByKeys<TLink>(this ILinks<TLink> links, TLink root, params int[] path)
    {
        links.EnsureLinkExists(root, "root");
        var currentLink = root;
        for (var i = 0; i < path.Length; i++)
        {
            currentLink = links.GetLink(currentLink)[path[i]];
        }
        return currentLink;
    }

    public static TLink GetSquareMatrixSequenceElementByIndex<TLink>(this ILinks<TLink> links, TLink root, ulong size, ulong index)
    {
        var constants = links.Constants;
        var source = constants.SourcePart;
        var target = constants.TargetPart;
        if (!Platform.Numbers.Math.IsPowerOfTwo(size))
        {
            throw new ArgumentOutOfRangeException(nameof(size), "Sequences with sizes other than powers of two are not supported.");
        }
        var path = new BitArray(BitConverter.GetBytes(index));
        var length = Bit.GetLowestPosition(size);
        links.EnsureLinkExists(root, "root");
        var currentLink = root;
        for (var i = length - 1; i >= 0; i--)
        {
            currentLink = links.GetLink(currentLink)[path[i] ? target : source];
        }
        return currentLink;
    }

    #endregion

    /// <summary>
    /// Возвращает индекс указанной связи.
    /// </summary>
    /// <param name="links">Хранилище связей.</param>
    /// <param name="link">Связь представленная списком, состоящим из её адреса и содержимого.</param>
    /// <returns>Индекс начальной связи для указанной связи.</returns>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public static TLink GetIndex<TLink>(this ILinks<TLink> links, IList<TLink> link) => link[links.Constants.IndexPart];

    /// <summary>
    /// Возвращает индекс начальной (Source) связи для указанной связи.
    /// </summary>
    /// <param name="links">Хранилище связей.</param>
    /// <param name="link">Индекс связи.</param>
    /// <returns>Индекс начальной связи для указанной связи.</returns>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public static TLink GetSource<TLink>(this ILinks<TLink> links, TLink link) => links.GetLink(link)[links.Constants.SourcePart];

    /// <summary>
    /// Возвращает индекс начальной (Source) связи для указанной связи.
    /// </summary>
    /// <param name="links">Хранилище связей.</param>
    /// <param name="link">Связь представленная списком, состоящим из её адреса и содержимого.</param>
    /// <returns>Индекс начальной связи для указанной связи.</returns>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public static TLink GetSource<TLink>(this ILinks<TLink> links, IList<TLink> link) => link[links.Constants.SourcePart];
```

```
201
202         /// <summary>
203         /// Возвращает индекс конечной (Target) связи для указанной связи.
204         /// </summary>
205         /// <param name="links">Хранилище связей.</param>
206         /// <param name="link">Индекс связи.</param>
207         /// <returns>Индекс конечной связи для указанной связи.</returns>
208         [MethodImpl(MethodImplOptions.AggressiveInlining)]
209         public static TLink GetTarget<TLink>(this ILinks<TLink> links, TLink link) =>
            ↪ links.GetLink(link)[links.Constants.TargetPart];
210
211         /// <summary>
212         /// Возвращает индекс конечной (Target) связи для указанной связи.
213         /// </summary>
214         /// <param name="links">Хранилище связей.</param>
215         /// <param name="link">Связь представленная списком, состоящим из её адреса и
            ↪ содержимого.</param>
216         /// <returns>Индекс конечной связи для указанной связи.</returns>
217         [MethodImpl(MethodImplOptions.AggressiveInlining)]
218         public static TLink GetTarget<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
            ↪ link[links.Constants.TargetPart];
219
220         /// <summary>
221         /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
            ↪ (handler) для каждой подходящей связи.
222         /// </summary>
223         /// <param name="links">Хранилище связей.</param>
224         /// <param name="handler">Обработчик каждой подходящей связи.</param>
225         /// <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>
226         /// <returns>True, в случае если проход по связям не был прерван и False в обратном
            ↪ случае.</returns>
227         [MethodImpl(MethodImplOptions.AggressiveInlining)]
228         public static bool Each<TLink>(this ILinks<TLink> links, Func<IList<TLink>, TLink>
            ↪ handler, params TLink[] restrictions)
229             => EqualityComparer<TLink>.Default.Equals(links.Each(handler, restrictions),
                ↪ links.Constants.Continue);
230
231         /// <summary>
232         /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
            ↪ (handler) для каждой подходящей связи.
233         /// </summary>
234         /// <param name="links">Хранилище связей.</param>
235         /// <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>
236         /// <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>
237         /// <param name="handler">Обработчик каждой подходящей связи.</param>
238         /// <returns>True, в случае если проход по связям не был прерван и False в обратном
            ↪ случае.</returns>
239         [MethodImpl(MethodImplOptions.AggressiveInlining)]
240         public static bool Each<TLink>(this ILinks<TLink> links, TLink source, TLink target,
            ↪ Func<TLink, bool> handler)
241         {
242             var constants = links.Constants;
243             return links.Each(link => handler(link[constants.IndexPart]) ? constants.Continue :
                ↪ constants.Break, constants.Any, source, target);
244         }
245
246         /// <summary>
247         /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
            ↪ (handler) для каждой подходящей связи.
248         /// </summary>
249         /// <param name="links">Хранилище связей.</param>
250         /// <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>
251         /// <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>
252         /// <param name="handler">Обработчик каждой подходящей связи.</param>
253         /// <returns>True, в случае если проход по связям не был прерван и False в обратном
            ↪ случае.</returns>
```

```
254         [MethodImpl(MethodImplOptions.AggressiveInlining)]
255         public static bool Each<TLink>(this ILinks<TLink> links, TLink source, TLink target,
            ↪  Func<IList<TLink>, TLink> handler)
256         {
257             var constants = links.Constants;
258             return links.Each(handler, constants.Any, source, target);
259         }
260
261         [MethodImpl(MethodImplOptions.AggressiveInlining)]
262         public static IList<IList<TLink>> All<TLink>(this ILinks<TLink> links, params TLink[]
            ↪  restrictions)
263         {
264             long arraySize = (Integer<TLink>)links.Count(restrictions);
265             var array = new IList<TLink>[arraySize];
266             if (arraySize > 0)
267             {
268                 var filler = new ArrayFiller<IList<TLink>, TLink>(array,
                    ↪  links.Constants.Continue);
269                 links.Each(filler.AddAndReturnConstant, restrictions);
270             }
271             return array;
272         }
273
274         [MethodImpl(MethodImplOptions.AggressiveInlining)]
275         public static IList<TLink> AllIndices<TLink>(this ILinks<TLink> links, params TLink[]
            ↪  restrictions)
276         {
277             long arraySize = (Integer<TLink>)links.Count(restrictions);
278             var array = new TLink[arraySize];
279             if (arraySize > 0)
280             {
281                 var filler = new ArrayFiller<TLink, TLink>(array, links.Constants.Continue);
282                 links.Each(filler.AddFirstAndReturnConstant, restrictions);
283             }
284             return array;
285         }
286
287         /// <summary>
288         /// Возвращает значение, определяющее существует ли связь с указанными началом и концом
            ↪  в хранилище связей.
289         /// </summary>
290         /// <param name="links">Хранилище связей.</param>
291         /// <param name="source">Начало связи.</param>
292         /// <param name="target">Конец связи.</param>
293         /// <returns>Значение, определяющее существует ли связь.</returns>
294         [MethodImpl(MethodImplOptions.AggressiveInlining)]
295         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;
296
297         #region Ensure
298         // TODO: May be move to EnsureExtensions or make it both there and here
299
300         [MethodImpl(MethodImplOptions.AggressiveInlining)]
301         public static void EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links, TLink
            ↪  reference, string argumentName)
302         {
303             if (links.Constants.IsInnerReference(reference) && !links.Exists(reference))
304             {
305                 throw new ArgumentLinkDoesNotExistsException<TLink>(reference, argumentName);
306             }
307         }
308
309         [MethodImpl(MethodImplOptions.AggressiveInlining)]
310         public static void EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links,
            ↪  IList<TLink> restrictions, string argumentName)
311         {
312             for (int i = 0; i < restrictions.Count; i++)
313             {
314                 links.EnsureInnerReferenceExists(restrictions[i], argumentName);
315             }
316         }
317
318         [MethodImpl(MethodImplOptions.AggressiveInlining)]
319         public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, IList<TLink>
            ↪  restrictions)
320         {
321             for (int i = 0; i < restrictions.Count; i++)
```

```
            {
                links.EnsureLinkIsAnyOrExists(restrictions[i], nameof(restrictions));
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, TLink link,
        ↪  string argumentName)
        {
            var equalityComparer = EqualityComparer<TLink>.Default;
            if (!equalityComparer.Equals(link, links.Constants.Any) && !links.Exists(link))
            {
                throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static void EnsureLinkIsItselfOrExists<TLink>(this ILinks<TLink> links, TLink
        ↪  link, string argumentName)
        {
            var equalityComparer = EqualityComparer<TLink>.Default;
            if (!equalityComparer.Equals(link, links.Constants.Itself) && !links.Exists(link))
            {
                throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
            }
        }

        /// <param name="links">Хранилище связей.</param>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static void EnsureDoesNotExists<TLink>(this ILinks<TLink> links, TLink source,
        ↪  TLink target)
        {
            if (links.Exists(source, target))
            {
                throw new LinkWithSameValueAlreadyExistsException();
            }
        }

        /// <param name="links">Хранилище связей.</param>
        public static void EnsureNoUsages<TLink>(this ILinks<TLink> links, TLink link)
        {
            if (links.HasUsages(link))
            {
                throw new ArgumentLinkHasDependenciesException<TLink>(link);
            }
        }

        /// <param name="links">Хранилище связей.</param>
        public static void EnsureCreated<TLink>(this ILinks<TLink> links, params TLink[]
        ↪  addresses) => links.EnsureCreated(links.Create, addresses);

        /// <param name="links">Хранилище связей.</param>
        public static void EnsurePointsCreated<TLink>(this ILinks<TLink> links, params TLink[]
        ↪  addresses) => links.EnsureCreated(links.CreatePoint, addresses);

        /// <param name="links">Хранилище связей.</param>
        public static void EnsureCreated<TLink>(this ILinks<TLink> links, Func<TLink> creator,
        ↪  params TLink[] addresses)
        {
            var constants = links.Constants;

            var nonExistentAddresses = new HashSet<TLink>(addresses.Where(x =>
            ↪  !links.Exists(x)));
            if (nonExistentAddresses.Count > 0)
            {
                var max = nonExistentAddresses.Max();
                max = (Integer<TLink>)System.Math.Min((ulong)(Integer<TLink>)max,
                ↪  (ulong)(Integer<TLink>)constants.PossibleInnerReferencesRange.Maximum);
                var createdLinks = new List<TLink>();
                var equalityComparer = EqualityComparer<TLink>.Default;
                TLink createdLink = creator();
                while (!equalityComparer.Equals(createdLink, max))
                {
                    createdLinks.Add(createdLink);
                }
                for (var i = 0; i < createdLinks.Count; i++)
                {
                    if (!nonExistentAddresses.Contains(createdLinks[i]))
```

```
                {
                    links.Delete(createdLinks[i]);
                }
            }
        }
    }

    #endregion

    /// <param name="links">Хранилище связей.</param>
    public static TLink CountUsages<TLink>(this ILinks<TLink> links, TLink link)
    {
        var constants = links.Constants;
        var values = links.GetLink(link);
        TLink usagesAsSource = links.Count(new Link<TLink>(constants.Any, link,
        ↪  constants.Any));
        var equalityComparer = EqualityComparer<TLink>.Default;
        if (equalityComparer.Equals(values[constants.SourcePart], link))
        {
            usagesAsSource = Arithmetic<TLink>.Decrement(usagesAsSource);
        }
        TLink usagesAsTarget = links.Count(new Link<TLink>(constants.Any, constants.Any,
        ↪  link));
        if (equalityComparer.Equals(values[constants.TargetPart], link))
        {
            usagesAsTarget = Arithmetic<TLink>.Decrement(usagesAsTarget);
        }
        return Arithmetic<TLink>.Add(usagesAsSource, usagesAsTarget);
    }

    /// <param name="links">Хранилище связей.</param>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public static bool HasUsages<TLink>(this ILinks<TLink> links, TLink link) =>
    ↪  Comparer<TLink>.Default.Compare(links.CountUsages(link), Integer<TLink>.Zero) > 0;

    /// <param name="links">Хранилище связей.</param>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public static bool Equals<TLink>(this ILinks<TLink> links, TLink link, TLink source,
    ↪  TLink target)
    {
        var constants = links.Constants;
        var values = links.GetLink(link);
        var equalityComparer = EqualityComparer<TLink>.Default;
        return equalityComparer.Equals(values[constants.SourcePart], source) &&
        ↪  equalityComparer.Equals(values[constants.TargetPart], target);
    }

    /// <summary>
    /// Выполняет поиск связи с указанными Source (началом) и Target (концом).
    /// </summary>
    /// <param name="links">Хранилище связей.</param>
    /// <param name="source">Индекс связи, которая является началом для искомой
    ↪  связи.</param>
    /// <param name="target">Индекс связи, которая является концом для искомой связи.</param>
    /// <returns>Индекс искомой связи с указанными Source (началом) и Target
    ↪  (концом).</returns>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public static TLink SearchOrDefault<TLink>(this ILinks<TLink> links, TLink source, TLink
    ↪  target)
    {
        var contants = links.Constants;
        var setter = new Setter<TLink, TLink>(contants.Continue, contants.Break, default);
        links.Each(setter.SetFirstAndReturnFalse, contants.Any, source, target);
        return setter.Result;
    }

    /// <param name="links">Хранилище связей.</param>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public static TLink Create<TLink>(this ILinks<TLink> links) => links.Create(null);

    /// <param name="links">Хранилище связей.</param>
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public static TLink CreatePoint<TLink>(this ILinks<TLink> links)
    {
        var link = links.Create();
        return links.Update(link, link, link);
    }

```

```
462         /// <param name="links">Хранилище связей.</param>
463         [MethodImpl(MethodImplOptions.AggressiveInlining)]
464         public static TLink CreateAndUpdate<TLink>(this ILinks<TLink> links, TLink source, TLink
            ↪ target) => links.Update(links.Create(), source, target);
465
466         /// <summary>
467         /// Обновляет связь с указанными началом (Source) и концом (Target)
468         /// на связь с указанными началом (NewSource) и концом (NewTarget).
469         /// </summary>
470         /// <param name="links">Хранилище связей.</param>
471         /// <param name="link">Индекс обновляемой связи.</param>
472         /// <param name="newSource">Индекс связи, которая является началом связи, на которую
            ↪ выполняется обновление.</param>
473         /// <param name="newTarget">Индекс связи, которая является концом связи, на которую
            ↪ выполняется обновление.</param>
474         /// <returns>Индекс обновлённой связи.</returns>
475         [MethodImpl(MethodImplOptions.AggressiveInlining)]
476         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));
477
478         /// <summary>
479         /// Обновляет связь с указанными началом (Source) и концом (Target)
480         /// на связь с указанными началом (NewSource) и концом (NewTarget).
481         /// </summary>
482         /// <param name="links">Хранилище связей.</param>
483         /// <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>
484         /// <returns>Индекс обновлённой связи.</returns>
485         [MethodImpl(MethodImplOptions.AggressiveInlining)]
486         public static TLink Update<TLink>(this ILinks<TLink> links, params TLink[] restrictions)
487         {
488             if (restrictions.Length == 2)
489             {
490                 return links.MergeAndDelete(restrictions[0], restrictions[1]);
491             }
492             if (restrictions.Length == 4)
493             {
494                 return links.UpdateOrCreateOrGet(restrictions[0], restrictions[1],
                    ↪ restrictions[2], restrictions[3]);
495             }
496             else
497             {
498                 return links.Update(new LinkAddress<TLink>(restrictions[0]), restrictions);
499             }
500         }
501
502         [MethodImpl(MethodImplOptions.AggressiveInlining)]
503         public static IList<TLink> ResolveConstantAsSelfReference<TLink>(this ILinks<TLink>
            ↪ links, TLink constant, IList<TLink> restrictions, IList<TLink> substitution)
504         {
505             var equalityComparer = EqualityComparer<TLink>.Default;
506             var constants = links.Constants;
507             var restrictionsIndex = restrictions[constants.IndexPart];
508             var substitutionIndex = substitution[constants.IndexPart];
509             if (equalityComparer.Equals(substitutionIndex, default))
510             {
511                 substitutionIndex = restrictionsIndex;
512             }
513             var source = substitution[constants.SourcePart];
514             var target = substitution[constants.TargetPart];
515             source = equalityComparer.Equals(source, constant) ? substitutionIndex : source;
516             target = equalityComparer.Equals(target, constant) ? substitutionIndex : target;
517             return new Link<TLink>(substitutionIndex, source, target);
518         }
519
520         /// <summary>
521         /// Создаёт связь (если она не существовала), либо возвращает индекс существующей связи
            ↪ с указанными Source (началом) и Target (концом).
522         /// </summary>
523         /// <param name="links">Хранилище связей.</param>
524         /// <param name="source">Индекс связи, которая является началом на создаваемой
            ↪ связи.</param>
525         /// <param name="target">Индекс связи, которая является концом для создаваемой
            ↪ связи.</param>
```

```
526         /// <returns>Индекс связи, с указанным Source (началом) и Target (концом)</returns>
527         [MethodImpl(MethodImplOptions.AggressiveInlining)]
528         public static TLink GetOrCreate<TLink>(this ILinks<TLink> links, TLink source, TLink
            ↪ target)
529         {
530             var link = links.SearchOrDefault(source, target);
531             if (EqualityComparer<TLink>.Default.Equals(link, default))
532             {
533                 link = links.CreateAndUpdate(source, target);
534             }
535             return link;
536         }
537 
538         /// <summary>
539         /// Обновляет связь с указанными началом (Source) и концом (Target)
540         /// на связь с указанными началом (NewSource) и концом (NewTarget).
541         /// </summary>
542         /// <param name="links">Хранилище связей.</param>
543         /// <param name="source">Индекс связи, которая является началом обновляемой
            ↪ связи.</param>
544         /// <param name="target">Индекс связи, которая является концом обновляемой связи.</param>
545         /// <param name="newSource">Индекс связи, которая является началом связи, на которую
            ↪ выполняется обновление.</param>
546         /// <param name="newTarget">Индекс связи, которая является концом связи, на которую
            ↪ выполняется обновление.</param>
547         /// <returns>Индекс обновлённой связи.</returns>
548         [MethodImpl(MethodImplOptions.AggressiveInlining)]
549         public static TLink UpdateOrCreateOrGet<TLink>(this ILinks<TLink> links, TLink source,
            ↪ TLink target, TLink newSource, TLink newTarget)
550         {
551             var equalityComparer = EqualityComparer<TLink>.Default;
552             var link = links.SearchOrDefault(source, target);
553             if (equalityComparer.Equals(link, default))
554             {
555                 return links.CreateAndUpdate(newSource, newTarget);
556             }
557             if (equalityComparer.Equals(newSource, source) && equalityComparer.Equals(newTarget,
                ↪ target))
558             {
559                 return link;
560             }
561             return links.Update(link, newSource, newTarget);
562         }
563 
564         /// <summary>Удаляет связь с указанными началом (Source) и концом (Target).</summary>
565         /// <param name="links">Хранилище связей.</param>
566         /// <param name="source">Индекс связи, которая является началом удаляемой связи.</param>
567         /// <param name="target">Индекс связи, которая является концом удаляемой связи.</param>
568         [MethodImpl(MethodImplOptions.AggressiveInlining)]
569         public static TLink DeleteIfExists<TLink>(this ILinks<TLink> links, TLink source, TLink
            ↪ target)
570         {
571             var link = links.SearchOrDefault(source, target);
572             if (!EqualityComparer<TLink>.Default.Equals(link, default))
573             {
574                 links.Delete(link);
575                 return link;
576             }
577             return default;
578         }
579 
580         /// <summary>Удаляет несколько связей.</summary>
581         /// <param name="links">Хранилище связей.</param>
582         /// <param name="deletedLinks">Список адресов связей к удалению.</param>
583         [MethodImpl(MethodImplOptions.AggressiveInlining)]
584         public static void DeleteMany<TLink>(this ILinks<TLink> links, IList<TLink> deletedLinks)
585         {
586             for (int i = 0; i < deletedLinks.Count; i++)
587             {
588                 links.Delete(deletedLinks[i]);
589             }
590         }
591 
592         /// <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>
593         public static void DeleteAllUsages<TLink>(this ILinks<TLink> links, TLink linkIndex)
594         {
```

```
595             var anyConstant = links.Constants.Any;
596             var usagesAsSourceQuery = new Link<TLink>(anyConstant, linkIndex, anyConstant);
597             links.DeleteByQuery(usagesAsSourceQuery);
598             var usagesAsTargetQuery = new Link<TLink>(anyConstant, linkIndex, anyConstant);
599             links.DeleteByQuery(usagesAsTargetQuery);
600         }
601
602         public static void DeleteByQuery<TLink>(this ILinks<TLink> links, Link<TLink> query)
603         {
604             var count = (Integer<TLink>)links.Count(query);
605             if (count > 0)
606             {
607                 var queryResult = new TLink[count];
608                 var queryResultFiller = new ArrayFiller<TLink, TLink>(queryResult,
                    ↪ links.Constants.Continue);
609                 links.Each(queryResultFiller.AddFirstAndReturnConstant, query);
610                 for (var i = (long)count - 1; i >= 0; i--)
611                 {
612                     links.Delete(queryResult[i]);
613                 }
614             }
615         }
616
617         // TODO: Move to Platform.Data
618         public static bool AreValuesReset<TLink>(this ILinks<TLink> links, TLink linkIndex)
619         {
620             var nullConstant = links.Constants.Null;
621             var equalityComparer = EqualityComparer<TLink>.Default;
622             var link = links.GetLink(linkIndex);
623             for (int i = 1; i < link.Count; i++)
624             {
625                 if (!equalityComparer.Equals(link[i], nullConstant))
626                 {
627                     return false;
628                 }
629             }
630             return true;
631         }
632
633         // TODO: Create a universal version of this method in Platform.Data (with using of for
            ↪ loop)
634         public static void ResetValues<TLink>(this ILinks<TLink> links, TLink linkIndex)
635         {
636             var nullConstant = links.Constants.Null;
637             var updateRequest = new Link<TLink>(linkIndex, nullConstant, nullConstant);
638             links.Update(updateRequest);
639         }
640
641         // TODO: Create a universal version of this method in Platform.Data (with using of for
            ↪ loop)
642         public static void EnforceResetValues<TLink>(this ILinks<TLink> links, TLink linkIndex)
643         {
644             if (!links.AreValuesReset(linkIndex))
645             {
646                 links.ResetValues(linkIndex);
647             }
648         }
649
650         /// <summary>
651         /// Merging two usages graphs, all children of old link moved to be children of new link
            ↪ or deleted.
652         /// </summary>
653         public static TLink MergeUsages<TLink>(this ILinks<TLink> links, TLink oldLinkIndex,
            ↪ TLink newLinkIndex)
654         {
655             var equalityComparer = EqualityComparer<TLink>.Default;
656             if (!equalityComparer.Equals(oldLinkIndex, newLinkIndex))
657             {
658                 var constants = links.Constants;
659                 var usagesAsSourceQuery = new Link<TLink>(constants.Any, oldLinkIndex,
                    ↪ constants.Any);
660                 long usagesAsSourceCount = (Integer<TLink>)links.Count(usagesAsSourceQuery);
661                 var usagesAsTargetQuery = new Link<TLink>(constants.Any, constants.Any,
                    ↪ oldLinkIndex);
662                 long usagesAsTargetCount = (Integer<TLink>)links.Count(usagesAsTargetQuery);
663                 var isStandalonePoint = Point<TLink>.IsFullPoint(links.GetLink(oldLinkIndex)) &&
                    ↪ usagesAsSourceCount == 1 && usagesAsTargetCount == 1;
664                 if (!isStandalonePoint)
```

```
                {
                    var totalUsages = usagesAsSourceCount + usagesAsTargetCount;
                    if (totalUsages > 0)
                    {
                        var usages = ArrayPool.Allocate<TLink>(totalUsages);
                        var usagesFiller = new ArrayFiller<TLink, TLink>(usages,
                        ↪  links.Constants.Continue);
                        var i = 0L;
                        if (usagesAsSourceCount > 0)
                        {
                            links.Each(usagesFiller.AddFirstAndReturnConstant,
                            ↪  usagesAsSourceQuery);
                            for (; i < usagesAsSourceCount; i++)
                            {
                                var usage = usages[i];
                                if (!equalityComparer.Equals(usage, oldLinkIndex))
                                {
                                    links.Update(usage, newLinkIndex, links.GetTarget(usage));
                                }
                            }
                        }
                        if (usagesAsTargetCount > 0)
                        {
                            links.Each(usagesFiller.AddFirstAndReturnConstant,
                            ↪  usagesAsTargetQuery);
                            for (; i < usages.Length; i++)
                            {
                                var usage = usages[i];
                                if (!equalityComparer.Equals(usage, oldLinkIndex))
                                {
                                    links.Update(usage, links.GetSource(usage), newLinkIndex);
                                }
                            }
                        }
                        ArrayPool.Free(usages);
                    }
                }
            }
            return newLinkIndex;
        }

        /// <summary>
        /// Replace one link with another (replaced link is deleted, children are updated or
        ↪  deleted).
        /// </summary>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static TLink MergeAndDelete<TLink>(this ILinks<TLink> links, TLink oldLinkIndex,
        ↪  TLink newLinkIndex)
        {
            var equalityComparer = EqualityComparer<TLink>.Default;
            if (!equalityComparer.Equals(oldLinkIndex, newLinkIndex))
            {
                links.MergeUsages(oldLinkIndex, newLinkIndex);
                links.Delete(oldLinkIndex);
            }
            return newLinkIndex;
        }

        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;
        }
    }
}
```

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

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

#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;

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

        public TLink Increment(TLink frequency)
        {
            if (_equalityComparer.Equals(frequency, default))
            {
                return Links.GetOrCreate(_unaryOne, _frequencyMarker);
            }
            var source = Links.GetSource(frequency);
            var incrementedSource = _unaryNumberIncrementer.Increment(source);
            return Links.GetOrCreate(incrementedSource, _frequencyMarker);
        }
    }
}
```

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

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

#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;

        public UnaryNumberIncrementer(ILinks<TLink> links, TLink unaryOne) : base(links) =>
        ↪ _unaryOne = unaryOne;

        public TLink Increment(TLink unaryNumber)
        {
            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));
            }
        }
    }
}
```

./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>
    {
    }
}
```

./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);

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public Link(object other)
        {
            if (other is Link<TLink> otherLink)
            {
                SetValues(ref otherLink, out Index, out Source, out Target);
            }
            else if(other is IList<TLink> otherList)
            {
                SetValues(otherList, out Index, out Source, out Target);
            }
            else
            {
                throw new NotSupportedException();
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public Link(ref Link<TLink> other) => SetValues(ref other, out Index, out Source, out Target);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public Link(TLink index, TLink source, TLink target)
        {
            Index = index;
            Source = source;
            Target = target;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static void SetValues(ref Link<TLink> other, out TLink index, out TLink source, out TLink target)
        {
            index = other.Index;
            source = other.Source;
            target = other.Target;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static void SetValues(IList<TLink> values, out TLink index, out TLink source, out TLink target)
```

```
        {
            switch (values.Count)
            {
                case 3:
                    index = values[0];
                    source = values[1];
                    target = values[2];
                    break;
                case 2:
                    index = values[0];
                    source = values[1];
                    target = default;
                    break;
                case 1:
                    index = values[0];
                    source = default;
                    target = default;
                    break;
                default:
                    index = default;
                    source = default;
                    target = default;
                    break;
            }
        }

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool IsNull() => _equalityComparer.Equals(Index, _constants.Null)
                             && _equalityComparer.Equals(Source, _constants.Null)
                             && _equalityComparer.Equals(Target, _constants.Null);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override bool Equals(object other) => other is Link<TLink> &&
        ↪  Equals((Link<TLink>)other);

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static string ToString(TLink index, TLink source, TLink target) => $"({index}:
        ↪  {source}->{target})";

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static string ToString(TLink source, TLink target) => $"({source}->{target})";

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator TLink[](Link<TLink> link) => link.ToArray();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static implicit operator Link<TLink>(TLink[] linkArray) => new
        ↪  Link<TLink>(linkArray);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override string ToString() => _equalityComparer.Equals(Index, _constants.Null) ?
        ↪  ToString(Source, Target) : ToString(Index, Source, Target);

        #region IList

        public int Count => Length;

        public bool IsReadOnly => true;

        public TLink this[int index]
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get
            {
                Ensure.OnDebug.ArgumentInRange(index, new Range<int>(0, Length - 1),
                ↪  nameof(index));
                if (index == _constants.IndexPart)
                {
                    return Index;
                }
                if (index == _constants.SourcePart)
                {
```

```
                    return Source;
                }
                if (index == _constants.TargetPart)
                {
                    return Target;
                }
                throw new NotSupportedException(); // Impossible path due to Ensure.ArgumentInRange
            }
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set => throw new NotSupportedException();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        IEnumerator IEnumerable.GetEnumerator() => GetEnumerator();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public IEnumerator<TLink> GetEnumerator()
        {
            yield return Index;
            yield return Source;
            yield return Target;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Add(TLink item) => throw new NotSupportedException();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Clear() => throw new NotSupportedException();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Contains(TLink item) => IndexOf(item) >= 0;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void CopyTo(TLink[] array, int arrayIndex)
        {
            Ensure.OnDebug.ArgumentNotNull(array, nameof(array));
            Ensure.OnDebug.ArgumentInRange(arrayIndex, new Range<int>(0, array.Length - 1), nameof(arrayIndex));
            if (arrayIndex + Length > array.Length)
            {
                throw new InvalidOperationException();
            }
            array[arrayIndex++] = Index;
            array[arrayIndex++] = Source;
            array[arrayIndex] = Target;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Remove(TLink item) => Throw.A.NotSupportedExceptionAndReturn<bool>();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public int IndexOf(TLink item)
        {
            if (_equalityComparer.Equals(Index, item))
            {
                return _constants.IndexPart;
            }
            if (_equalityComparer.Equals(Source, item))
            {
                return _constants.SourcePart;
            }
            if (_equalityComparer.Equals(Target, item))
            {
                return _constants.TargetPart;
            }
            return -1;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Insert(int index, TLink item) => throw new NotSupportedException();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void RemoveAt(int index) => throw new NotSupportedException();

        #endregion
    }
}
```

./Platform.Data.Doublets/LinkExtensions.cs

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

namespace Platform.Data.Doublets
{
    public static class LinkExtensions
    {
        public static bool IsFullPoint<TLink>(this Link<TLink> link) =>
        ↪ Point<TLink>.IsFullPoint(link);
        public static bool IsPartialPoint<TLink>(this Link<TLink> link) =>
        ↪ Point<TLink>.IsPartialPoint(link);
    }
}
```

./Platform.Data.Doublets/LinksOperatorBase.cs

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

namespace Platform.Data.Doublets
{
    public abstract class LinksOperatorBase<TLink>
    {
        public ILinks<TLink> Links { get; }
        protected LinksOperatorBase(ILinks<TLink> links) => Links = links;
    }
}
```

./Platform.Data.Doublets/Numbers/Raw/AddressToRawNumberConverter.cs

```
using Platform.Interfaces;

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

namespace Platform.Data.Doublets.Numbers.Raw
{
    public class AddressToRawNumberConverter<TLink> : IConverter<TLink>
    {
        public TLink Convert(TLink source) => new Hybrid<TLink>(source, isExternal: true);
    }
}
```

./Platform.Data.Doublets/Numbers/Raw/RawNumberToAddressConverter.cs

```
using Platform.Interfaces;
using Platform.Numbers;

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

namespace Platform.Data.Doublets.Numbers.Raw
{
    public class RawNumberToAddressConverter<TLink> : IConverter<TLink>
    {
        public TLink Convert(TLink source) => (Integer<TLink>)new
        ↪ Hybrid<TLink>(source).AbsoluteValue;
    }
}
```

./Platform.Data.Doublets/Numbers/Unary/AddressToUnaryNumberConverter.cs

```
using System.Collections.Generic;
using Platform.Interfaces;
using Platform.Reflection;
using Platform.Numbers;

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

namespace Platform.Data.Doublets.Numbers.Unary
{
    public class AddressToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;

        private readonly IConverter<int, TLink> _powerOf2ToUnaryNumberConverter;

        public AddressToUnaryNumberConverter(ILinks<TLink> links, IConverter<int, TLink>
        ↪ powerOf2ToUnaryNumberConverter) : base(links) => _powerOf2ToUnaryNumberConverter =
        ↪ powerOf2ToUnaryNumberConverter;

        public TLink Convert(TLink number)
        {
            var nullConstant = Links.Constants.Null;
```

```
            var one = Integer<TLink>.One;
            var target = nullConstant;
            for (int i = 0; !_equalityComparer.Equals(number, default) && i < NumericType<TLink>.BitsLength; 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;
        }
    }
}
```

./Platform.Data.Doublets/Numbers/Unary/LinkToItsFrequencyNumberConveter.cs

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

#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 IPropertyOperator<TLink, TLink> _frequencyPropertyOperator;
        private readonly IConverter<TLink> _unaryNumberToAddressConverter;

        public LinkToItsFrequencyNumberConveter(
            ILinks<TLink> links,
            IPropertyOperator<TLink, TLink> frequencyPropertyOperator,
            IConverter<TLink> unaryNumberToAddressConverter)
            : base(links)
        {
            _frequencyPropertyOperator = frequencyPropertyOperator;
            _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
        }

        public TLink Convert(Doublet<TLink> doublet)
        {
            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);
        }
    }
}
```

./Platform.Data.Doublets/Numbers/Unary/PowerOf2ToUnaryNumberConverter.cs

```
using System.Collections.Generic;
using Platform.Exceptions;
using Platform.Interfaces;
using Platform.Ranges;

#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;

        public PowerOf2ToUnaryNumberConverter(ILinks<TLink> links, TLink one) : base(links)
        {
            _unaryNumberPowersOf2 = new TLink[64];
            _unaryNumberPowersOf2[0] = one;
        }

        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;
        }
    }
}
```

./Platform.Data.Doublets/Numbers/Unary/UnaryNumberToAddressAddOperationConverter.cs

```
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.Numbers.Unary
{
    public class UnaryNumberToAddressAddOperationConverter<TLink> : LinksOperatorBase<TLink>, IConverter<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer = EqualityComparer<TLink>.Default;

        private Dictionary<TLink, TLink> _unaryToUInt64;
        private readonly TLink _unaryOne;

        public UnaryNumberToAddressAddOperationConverter(ILinks<TLink> links, TLink unaryOne)
            : base(links)
        {
            _unaryOne = unaryOne;
            InitUnaryToUInt64();
        }

        private void InitUnaryToUInt64()
        {
            var one = Integer<TLink>.One;
            _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);
            }
        }

        public TLink Convert(TLink unaryNumber)
        {
            if (_equalityComparer.Equals(unaryNumber, default))
            {
                return default;
            }
            if (_equalityComparer.Equals(unaryNumber, _unaryOne))
            {
                return Integer<TLink>.One;
            }
            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 TLink Double(TLink number) => (Integer<TLink>)((Integer<TLink>)number *
        ↪  2UL);
    }
}
```

./Platform.Data.Doublets/Numbers/Unary/UnaryNumberToAddressOrOperationConverter.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Reflection;
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 readonly IDictionary<TLink, int> _unaryNumberPowerOf2Indicies;

        public UnaryNumberToAddressOrOperationConverter(ILinks<TLink> links, IConverter<int,
        ↪  TLink> powerOf2ToUnaryNumberConverter)
            : base(links)
        {
            _unaryNumberPowerOf2Indicies = new Dictionary<TLink, int>();
            for (int i = 0; i < NumericType<TLink>.BitsLength; i++)
            {
                _unaryNumberPowerOf2Indicies.Add(powerOf2ToUnaryNumberConverter.Convert(i), i);
            }
        }

        public TLink Convert(TLink sourceNumber)
        {
            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)]
```

```
53          private static void SetBit(ref TLink target, int powerOf2Index) => target =
            ↪ Bit.Or(target, Bit.ShiftLeft(Integer<TLink>.One, powerOf2Index));
54      }
55  }
```

./Platform.Data.Doublets/PropertyOperators/PropertiesOperator.cs

```
1   using System.Linq;
2   using System.Collections.Generic;
3   using Platform.Interfaces;
4
5   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7   namespace Platform.Data.Doublets.PropertyOperators
8   {
9       public class PropertiesOperator<TLink> : LinksOperatorBase<TLink>,
        ↪ IPropertiesOperator<TLink, TLink, TLink>
10      {
11          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪ EqualityComparer<TLink>.Default;
12
13          public PropertiesOperator(ILinks<TLink> links) : base(links) { }
14
15          public TLink GetValue(TLink @object, TLink property)
16          {
17              var objectProperty = Links.SearchOrDefault(@object, property);
18              if (_equalityComparer.Equals(objectProperty, default))
19              {
20                  return default;
21              }
22              var valueLink = Links.All(Links.Constants.Any, objectProperty).SingleOrDefault();
23              if (valueLink == null)
24              {
25                  return default;
26              }
27              return Links.GetTarget(valueLink[Links.Constants.IndexPart]);
28          }
29
30          public void SetValue(TLink @object, TLink property, TLink value)
31          {
32              var objectProperty = Links.GetOrCreate(@object, property);
33              Links.DeleteMany(Links.AllIndices(Links.Constants.Any, objectProperty));
34              Links.GetOrCreate(objectProperty, value);
35          }
36      }
37  }
```

./Platform.Data.Doublets/PropertyOperators/PropertyOperator.cs

```
1   using System.Collections.Generic;
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.PropertyOperators
7   {
8       public class PropertyOperator<TLink> : LinksOperatorBase<TLink>, IPropertyOperator<TLink,
        ↪ TLink>
9       {
10          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪ EqualityComparer<TLink>.Default;
11
12          private readonly TLink _propertyMarker;
13          private readonly TLink _propertyValueMarker;
14
15          public PropertyOperator(ILinks<TLink> links, TLink propertyMarker, TLink
            ↪ propertyValueMarker) : base(links)
16          {
17              _propertyMarker = propertyMarker;
18              _propertyValueMarker = propertyValueMarker;
19          }
20
21          public TLink Get(TLink link)
22          {
23              var property = Links.SearchOrDefault(link, _propertyMarker);
24              var container = GetContainer(property);
25              var value = GetValue(container);
26              return value;
27          }
28
29          private TLink GetContainer(TLink property)
30          {
```

```
            var valueContainer = default(TLink);
            if (_equalityComparer.Equals(property, default))
            {
                return valueContainer;
            }
            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;
        }

        private TLink GetValue(TLink container) => _equalityComparer.Equals(container, default)
        ↪  ? default : Links.GetTarget(container);

        public void Set(TLink link, TLink value)
        {
            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);
            }
        }
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/ILinksListMethods.cs

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public interface ILinksListMethods<TLink>
    {
        void Detach(TLink freeLink);
        void AttachAsFirst(TLink link);
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/ILinksTreeMethods.cs

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

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public interface ILinksTreeMethods<TLink>
    {
        TLink CountUsages(TLink link);
        TLink Search(TLink source, TLink target);
        TLink EachUsage(TLink source, Func<IList<TLink>, TLink> handler);
        void Detach(ref TLink firstAsSource, TLink linkIndex);
        void Attach(ref TLink firstAsSource, TLink linkIndex);
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/LinksAVLBalancedTreeMethodsBase.cs

```
using System;
using System.Text;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Numbers;
```

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

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public unsafe abstract class LinksAVLBalancedTreeMethodsBase<TLink> :
    ↪ SizedAndThreadedAVLBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
    {
        protected readonly TLink Break;
        protected readonly TLink Continue;
        protected readonly byte* Links;
        protected readonly byte* Header;

        public 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 * (Integer<TLink>)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);

```

```
75          [MethodImpl(MethodImplOptions.AggressiveInlining)]
76          protected virtual bool GetLeftIsChildValue(TLink value)
77          {
78              unchecked
79              {
80                  //return (Integer<TLink>)Bit<TLink>.PartialRead(previousValue, 4, 1);
81                  return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 4, 1), default);
82              }
83          }
84
85          [MethodImpl(MethodImplOptions.AggressiveInlining)]
86          protected virtual void SetLeftIsChildValue(ref TLink storedValue, bool value)
87          {
88              unchecked
89              {
90                  var previousValue = storedValue;
91                  var modified = Bit<TLink>.PartialWrite(previousValue, (Integer<TLink>)value, 4,
                        ↪  1);
92                  storedValue = modified;
93              }
94          }
95
96          [MethodImpl(MethodImplOptions.AggressiveInlining)]
97          protected virtual bool GetRightIsChildValue(TLink value)
98          {
99              unchecked
100             {
101                 //return (Integer<TLink>)Bit<TLink>.PartialRead(previousValue, 3, 1);
102                 return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 3, 1), default);
103             }
104         }
105
106         [MethodImpl(MethodImplOptions.AggressiveInlining)]
107         protected virtual void SetRightIsChildValue(ref TLink storedValue, bool value)
108         {
109             unchecked
110             {
111                 var previousValue = storedValue;
112                 var modified = Bit<TLink>.PartialWrite(previousValue, (Integer<TLink>)value, 3,
                        ↪  1);
113                 storedValue = modified;
114             }
115         }
116
117         [MethodImpl(MethodImplOptions.AggressiveInlining)]
118         protected virtual sbyte GetBalanceValue(TLink storedValue)
119         {
120             unchecked
121             {
122                 var value = (int)(Integer<TLink>)Bit<TLink>.PartialRead(storedValue, 0, 3);
123                 value |= 0xF8 * ((value & 4) >> 2); // if negative, then continue ones to the
                        ↪  end of sbyte
124                 return (sbyte)value;
125             }
126         }
127
128         [MethodImpl(MethodImplOptions.AggressiveInlining)]
129         protected virtual void SetBalanceValue(ref TLink storedValue, sbyte value)
130         {
131             unchecked
132             {
133                 var packagedValue = (TLink)(Integer<TLink>)((((byte)value >> 5) & 4) | value &
                        ↪  3);
134                 var modified = Bit<TLink>.PartialWrite(storedValue, packagedValue, 0, 3);
135                 storedValue = modified;
136             }
137         }
138
139         public TLink this[TLink index]
140         {
141             get
142             {
143                 var root = GetTreeRoot();
144                 if (GreaterOrEqualThan(index, GetSize(root)))
145                 {
146                     return Zero;
147                 }
148                 while (!EqualToZero(root))
149                 {
```

```
                    var left = GetLeftOrDefault(root);
                    var leftSize = GetSizeOrZero(left);
                    if (LessThan(index, leftSize))
                    {
                        root = left;
                        continue;
                    }
                    if (IsEquals(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>
        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
        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);
        }

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

        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);
        }
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/LinksHeader.cs

```
using Platform.Unsafe;

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public struct LinksHeader<TLink>
    {
        public static readonly long SizeInBytes = Structure<LinksHeader<TLink>>.Size;

        public TLink AllocatedLinks;
```

```
        public TLink ReservedLinks;
        public TLink FreeLinks;
        public TLink FirstFreeLink;
        public TLink FirstAsSource;
        public TLink FirstAsTarget;
        public TLink LastFreeLink;
        public TLink Reserved8;
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/LinksSizeBalancedTreeMethodsBase.cs

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

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public unsafe abstract class LinksSizeBalancedTreeMethodsBase<TLink> : SizeBalancedTreeMethods2<TLink>, ILinksTreeMethods<TLink>
    {
        protected readonly TLink Break;
        protected readonly TLink Continue;
        protected readonly byte* Links;
        protected readonly byte* Header;

        public 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 * (Integer<TLink>)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)
```

```
63          {
64              ref var firstLink = ref GetLinkReference(first);
65              ref var secondLink = ref GetLinkReference(second);
66              return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
                ↪  secondLink.Source, secondLink.Target);
67          }
68
69          public TLink this[TLink index]
70          {
71              get
72              {
73                  var root = GetTreeRoot();
74                  if (GreaterOrEqualThan(index, GetSize(root)))
75                  {
76                      return Zero;
77                  }
78                  while (!EqualToZero(root))
79                  {
80                      var left = GetLeftOrDefault(root);
81                      var leftSize = GetSizeOrZero(left);
82                      if (LessThan(index, leftSize))
83                      {
84                          root = left;
85                          continue;
86                      }
87                      if (IsEquals(index, leftSize))
88                      {
89                          return root;
90                      }
91                      root = GetRightOrDefault(root);
92                      index = Subtract(index, Increment(leftSize));
93                  }
94                  return Zero; // TODO: Impossible situation exception (only if tree structure
                    ↪  broken)
95              }
96          }
97
98          /// <summary>
99          /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
                ↪  (концом).
100         /// </summary>
101         /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
102         /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
103         /// <returns>Индекс искомой связи.</returns>
104         public TLink Search(TLink source, TLink target)
105         {
106             var root = GetTreeRoot();
107             while (!EqualToZero(root))
108             {
109                 ref var rootLink = ref GetLinkReference(root);
110                 var rootSource = rootLink.Source;
111                 var rootTarget = rootLink.Target;
112                 if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
                    ↪  node.Key < root.Key
113                 {
114                     root = GetLeftOrDefault(root);
115                 }
116                 else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget)) //
                    ↪  node.Key > root.Key
117                 {
118                     root = GetRightOrDefault(root);
119                 }
120                 else // node.Key == root.Key
121                 {
122                     return root;
123                 }
124             }
125             return Zero;
126         }
127
128         // TODO: Return indices range instead of references count
129         public TLink CountUsages(TLink link)
130         {
131             var root = GetTreeRoot();
132             var total = GetSize(root);
133             var totalRightIgnore = Zero;
134             while (!EqualToZero(root))
135             {
```

```
                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.
        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 (IsEquals(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
                {
                    return @break;
                }
            }
            else if (LessThan(linkBasePart, @base))
            {
                if (IsEquals(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
                {
                    return @break;
                }
            }
            else //if (linkBasePart == @base)
            {
                if (IsEquals(handler(GetLinkValues(link)), @break))
                {
                    return @break;
                }
                if (IsEquals(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
                {
                    return @break;
                }
                if (IsEquals(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
                {
                    return @break;
                }
            }
            return @continue;
        }

        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);
        }
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/LinksSourcesAVLBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public unsafe class LinksSourcesAVLBalancedTreeMethods<TLink> :
    ↪ LinksAVLBalancedTreeMethodsBase<TLink>
    {
        public LinksSourcesAVLBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
        ↪ byte* header) : base(constants, links, header) { }

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected unsafe 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().FirstAsSource;

        [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) ||
        ↪  (IsEquals(firstSource, secondSource) && LessThan(firstTarget, secondTarget));

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

./Platform.Data.Doublets/ResizableDirectMemory/LinksSourcesSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public unsafe class LinksSourcesSizeBalancedTreeMethods<TLink> :
    ↪  LinksSizeBalancedTreeMethodsBase<TLink>
    {
        public LinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
        ↪  byte* header) : base(constants, links, header) { }

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected unsafe 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().FirstAsSource;

        [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) ||
        ↪  (IsEquals(firstSource, secondSource) && LessThan(firstTarget, secondTarget));

```

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

./Platform.Data.Doublets/ResizableDirectMemory/LinksTargetsAVLBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public unsafe class LinksTargetsAVLBalancedTreeMethods<TLink> :
    ↪  LinksAVLBalancedTreeMethodsBase<TLink>
    {
        public LinksTargetsAVLBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
        ↪  byte* header) : base(constants, links, header) { }

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

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

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

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

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

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

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

```

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

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

        [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) ||
        ↪  (IsEquals(firstTarget, secondTarget) && LessThan(firstSource, secondSource));

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

./Platform.Data.Doublets/ResizableDirectMemory/LinksTargetsSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public unsafe class LinksTargetsSizeBalancedTreeMethods<TLink> :
    ↪  LinksSizeBalancedTreeMethodsBase<TLink>
    {
        public LinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
        ↪  byte* header) : base(constants, links, header) { }

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

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

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

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

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

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

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

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

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

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

```
40
41          [MethodImpl(MethodImplOptions.AggressiveInlining)]
42          protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
            ↪  TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
            ↪  (IsEquals(firstTarget, secondTarget) && LessThan(firstSource, secondSource));
43
44          [MethodImpl(MethodImplOptions.AggressiveInlining)]
45          protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
            ↪  TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
            ↪  (IsEquals(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource));
46
47          [MethodImpl(MethodImplOptions.AggressiveInlining)]
48          protected override void ClearNode(TLink node)
49          {
50              ref var link = ref GetLinkReference(node);
51              link.LeftAsTarget = Zero;
52              link.RightAsTarget = Zero;
53              link.SizeAsTarget = Zero;
54          }
55      }
56  }
```

./Platform.Data.Doublets/ResizableDirectMemory/RawLink.cs

```
1   using Platform.Unsafe;
2
3   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5   namespace Platform.Data.Doublets.ResizableDirectMemory
6   {
7       public struct RawLink<TLink>
8       {
9           public static readonly long SizeInBytes = Structure<RawLink<TLink>>.Size;
10
11          public TLink Source;
12          public TLink Target;
13          public TLink LeftAsSource;
14          public TLink RightAsSource;
15          public TLink SizeAsSource;
16          public TLink LeftAsTarget;
17          public TLink RightAsTarget;
18          public TLink SizeAsTarget;
19      }
20  }
```

./Platform.Data.Doublets/ResizableDirectMemory/ResizableDirectMemoryLinksBase.cs

```
1   using System;
2   using System.Collections.Generic;
3   using System.Runtime.CompilerServices;
4   using Platform.Collections.Arrays;
5   using Platform.Data.Exceptions;
6   using Platform.Disposables;
7   using Platform.Memory;
8   using Platform.Numbers;
9   using Platform.Singletons;
10
11  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
12
13  namespace Platform.Data.Doublets.ResizableDirectMemory
14  {
15      public abstract class ResizableDirectMemoryLinksBase<TLink> : DisposableBase, ILinks<TLink>
16      {
17          protected static readonly EqualityComparer<TLink> EqualityComparer =
            ↪  EqualityComparer<TLink>.Default;
18          protected static readonly Comparer<TLink> Comparer = Comparer<TLink>.Default;
19
20          /// <summary>Возвращает размер одной связи в байтах.</summary>
21          /// <remarks>
22          /// Используется только во вне класса, не рекомедуется использовать внутри.
23          /// Так как во вне не обязательно будет доступен unsafe C#.
24          /// </remarks>
25          public static readonly long LinkSizeInBytes = RawLink<TLink>.SizeInBytes;
26
27          public static readonly long LinkHeaderSizeInBytes = LinksHeader<TLink>.SizeInBytes;
28
29          public static readonly long DefaultLinksSizeStep = LinkSizeInBytes * 1024 * 1024;
30
31          protected readonly IResizableDirectMemory _memory;
32          protected readonly long _memoryReservationStep;
33
34          protected ILinksTreeMethods<TLink> TargetsTreeMethods;
35          protected ILinksTreeMethods<TLink> SourcesTreeMethods;
```

```
        // 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
        protected ILinksListMethods<TLink> UnusedLinksListMethods;

        /// <summary>
        /// Возвращает общее число связей находящихся в хранилище.
        /// </summary>
        protected virtual TLink Total
        {
            get
            {
                ref var header = ref GetHeaderReference();
                return Subtract(header.AllocatedLinks, header.FreeLinks);
            }
        }

        public virtual LinksConstants<TLink> Constants { get; }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ResizableDirectMemoryLinksBase(IResizableDirectMemory memory, long memoryReservationStep)
        {
            _memory = memory;
            _memoryReservationStep = memoryReservationStep;
            Constants = Default<LinksConstants<TLink>>.Instance;
        }

        protected virtual void Init(IResizableDirectMemory memory, long memoryReservationStep)
        {
            if (memory.ReservedCapacity < memoryReservationStep)
            {
                memory.ReservedCapacity = memoryReservationStep;
            }
            SetPointers(_memory);
            ref var header = ref GetHeaderReference();
            // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
            _memory.UsedCapacity = (ConvertToUInt64(header.AllocatedLinks) * LinkSizeInBytes) + LinkHeaderSizeInBytes;
            // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
            header.ReservedLinks = ConvertToAddress((_memory.ReservedCapacity - LinkHeaderSizeInBytes) / LinkSizeInBytes);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual TLink Count(IList<TLink> restrictions)
        {
            // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
            if (restrictions.Count == 0)
            {
                return Total;
            }
            var constants = Constants;
            var any = constants.Any;
            var index = restrictions[constants.IndexPart];
            if (restrictions.Count == 1)
            {
                if (AreEqual(index, any))
                {
                    return Total;
                }
                return Exists(index) ? GetOne() : GetZero();
            }
            if (restrictions.Count == 2)
            {
                var value = restrictions[1];
                if (AreEqual(index, any))
                {
                    if (AreEqual(value, any))
                    {
                        return Total; // Any - как отсутствие ограничения
                    }
                    return Add(SourcesTreeMethods.CountUsages(value), TargetsTreeMethods.CountUsages(value));
                }
                else
                {
                    if (!Exists(index))
                    {
```

```
                        return GetZero();
                    }
                    if (AreEqual(value, any))
                    {
                        return GetOne();
                    }
                    ref var storedLinkValue = ref GetLinkReference(index);
                    if (AreEqual(storedLinkValue.Source, value) ||
                    ↪  AreEqual(storedLinkValue.Target, value))
                    {
                        return GetOne();
                    }
                    return GetZero();
                }
            }
            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 Total;
                    }
                    else if (AreEqual(source, any))
                    {
                        return TargetsTreeMethods.CountUsages(target);
                    }
                    else if (AreEqual(target, any))
                    {
                        return SourcesTreeMethods.CountUsages(source);
                    }
                    else //if(source != Any && target != Any)
                    {
                        // Эквивалент Exists(source, target) => Count(Any, source, target) > 0
                        var link = SourcesTreeMethods.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 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();
                }
            }
```

```
183             throw new NotSupportedException("Другие размеры и способы ограничений не
                ↪ поддерживаются.");
184         }
185
186         [MethodImpl(MethodImplOptions.AggressiveInlining)]
187         public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
188         {
189             var constants = Constants;
190             var @break = constants.Break;
191             if (restrictions.Count == 0)
192             {
193                 for (var link = GetOne(); LessOrEqualThan(link,
                    ↪ GetHeaderReference().AllocatedLinks); link = Increment(link))
194                 {
195                     if (Exists(link) && AreEqual(handler(GetLinkStruct(link)), @break))
196                     {
197                         return @break;
198                     }
199                 }
200                 return @break;
201             }
202             var @continue = constants.Continue;
203             var any = constants.Any;
204             var index = restrictions[constants.IndexPart];
205             if (restrictions.Count == 1)
206             {
207                 if (AreEqual(index, any))
208                 {
209                     return Each(handler, GetEmptyList());
210                 }
211                 if (!Exists(index))
212                 {
213                     return @continue;
214                 }
215                 return handler(GetLinkStruct(index));
216             }
217             if (restrictions.Count == 2)
218             {
219                 var value = restrictions[1];
220                 if (AreEqual(index, any))
221                 {
222                     if (AreEqual(value, any))
223                     {
224                         return Each(handler, GetEmptyList());
225                     }
226                     if (AreEqual(Each(handler, new Link<TLink>(index, value, any)), @break))
227                     {
228                         return @break;
229                     }
230                     return Each(handler, new Link<TLink>(index, any, value));
231                 }
232                 else
233                 {
234                     if (!Exists(index))
235                     {
236                         return @continue;
237                     }
238                     if (AreEqual(value, any))
239                     {
240                         return handler(GetLinkStruct(index));
241                     }
242                     ref var storedLinkValue = ref GetLinkReference(index);
243                     if (AreEqual(storedLinkValue.Source, value) ||
244                         AreEqual(storedLinkValue.Target, value))
245                     {
246                         return handler(GetLinkStruct(index));
247                     }
248                     return @continue;
249                 }
250             }
251             if (restrictions.Count == 3)
252             {
253                 var source = restrictions[constants.SourcePart];
254                 var target = restrictions[constants.TargetPart];
255                 if (AreEqual(index, any))
256                 {
257                     if (AreEqual(source, any) && AreEqual(target, any))
258                     {
```

```
259                         return Each(handler, GetEmptyList());
260                     }
261                     else if (AreEqual(source, any))
262                     {
263                         return TargetsTreeMethods.EachUsage(target, handler);
264                     }
265                     else if (AreEqual(target, any))
266                     {
267                         return SourcesTreeMethods.EachUsage(source, handler);
268                     }
269                     else //if(source != Any && target != Any)
270                     {
271                         var link = SourcesTreeMethods.Search(source, target);
272                         return AreEqual(link, constants.Null) ? @continue :
                            ↪ handler(GetLinkStruct(link));
273                     }
274                 }
275                 else
276                 {
277                     if (!Exists(index))
278                     {
279                         return @continue;
280                     }
281                     if (AreEqual(source, any) && AreEqual(target, any))
282                     {
283                         return handler(GetLinkStruct(index));
284                     }
285                     ref var storedLinkValue = ref GetLinkReference(index);
286                     if (!AreEqual(source, any) && !AreEqual(target, any))
287                     {
288                         if (AreEqual(storedLinkValue.Source, source) &&
289                             AreEqual(storedLinkValue.Target, target))
290                         {
291                             return handler(GetLinkStruct(index));
292                         }
293                         return @continue;
294                     }
295                     var value = default(TLink);
296                     if (AreEqual(source, any))
297                     {
298                         value = target;
299                     }
300                     if (AreEqual(target, any))
301                     {
302                         value = source;
303                     }
304                     if (AreEqual(storedLinkValue.Source, value) ||
305                         AreEqual(storedLinkValue.Target, value))
306                     {
307                         return handler(GetLinkStruct(index));
308                     }
309                     return @continue;
310                 }
311             }
312             throw new NotSupportedException("Другие размеры и способы ограничений не
                ↪ поддерживаются.");
313         }
314 
315         /// <remarks>
316         /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
                ↪ в другом месте (но не в менеджере памяти, а в логике Links)
317         /// </remarks>
318         [MethodImpl(MethodImplOptions.AggressiveInlining)]
319         public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
320         {
321             var constants = Constants;
322             var @null = constants.Null;
323             var linkIndex = restrictions[constants.IndexPart];
324             ref var link = ref GetLinkReference(linkIndex);
325             ref var header = ref GetHeaderReference();
326             ref var firstAsSource = ref header.FirstAsSource;
327             ref var firstAsTarget = ref header.FirstAsTarget;
328             // Будет корректно работать только в том случае, если пространство выделенной связи
                ↪ предварительно заполнено нулями
329             if (!AreEqual(link.Source, @null))
330             {
331                 SourcesTreeMethods.Detach(ref firstAsSource, linkIndex);
332             }
```

```
333             if (!AreEqual(link.Target, @null))
334             {
335                 TargetsTreeMethods.Detach(ref firstAsTarget, linkIndex);
336             }
337             link.Source = substitution[constants.SourcePart];
338             link.Target = substitution[constants.TargetPart];
339             if (!AreEqual(link.Source, @null))
340             {
341                 SourcesTreeMethods.Attach(ref firstAsSource, linkIndex);
342             }
343             if (!AreEqual(link.Target, @null))
344             {
345                 TargetsTreeMethods.Attach(ref firstAsTarget, linkIndex);
346             }
347             return linkIndex;
348         }
349 
350         /// <remarks>
351         /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
              ↪ пространство
352         /// </remarks>
353         public virtual TLink Create(IList<TLink> restrictions)
354         {
355             ref var header = ref GetHeaderReference();
356             var freeLink = header.FirstFreeLink;
357             if (!AreEqual(freeLink, Constants.Null))
358             {
359                 UnusedLinksListMethods.Detach(freeLink);
360             }
361             else
362             {
363                 var maximumPossibleInnerReference =
                      ↪ Constants.PossibleInnerReferencesRange.Maximum;
364                 if (GreaterThan(header.AllocatedLinks, maximumPossibleInnerReference))
365                 {
366                     throw new LinksLimitReachedException<TLink>(maximumPossibleInnerReference);
367                 }
368                 if (GreaterOrEqualThan(header.AllocatedLinks, Decrement(header.ReservedLinks)))
369                 {
370                     _memory.ReservedCapacity += _memoryReservationStep;
371                     SetPointers(_memory);
372                     header.ReservedLinks = ConvertToAddress(_memory.ReservedCapacity /
                          ↪ LinkSizeInBytes);
373                 }
374                 header.AllocatedLinks = Increment(header.AllocatedLinks);
375                 _memory.UsedCapacity += LinkSizeInBytes;
376                 freeLink = header.AllocatedLinks;
377             }
378             return freeLink;
379         }
380 
381         [MethodImpl(MethodImplOptions.AggressiveInlining)]
382         public virtual void Delete(IList<TLink> restrictions)
383         {
384             ref var header = ref GetHeaderReference();
385             var link = restrictions[Constants.IndexPart];
386             if (LessThan(link, header.AllocatedLinks))
387             {
388                 UnusedLinksListMethods.AttachAsFirst(link);
389             }
390             else if (AreEqual(link, header.AllocatedLinks))
391             {
392                 header.AllocatedLinks = Decrement(header.AllocatedLinks);
393                 _memory.UsedCapacity -= LinkSizeInBytes;
394                 // Убираем все связи, находящиеся в списке свободных в конце файла, до тех пор,
                      ↪ пока не дойдём до первой существующей связи
395                 // Позволяет оптимизировать количество выделенных связей (AllocatedLinks)
396                 while (GreaterThan(header.AllocatedLinks, GetZero()) &&
                      ↪ IsUnusedLink(header.AllocatedLinks))
397                 {
398                     UnusedLinksListMethods.Detach(header.AllocatedLinks);
399                     header.AllocatedLinks = Decrement(header.AllocatedLinks);
400                     _memory.UsedCapacity -= LinkSizeInBytes;
401                 }
402             }
403         }
404 
405         [MethodImpl(MethodImplOptions.AggressiveInlining)]
406         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.PossibleInnerReferencesRange.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() => Integer<TLink>.One;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual TLink GetZero() => Integer<TLink>.Zero;

        [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 ConvertToUInt64(TLink value) => (Integer<TLink>)value;
```

```

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual IList<TLink> GetEmptyList() => ArrayPool<TLink>.Empty;

        #region Disposable

        protected override bool AllowMultipleDisposeCalls => true;

        protected override void Dispose(bool manual, bool wasDisposed)
        {
            if (!wasDisposed)
            {
                ResetPointers();
                _memory.DisposeIfPossible();
            }
        }

        #endregion
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/ResizableDirectMemoryLinks.cs

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

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public unsafe partial class ResizableDirectMemoryLinks<TLink> :
    ↪  ResizableDirectMemoryLinksBase<TLink>
    {
        private readonly Func<ILinksTreeMethods<TLink>> _createSourceTreeMethods;
        private readonly Func<ILinksTreeMethods<TLink>> _createTargetTreeMethods;
        private byte* _header;
        private byte* _links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ResizableDirectMemoryLinks(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 ResizableDirectMemoryLinks(string address, long memoryReservationStep) : this(new
        ↪  FileMappedResizableDirectMemory(address, memoryReservationStep),
        ↪  memoryReservationStep) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ResizableDirectMemoryLinks(IResizableDirectMemory memory) : this(memory,
        ↪  DefaultLinksSizeStep) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
        ↪  memoryReservationStep) : this(memory, memoryReservationStep, true) { }
```

```

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
        ↪  memoryReservationStep, bool useAvlBasedIndex) : base(memory, memoryReservationStep)
        {
            if (useAvlBasedIndex)
            {
                _createSourceTreeMethods = () => new
                ↪  LinksSourcesAVLBalancedTreeMethods<TLink>(Constants, _links, _header);
                _createTargetTreeMethods = () => new
                ↪  LinksTargetsAVLBalancedTreeMethods<TLink>(Constants, _links, _header);
            }
            else
            {
                _createSourceTreeMethods = () => new
                ↪  LinksSourcesSizeBalancedTreeMethods<TLink>(Constants, _links, _header);
                _createTargetTreeMethods = () => new
                ↪  LinksTargetsSizeBalancedTreeMethods<TLink>(Constants, _links, _header);
            }
            Init(memory, memoryReservationStep);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetPointers(IResizableDirectMemory memory)
        {
            _links = (byte*)memory.Pointer;
            _header = _links;
            SourcesTreeMethods = _createSourceTreeMethods();
            TargetsTreeMethods = _createTargetTreeMethods();
            UnusedLinksListMethods = new UnusedLinksListMethods<TLink>(_links, _header);
        }

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

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref RawLink<TLink> GetLinkReference(TLink linkIndex) => ref
        ↪  AsRef<RawLink<TLink>>(_links + LinkSizeInBytes * (Integer<TLink>)linkIndex);
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/UInt64LinksAVLBalancedTreeMethodsBase.cs

```
using System.Runtime.CompilerServices;
using static System.Runtime.CompilerServices.Unsafe;

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public unsafe abstract class UInt64LinksAVLBalancedTreeMethodsBase :
    ↪  LinksAVLBalancedTreeMethodsBase<ulong>
    {
        protected new readonly RawLink<ulong>* Links;
        protected new readonly LinksHeader<ulong>* Header;

        public 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 IsEquals(ulong first, ulong second) => first == second;

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

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

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

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

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

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

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

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

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

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

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

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(ulong first, ulong 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(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 ulong GetSizeValue(ulong value) => unchecked((value & 4294967264UL)
        ↪  >> 5);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetSizeValue(ref ulong storedValue, ulong size) => storedValue =
        ↪  unchecked((storedValue & 31UL) | ((size & 134217727UL) << 5));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GetLeftIsChildValue(ulong value) => unchecked((value & 16UL) >>
        ↪  4 == 1UL);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetLeftIsChildValue(ref ulong storedValue, bool value) =>
        ↪  storedValue = unchecked((storedValue & 4294967279UL) | ((As<bool, byte>(ref value) &
        ↪  1UL) << 4));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool GetRightIsChildValue(ulong value) => unchecked((value & 8UL) >>
        ↪  3 == 1UL);
```

```

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetRightIsChildValue(ref ulong storedValue, bool value) =>
        ↪  storedValue = unchecked((storedValue & 4294967287UL) | ((As<bool, byte>(ref value) &
        ↪  1UL) << 3));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override sbyte GetBalanceValue(ulong value) => unchecked((sbyte)((value & 7UL)
        ↪  | 0xF8UL * ((value & 4UL) >> 2))); // if negative, then continue ones to the end of
        ↪  sbyte

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void SetBalanceValue(ref ulong storedValue, sbyte value) =>
        ↪  storedValue = unchecked((storedValue & 4294967288UL) | ((ulong)((((byte)value >> 5)
        ↪  & 4) | value & 3) & 7UL));

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

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

./Platform.Data.Doublets/ResizableDirectMemory/UInt64LinksSizeBalancedTreeMethodsBase.cs

```
using System.Runtime.CompilerServices;

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public unsafe abstract class UInt64LinksSizeBalancedTreeMethodsBase :
    ↪  LinksSizeBalancedTreeMethodsBase<ulong>
    {
        protected new readonly RawLink<ulong>* Links;
        protected new readonly LinksHeader<ulong>* Header;

        public UInt64LinksSizeBalancedTreeMethodsBase(LinksConstants<ulong> constants,
        ↪  RawLink<ulong>* links, LinksHeader<ulong>* header)
            : base(constants, (byte*)links, (byte*)header)
        {
            Links = links;
            Header = header;
        }

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

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

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

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

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

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

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

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

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

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
        protected override bool LessThan(ulong first, ulong second) => first < second;

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

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

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

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool FirstIsToTheLeftOfSecond(ulong first, ulong 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(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];
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/UInt64LinksSourcesAVLBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    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 void SetLeftIsChild(ulong node, bool value) => SetLeftIsChildValue(ref Links[node].SizeAsSource, value);

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

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

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

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

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

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

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

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(ulong node)
        {
            ref var link = ref Links[node];
            link.LeftAsSource = 0UL;
            link.RightAsSource = 0UL;
            link.SizeAsSource = 0UL;
        }
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/UInt64LinksSourcesSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public unsafe class UInt64LinksSourcesSizeBalancedTreeMethods :
    UInt64LinksSizeBalancedTreeMethodsBase
    {
        public UInt64LinksSourcesSizeBalancedTreeMethods(LinksConstants<ulong> constants,
        RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
        { }

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override ref ulong GetRightReference(ulong node) => ref
        Links[node].RightAsSource;
```

```

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

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

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

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

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

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

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

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

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

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void ClearNode(ulong node)
        {
            ref var link = ref Links[node];
            link.LeftAsSource = 0UL;
            link.RightAsSource = 0UL;
            link.SizeAsSource = 0UL;
        }
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/UInt64LinksTargetsAVLBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    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->FirstAsTarget;

        [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;
        }
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/UInt64LinksTargetsSizeBalancedTreeMethods.cs

```
using System.Runtime.CompilerServices;

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    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->FirstAsTarget;

        [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;
        }
    }
}
```

./Platform.Data.Doublets/ResizableDirectMemory/UInt64ResizableDirectMemoryLinks.cs

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

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

namespace Platform.Data.Doublets.ResizableDirectMemory
{
    public unsafe class UInt64ResizableDirectMemoryLinks : ResizableDirectMemoryLinksBase<ulong>
    {
        private readonly Func<ILinksTreeMethods<ulong>> _createSourceTreeMethods;
        private readonly Func<ILinksTreeMethods<ulong>> _createTargetTreeMethods;
        private LinksHeader<ulong>* _header;
        private RawLink<ulong>* _links;

```

```
17          [MethodImpl(MethodImplOptions.AggressiveInlining)]
18          public UInt64ResizableDirectMemoryLinks(string address) : this(address,
            ↪  DefaultLinksSizeStep) { }
19
20          /// <summary>
21          /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
            ↪  минимальным шагом расширения базы данных.
22          /// </summary>
23          /// <param name="address">Полный пусть к файлу базы данных.</param>
24          /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
            ↪  байтах.</param>
25          [MethodImpl(MethodImplOptions.AggressiveInlining)]
26          public UInt64ResizableDirectMemoryLinks(string address, long memoryReservationStep) :
            ↪  this(new FileMappedResizableDirectMemory(address, memoryReservationStep),
            ↪  memoryReservationStep) { }
27
28          [MethodImpl(MethodImplOptions.AggressiveInlining)]
29          public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory) : this(memory,
            ↪  DefaultLinksSizeStep) { }
30
31          [MethodImpl(MethodImplOptions.AggressiveInlining)]
32          public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
            ↪  memoryReservationStep) : this(memory, memoryReservationStep, true) { }
33
34          [MethodImpl(MethodImplOptions.AggressiveInlining)]
35          public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
            ↪  memoryReservationStep, bool useAvlBasedIndex) : base(memory, memoryReservationStep)
36          {
37              if (useAvlBasedIndex)
38              {
39                  _createSourceTreeMethods = () => new
                    ↪  UInt64LinksSourcesAVLBalancedTreeMethods(Constants, _links, _header);
40                  _createTargetTreeMethods = () => new
                    ↪  UInt64LinksTargetsAVLBalancedTreeMethods(Constants, _links, _header);
41              }
42              else
43              {
44                  _createSourceTreeMethods = () => new
                    ↪  UInt64LinksSourcesSizeBalancedTreeMethods(Constants, _links, _header);
45                  _createTargetTreeMethods = () => new
                    ↪  UInt64LinksTargetsSizeBalancedTreeMethods(Constants, _links, _header);
46              }
47              Init(memory, memoryReservationStep);
48          }
49
50          [MethodImpl(MethodImplOptions.AggressiveInlining)]
51          protected override void SetPointers(IResizableDirectMemory memory)
52          {
53              _header = (LinksHeader<ulong>*)memory.Pointer;
54              _links = (RawLink<ulong>*)memory.Pointer;
55              SourcesTreeMethods = _createSourceTreeMethods();
56              TargetsTreeMethods = _createTargetTreeMethods();
57              UnusedLinksListMethods = new UInt64UnusedLinksListMethods(_links, _header);
58          }
59
60          [MethodImpl(MethodImplOptions.AggressiveInlining)]
61          protected override void ResetPointers()
62          {
63              base.ResetPointers();
64              _links = null;
65              _header = null;
66          }
67
68          [MethodImpl(MethodImplOptions.AggressiveInlining)]
69          protected override ref LinksHeader<ulong> GetHeaderReference() => ref *_header;
70
71          [MethodImpl(MethodImplOptions.AggressiveInlining)]
72          protected override ref RawLink<ulong> GetLinkReference(ulong linkIndex) => ref
            ↪  _links[linkIndex];
73
74          [MethodImpl(MethodImplOptions.AggressiveInlining)]
75          protected override bool AreEqual(ulong first, ulong second) => first == second;
76
77          [MethodImpl(MethodImplOptions.AggressiveInlining)]
78          protected override bool LessThan(ulong first, ulong second) => first < second;
79
80          [MethodImpl(MethodImplOptions.AggressiveInlining)]
81          protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
```

```
82
83          [MethodImpl(MethodImplOptions.AggressiveInlining)]
84          protected override bool GreaterThan(ulong first, ulong second) => first > second;
85
86          [MethodImpl(MethodImplOptions.AggressiveInlining)]
87          protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
88
89          [MethodImpl(MethodImplOptions.AggressiveInlining)]
90          protected override ulong GetZero() => 0UL;
91
92          [MethodImpl(MethodImplOptions.AggressiveInlining)]
93          protected override ulong GetOne() => 1UL;
94
95          [MethodImpl(MethodImplOptions.AggressiveInlining)]
96          protected override long ConvertToUInt64(ulong value) => (long)value;
97
98          [MethodImpl(MethodImplOptions.AggressiveInlining)]
99          protected override ulong ConvertToAddress(long value) => (ulong)value;
100
101         [MethodImpl(MethodImplOptions.AggressiveInlining)]
102         protected override ulong Add(ulong first, ulong second) => first + second;
103
104         [MethodImpl(MethodImplOptions.AggressiveInlining)]
105         protected override ulong Subtract(ulong first, ulong second) => first - second;
106
107         [MethodImpl(MethodImplOptions.AggressiveInlining)]
108         protected override ulong Increment(ulong link) => ++link;
109
110         [MethodImpl(MethodImplOptions.AggressiveInlining)]
111         protected override ulong Decrement(ulong link) => --link;
112
113         [MethodImpl(MethodImplOptions.AggressiveInlining)]
114         protected override IList<ulong> GetEmptyList() => new ulong[0];
115     }
116 }
```

./Platform.Data.Doublets/ResizableDirectMemory/UInt64UnusedLinksListMethods.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.ResizableDirectMemory
6  {
7      public unsafe class UInt64UnusedLinksListMethods : UnusedLinksListMethods<ulong>
8      {
9          private readonly RawLink<ulong>* _links;
10         private readonly LinksHeader<ulong>* _header;
11
12         [MethodImpl(MethodImplOptions.AggressiveInlining)]
13         public UInt64UnusedLinksListMethods(RawLink<ulong>* links, LinksHeader<ulong>* header)
14             : base((byte*)links, (byte*)header)
15         {
16             _links = links;
17             _header = header;
18         }
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref _links[link];
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected override ref LinksHeader<ulong> GetHeaderReference() => ref *_header;
25     }
26 }
```

./Platform.Data.Doublets/ResizableDirectMemory/UnusedLinksListMethods.cs

```
1  using System.Runtime.CompilerServices;
2  using Platform.Collections.Methods.Lists;
3  using Platform.Numbers;
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.ResizableDirectMemory
9  {
10     public unsafe class UnusedLinksListMethods<TLink> : CircularDoublyLinkedListMethods<TLink>,
       ↪  ILinksListMethods<TLink>
11     {
12         private readonly byte* _links;
13         private readonly byte* _header;
14
```

```
        [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 * (Integer<TLink>)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;
    }
}
```

./Platform.Data.Doublets/Sequences/ArrayExtensions.cs

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

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

namespace Platform.Data.Doublets.Sequences
{
    public static class ArrayExtensions
    {
        public static IList<TLink> ConvertToRestrictionsValues<TLink>(this TLink[] array)
        {
            var restrictions = new TLink[array.Length + 1];
            Array.Copy(array, 0, restrictions, 1, array.Length);
            return restrictions;
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Converters/BalancedVariantConverter.cs

```
using System.Collections.Generic;

#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>
    {
```

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

        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]);
        }

        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];
            }
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Converters/CompressingConverter.cs

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Collections;
using Platform.Singletons;
using Platform.Numbers;
using Platform.Data.Doublets.Sequences.Frequencies.Cache;

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

namespace Platform.Data.Doublets.Sequences.Converters
{
    /// <remarks>
    /// TODO: Возможно будет лучше если алгоритм будет выполняться полностью изолированно от
    ↪  Links на этапе сжатия.
    ///     А именно будет создаваться временный список пар необходимых для выполнения сжатия, в
    ↪  таком случае тип значения элемента массива может быть любым, как char так и ulong.
    ///     Как только список/словарь пар был выявлен можно разом выполнить создание всех этих
    ↪  пар, а так же разом выполнить замену.
    /// </remarks>
    public class CompressingConverter<TLink> : LinksListToSequenceConverterBase<TLink>
    {
        private static readonly LinksConstants<TLink> _constants =
        ↪  Default<LinksConstants<TLink>>.Instance;
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;
        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;

        private readonly IConverter<IList<TLink>, TLink> _baseConverter;
        private readonly LinkFrequenciesCache<TLink> _doubletFrequenciesCache;
        private readonly TLink _minFrequencyToCompress;
```

```
28          private readonly bool _doInitialFrequenciesIncrement;
29          private Doublet<TLink> _maxDoublet;
30          private LinkFrequency<TLink> _maxDoubletData;
31
32          private struct HalfDoublet
33          {
34              public TLink Element;
35              public LinkFrequency<TLink> DoubletData;
36
37              public HalfDoublet(TLink element, LinkFrequency<TLink> doubletData)
38              {
39                  Element = element;
40                  DoubletData = doubletData;
41              }
42
43              public override string ToString() => $"{Element}: ({DoubletData})";
44          }
45
46          public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
            ↪  baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache)
47              : this(links, baseConverter, doubletFrequenciesCache, Integer<TLink>.One, true)
48          {
49          }
50
51          public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
            ↪  baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, bool
            ↪  doInitialFrequenciesIncrement)
52              : this(links, baseConverter, doubletFrequenciesCache, Integer<TLink>.One,
                ↪  doInitialFrequenciesIncrement)
53          {
54          }
55
56          public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
            ↪  baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, TLink
            ↪  minFrequencyToCompress, bool doInitialFrequenciesIncrement)
57              : base(links)
58          {
59              _baseConverter = baseConverter;
60              _doubletFrequenciesCache = doubletFrequenciesCache;
61              if (_comparer.Compare(minFrequencyToCompress, Integer<TLink>.One) < 0)
62              {
63                  minFrequencyToCompress = Integer<TLink>.One;
64              }
65              _minFrequencyToCompress = minFrequencyToCompress;
66              _doInitialFrequenciesIncrement = doInitialFrequenciesIncrement;
67              ResetMaxDoublet();
68          }
69
70          public override TLink Convert(IList<TLink> source) =>
            ↪  _baseConverter.Convert(Compress(source));
71
72          /// <remarks>
73          /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte_pair_encoding .
74          /// Faster version (doublets' frequencies dictionary is not recreated).
75          /// </remarks>
76          private IList<TLink> Compress(IList<TLink> sequence)
77          {
78              if (sequence.IsNullOrEmpty())
79              {
80                  return null;
81              }
82              if (sequence.Count == 1)
83              {
84                  return sequence;
85              }
86              if (sequence.Count == 2)
87              {
88                  return new[] { Links.GetOrCreate(sequence[0], sequence[1]) };
89              }
90              // TODO: arraypool with min size (to improve cache locality) or stackallow with Sigil
91              var copy = new HalfDoublet[sequence.Count];
92              Doublet<TLink> doublet = default;
93              for (var i = 1; i < sequence.Count; i++)
94              {
95                  doublet.Source = sequence[i - 1];
96                  doublet.Target = sequence[i];
97                  LinkFrequency<TLink> data;
98                  if (_doInitialFrequenciesIncrement)
99                  {
```

```
                    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>
        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);
                }
                var maxDoubletReplacementLink = _maxDoubletData.Link;
                oldLength--;
                var oldLengthMinusTwo = oldLength - 1;
                // Substitute all usages
                int w = 0, r = 0; // (r == read, w == write)
                for (; r < oldLength; r++)
                {
                    if (_equalityComparer.Equals(copy[r].Element, maxDoubletSource) &&
                    ↪  _equalityComparer.Equals(copy[r + 1].Element, maxDoubletTarget))
                    {
                        if (r > 0)
                        {
                            var previous = copy[w - 1].Element;
                            copy[w - 1].DoubletData.DecrementFrequency();
                            copy[w - 1].DoubletData =
                            ↪  _doubletFrequenciesCache.IncrementFrequency(previous,
                            ↪  maxDoubletReplacementLink);
                        }
                        if (r < oldLengthMinusTwo)
                        {
                            var next = copy[r + 2].Element;
                            copy[r + 1].DoubletData.DecrementFrequency();
                            copy[w].DoubletData = _doubletFrequenciesCache.IncrementFrequency(ma
                            ↪  xDoubletReplacementLink,
                            ↪  next);
                        }
                        copy[w++].Element = maxDoubletReplacementLink;
                        r++;
                        newLength--;
                    }
                    else
                    {
                        copy[w++] = copy[r];
```

```
                    }
                }
                if (w < newLength)
                {
                    copy[w] = copy[r];
                }
                oldLength = newLength;
                ResetMaxDoublet();
                UpdateMaxDoublet(copy, newLength);
            }
            return newLength;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void ResetMaxDoublet()
        {
            _maxDoublet = new Doublet<TLink>();
            _maxDoubletData = new LinkFrequency<TLink>();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void UpdateMaxDoublet(HalfDoublet[] copy, int length)
        {
            Doublet<TLink> doublet = default;
            for (var i = 1; i < length; i++)
            {
                doublet.Source = copy[i - 1].Element;
                doublet.Target = copy[i].Element;
                UpdateMaxDoublet(ref doublet, copy[i - 1].DoubletData);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void UpdateMaxDoublet(ref Doublet<TLink> doublet, LinkFrequency<TLink> data)
        {
            var frequency = data.Frequency;
            var maxFrequency = _maxDoubletData.Frequency;
            //if (frequency > _minFrequencyToCompress && (maxFrequency < frequency ||
            ↪  (maxFrequency == frequency && doublet.Source + doublet.Target < /* gives better
            ↪  compression string data (and gives collisions quickly) */ _maxDoublet.Source +
            ↪  _maxDoublet.Target)))
            if (_comparer.Compare(frequency, _minFrequencyToCompress) > 0 &&
               (_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) */
            {
                _maxDoublet = doublet;
                _maxDoubletData = data;
            }
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Converters/LinksListToSequenceConverterBase.cs

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

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

namespace Platform.Data.Doublets.Sequences.Converters
{
    public abstract class LinksListToSequenceConverterBase<TLink> : IConverter<IList<TLink>,
    ↪  TLink>
    {
        protected readonly ILinks<TLink> Links;
        public LinksListToSequenceConverterBase(ILinks<TLink> links) => Links = links;
        public abstract TLink Convert(IList<TLink> source);
    }
}
```

./Platform.Data.Doublets/Sequences/Converters/OptimalVariantConverter.cs

```
using System.Collections.Generic;
using System.Linq;
using Platform.Interfaces;

#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 OptimalVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
10      {
11          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪  EqualityComparer<TLink>.Default;
12          private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
13
14          private readonly IConverter<IList<TLink>> _sequenceToItsLocalElementLevelsConverter;
15
16          public OptimalVariantConverter(ILinks<TLink> links, IConverter<IList<TLink>>
            ↪  sequenceToItsLocalElementLevelsConverter) : base(links)
17              => _sequenceToItsLocalElementLevelsConverter =
                ↪  sequenceToItsLocalElementLevelsConverter;
18
19          public override TLink Convert(IList<TLink> sequence)
20          {
21              var length = sequence.Count;
22              if (length == 1)
23              {
24                  return sequence[0];
25              }
26              var links = Links;
27              if (length == 2)
28              {
29                  return links.GetOrCreate(sequence[0], sequence[1]);
30              }
31              sequence = sequence.ToArray();
32              var levels = _sequenceToItsLocalElementLevelsConverter.Convert(sequence);
33              while (length > 2)
34              {
35                  var levelRepeat = 1;
36                  var currentLevel = levels[0];
37                  var previousLevel = levels[0];
38                  var skipOnce = false;
39                  var w = 0;
40                  for (var i = 1; i < length; i++)
41                  {
42                      if (_equalityComparer.Equals(currentLevel, levels[i]))
43                      {
44                          levelRepeat++;
45                          skipOnce = false;
46                          if (levelRepeat == 2)
47                          {
48                              sequence[w] = links.GetOrCreate(sequence[i - 1], sequence[i]);
49                              var newLevel = i >= length - 1 ?
50                                  GetPreviousLowerThanCurrentOrCurrent(previousLevel,
                                    ↪  currentLevel) :
51                                  i < 2 ?
52                                  GetNextLowerThanCurrentOrCurrent(currentLevel, levels[i + 1]) :
53                                  GetGreatestNeigbourLowerThanCurrentOrCurrent(previousLevel,
                                    ↪  currentLevel, levels[i + 1]);
54                              levels[w] = newLevel;
55                              previousLevel = currentLevel;
56                              w++;
57                              levelRepeat = 0;
58                              skipOnce = true;
59                          }
60                          else if (i == length - 1)
61                          {
62                              sequence[w] = sequence[i];
63                              levels[w] = levels[i];
64                              w++;
65                          }
66                      }
67                      else
68                      {
69                          currentLevel = levels[i];
70                          levelRepeat = 1;
71                          if (skipOnce)
72                          {
73                              skipOnce = false;
74                          }
75                          else
76                          {
77                              sequence[w] = sequence[i - 1];
78                              levels[w] = levels[i - 1];
79                              previousLevel = levels[w];
80                              w++;
```

```
                        }
                        if (i == length - 1)
                        {
                            sequence[w] = sequence[i];
                            levels[w] = levels[i];
                            w++;
                        }
                    }
                }
                length = w;
            }
            return links.GetOrCreate(sequence[0], sequence[1]);
        }

        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;
        }

        private static TLink GetNextLowerThanCurrentOrCurrent(TLink current, TLink next) =>
        ↪  _comparer.Compare(next, current) < 0 ? next : current;

        private static TLink GetPreviousLowerThanCurrentOrCurrent(TLink previous, TLink current)
        ↪  => _comparer.Compare(previous, current) < 0 ? previous : current;
    }
}
```

./Platform.Data.Doublets/Sequences/Converters/SequenceToItsLocalElementLevelsConverter.cs

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

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

namespace Platform.Data.Doublets.Sequences.Converters
{
    public class SequenceToItsLocalElementLevelsConverter<TLink> : LinksOperatorBase<TLink>,
    ↪  IConverter<IList<TLink>>
    {
        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;

        private readonly IConverter<Doublet<TLink>, TLink> _linkToItsFrequencyToNumberConveter;

        public SequenceToItsLocalElementLevelsConverter(ILinks<TLink> links,
        ↪  IConverter<Doublet<TLink>, TLink> linkToItsFrequencyToNumberConveter) : base(links)
        ↪  => _linkToItsFrequencyToNumberConveter = linkToItsFrequencyToNumberConveter;

        public IList<TLink> Convert(IList<TLink> sequence)
        {
            var levels = new TLink[sequence.Count];
            levels[0] = GetFrequencyNumber(sequence[0], sequence[1]);
            for (var i = 1; i < sequence.Count - 1; i++)
            {
                var previous = GetFrequencyNumber(sequence[i - 1], sequence[i]);
                var next = GetFrequencyNumber(sequence[i], sequence[i + 1]);
                levels[i] = _comparer.Compare(previous, next) > 0 ? previous : next;
            }
            levels[levels.Length - 1] = GetFrequencyNumber(sequence[sequence.Count - 2],
            ↪  sequence[sequence.Count - 1]);
            return levels;
        }

        public TLink GetFrequencyNumber(TLink source, TLink target) =>
        ↪  _linkToItsFrequencyToNumberConveter.Convert(new Doublet<TLink>(source, target));
    }
}
```

./Platform.Data.Doublets/Sequences/CreteriaMatchers/DefaultSequenceElementCriterionMatcher.cs

```
using Platform.Interfaces;

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

namespace Platform.Data.Doublets.Sequences.CreteriaMatchers
{
    public class DefaultSequenceElementCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
    ↪  ICriterionMatcher<TLink>
    {
```

```
        public DefaultSequenceElementCriterionMatcher(ILinks<TLink> links) : base(links) { }
        public bool IsMatched(TLink argument) => Links.IsPartialPoint(argument);
    }
}
```

./Platform.Data.Doublets/Sequences/CreteriaMatchers/MarkedSequenceCriterionMatcher.cs

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

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

namespace Platform.Data.Doublets.Sequences.CreteriaMatchers
{
    public class MarkedSequenceCriterionMatcher<TLink> : ICriterionMatcher<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly ILinks<TLink> _links;
        private readonly TLink _sequenceMarkerLink;

        public MarkedSequenceCriterionMatcher(ILinks<TLink> links, TLink sequenceMarkerLink)
        {
            _links = links;
            _sequenceMarkerLink = sequenceMarkerLink;
        }

        public bool IsMatched(TLink sequenceCandidate)
            => _equalityComparer.Equals(_links.GetSource(sequenceCandidate), _sequenceMarkerLink)
            || !_equalityComparer.Equals(_links.SearchOrDefault(_sequenceMarkerLink,
            ↪  sequenceCandidate), _links.Constants.Null);
    }
}
```

./Platform.Data.Doublets/Sequences/DefaultSequenceAppender.cs

```
using System.Collections.Generic;
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;

        public DefaultSequenceAppender(ILinks<TLink> links, IStack<TLink> stack,
        ↪  ISequenceHeightProvider<TLink> heightProvider)
            : base(links)
        {
            _stack = stack;
            _heightProvider = heightProvider;
        }

        public TLink Append(TLink sequence, TLink appendant)
        {
            var cursor = sequence;
            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);
        }
    }
}
```

./Platform.Data.Doublets/Sequences/DuplicateSegmentsCounter.cs

```
using System.Collections.Generic;
using System.Linq;
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;
        public DuplicateSegmentsCounter(IProvider<IList<KeyValuePair<IList<TLink>,
        ↪  IList<TLink>>>> duplicateFragmentsProvider) => _duplicateFragmentsProvider =
        ↪  duplicateFragmentsProvider;
        public int Count() => _duplicateFragmentsProvider.Get().Sum(x => x.Value.Count);
    }
}
```

./Platform.Data.Doublets/Sequences/DuplicateSegmentsProvider.cs

```
using System;
using System.Linq;
using System.Collections.Generic;
using Platform.Interfaces;
using Platform.Collections;
using Platform.Collections.Lists;
using Platform.Collections.Segments;
using Platform.Collections.Segments.Walkers;
using Platform.Singletons;
using Platform.Numbers;
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 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;
            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);
            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;

            public ItemComparer() => _listComparer = Default<IListComparer<TLink>>.Instance;

            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;
            }
        }

        public DuplicateSegmentsProvider(ILinks<TLink> links, ILinks<TLink> sequences)
            : base(minimumStringSegmentLength: 2)
        {
            _links = links;
            _sequences = sequences;
        }

        public IList<KeyValuePair<IList<TLink>, IList<TLink>>> Get()
        {
            _groups = new HashSet<KeyValuePair<IList<TLink>,
            ↪  IList<TLink>>>(Default<ItemEquilityComparer>.Instance);
            var count = _links.Count();
            _visited = new BitString((long)(Integer<TLink>)count + 1);
            _links.Each(link =>
            {
                var linkIndex = _links.GetIndex(link);
                var linkBitIndex = (long)(Integer<TLink>)linkIndex;
                if (!_visited.Get(linkBitIndex))
                {
                    var sequenceElements = new List<TLink>();
                    var filler = new ListFiller<TLink, TLink>(sequenceElements,
                    ↪  _sequences.Constants.Break);
                    _sequences.Each(filler.AddAllValuesAndReturnConstant, new
                    ↪  LinkAddress<TLink>(linkIndex));
                    if (sequenceElements.Count > 2)
                    {
                        WalkAll(sequenceElements);
                    }
                }
                return _links.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;
        }

        protected override Segment<TLink> CreateSegment(IList<TLink> elements, int offset, int
        ↪  length) => new Segment<TLink>(elements, offset, length);

        protected override void OnDublicateFound(Segment<TLink> segment)
        {
            var duplicates = CollectDuplicatesForSegment(segment);
            if (duplicates.Count > 1)
            {
                _groups.Add(new KeyValuePair<IList<TLink>, IList<TLink>>(segment.ToArray(),
                ↪  duplicates));
            }
        }

        private List<TLink> CollectDuplicatesForSegment(Segment<TLink> segment)
        {
            var duplicates = new List<TLink>();
            var readAsElement = new HashSet<TLink>();
            var restrictions = segment.ConvertToRestrictionsValues();
            restrictions[0] = _sequences.Constants.Any;
            _sequences.Each(sequence =>
            {
                var sequenceIndex = sequence[_sequences.Constants.IndexPart];
                duplicates.Add(sequenceIndex);
                readAsElement.Add(sequenceIndex);
                return _sequences.Constants.Continue;
```

```
            }, restrictions);
            if (duplicates.Any(x => _visited.Get((Integer<TLink>)x)))
            {
                return new List<TLink>();
            }
            foreach (var duplicate in duplicates)
            {
                var duplicateBitIndex = (long)(Integer<TLink>)duplicate;
                _visited.Set(duplicateBitIndex);
            }
            if (_sequences is Sequences sequencesExperiments)
            {
                var partiallyMatched = sequencesExperiments.GetAllPartiallyMatchingSequences4((HashSet<ulong>)(object)readAsElement, (IList<ulong>)segment);
                foreach (var partiallyMatchedSequence in partiallyMatched)
                {
                    TLink sequenceIndex = (Integer<TLink>)partiallyMatchedSequence;
                    duplicates.Add(sequenceIndex);
                }
            }
            duplicates.Sort();
            return duplicates;
        }

        private void PrintDuplicates(KeyValuePair<IList<TLink>, IList<TLink>> duplicatesItem)
        {
            if (!(_links is ILinks<ulong> ulongLinks))
            {
                return;
            }
            var duplicatesKey = duplicatesItem.Key;
            var keyString = UnicodeMap.FromLinksToString((IList<ulong>)duplicatesKey);
            Console.WriteLine($"> {keyString} ({string.Join(", ", duplicatesKey)})");
            var duplicatesList = duplicatesItem.Value;
            for (int i = 0; i < duplicatesList.Count; i++)
            {
                ulong sequenceIndex = (Integer<TLink>)duplicatesList[i];
                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));
                Console.WriteLine(formatedSequenceStructure);
                var sequenceString = UnicodeMap.FromSequenceLinkToString(sequenceIndex, ulongLinks);
                Console.WriteLine(sequenceString);
            }
            Console.WriteLine();
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Frequencies/Cache/LinkFrequenciesCache.cs

```
using System;
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 readonly Dictionary<Doublet<TLink>, LinkFrequency<TLink>> _doubletsCache;
        private readonly ICounter<TLink, TLink> _frequencyCounter;

        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;
        }

        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);
        }

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

        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>(Integer<TLink>.One, link);
                if (!_equalityComparer.Equals(link, default))
                {
                    data.Frequency = Arithmetic.Add(data.Frequency,
                    ↪  _frequencyCounter.Count(link));
                }
                _doubletsCache.Add(doublet, data);
            }
            return data;
        }

        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),
                     ↪  Integer<TLink>.One) > 0))
                     || ((_comparer.Compare(count, frequency) > 0) &&
                      ↪  (_comparer.Compare(Arithmetic.Subtract(count, frequency),
                      ↪  Integer<TLink>.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 Exception("Frequencies validation failed.");
                //    }
                //}
            }
        }
    }
}
```

./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; }

        public LinkFrequency(TLink frequency, TLink link)
        {
            Frequency = frequency;
            Link = link;
        }

        public LinkFrequency() { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void IncrementFrequency() => Frequency = Arithmetic<TLink>.Increment(Frequency);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void DecrementFrequency() => Frequency = Arithmetic<TLink>.Decrement(Frequency);

        public override string ToString() => $"F: {Frequency}, L: {Link}";
    }
}
```

./Platform.Data.Doublets/Sequences/Frequencies/Cache/LinkToItsFrequencyValueConverter.cs

```
using Platform.Interfaces;

#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;
        public
         ↪  FrequenciesCacheBasedLinkToItsFrequencyNumberConverter(LinkFrequenciesCache<TLink>
         ↪  cache) => _cache = cache;
        public TLink Convert(Doublet<TLink> source) => _cache.GetFrequency(ref source).Frequency;
    }
}
```

./Platform.Data.Doublets/Sequences/Frequencies/Counters/MarkedSequenceSymbolFrequencyOneOffCounter.cs

```
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;

        public MarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
        ↪  ICriterionMatcher<TLink> markedSequenceMatcher, TLink sequenceLink, TLink symbol)
            : base(links, sequenceLink, symbol)
            => _markedSequenceMatcher = markedSequenceMatcher;

        public override TLink Count()
        {
            if (!_markedSequenceMatcher.IsMatched(_sequenceLink))
            {
                return default;
            }
            return base.Count();
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Frequencies/Counters/SequenceSymbolFrequencyOneOffCounter.cs

```
using System.Collections.Generic;
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;

        public SequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink sequenceLink,
        ↪  TLink symbol)
        {
            _links = links;
            _sequenceLink = sequenceLink;
            _symbol = symbol;
            _total = default;
        }

        public virtual TLink Count()
        {
            if (_comparer.Compare(_total, default) > 0)
            {
                return _total;
            }
            StopableSequenceWalker.WalkRight(_sequenceLink, _links.GetSource, _links.GetTarget,
            ↪  IsElement, VisitElement);
            return _total;
        }

        private bool IsElement(TLink x) => _equalityComparer.Equals(x, _symbol) ||
        ↪  _links.IsPartialPoint(x); // TODO: Use SequenceElementCreteriaMatcher instead of
        ↪  IsPartialPoint

        private bool VisitElement(TLink element)
        {
            if (_equalityComparer.Equals(element, _symbol))
            {
                _total = Arithmetic.Increment(_total);
            }
            return true;
```

```
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalMarkedSequenceSymbolFrequencyCounter.cs

```
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;

        public TotalMarkedSequenceSymbolFrequencyCounter(ILinks<TLink> links,
        ↪  ICriterionMatcher<TLink> markedSequenceMatcher)
        {
            _links = links;
            _markedSequenceMatcher = markedSequenceMatcher;
        }

        public TLink Count(TLink argument) => new
        ↪  TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
        ↪  _markedSequenceMatcher, argument).Count();
    }
}
```

./Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalMarkedSequenceSymbolFrequencyOneOffCounter

```
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;

        public TotalMarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
        ↪  ICriterionMatcher<TLink> markedSequenceMatcher, TLink symbol)
            : base(links, symbol)
            => _markedSequenceMatcher = markedSequenceMatcher;

        protected override void CountSequenceSymbolFrequency(TLink link)
        {
            var symbolFrequencyCounter = new
            ↪  MarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
            ↪  _markedSequenceMatcher, link, _symbol);
            _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalSequenceSymbolFrequencyCounter.cs

```
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;
        public TotalSequenceSymbolFrequencyCounter(ILinks<TLink> links) => _links = links;
        public TLink Count(TLink symbol) => new
        ↪  TotalSequenceSymbolFrequencyOneOffCounter<TLink>(_links, symbol).Count();
    }
}
```

./Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalSequenceSymbolFrequencyOneOffCounter.cs

```
using System.Collections.Generic;
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;

        public TotalSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink symbol)
        {
            _links = links;
            _symbol = symbol;
            _visits = new HashSet<TLink>();
            _total = default;
        }

        public TLink Count()
        {
            if (_comparer.Compare(_total, default) > 0 || _visits.Count > 0)
            {
                return _total;
            }
            CountCore(_symbol);
            return _total;
        }

        private void CountCore(TLink link)
        {
            var any = _links.Constants.Any;
            if (_equalityComparer.Equals(_links.Count(any, link), default))
            {
                CountSequenceSymbolFrequency(link);
            }
            else
            {
                _links.Each(EachElementHandler, any, link);
            }
        }

        protected virtual void CountSequenceSymbolFrequency(TLink link)
        {
            var symbolFrequencyCounter = new SequenceSymbolFrequencyOneOffCounter<TLink>(_links,
            ↪  link, _symbol);
            _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
        }

        private TLink EachElementHandler(IList<TLink> doublet)
        {
            var constants = _links.Constants;
            var doubletIndex = doublet[constants.IndexPart];
            if (_visits.Add(doubletIndex))
            {
                CountCore(doubletIndex);
            }
            return constants.Continue;
        }
    }
}
```

./Platform.Data.Doublets/Sequences/HeightProviders/CachedSequenceHeightProvider.cs

```

using System.Collections.Generic;
using Platform.Interfaces;

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

namespace Platform.Data.Doublets.Sequences.HeightProviders
{
    public class CachedSequenceHeightProvider<TLink> : LinksOperatorBase<TLink>,
    ↪  ISequenceHeightProvider<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly TLink _heightPropertyMarker;
```

```
        private readonly ISequenceHeightProvider<TLink> _baseHeightProvider;
        private readonly IConverter<TLink> _addressToUnaryNumberConverter;
        private readonly IConverter<TLink> _unaryNumberToAddressConverter;
        private readonly IPropertiesOperator<TLink, TLink, TLink> _propertyOperator;

        public CachedSequenceHeightProvider(
            ILinks<TLink> links,
            ISequenceHeightProvider<TLink> baseHeightProvider,
            IConverter<TLink> addressToUnaryNumberConverter,
            IConverter<TLink> unaryNumberToAddressConverter,
            TLink heightPropertyMarker,
            IPropertiesOperator<TLink, TLink, TLink> propertyOperator)
            : base(links)
        {
            _heightPropertyMarker = heightPropertyMarker;
            _baseHeightProvider = baseHeightProvider;
            _addressToUnaryNumberConverter = addressToUnaryNumberConverter;
            _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
            _propertyOperator = propertyOperator;
        }

        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;
        }
    }
}
```

./Platform.Data.Doublets/Sequences/HeightProviders/DefaultSequenceRightHeightProvider.cs

```
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;

        public DefaultSequenceRightHeightProvider(ILinks<TLink> links, ICriterionMatcher<TLink>
        ↪  elementMatcher) : base(links) => _elementMatcher = elementMatcher;

        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;
        }
    }
}
```

./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>
    {
    }
}
```

./Platform.Data.Doublets/Sequences/IListExtensions.cs

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

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

namespace Platform.Data.Doublets.Sequences
{
    public static class IListExtensions
    {
        public static TLink[] ExtractValues<TLink>(this IList<TLink> restrictions)
        {
            if(restrictions.IsNullOrEmpty() || restrictions.Count == 1)
            {
                return new TLink[0];
            }
            var values = new TLink[restrictions.Count - 1];
            for (int i = 1, j = 0; i < restrictions.Count; i++, j++)
            {
                values[j] = restrictions[i];
            }
            return values;
        }

        public static IList<TLink> ConvertToRestrictionsValues<TLink>(this IList<TLink> list)
        {
            var restrictions = new TLink[list.Count + 1];
            for (int i = 0, j = 1; i < list.Count; i++, j++)
            {
                restrictions[j] = list[i];
            }
            return restrictions;
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Indexes/CachedFrequencyIncrementingSequenceIndex.cs

```
using System.Collections.Generic;
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;

        public CachedFrequencyIncrementingSequenceIndex(LinkFrequenciesCache<TLink> cache) =>
        ↪  _cache = cache;

        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;
        }

        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;
```

```
        }

        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;
        }

        private bool IsIndexed(TLink source, TLink target)
        {
            var frequency = _cache.GetFrequency(source, target);
            if (frequency == null)
            {
                return false;
            }
            return !_equalityComparer.Equals(frequency.Frequency, default);
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Indexes/FrequencyIncrementingSequenceIndex.cs

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

#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 IPropertyOperator<TLink, TLink> _frequencyPropertyOperator;
        private readonly IIncrementer<TLink> _frequencyIncrementer;

        public FrequencyIncrementingSequenceIndex(ILinks<TLink> links, IPropertyOperator<TLink,
        ↪ TLink> frequencyPropertyOperator, IIncrementer<TLink> frequencyIncrementer)
            : base(links)
        {
            _frequencyPropertyOperator = frequencyPropertyOperator;
            _frequencyIncrementer = frequencyIncrementer;
        }

        public override bool Add(IList<TLink> sequence)
        {
            var indexed = true;
            var i = sequence.Count;
            while (--i >= 1 && (indexed = IsIndexedWithIncrement(sequence[i - 1], sequence[i])))
            ↪ { }
            for (; i >= 1; i--)
            {
                Increment(Links.GetOrCreate(sequence[i - 1], sequence[i]));
            }
            return indexed;
        }

        private bool IsIndexedWithIncrement(TLink source, TLink target)
        {
            var link = Links.SearchOrDefault(source, target);
            var indexed = !_equalityComparer.Equals(link, default);
            if (indexed)
            {
                Increment(link);
            }
            return indexed;
        }

        private void Increment(TLink link)
        {
            var previousFrequency = _frequencyPropertyOperator.Get(link);
            var frequency = _frequencyIncrementer.Increment(previousFrequency);
            _frequencyPropertyOperator.Set(link, frequency);
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Indexes/ISequenceIndex.cs

```
using System.Collections.Generic;

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

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public interface ISequenceIndex<TLink>
    {
        /// <summary>
        /// Индексирует последовательность глобально, и возвращает значение,
        /// определяющие была ли запрошенная последовательность проиндексирована ранее.
        /// </summary>
        /// <param name="sequence">Последовательность для индексации.</param>
        bool Add(IList<TLink> sequence);

        bool MightContain(IList<TLink> sequence);
    }
}
```

./Platform.Data.Doublets/Sequences/Indexes/SequenceIndex.cs

```
using System.Collections.Generic;

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

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public class SequenceIndex<TLink> : LinksOperatorBase<TLink>, ISequenceIndex<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

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

        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;
        }

        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;
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Indexes/SynchronizedSequenceIndex.cs

```
using System.Collections.Generic;

#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;

        public SynchronizedSequenceIndex(ISynchronizedLinks<TLink> links) => _links = links;

        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;
        }

        public bool MightContain(IList<TLink> sequence)
        {
            var links = _links.Unsync;
            return _links.SyncRoot.ExecuteReadOperation(() =>
            {
                var indexed = true;
                var i = sequence.Count;
                while (--i >= 1 && (indexed =
                ↪  !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
                ↪  sequence[i]), default))) { }
                return indexed;
            });
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Indexes/Unindex.cs

```
using System.Collections.Generic;

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

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public class Unindex<TLink> : ISequenceIndex<TLink>
    {
        public virtual bool Add(IList<TLink> sequence) => false;

        public virtual bool MightContain(IList<TLink> sequence) => true;
    }
}
```

./Platform.Data.Doublets/Sequences/ListFiller.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
{
    public class ListFiller<TElement, TReturnConstant>
    {
        protected readonly List<TElement> _list;
        protected readonly TReturnConstant _returnConstant;

        public ListFiller(List<TElement> list, TReturnConstant returnConstant)
        {
            _list = list;
            _returnConstant = returnConstant;
        }

        public ListFiller(List<TElement> list) : this(list, default) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Add(TElement element) => _list.Add(element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool AddAndReturnTrue(TElement element)
        {
            _list.Add(element);
```

```
            return true;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool AddFirstAndReturnTrue(IList<TElement> collection)
        {
            _list.Add(collection[0]);
            return true;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TReturnConstant AddAndReturnConstant(TElement element)
        {
            _list.Add(element);
            return _returnConstant;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TReturnConstant AddFirstAndReturnConstant(IList<TElement> collection)
        {
            _list.Add(collection[0]);
            return _returnConstant;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TReturnConstant AddAllValuesAndReturnConstant(IList<TElement> collection)
        {
            for (int i = 1; i < collection.Count; i++)
            {
                _list.Add(collection[i]);
            }
            return _returnConstant;
        }
    }
}
```

./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.Threading.Synchronization;
using Platform.Singletons;
using LinkIndex = System.UInt64;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Collections.Stacks;
using Platform.Collections.Arrays;

#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?
    ///
```

```
40      /// Писать тесты.
41      ///
42      ///
43      /// Можно убрать зависимость от конкретной реализации Links,
44      /// на зависимость от абстрактного элемента, который может быть представлен несколькими
        ↪  способами.
45      ///
46      /// Можно ли как-то сделать один общий интерфейс
47      ///
48      ///
49      /// Блокчейн и/или гит для распределённой записи транзакций.
50      ///
51      /// </remarks>
52      public partial class Sequences : ILinks<LinkIndex> // IList<string>, IList<LinkIndex[]>
        ↪  (после завершения реализации Sequences)
53      {
54          /// <summary>Возвращает значение LinkIndex, обозначающее любое количество
            ↪  связей.</summary>
55          public const LinkIndex ZeroOrMany = LinkIndex.MaxValue;
56
57          public SequencesOptions<LinkIndex> Options { get; }
58          public SynchronizedLinks<LinkIndex> Links { get; }
59          private readonly ISynchronization _sync;
60
61          public LinksConstants<LinkIndex> Constants { get; }
62
63          public Sequences(SynchronizedLinks<LinkIndex> links, SequencesOptions<LinkIndex> options)
64          {
65              Links = links;
66              _sync = links.SyncRoot;
67              Options = options;
68              Options.ValidateOptions();
69              Options.InitOptions(Links);
70              Constants = Default<LinksConstants<LinkIndex>>.Instance;
71          }
72
73          public Sequences(SynchronizedLinks<LinkIndex> links)
74              : this(links, new SequencesOptions<LinkIndex>())
75          {
76          }
77
78          public bool IsSequence(LinkIndex sequence)
79          {
80              return _sync.ExecuteReadOperation(() =>
81              {
82                  if (Options.UseSequenceMarker)
83                  {
84                      return Options.MarkedSequenceMatcher.IsMatched(sequence);
85                  }
86                  return !Links.Unsync.IsPartialPoint(sequence);
87              });
88          }
89
90          [MethodImpl(MethodImplOptions.AggressiveInlining)]
91          private LinkIndex GetSequenceByElements(LinkIndex sequence)
92          {
93              if (Options.UseSequenceMarker)
94              {
95                  return Links.SearchOrDefault(Options.SequenceMarkerLink, sequence);
96              }
97              return sequence;
98          }
99
100         private LinkIndex GetSequenceElements(LinkIndex sequence)
101         {
102             if (Options.UseSequenceMarker)
103             {
104                 var linkContents = new Link<ulong>(Links.GetLink(sequence));
105                 if (linkContents.Source == Options.SequenceMarkerLink)
106                 {
107                     return linkContents.Target;
108                 }
109                 if (linkContents.Target == Options.SequenceMarkerLink)
110                 {
111                     return linkContents.Source;
112                 }
113             }
114             return sequence;
115         }
```

```
116
117         #region Count
118
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         private LinkIndex CountUsages(params LinkIndex[] restrictions)
146         {
147             if (restrictions.Length == 0)
148             {
149                 return 0;
150             }
151             if (restrictions.Length == 1) // Первая связь это адрес
152             {
153                 if (restrictions[0] == Constants.Null)
154                 {
155                     return 0;
156                 }
157                 if (Options.UseSequenceMarker)
158                 {
159                     var elementsLink = GetSequenceElements(restrictions[0]);
160                     var sequenceLink = GetSequenceByElements(elementsLink);
161                     if (sequenceLink != Constants.Null)
162                     {
163                         return Links.Count(sequenceLink) + Links.Count(elementsLink) - 1;
164                     }
165                     return Links.Count(elementsLink);
166                 }
167                 return Links.Count(restrictions[0]);
168             }
169             throw new NotImplementedException();
170         }
171
172         #endregion
173
174         #region Create
175
176         public LinkIndex Create(IList<LinkIndex> restrictions)
177         {
178             return _sync.ExecuteWriteOperation(() =>
179             {
180                 if (restrictions.IsNullOrEmpty())
181                 {
182                     return Constants.Null;
183                 }
184                 Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
185                 return CreateCore(restrictions);
186             });
187         }
188
189         private LinkIndex CreateCore(IList<LinkIndex> restrictions)
190         {
191             LinkIndex[] sequence = restrictions.ExtractValues();
192             if (Options.UseIndex)
193             {
194                 Options.Index.Add(sequence);
```

```
195             }
196             var sequenceRoot = default(LinkIndex);
197             if (Options.EnforceSingleSequenceVersionOnWriteBasedOnExisting)
198             {
199                 var matches = Each(restrictions);
200                 if (matches.Count > 0)
201                 {
202                     sequenceRoot = matches[0];
203                 }
204             }
205             else if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew)
206             {
207                 return CompactCore(sequence);
208             }
209             if (sequenceRoot == default)
210             {
211                 sequenceRoot = Options.LinksToSequenceConverter.Convert(sequence);
212             }
213             if (Options.UseSequenceMarker)
214             {
215                 Links.Unsync.CreateAndUpdate(Options.SequenceMarkerLink, sequenceRoot);
216             }
217             return sequenceRoot; // Возвращаем корень последовательности (т.е. сами элементы)
218         }
219 
220         #endregion
221 
222         #region Each
223 
224         public List<LinkIndex> Each(IList<LinkIndex> sequence)
225         {
226             var results = new List<LinkIndex>();
227             var filler = new ListFiller<LinkIndex, LinkIndex>(results, Constants.Continue);
228             Each(filler.AddFirstAndReturnConstant, sequence);
229             return results;
230         }
231 
232         public LinkIndex Each(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
        ↪ restrictions)
233         {
234             return _sync.ExecuteReadOperation(() =>
235             {
236                 if (restrictions.IsNullOrEmpty())
237                 {
238                     return Constants.Continue;
239                 }
240                 Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
241                 if (restrictions.Count == 1)
242                 {
243                     var link = restrictions[0];
244                     var any = Constants.Any;
245                     if (link == any)
246                     {
247                         if (Options.UseSequenceMarker)
248                         {
249                             return Links.Unsync.Each(handler, new Link<LinkIndex>(any,
                            ↪ Options.SequenceMarkerLink, any));
250                         }
251                         else
252                         {
253                             return Links.Unsync.Each(handler, new Link<LinkIndex>(any, any,
                            ↪ any));
254                         }
255                     }
256                     var sequence =
                    ↪ Options.Walker.Walk(link).ToArray().ConvertToRestrictionsValues();
257                     sequence[0] = link;
258                     return handler(sequence);
259                 }
260                 else if (restrictions.Count == 2)
261                 {
262                     throw new NotImplementedException();
263                 }
264                 else if (restrictions.Count == 3)
265                 {
266                     return Links.Unsync.Each(handler, restrictions);
267                 }
268                 else
```

```
269                 {
270                     var sequence = restrictions.ExtractValues();
271                     if (Options.UseIndex && !Options.Index.MightContain(sequence))
272                     {
273                         return Constants.Break;
274                     }
275                     return EachCore(handler, sequence);
276                 }
277             });
278         }
279 
280         private LinkIndex EachCore(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
            ↪ values)
281         {
282             var matcher = new Matcher(this, values, new HashSet<LinkIndex>(), handler);
283             // TODO: Find out why matcher.HandleFullMatched executed twice for the same sequence
                ↪ Id.
284             Func<IList<LinkIndex>, LinkIndex> innerHandler = Options.UseSequenceMarker ?
                ↪ (Func<IList<LinkIndex>, LinkIndex>)matcher.HandleFullMatchedSequence :
                ↪ matcher.HandleFullMatched;
285             //if (sequence.Length >= 2)
286             if (StepRight(innerHandler, values[0], values[1]) != Constants.Continue)
287             {
288                 return Constants.Break;
289             }
290             var last = values.Count - 2;
291             for (var i = 1; i < last; i++)
292             {
293                 if (PartialStepRight(innerHandler, values[i], values[i + 1]) !=
                    ↪ Constants.Continue)
294                 {
295                     return Constants.Break;
296                 }
297             }
298             if (values.Count >= 3)
299             {
300                 if (StepLeft(innerHandler, values[values.Count - 2], values[values.Count - 1])
                    ↪ != Constants.Continue)
301                 {
302                     return Constants.Break;
303                 }
304             }
305             return Constants.Continue;
306         }
307 
308         private LinkIndex PartialStepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
            ↪ left, LinkIndex right)
309         {
310             return Links.Unsync.Each(doublet =>
311             {
312                 var doubletIndex = doublet[Constants.IndexPart];
313                 if (StepRight(handler, doubletIndex, right) != Constants.Continue)
314                 {
315                     return Constants.Break;
316                 }
317                 if (left != doubletIndex)
318                 {
319                     return PartialStepRight(handler, doubletIndex, right);
320                 }
321                 return Constants.Continue;
322             }, new Link<LinkIndex>(Constants.Any, Constants.Any, left));
323         }
324 
325         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));
326 
327         private LinkIndex TryStepRightUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
            ↪ right, LinkIndex stepFrom)
328         {
329             var upStep = stepFrom;
330             var firstSource = Links.Unsync.GetTarget(upStep);
331             while (firstSource != right && firstSource != upStep)
332             {
333                 upStep = firstSource;
334                 firstSource = Links.Unsync.GetSource(upStep);
335             }
```

```
336             if (firstSource == right)
337             {
338                 return handler(new LinkAddress<LinkIndex>(stepFrom));
339             }
340             return Constants.Continue;
341         }
342 
343         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));
344 
345         private LinkIndex TryStepLeftUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
        ↪   left, LinkIndex stepFrom)
346         {
347             var upStep = stepFrom;
348             var firstTarget = Links.Unsync.GetSource(upStep);
349             while (firstTarget != left && firstTarget != upStep)
350             {
351                 upStep = firstTarget;
352                 firstTarget = Links.Unsync.GetTarget(upStep);
353             }
354             if (firstTarget == left)
355             {
356                 return handler(new LinkAddress<LinkIndex>(stepFrom));
357             }
358             return Constants.Continue;
359         }
360 
361         #endregion
362 
363         #region Update
364 
365         public LinkIndex Update(IList<LinkIndex> restrictions, IList<LinkIndex> substitution)
366         {
367             var sequence = restrictions.ExtractValues();
368             var newSequence = substitution.ExtractValues();
369 
370             if (sequence.IsNullOrEmpty() && newSequence.IsNullOrEmpty())
371             {
372                 return Constants.Null;
373             }
374             if (sequence.IsNullOrEmpty())
375             {
376                 return Create(substitution);
377             }
378             if (newSequence.IsNullOrEmpty())
379             {
380                 Delete(restrictions);
381                 return Constants.Null;
382             }
383             return _sync.ExecuteWriteOperation(() =>
384             {
385                 Links.EnsureEachLinkIsAnyOrExists(sequence);
386                 Links.EnsureEachLinkExists(newSequence);
387                 return UpdateCore(sequence, newSequence);
388             });
389         }
390 
391         private LinkIndex UpdateCore(LinkIndex[] sequence, LinkIndex[] newSequence)
392         {
393             LinkIndex bestVariant;
394             if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew &&
        ↪   !sequence.EqualTo(newSequence))
395             {
396                 bestVariant = CompactCore(newSequence);
397             }
398             else
399             {
400                 bestVariant = CreateCore(newSequence);
401             }
402             // TODO: Check all options only ones before loop execution
403             // Возможно нужно две версии Each, возвращающий фактические последовательности и с
        ↪   маркером,
404             // или возможно даже возвращать и тот и тот вариант. С другой стороны все варианты
        ↪   можно получить имея только фактические последовательности.
405             foreach (var variant in Each(sequence))
406             {
407                 if (variant != bestVariant)
```

```
                {
                    UpdateOneCore(variant, bestVariant);
                }
            }
            return bestVariant;
        }

        private void UpdateOneCore(LinkIndex sequence, LinkIndex newSequence)
        {
            if (Options.UseGarbageCollection)
            {
                var sequenceElements = GetSequenceElements(sequence);
                var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
                var sequenceLink = GetSequenceByElements(sequenceElements);
                var newSequenceElements = GetSequenceElements(newSequence);
                var newSequenceLink = GetSequenceByElements(newSequenceElements);
                if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
                {
                    if (sequenceLink != Constants.Null)
                    {
                        Links.Unsync.MergeUsages(sequenceLink, newSequenceLink);
                    }
                    Links.Unsync.MergeUsages(sequenceElements, newSequenceElements);
                }
                ClearGarbage(sequenceElementsContents.Source);
                ClearGarbage(sequenceElementsContents.Target);
            }
            else
            {
                if (Options.UseSequenceMarker)
                {
                    var sequenceElements = GetSequenceElements(sequence);
                    var sequenceLink = GetSequenceByElements(sequenceElements);
                    var newSequenceElements = GetSequenceElements(newSequence);
                    var newSequenceLink = GetSequenceByElements(newSequenceElements);
                    if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
                    {
                        if (sequenceLink != Constants.Null)
                        {
                            Links.Unsync.MergeUsages(sequenceLink, newSequenceLink);
                        }
                        Links.Unsync.MergeUsages(sequenceElements, newSequenceElements);
                    }
                }
                else
                {
                    if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
                    {
                        Links.Unsync.MergeUsages(sequence, newSequence);
                    }
                }
            }
        }

        #endregion

        #region Delete

        public void Delete(IList<LinkIndex> restrictions)
        {
            _sync.ExecuteWriteOperation(() =>
            {
                var sequence = restrictions.ExtractValues();
                // TODO: Check all options only ones before loop execution
                foreach (var linkToDelete in Each(sequence))
                {
                    DeleteOneCore(linkToDelete);
                }
            });
        }

        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

        /// <remarks>
        /// bestVariant можно выбирать по максимальному числу использований,
        /// но балансированный позволяет гарантировать уникальность (если есть возможность,
        /// гарантировать его использование в других местах).
        ///
        /// Получается этот метод должен игнорировать Options.EnforceSingleSequenceVersionOnWrite
        /// </remarks>
        public LinkIndex Compact(params LinkIndex[] sequence)
        {
            return _sync.ExecuteWriteOperation(() =>
            {
                if (sequence.IsNullOrEmpty())
                {
                    return Constants.Null;
                }
                Links.EnsureEachLinkExists(sequence);
                return CompactCore(sequence);
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private LinkIndex CompactCore(params LinkIndex[] sequence) => UpdateCore(sequence,
        ↪  sequence);

        #endregion

        #region Garbage Collection

        /// <remarks>
        /// TODO: Добавить дополнительный обработчик / событие CanBeDeleted которое можно
        ↪  определить извне или в унаследованном классе
        /// </remarks>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool IsGarbage(LinkIndex link) => link != Options.SequenceMarkerLink &&
        ↪  !Links.Unsync.IsPartialPoint(link) && Links.Count(link) == 0;

        private void ClearGarbage(LinkIndex link)
        {
            if (IsGarbage(link))
```

```
562             {
563                 var contents = new Link<ulong>(Links.GetLink(link));
564                 Links.Unsync.Delete(link);
565                 ClearGarbage(contents.Source);
566                 ClearGarbage(contents.Target);
567             }
568         }
569 
570         #endregion
571 
572         #region Walkers
573 
574         public bool EachPart(Func<LinkIndex, bool> handler, LinkIndex sequence)
575         {
576             return _sync.ExecuteReadOperation(() =>
577             {
578                 var links = Links.Unsync;
579                 foreach (var part in Options.Walker.Walk(sequence))
580                 {
581                     if (!handler(part))
582                     {
583                         return false;
584                     }
585                 }
586                 return true;
587             });
588         }
589 
590         public class Matcher : RightSequenceWalker<LinkIndex>
591         {
592             private readonly Sequences _sequences;
593             private readonly IList<LinkIndex> _patternSequence;
594             private readonly HashSet<LinkIndex> _linksInSequence;
595             private readonly HashSet<LinkIndex> _results;
596             private readonly Func<IList<LinkIndex>, LinkIndex> _stopableHandler;
597             private readonly HashSet<LinkIndex> _readAsElements;
598             private int _filterPosition;
599 
600             public Matcher(Sequences sequences, IList<LinkIndex> patternSequence,
                ↪  HashSet<LinkIndex> results, Func<IList<LinkIndex>, LinkIndex> stopableHandler,
                ↪  HashSet<LinkIndex> readAsElements = null)
601                 : base(sequences.Links.Unsync, new DefaultStack<LinkIndex>())
602             {
603                 _sequences = sequences;
604                 _patternSequence = patternSequence;
605                 _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
                    ↪  Links.Constants.Any && x != ZeroOrMany));
606                 _results = results;
607                 _stopableHandler = stopableHandler;
608                 _readAsElements = readAsElements;
609             }
610 
611             protected override bool IsElement(LinkIndex link) => base.IsElement(link) ||
                ↪  (_readAsElements != null && _readAsElements.Contains(link)) ||
                ↪  _linksInSequence.Contains(link);
612 
613             public bool FullMatch(LinkIndex sequenceToMatch)
614             {
615                 _filterPosition = 0;
616                 foreach (var part in Walk(sequenceToMatch))
617                 {
618                     if (!FullMatchCore(part))
619                     {
620                         break;
621                     }
622                 }
623                 return _filterPosition == _patternSequence.Count;
624             }
625 
626             private bool FullMatchCore(LinkIndex element)
627             {
628                 if (_filterPosition == _patternSequence.Count)
629                 {
630                     _filterPosition = -2; // Длиннее чем нужно
631                     return false;
632                 }
633                 if (_patternSequence[_filterPosition] != Links.Constants.Any
634                  && element != _patternSequence[_filterPosition])
635                 {
636                     _filterPosition = -1;
```

```
637                     return false; // Начинается/Продолжается иначе
638                 }
639                 _filterPosition++;
640                 return true;
641             }
642 
643             public void AddFullMatchedToResults(IList<LinkIndex> restrictions)
644             {
645                 var sequenceToMatch = restrictions[Links.Constants.IndexPart];
646                 if (FullMatch(sequenceToMatch))
647                 {
648                     _results.Add(sequenceToMatch);
649                 }
650             }
651 
652             public LinkIndex HandleFullMatched(IList<LinkIndex> restrictions)
653             {
654                 var sequenceToMatch = restrictions[Links.Constants.IndexPart];
655                 if (FullMatch(sequenceToMatch) && _results.Add(sequenceToMatch))
656                 {
657                     return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
658                 }
659                 return Links.Constants.Continue;
660             }
661 
662             public LinkIndex HandleFullMatchedSequence(IList<LinkIndex> restrictions)
663             {
664                 var sequenceToMatch = restrictions[Links.Constants.IndexPart];
665                 var sequence = _sequences.GetSequenceByElements(sequenceToMatch);
666                 if (sequence != Links.Constants.Null && FullMatch(sequenceToMatch) &&
                    ↪  _results.Add(sequenceToMatch))
667                 {
668                     return _stopableHandler(new LinkAddress<LinkIndex>(sequence));
669                 }
670                 return Links.Constants.Continue;
671             }
672 
673             /// <remarks>
674             /// TODO: Add support for LinksConstants.Any
675             /// </remarks>
676             public bool PartialMatch(LinkIndex sequenceToMatch)
677             {
678                 _filterPosition = -1;
679                 foreach (var part in Walk(sequenceToMatch))
680                 {
681                     if (!PartialMatchCore(part))
682                     {
683                         break;
684                     }
685                 }
686                 return _filterPosition == _patternSequence.Count - 1;
687             }
688 
689             private bool PartialMatchCore(LinkIndex element)
690             {
691                 if (_filterPosition == (_patternSequence.Count - 1))
692                 {
693                     return false; // Нашлось
694                 }
695                 if (_filterPosition >= 0)
696                 {
697                     if (element == _patternSequence[_filterPosition + 1])
698                     {
699                         _filterPosition++;
700                     }
701                     else
702                     {
703                         _filterPosition = -1;
704                     }
705                 }
706                 if (_filterPosition < 0)
707                 {
708                     if (element == _patternSequence[0])
709                     {
710                         _filterPosition = 0;
711                     }
712                 }
713                 return true; // Ищем дальше
714             }
```

```
715
716             public void AddPartialMatchedToResults(LinkIndex sequenceToMatch)
717             {
718                 if (PartialMatch(sequenceToMatch))
719                 {
720                     _results.Add(sequenceToMatch);
721                 }
722             }
723
724             public LinkIndex HandlePartialMatched(IList<LinkIndex> restrictions)
725             {
726                 var sequenceToMatch = restrictions[Links.Constants.IndexPart];
727                 if (PartialMatch(sequenceToMatch))
728                 {
729                     return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
730                 }
731                 return Links.Constants.Continue;
732             }
733
734             public void AddAllPartialMatchedToResults(IEnumerable<LinkIndex> sequencesToMatch)
735             {
736                 foreach (var sequenceToMatch in sequencesToMatch)
737                 {
738                     if (PartialMatch(sequenceToMatch))
739                     {
740                         _results.Add(sequenceToMatch);
741                     }
742                 }
743             }
744
745             public void AddAllPartialMatchedToResultsAndReadAsElements(IEnumerable<LinkIndex>
                ↪ sequencesToMatch)
746             {
747                 foreach (var sequenceToMatch in sequencesToMatch)
748                 {
749                     if (PartialMatch(sequenceToMatch))
750                     {
751                         _readAsElements.Add(sequenceToMatch);
752                         _results.Add(sequenceToMatch);
753                     }
754                 }
755             }
756         }
757
758         #endregion
759     }
760 }
```

./Platform.Data.Doublets/Sequences/Sequences.Experiments.cs

```
1  using System;
2  using LinkIndex = System.UInt64;
3  using System.Collections.Generic;
4  using Stack = System.Collections.Generic.Stack<ulong>;
5  using System.Linq;
6  using System.Text;
7  using Platform.Collections;
8  using Platform.Data.Exceptions;
9  using Platform.Data.Sequences;
10 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
11 using Platform.Data.Doublets.Sequences.Walkers;
12 using Platform.Collections.Stacks;
13
14 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
15
16 namespace Platform.Data.Doublets.Sequences
17 {
18     partial class Sequences
19     {
20         #region Create All Variants (Not Practical)
21
22         /// <remarks>
23         /// Number of links that is needed to generate all variants for
24         /// sequence of length N corresponds to https://oeis.org/A014143/list sequence.
25         /// </remarks>
26         public ulong[] CreateAllVariants2(ulong[] sequence)
27         {
28             return _sync.ExecuteWriteOperation(() =>
29             {
30                 if (sequence.IsNullOrEmpty())
31                 {
```

```
                    return new ulong[0];
                }
                Links.EnsureEachLinkExists(sequence);
                if (sequence.Length == 1)
                {
                    return sequence;
                }
                return CreateAllVariants2Core(sequence, 0, sequence.Length - 1);
            });
        }

        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.CreateAndUpdate(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.CreateAndUpdate(left[i], right[j]);
                        if (variant == Constants.Null)
                        {
                            throw new NotImplementedException("Creation cancellation is not implemented.");
                        }
                        variants[last++] = variant;
                    }
                }
            }
            return variants;
        }

        public List<ulong> CreateAllVariants1(params ulong[] sequence)
        {
            return _sync.ExecuteWriteOperation(() =>
            {
                if (sequence.IsNullOrEmpty())
                {
                    return new List<ulong>();
                }
                Links.Unsync.EnsureEachLinkExists(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);
            });
        }

        private List<ulong> CreateAllVariants1Core(ulong[] sequence, List<ulong> results)
        {
            if (sequence.Length == 2)
            {
                var link = Links.Unsync.CreateAndUpdate(sequence[0], sequence[1]);
                if (link == Constants.Null)
                {
```

```
106                     throw new NotImplementedException("Creation cancellation is not
                        ↪  implemented.");
107                 }
108                 results.Add(link);
109                 return results;
110             }
111             var innerSequenceLength = sequence.Length - 1;
112             var innerSequence = new ulong[innerSequenceLength];
113             for (var li = 0; li < innerSequenceLength; li++)
114             {
115                 var link = Links.Unsync.CreateAndUpdate(sequence[li], sequence[li + 1]);
116                 if (link == Constants.Null)
117                 {
118                     throw new NotImplementedException("Creation cancellation is not
                        ↪  implemented.");
119                 }
120                 for (var isi = 0; isi < li; isi++)
121                 {
122                     innerSequence[isi] = sequence[isi];
123                 }
124                 innerSequence[li] = link;
125                 for (var isi = li + 1; isi < innerSequenceLength; isi++)
126                 {
127                     innerSequence[isi] = sequence[isi + 1];
128                 }
129                 CreateAllVariants1Core(innerSequence, results);
130             }
131             return results;
132         }
133 
134         #endregion
135 
136         public HashSet<ulong> Each1(params ulong[] sequence)
137         {
138             var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
139             Each1(link =>
140             {
141                 if (!visitedLinks.Contains(link))
142                 {
143                     visitedLinks.Add(link); // изучить почему случаются повторы
144                 }
145                 return true;
146             }, sequence);
147             return visitedLinks;
148         }
149 
150         private void Each1(Func<ulong, bool> handler, params ulong[] sequence)
151         {
152             if (sequence.Length == 2)
153             {
154                 Links.Unsync.Each(sequence[0], sequence[1], handler);
155             }
156             else
157             {
158                 var innerSequenceLength = sequence.Length - 1;
159                 for (var li = 0; li < innerSequenceLength; li++)
160                 {
161                     var left = sequence[li];
162                     var right = sequence[li + 1];
163                     if (left == 0 && right == 0)
164                     {
165                         continue;
166                     }
167                     var linkIndex = li;
168                     ulong[] innerSequence = null;
169                     Links.Unsync.Each(doublet =>
170                     {
171                         if (innerSequence == null)
172                         {
173                             innerSequence = new ulong[innerSequenceLength];
174                             for (var isi = 0; isi < linkIndex; isi++)
175                             {
176                                 innerSequence[isi] = sequence[isi];
177                             }
178                             for (var isi = linkIndex + 1; isi < innerSequenceLength; isi++)
179                             {
180                                 innerSequence[isi] = sequence[isi + 1];
181                             }
```

```
                    }
                    innerSequence[linkIndex] = doublet[Constants.IndexPart];
                    Each1(handler, innerSequence);
                    return Constants.Continue;
                }, Constants.Any, left, right);
            }
        }
    }

    public HashSet<ulong> EachPart(params ulong[] sequence)
    {
        var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
        EachPartCore(link =>
        {
            var linkIndex = link[Constants.IndexPart];
            if (!visitedLinks.Contains(linkIndex))
            {
                visitedLinks.Add(linkIndex); // изучить почему случаются повторы
            }
            return Constants.Continue;
        }, sequence);
        return visitedLinks;
    }

    public void EachPart(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[] sequence)
    {
        var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
        EachPartCore(link =>
        {
            var linkIndex = link[Constants.IndexPart];
            if (!visitedLinks.Contains(linkIndex))
            {
                visitedLinks.Add(linkIndex); // изучить почему случаются повторы
                return handler(new LinkAddress<LinkIndex>(linkIndex));
            }
            return Constants.Continue;
        }, sequence);
    }

    private void EachPartCore(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[]
    ↪ sequence)
    {
        if (sequence.IsNullOrEmpty())
        {
            return;
        }
        Links.EnsureEachLinkIsAnyOrExists(sequence);
        if (sequence.Length == 1)
        {
            var link = sequence[0];
            if (link > 0)
            {
                handler(new LinkAddress<LinkIndex>(link));
            }
            else
            {
                Links.Each(Constants.Any, Constants.Any, handler);
            }
        }
        else if (sequence.Length == 2)
        {
            //_links.Each(sequence[0], sequence[1], handler);
            //  o_|      x_o ...
            // x_|        |___|
            Links.Each(sequence[1], Constants.Any, doublet =>
            {
                var match = Links.SearchOrDefault(sequence[0], doublet);
                if (match != Constants.Null)
                {
                    handler(new LinkAddress<LinkIndex>(match));
                }
                return true;
            });
            // |_x      ... x_o
            //  |_o      |___|
            Links.Each(Constants.Any, sequence[0], doublet =>
            {
                var match = Links.SearchOrDefault(doublet, sequence[1]);
```

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

    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;
        });
    }

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

    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
    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;
        });
    }

    private void StepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
    {
        Links.Unsync.Each(Constants.Any, right, leftStep =>
        {
            TryStepLeftUp(handler, left, leftStep);
            return true;
        });
    }

    private void TryStepLeftUp(Action<IList<LinkIndex>> handler, ulong left, ulong stepFrom)
    {
```

```
            var upStep = stepFrom;
            var firstTarget = Links.Unsync.GetSource(upStep);
            while (firstTarget != left && firstTarget != upStep)
            {
                upStep = firstTarget;
                firstTarget = Links.Unsync.GetTarget(upStep);
            }
            if (firstTarget == left)
            {
                handler(new LinkAddress<LinkIndex>(stepFrom));
            }
        }

        private bool StartsWith(ulong sequence, ulong link)
        {
            var upStep = sequence;
            var firstSource = Links.Unsync.GetSource(upStep);
            while (firstSource != link && firstSource != upStep)
            {
                upStep = firstSource;
                firstSource = Links.Unsync.GetSource(upStep);
            }
            return firstSource == link;
        }

        private bool EndsWith(ulong sequence, ulong link)
        {
            var upStep = sequence;
            var lastTarget = Links.Unsync.GetTarget(upStep);
            while (lastTarget != link && lastTarget != upStep)
            {
                upStep = lastTarget;
                lastTarget = Links.Unsync.GetTarget(upStep);
            }
            return lastTarget == link;
        }

        public List<ulong> GetAllMatchingSequences0(params ulong[] sequence)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                var results = new List<ulong>();
                if (sequence.Length > 0)
                {
                    Links.EnsureEachLinkExists(sequence);
                    var firstElement = sequence[0];
                    if (sequence.Length == 1)
                    {
                        results.Add(firstElement);
                        return results;
                    }
                    if (sequence.Length == 2)
                    {
                        var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
                        if (doublet != Constants.Null)
                        {
                            results.Add(doublet);
                        }
                        return results;
                    }
                    var linksInSequence = new HashSet<ulong>(sequence);
                    void handler(IList<LinkIndex> result)
                    {
                        var resultIndex = result[Links.Constants.IndexPart];
                        var filterPosition = 0;
                        StopableSequenceWalker.WalkRight(resultIndex, Links.Unsync.GetSource,
                        ↪  Links.Unsync.GetTarget,
                            x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
                            ↪  x =>
                            {
                                if (filterPosition == sequence.Length)
                                {
                                    filterPosition = -2; // Длиннее чем нужно
                                    return false;
                                }
                                if (x != sequence[filterPosition])
                                {
                                    filterPosition = -1;
                                    return false; // Начинается иначе
```

```
                            }
                            filterPosition++;

                            return true;
                        });
                    if (filterPosition == sequence.Length)
                    {
                        results.Add(resultIndex);
                    }
                }
                if (sequence.Length >= 2)
                {
                    StepRight(handler, sequence[0], sequence[1]);
                }
                var last = sequence.Length - 2;
                for (var i = 1; i < last; i++)
                {
                    PartialStepRight(handler, sequence[i], sequence[i + 1]);
                }
                if (sequence.Length >= 3)
                {
                    StepLeft(handler, sequence[sequence.Length - 2],
                    ↪  sequence[sequence.Length - 1]);
                }
            }
            return results;
        });
    }

    public HashSet<ulong> GetAllMatchingSequences1(params ulong[] sequence)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            var results = new HashSet<ulong>();
            if (sequence.Length > 0)
            {
                Links.EnsureEachLinkExists(sequence);
                var firstElement = sequence[0];
                if (sequence.Length == 1)
                {
                    results.Add(firstElement);
                    return results;
                }
                if (sequence.Length == 2)
                {
                    var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
                    if (doublet != Constants.Null)
                    {
                        results.Add(doublet);
                    }
                    return results;
                }
                var matcher = new Matcher(this, sequence, results, null);
                if (sequence.Length >= 2)
                {
                    StepRight(matcher.AddFullMatchedToResults, sequence[0], sequence[1]);
                }
                var last = sequence.Length - 2;
                for (var i = 1; i < last; i++)
                {
                    PartialStepRight(matcher.AddFullMatchedToResults, sequence[i],
                    ↪  sequence[i + 1]);
                }
                if (sequence.Length >= 3)
                {
                    StepLeft(matcher.AddFullMatchedToResults, sequence[sequence.Length - 2],
                    ↪  sequence[sequence.Length - 1]);
                }
            }
            return results;
        });
    }

    public const int MaxSequenceFormatSize = 200;

    public string FormatSequence(LinkIndex sequenceLink, params LinkIndex[] knownElements)
    ↪  => FormatSequence(sequenceLink, (sb, x) => sb.Append(x), true, knownElements);

```

```
488         public string FormatSequence(LinkIndex sequenceLink, Action<StringBuilder, LinkIndex>
            ↪ elementToString, bool insertComma, params LinkIndex[] knownElements) =>
            ↪ Links.SyncRoot.ExecuteReadOperation(() => FormatSequence(Links.Unsync, sequenceLink,
            ↪ elementToString, insertComma, knownElements));
489
490         private string FormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
            ↪ Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
            ↪ LinkIndex[] knownElements)
491         {
492             var linksInSequence = new HashSet<ulong>(knownElements);
493             //var entered = new HashSet<ulong>();
494             var sb = new StringBuilder();
495             sb.Append('{');
496             if (links.Exists(sequenceLink))
497             {
498                 StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
499                     x => linksInSequence.Contains(x) || links.IsPartialPoint(x), element => //
                        ↪ entered.AddAndReturnVoid, x => { }, entered.DoNotContains
500                     {
501                         if (insertComma && sb.Length > 1)
502                         {
503                             sb.Append(',');
504                         }
505                         //if (entered.Contains(element))
506                         //{
507                         //    sb.Append('{');
508                         //    elementToString(sb, element);
509                         //    sb.Append('}');
510                         //}
511                         //else
512                         elementToString(sb, element);
513                         if (sb.Length < MaxSequenceFormatSize)
514                         {
515                             return true;
516                         }
517                         sb.Append(insertComma ? ", ..." : "...");
518                         return false;
519                     });
520             }
521             sb.Append('}');
522             return sb.ToString();
523         }
524
525         public string SafeFormatSequence(LinkIndex sequenceLink, params LinkIndex[]
            ↪ knownElements) => SafeFormatSequence(sequenceLink, (sb, x) => sb.Append(x), true,
            ↪ knownElements);
526
527         public string SafeFormatSequence(LinkIndex sequenceLink, Action<StringBuilder,
            ↪ LinkIndex> elementToString, bool insertComma, params LinkIndex[] knownElements) =>
            ↪ Links.SyncRoot.ExecuteReadOperation(() => SafeFormatSequence(Links.Unsync,
            ↪ sequenceLink, elementToString, insertComma, knownElements));
528
529         private string SafeFormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
            ↪ Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
            ↪ LinkIndex[] knownElements)
530         {
531             var linksInSequence = new HashSet<ulong>(knownElements);
532             var entered = new HashSet<ulong>();
533             var sb = new StringBuilder();
534             sb.Append('{');
535             if (links.Exists(sequenceLink))
536             {
537                 StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
538                     x => linksInSequence.Contains(x) || links.IsFullPoint(x),
                        ↪ entered.AddAndReturnVoid, x => { }, entered.DoNotContains, element =>
539                     {
540                         if (insertComma && sb.Length > 1)
541                         {
542                             sb.Append(',');
543                         }
544                         if (entered.Contains(element))
545                         {
546                             sb.Append('{');
547                             elementToString(sb, element);
548                             sb.Append('}');
549                         }
550                         else
```

```
                    {
                        elementToString(sb, element);
                    }
                    if (sb.Length < MaxSequenceFormatSize)
                    {
                        return true;
                    }
                    sb.Append(insertComma ? ", ..." : "...");
                    return false;
                });
        }
        sb.Append('}');
        return sb.ToString();
    }

    public List<ulong> GetAllPartiallyMatchingSequences0(params ulong[] sequence)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            if (sequence.Length > 0)
            {
                Links.EnsureEachLinkExists(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>();
        });
    }

    public HashSet<ulong> GetAllPartiallyMatchingSequences1(params ulong[] sequence)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            if (sequence.Length > 0)
            {
                Links.EnsureEachLinkExists(sequence);
```

```
628                 var results = new HashSet<ulong>();
629                 for (var i = 0; i < sequence.Length; i++)
630                 {
631                     AllUsagesCore(sequence[i], results);
632                 }
633                 var filteredResults = new HashSet<ulong>();
634                 var matcher = new Matcher(this, sequence, filteredResults, null);
635                 matcher.AddAllPartialMatchedToResults(results);
636                 return filteredResults;
637             }
638             return new HashSet<ulong>();
639         });
640     }
641 
642     public bool GetAllPartiallyMatchingSequences2(Func<IList<LinkIndex>, LinkIndex> handler,
    ↪  params ulong[] sequence)
643     {
644         return _sync.ExecuteReadOperation(() =>
645         {
646             if (sequence.Length > 0)
647             {
648                 Links.EnsureEachLinkExists(sequence);
649 
650                 var results = new HashSet<ulong>();
651                 var filteredResults = new HashSet<ulong>();
652                 var matcher = new Matcher(this, sequence, filteredResults, handler);
653                 for (var i = 0; i < sequence.Length; i++)
654                 {
655                     if (!AllUsagesCore1(sequence[i], results, matcher.HandlePartialMatched))
656                     {
657                         return false;
658                     }
659                 }
660                 return true;
661             }
662             return true;
663         });
664     }
665 
666     //public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
667     //{
668     //    return Sync.ExecuteReadOperation(() =>
669     //    {
670     //        if (sequence.Length > 0)
671     //        {
672     //            _links.EnsureEachLinkIsAnyOrExists(sequence);
673 
674     //            var firstResults = new HashSet<ulong>();
675     //            var lastResults = new HashSet<ulong>();
676 
677     //            var first = sequence.First(x => x != LinksConstants.Any);
678     //            var last = sequence.Last(x => x != LinksConstants.Any);
679 
680     //            AllUsagesCore(first, firstResults);
681     //            AllUsagesCore(last, lastResults);
682 
683     //            firstResults.IntersectWith(lastResults);
684 
685     //            //for (var i = 0; i < sequence.Length; i++)
686     //            //    AllUsagesCore(sequence[i], results);
687 
688     //            var filteredResults = new HashSet<ulong>();
689     //            var matcher = new Matcher(this, sequence, filteredResults, null);
690     //            matcher.AddAllPartialMatchedToResults(firstResults);
691     //            return filteredResults;
692     //        }
693 
694     //        return new HashSet<ulong>();
695     //    });
696     //}
697 
698     public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
699     {
700         return _sync.ExecuteReadOperation(() =>
701         {
702             if (sequence.Length > 0)
703             {
704                 Links.EnsureEachLinkIsAnyOrExists(sequence);
705                 var firstResults = new HashSet<ulong>();
```

```
                var lastResults = new HashSet<ulong>();
                var first = sequence.First(x => x != Constants.Any);
                var last = sequence.Last(x => x != Constants.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);
                return filteredResults;
            }
            return new HashSet<ulong>();
        });
    }

    public HashSet<ulong> GetAllPartiallyMatchingSequences4(HashSet<ulong> readAsElements,
    ↪  IList<ulong> sequence)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            if (sequence.Count > 0)
            {
                Links.EnsureEachLinkExists(sequence);
                var results = new HashSet<LinkIndex>();
                //var nextResults = new HashSet<ulong>();
                //for (var i = 0; i < sequence.Length; i++)
                //{
                //    AllUsagesCore(sequence[i], nextResults);
                //    if (results.IsNullOrEmpty())
                //    {
                //        results = nextResults;
                //        nextResults = new HashSet<ulong>();
                //    }
                //    else
                //    {
                //        results.IntersectWith(nextResults);
                //        nextResults.Clear();
                //    }
                //}
                var collector1 = new AllUsagesCollector1(Links.Unsync, results);
                collector1.Collect(Links.Unsync.GetLink(sequence[0]));
                var next = new HashSet<ulong>();
                for (var i = 1; i < sequence.Count; i++)
                {
                    var collector = new AllUsagesCollector1(Links.Unsync, next);
                    collector.Collect(Links.Unsync.GetLink(sequence[i]));

                    results.IntersectWith(next);
                    next.Clear();
                }
                var filteredResults = new HashSet<ulong>();
                var matcher = new Matcher(this, sequence, filteredResults, null,
                ↪  readAsElements);
                matcher.AddAllPartialMatchedToResultsAndReadAsElements(results.OrderBy(x =>
                ↪  x)); // OrderBy is a Hack
                return filteredResults;
            }
            return new HashSet<ulong>();
        });
    }

    // Does not work
    //public HashSet<ulong> GetAllPartiallyMatchingSequences5(HashSet<ulong> readAsElements,
    ↪  params ulong[] sequence)
    //{
    //    var visited = new HashSet<ulong>();
    //    var results = new HashSet<ulong>();
    //    var matcher = new Matcher(this, sequence, visited, x => { results.Add(x); return
    ↪  true; }, readAsElements);
    //    var last = sequence.Length - 1;
    //    for (var i = 0; i < last; i++)
    //    {
    //        PartialStepRight(matcher.PartialMatch, sequence[i], sequence[i + 1]);
    //    }
    //    return results;
```

```
778         //}
779
780         public List<ulong> GetAllPartiallyMatchingSequences(params ulong[] sequence)
781         {
782             return _sync.ExecuteReadOperation(() =>
783             {
784                 if (sequence.Length > 0)
785                 {
786                     Links.EnsureEachLinkExists(sequence);
787                     //var firstElement = sequence[0];
788                     //if (sequence.Length == 1)
789                     //{
790                     //    //results.Add(firstElement);
791                     //    return results;
792                     //}
793                     //if (sequence.Length == 2)
794                     //{
795                     //    //var doublet = _links.SearchCore(firstElement, sequence[1]);
796                     //    //if (doublet != Doublets.Links.Null)
797                     //    //    results.Add(doublet);
798                     //    return results;
799                     //}
800                     //var lastElement = sequence[sequence.Length - 1];
801                     //Func<ulong, bool> handler = x =>
802                     //{
803                     //    if (StartsWith(x, firstElement) && EndsWith(x, lastElement))
                         ↪  results.Add(x);
804                     //    return true;
805                     //};
806                     //if (sequence.Length >= 2)
807                     //    StepRight(handler, sequence[0], sequence[1]);
808                     //var last = sequence.Length - 2;
809                     //for (var i = 1; i < last; i++)
810                     //    PartialStepRight(handler, sequence[i], sequence[i + 1]);
811                     //if (sequence.Length >= 3)
812                     //    StepLeft(handler, sequence[sequence.Length - 2],
                         ↪  sequence[sequence.Length - 1]);
813                     //////if (sequence.Length == 1)
814                     //////{
815                     //////    throw new NotImplementedException(); // all sequences, containing
                         ↪  this element?
816                     //////}
817                     //////if (sequence.Length == 2)
818                     //////{
819                     //////    var results = new List<ulong>();
820                     //////    PartialStepRight(results.Add, sequence[0], sequence[1]);
821                     //////    return results;
822                     //////}
823                     //////var matches = new List<List<ulong>>();
824                     //////var last = sequence.Length - 1;
825                     //////for (var i = 0; i < last; i++)
826                     //////{
827                     //////    var results = new List<ulong>();
828                     //////    //StepRight(results.Add, sequence[i], sequence[i + 1]);
829                     //////    PartialStepRight(results.Add, sequence[i], sequence[i + 1]);
830                     //////    if (results.Count > 0)
831                     //////        matches.Add(results);
832                     //////    else
833                     //////        return results;
834                     //////    if (matches.Count == 2)
835                     //////    {
836                     //////        var merged = new List<ulong>();
837                     //////        for (var j = 0; j < matches[0].Count; j++)
838                     //////            for (var k = 0; k < matches[1].Count; k++)
839                     //////                CloseInnerConnections(merged.Add, matches[0][j],
                         ↪  matches[1][k]);
840                     //////        if (merged.Count > 0)
841                     //////            matches = new List<List<ulong>> { merged };
842                     //////        else
843                     //////            return new List<ulong>();
844                     //////    }
845                     //////}
846                     //////if (matches.Count > 0)
847                     //////{
848                     //////    var usages = new HashSet<ulong>();
849                     //////    for (int i = 0; i < sequence.Length; i++)
850                     //////    {
```

```
851                     //////        AllUsagesCore(sequence[i], usages);
852                     //////    }
853                     //////    //for (int i = 0; i < matches[0].Count; i++)
854                     //////    //    AllUsagesCore(matches[0][i], usages);
855                     //////    //usages.UnionWith(matches[0]);
856                     //////    return usages.ToList();
857                     //////}
858                     var firstLinkUsages = new HashSet<ulong>();
859                     AllUsagesCore(sequence[0], firstLinkUsages);
860                     firstLinkUsages.Add(sequence[0]);
861                     //var previousMatchings = firstLinkUsages.ToList(); //new List<ulong>() {
                        ↪  sequence[0] }; // or all sequences, containing this element?
862                     //return GetAllPartiallyMatchingSequencesCore(sequence, firstLinkUsages,
                        ↪  1).ToList();
863                     var results = new HashSet<ulong>();
864                     foreach (var match in GetAllPartiallyMatchingSequencesCore(sequence,
                        ↪  firstLinkUsages, 1))
865                     {
866                         AllUsagesCore(match, results);
867                     }
868                     return results.ToList();
869                 }
870                 return new List<ulong>();
871             });
872         }
873
874         /// <remarks>
875         /// TODO: Может потробоваться ограничение на уровень глубины рекурсии
876         /// </remarks>
877         public HashSet<ulong> AllUsages(ulong link)
878         {
879             return _sync.ExecuteReadOperation(() =>
880             {
881                 var usages = new HashSet<ulong>();
882                 AllUsagesCore(link, usages);
883                 return usages;
884             });
885         }
886
887         // При сборе всех использований (последовательностей) можно сохранять обратный путь к
                ↪  той связи с которой начинался поиск (STTTSSSTT),
888         // причём достаточно одного бита для хранения перехода влево или вправо
889         private void AllUsagesCore(ulong link, HashSet<ulong> usages)
890         {
891             bool handler(ulong doublet)
892             {
893                 if (usages.Add(doublet))
894                 {
895                     AllUsagesCore(doublet, usages);
896                 }
897                 return true;
898             }
899             Links.Unsync.Each(link, Constants.Any, handler);
900             Links.Unsync.Each(Constants.Any, link, handler);
901         }
902
903         public HashSet<ulong> AllBottomUsages(ulong link)
904         {
905             return _sync.ExecuteReadOperation(() =>
906             {
907                 var visits = new HashSet<ulong>();
908                 var usages = new HashSet<ulong>();
909                 AllBottomUsagesCore(link, visits, usages);
910                 return usages;
911             });
912         }
913
914         private void AllBottomUsagesCore(ulong link, HashSet<ulong> visits, HashSet<ulong>
                ↪  usages)
915         {
916             bool handler(ulong doublet)
917             {
918                 if (visits.Add(doublet))
919                 {
920                     AllBottomUsagesCore(doublet, visits, usages);
921                 }
922                 return true;
923             }
```

```
924             if (Links.Unsync.Count(Constants.Any, link) == 0)
925             {
926                 usages.Add(link);
927             }
928             else
929             {
930                 Links.Unsync.Each(link, Constants.Any, handler);
931                 Links.Unsync.Each(Constants.Any, link, handler);
932             }
933         }
934 
935         public ulong CalculateTotalSymbolFrequencyCore(ulong symbol)
936         {
937             if (Options.UseSequenceMarker)
938             {
939                 var counter = new TotalMarkedSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
                    ↪ Options.MarkedSequenceMatcher, symbol);
940                 return counter.Count();
941             }
942             else
943             {
944                 var counter = new TotalSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
                    ↪ symbol);
945                 return counter.Count();
946             }
947         }
948 
949         private bool AllUsagesCore1(ulong link, HashSet<ulong> usages, Func<IList<LinkIndex>,
            ↪ LinkIndex> outerHandler)
950         {
951             bool handler(ulong doublet)
952             {
953                 if (usages.Add(doublet))
954                 {
955                     if (outerHandler(new LinkAddress<LinkIndex>(doublet)) != Constants.Continue)
956                     {
957                         return false;
958                     }
959                     if (!AllUsagesCore1(doublet, usages, outerHandler))
960                     {
961                         return false;
962                     }
963                 }
964                 return true;
965             }
966             return Links.Unsync.Each(link, Constants.Any, handler)
967                 && Links.Unsync.Each(Constants.Any, link, handler);
968         }
969 
970         public void CalculateAllUsages(ulong[] totals)
971         {
972             var calculator = new AllUsagesCalculator(Links, totals);
973             calculator.Calculate();
974         }
975 
976         public void CalculateAllUsages2(ulong[] totals)
977         {
978             var calculator = new AllUsagesCalculator2(Links, totals);
979             calculator.Calculate();
980         }
981 
982         private class AllUsagesCalculator
983         {
984             private readonly SynchronizedLinks<ulong> _links;
985             private readonly ulong[] _totals;
986 
987             public AllUsagesCalculator(SynchronizedLinks<ulong> links, ulong[] totals)
988             {
989                 _links = links;
990                 _totals = totals;
991             }
992 
993             public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
                ↪ CalculateCore);
994 
995             private bool CalculateCore(ulong link)
996             {
997                 if (_totals[link] == 0)
998                 {
```

```
                    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;

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

            public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
            ↪  CalculateCore);

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

            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;

        public AllUsagesCollector(ILinks<ulong> links, HashSet<ulong> usages)
        {
            _links = links;
            _usages = usages;
        }

        public bool Collect(ulong link)
        {
            if (_usages.Add(link))
            {
                _links.Each(link, _links.Constants.Any, Collect);
                _links.Each(_links.Constants.Any, link, Collect);
            }
            return true;
        }
    }

    private class AllUsagesCollector1
    {
        private readonly ILinks<ulong> _links;
        private readonly HashSet<ulong> _usages;
        private readonly ulong _continue;

        public AllUsagesCollector1(ILinks<ulong> links, HashSet<ulong> usages)
        {
            _links = links;
            _usages = usages;
            _continue = _links.Constants.Continue;
        }

        public ulong Collect(IList<ulong> link)
        {
            var linkIndex = _links.GetIndex(link);
            if (_usages.Add(linkIndex))
            {
                _links.Each(Collect, _links.Constants.Any, linkIndex);
            }
            return _continue;
        }
    }

    private class AllUsagesCollector2
    {
        private readonly ILinks<ulong> _links;
        private readonly BitString _usages;

        public AllUsagesCollector2(ILinks<ulong> links, BitString usages)
        {
            _links = links;
            _usages = usages;
```

```
1156                }
1157
1158                public bool Collect(ulong link)
1159                {
1160                    if (_usages.Add((long)link))
1161                    {
1162                        _links.Each(link, _links.Constants.Any, Collect);
1163                        _links.Each(_links.Constants.Any, link, Collect);
1164                    }
1165                    return true;
1166                }
1167            }
1168
1169            private class AllUsagesIntersectingCollector
1170            {
1171                private readonly SynchronizedLinks<ulong> _links;
1172                private readonly HashSet<ulong> _intersectWith;
1173                private readonly HashSet<ulong> _usages;
1174                private readonly HashSet<ulong> _enter;
1175
1176                public AllUsagesIntersectingCollector(SynchronizedLinks<ulong> links, HashSet<ulong>
                    ↪ intersectWith, HashSet<ulong> usages)
1177                {
1178                    _links = links;
1179                    _intersectWith = intersectWith;
1180                    _usages = usages;
1181                    _enter = new HashSet<ulong>(); // защита от зацикливания
1182                }
1183
1184                public bool Collect(ulong link)
1185                {
1186                    if (_enter.Add(link))
1187                    {
1188                        if (_intersectWith.Contains(link))
1189                        {
1190                            _usages.Add(link);
1191                        }
1192                        _links.Unsync.Each(link, _links.Constants.Any, Collect);
1193                        _links.Unsync.Each(_links.Constants.Any, link, Collect);
1194                    }
1195                    return true;
1196                }
1197            }
1198
1199            private void CloseInnerConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
                ↪ right)
1200            {
1201                TryStepLeftUp(handler, left, right);
1202                TryStepRightUp(handler, right, left);
1203            }
1204
1205            private void AllCloseConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
                ↪ right)
1206            {
1207                // Direct
1208                if (left == right)
1209                {
1210                    handler(new LinkAddress<LinkIndex>(left));
1211                }
1212                var doublet = Links.Unsync.SearchOrDefault(left, right);
1213                if (doublet != Constants.Null)
1214                {
1215                    handler(new LinkAddress<LinkIndex>(doublet));
1216                }
1217                // Inner
1218                CloseInnerConnections(handler, left, right);
1219                // Outer
1220                StepLeft(handler, left, right);
1221                StepRight(handler, left, right);
1222                PartialStepRight(handler, left, right);
1223                PartialStepLeft(handler, left, right);
1224            }
1225
1226            private HashSet<ulong> GetAllPartiallyMatchingSequencesCore(ulong[] sequence,
                ↪ HashSet<ulong> previousMatchings, long startAt)
1227            {
1228                if (startAt >= sequence.Length) // ?
1229                {
1230                    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); // ??
        }

        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
        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;
                }
```

```
1298                 return new HashSet<ulong>();
1299             });
1300         }
1301 
1302         // Найти все возможные связи между указанным списком связей.
1303         // Находит связи между всеми указанными связями в любом порядке.
1304         // TODO: решить что делать с повторами (когда одни и те же элементы встречаются
         ↪  несколько раз в последовательности)
1305         public HashSet<ulong> GetAllConnections(params ulong[] linksToConnect)
1306         {
1307             return _sync.ExecuteReadOperation(() =>
1308             {
1309                 var results = new HashSet<ulong>();
1310                 if (linksToConnect.Length > 0)
1311                 {
1312                     Links.EnsureEachLinkExists(linksToConnect);
1313                     AllUsagesCore(linksToConnect[0], results);
1314                     for (var i = 1; i < linksToConnect.Length; i++)
1315                     {
1316                         var next = new HashSet<ulong>();
1317                         AllUsagesCore(linksToConnect[i], next);
1318                         results.IntersectWith(next);
1319                     }
1320                 }
1321                 return results;
1322             });
1323         }
1324 
1325         public HashSet<ulong> GetAllConnections1(params ulong[] linksToConnect)
1326         {
1327             return _sync.ExecuteReadOperation(() =>
1328             {
1329                 var results = new HashSet<ulong>();
1330                 if (linksToConnect.Length > 0)
1331                 {
1332                     Links.EnsureEachLinkExists(linksToConnect);
1333                     var collector1 = new AllUsagesCollector(Links.Unsync, results);
1334                     collector1.Collect(linksToConnect[0]);
1335                     var next = new HashSet<ulong>();
1336                     for (var i = 1; i < linksToConnect.Length; i++)
1337                     {
1338                         var collector = new AllUsagesCollector(Links.Unsync, next);
1339                         collector.Collect(linksToConnect[i]);
1340                         results.IntersectWith(next);
1341                         next.Clear();
1342                     }
1343                 }
1344                 return results;
1345             });
1346         }
1347 
1348         public HashSet<ulong> GetAllConnections2(params ulong[] linksToConnect)
1349         {
1350             return _sync.ExecuteReadOperation(() =>
1351             {
1352                 var results = new HashSet<ulong>();
1353                 if (linksToConnect.Length > 0)
1354                 {
1355                     Links.EnsureEachLinkExists(linksToConnect);
1356                     var collector1 = new AllUsagesCollector(Links, results);
1357                     collector1.Collect(linksToConnect[0]);
1358                     //AllUsagesCore(linksToConnect[0], results);
1359                     for (var i = 1; i < linksToConnect.Length; i++)
1360                     {
1361                         var next = new HashSet<ulong>();
1362                         var collector = new AllUsagesIntersectingCollector(Links, results, next);
1363                         collector.Collect(linksToConnect[i]);
1364                         //AllUsagesCore(linksToConnect[i], next);
1365                         //results.IntersectWith(next);
1366                         results = next;
1367                     }
1368                 }
1369                 return results;
1370             });
1371         }
1372 
1373         public List<ulong> GetAllConnections3(params ulong[] linksToConnect)
1374         {
```

```
            return _sync.ExecuteReadOperation(() =>
            {
                var results = new BitString((long)Links.Unsync.Count() + 1); // new
                ↪  BitArray((int)_links.Total + 1);
                if (linksToConnect.Length > 0)
                {
                    Links.EnsureEachLinkExists(linksToConnect);
                    var collector1 = new AllUsagesCollector2(Links.Unsync, results);
                    collector1.Collect(linksToConnect[0]);
                    for (var i = 1; i < linksToConnect.Length; i++)
                    {
                        var next = new BitString((long)Links.Unsync.Count() + 1); //new
                        ↪  BitArray((int)_links.Total + 1);
                        var collector = new AllUsagesCollector2(Links.Unsync, next);
                        collector.Collect(linksToConnect[i]);
                        results = results.And(next);
                    }
                }
                return results.GetSetUInt64Indices();
            });
        }

        private static ulong[] Simplify(ulong[] sequence)
        {
            // Считаем новый размер последовательности
            long newLength = 0;
            var zeroOrManyStepped = false;
            for (var i = 0; i < sequence.Length; i++)
            {
                if (sequence[i] == ZeroOrMany)
                {
                    if (zeroOrManyStepped)
                    {
                        continue;
                    }
                    zeroOrManyStepped = true;
                }
                else
                {
                    //if (zeroOrManyStepped) Is it efficient?
                    zeroOrManyStepped = false;
                }
                newLength++;
            }
            // Строим новую последовательность
            zeroOrManyStepped = false;
            var newSequence = new ulong[newLength];
            long j = 0;
            for (var i = 0; i < sequence.Length; i++)
            {
                //var current = zeroOrManyStepped;
                //zeroOrManyStepped = patternSequence[i] == zeroOrMany;
                //if (current && zeroOrManyStepped)
                //    continue;
                //var newZeroOrManyStepped = patternSequence[i] == zeroOrMany;
                //if (zeroOrManyStepped && newZeroOrManyStepped)
                //    continue;
                //zeroOrManyStepped = newZeroOrManyStepped;
                if (sequence[i] == ZeroOrMany)
                {
                    if (zeroOrManyStepped)
                    {
                        continue;
                    }
                    zeroOrManyStepped = true;
                }
                else
                {
                    //if (zeroOrManyStepped) Is it efficient?
                    zeroOrManyStepped = false;
                }
                newSequence[j++] = sequence[i];
            }
            return newSequence;
        }

        public static void TestSimplify()
        {
```

```
1451            var sequence = new ulong[] { ZeroOrMany, ZeroOrMany, 2, 3, 4, ZeroOrMany,
                ↪  ZeroOrMany, ZeroOrMany, 4, ZeroOrMany, ZeroOrMany, ZeroOrMany };
1452            var simplifiedSequence = Simplify(sequence);
1453        }
1454
1455        public List<ulong> GetSimilarSequences() => new List<ulong>();
1456
1457        public void Prediction()
1458        {
1459            //_links
1460            //sequences
1461        }
1462
1463        #region From Triplets
1464
1465        //public static void DeleteSequence(Link sequence)
1466        //{
1467        //}
1468
1469        public List<ulong> CollectMatchingSequences(ulong[] links)
1470        {
1471            if (links.Length == 1)
1472            {
1473                throw new Exception("Подпоследовательности с одним элементом не
                    ↪  поддерживаются.");
1474            }
1475            var leftBound = 0;
1476            var rightBound = links.Length - 1;
1477            var left = links[leftBound++];
1478            var right = links[rightBound--];
1479            var results = new List<ulong>();
1480            CollectMatchingSequences(left, leftBound, links, right, rightBound, ref results);
1481            return results;
1482        }
1483
1484        private void CollectMatchingSequences(ulong leftLink, int leftBound, ulong[]
            ↪  middleLinks, ulong rightLink, int rightBound, ref List<ulong> results)
1485        {
1486            var leftLinkTotalReferers = Links.Unsync.Count(leftLink);
1487            var rightLinkTotalReferers = Links.Unsync.Count(rightLink);
1488            if (leftLinkTotalReferers <= rightLinkTotalReferers)
1489            {
1490                var nextLeftLink = middleLinks[leftBound];
1491                var elements = GetRightElements(leftLink, nextLeftLink);
1492                if (leftBound <= rightBound)
1493                {
1494                    for (var i = elements.Length - 1; i >= 0; i--)
1495                    {
1496                        var element = elements[i];
1497                        if (element != 0)
1498                        {
1499                            CollectMatchingSequences(element, leftBound + 1, middleLinks,
                                ↪  rightLink, rightBound, ref results);
1500                        }
1501                    }
1502                }
1503                else
1504                {
1505                    for (var i = elements.Length - 1; i >= 0; i--)
1506                    {
1507                        var element = elements[i];
1508                        if (element != 0)
1509                        {
1510                            results.Add(element);
1511                        }
1512                    }
1513                }
1514            }
1515            else
1516            {
1517                var nextRightLink = middleLinks[rightBound];
1518                var elements = GetLeftElements(rightLink, nextRightLink);
1519                if (leftBound <= rightBound)
1520                {
1521                    for (var i = elements.Length - 1; i >= 0; i--)
1522                    {
1523                        var element = elements[i];
1524                        if (element != 0)
```

```
                    {
                        CollectMatchingSequences(leftLink, leftBound, middleLinks,
                        ↪  elements[i], rightBound - 1, ref results);
                    }
                }
            }
            else
            {
                for (var i = elements.Length - 1; i >= 0; i--)
                {
                    var element = elements[i];
                    if (element != 0)
                    {
                        results.Add(element);
                    }
                }
            }
        }
    }

    public ulong[] GetRightElements(ulong startLink, ulong rightLink)
    {
        var result = new ulong[5];
        TryStepRight(startLink, rightLink, result, 0);
        Links.Each(Constants.Any, startLink, couple =>
        {
            if (couple != startLink)
            {
                if (TryStepRight(couple, rightLink, result, 2))
                {
                    return false;
                }
            }
            return true;
        });
        if (Links.GetTarget(Links.GetTarget(startLink)) == rightLink)
        {
            result[4] = startLink;
        }
        return result;
    }

    public bool TryStepRight(ulong startLink, ulong rightLink, ulong[] result, int offset)
    {
        var added = 0;
        Links.Each(startLink, Constants.Any, couple =>
        {
            if (couple != startLink)
            {
                var coupleTarget = Links.GetTarget(couple);
                if (coupleTarget == rightLink)
                {
                    result[offset] = couple;
                    if (++added == 2)
                    {
                        return false;
                    }
                }
                else if (Links.GetSource(coupleTarget) == rightLink) // coupleTarget.Linker
                ↪  == Net.And &&
                {
                    result[offset + 1] = couple;
                    if (++added == 2)
                    {
                        return false;
                    }
                }
            }
            return true;
        });
        return added > 0;
    }

    public ulong[] GetLeftElements(ulong startLink, ulong leftLink)
    {
        var result = new ulong[5];
        TryStepLeft(startLink, leftLink, result, 0);
        Links.Each(startLink, Constants.Any, couple =>
```

```
            {
                if (couple != startLink)
                {
                    if (TryStepLeft(couple, leftLink, result, 2))
                    {
                        return false;
                    }
                }
                return true;
            });
            if (Links.GetSource(Links.GetSource(leftLink)) == startLink)
            {
                result[4] = leftLink;
            }
            return result;
        }

        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
```

```
1681                public PatternMatcher(Sequences sequences, LinkIndex[] patternSequence,
                    ↪  HashSet<LinkIndex> results)
1682                    : base(sequences.Links.Unsync, new DefaultStack<ulong>())
1683                {
1684                    _sequences = sequences;
1685                    _patternSequence = patternSequence;
1686                    _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
                        ↪  _sequences.Constants.Any && x != ZeroOrMany));
1687                    _results = results;
1688                    _pattern = CreateDetailedPattern();
1689                }
1690
1691                protected override bool IsElement(ulong link) => _linksInSequence.Contains(link) ||
                    ↪  base.IsElement(link);
1692
1693                public bool PatternMatch(LinkIndex sequenceToMatch)
1694                {
1695                    _patternPosition = 0;
1696                    _sequencePosition = 0;
1697                    foreach (var part in Walk(sequenceToMatch))
1698                    {
1699                        if (!PatternMatchCore(part))
1700                        {
1701                            break;
1702                        }
1703                    }
1704                    return _patternPosition == _pattern.Count || (_patternPosition == _pattern.Count
                        ↪  - 1 && _pattern[_patternPosition].Start == 0);
1705                }
1706
1707                private List<PatternBlock> CreateDetailedPattern()
1708                {
1709                    var pattern = new List<PatternBlock>();
1710                    var patternBlock = new PatternBlock();
1711                    for (var i = 0; i < _patternSequence.Length; i++)
1712                    {
1713                        if (patternBlock.Type == PatternBlockType.Undefined)
1714                        {
1715                            if (_patternSequence[i] == _sequences.Constants.Any)
1716                            {
1717                                patternBlock.Type = PatternBlockType.Gap;
1718                                patternBlock.Start = 1;
1719                                patternBlock.Stop = 1;
1720                            }
1721                            else if (_patternSequence[i] == ZeroOrMany)
1722                            {
1723                                patternBlock.Type = PatternBlockType.Gap;
1724                                patternBlock.Start = 0;
1725                                patternBlock.Stop = long.MaxValue;
1726                            }
1727                            else
1728                            {
1729                                patternBlock.Type = PatternBlockType.Elements;
1730                                patternBlock.Start = i;
1731                                patternBlock.Stop = i;
1732                            }
1733                        }
1734                        else if (patternBlock.Type == PatternBlockType.Elements)
1735                        {
1736                            if (_patternSequence[i] == _sequences.Constants.Any)
1737                            {
1738                                pattern.Add(patternBlock);
1739                                patternBlock = new PatternBlock
1740                                {
1741                                    Type = PatternBlockType.Gap,
1742                                    Start = 1,
1743                                    Stop = 1
1744                                };
1745                            }
1746                            else if (_patternSequence[i] == ZeroOrMany)
1747                            {
1748                                pattern.Add(patternBlock);
1749                                patternBlock = new PatternBlock
1750                                {
1751                                    Type = PatternBlockType.Gap,
1752                                    Start = 0,
1753                                    Stop = long.MaxValue
1754                                };
1755                            }
1756                            else
```

```
                    {
                        patternBlock.Stop = i;
                    }
                }
                else // patternBlock.Type == PatternBlockType.Gap
                {
                    if (_patternSequence[i] == _sequences.Constants.Any)
                    {
                        patternBlock.Start++;
                        if (patternBlock.Stop < patternBlock.Start)
                        {
                            patternBlock.Stop = patternBlock.Start;
                        }
                    }
                    else if (_patternSequence[i] == ZeroOrMany)
                    {
                        patternBlock.Stop = long.MaxValue;
                    }
                    else
                    {
                        pattern.Add(patternBlock);
                        patternBlock = new PatternBlock
                        {
                            Type = PatternBlockType.Elements,
                            Start = i,
                            Stop = i
                        };
                    }
                }
            }
            if (patternBlock.Type != PatternBlockType.Undefined)
            {
                pattern.Add(patternBlock);
            }
            return pattern;
        }

        // match: search for regexp anywhere in text
        //int match(char* regexp, char* text)
        //{
        //    do
        //    {
        //    } while (*text++ != '\0');
        //    return 0;
        //}

        // matchhere: search for regexp at beginning of text
        //int matchhere(char* regexp, char* text)
        //{
        //    if (regexp[0] == '\0')
        //        return 1;
        //    if (regexp[1] == '*')
        //        return matchstar(regexp[0], regexp + 2, text);
        //    if (regexp[0] == '$' && regexp[1] == '\0')
        //        return *text == '\0';
        //    if (*text != '\0' && (regexp[0] == '.' || regexp[0] == *text))
        //        return matchhere(regexp + 1, text + 1);
        //    return 0;
        //}

        // matchstar: search for c*regexp at beginning of text
        //int matchstar(int c, char* regexp, char* text)
        //{
        //    do
        //    {    /* a * matches zero or more instances */
        //        if (matchhere(regexp, text))
        //            return 1;
        //    } while (*text != '\0' && (*text++ == c || c == '.'));
        //    return 0;
        //}

        //private void GetNextPatternElement(out LinkIndex element, out long mininumGap, out
        ↪  long maximumGap)
        //{
        //    mininumGap = 0;
        //    maximumGap = 0;
        //    element = 0;
        //    for (; _patternPosition < _patternSequence.Length; _patternPosition++)
        //    {
```

```
1835                //        if (_patternSequence[_patternPosition] == Doublets.Links.Null)
1836                //            mininumGap++;
1837                //        else if (_patternSequence[_patternPosition] == ZeroOrMany)
1838                //            maximumGap = long.MaxValue;
1839                //        else
1840                //            break;
1841                //    }
1842
1843                //    if (maximumGap < mininumGap)
1844                //        maximumGap = mininumGap;
1845                //}
1846
1847                private bool PatternMatchCore(LinkIndex element)
1848                {
1849                    if (_patternPosition >= _pattern.Count)
1850                    {
1851                        _patternPosition = -2;
1852                        return false;
1853                    }
1854                    var currentPatternBlock = _pattern[_patternPosition];
1855                    if (currentPatternBlock.Type == PatternBlockType.Gap)
1856                    {
1857                        //var currentMatchingBlockLength = (_sequencePosition -
                            ↪  _lastMatchedBlockPosition);
1858                        if (_sequencePosition < currentPatternBlock.Start)
1859                        {
1860                            _sequencePosition++;
1861                            return true; // Двигаемся дальше
1862                        }
1863                        // Это последний блок
1864                        if (_pattern.Count == _patternPosition + 1)
1865                        {
1866                            _patternPosition++;
1867                            _sequencePosition = 0;
1868                            return false; // Полное соответствие
1869                        }
1870                        else
1871                        {
1872                            if (_sequencePosition > currentPatternBlock.Stop)
1873                            {
1874                                return false; // Соответствие невозможно
1875                            }
1876                            var nextPatternBlock = _pattern[_patternPosition + 1];
1877                            if (_patternSequence[nextPatternBlock.Start] == element)
1878                            {
1879                                if (nextPatternBlock.Start < nextPatternBlock.Stop)
1880                                {
1881                                    _patternPosition++;
1882                                    _sequencePosition = 1;
1883                                }
1884                                else
1885                                {
1886                                    _patternPosition += 2;
1887                                    _sequencePosition = 0;
1888                                }
1889                            }
1890                        }
1891                    }
1892                    else // currentPatternBlock.Type == PatternBlockType.Elements
1893                    {
1894                        var patternElementPosition = currentPatternBlock.Start + _sequencePosition;
1895                        if (_patternSequence[patternElementPosition] != element)
1896                        {
1897                            return false; // Соответствие невозможно
1898                        }
1899                        if (patternElementPosition == currentPatternBlock.Stop)
1900                        {
1901                            _patternPosition++;
1902                            _sequencePosition = 0;
1903                        }
1904                        else
1905                        {
1906                            _sequencePosition++;
1907                        }
1908                    }
1909                    return true;
1910                    //if (_patternSequence[_patternPosition] != element)
1911                    //    return false;
1912                    //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;
                //}
            }

            public void AddAllPatternMatchedToResults(IEnumerable<ulong> sequencesToMatch)
            {
                foreach (var sequenceToMatch in sequencesToMatch)
                {
                    if (PatternMatch(sequenceToMatch))
                    {
                        _results.Add(sequenceToMatch);
                    }
                }
            }
        }

        #endregion
    }
}
```

./Platform.Data.Doublets/Sequences/SequencesExtensions.cs

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

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

namespace Platform.Data.Doublets.Sequences
{
    public static class SequencesExtensions
    {
        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.ConvertToRestrictionsValues());
            }
            return sequences.Create(finalSequence.ConvertToRestrictionsValues());
        }

        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.AddAllValuesAndReturnConstant, new
            ↪  LinkAddress<TLink>(sequence));
```

```
            return list;
        }
    }
}
```

./Platform.Data.Doublets/Sequences/SequencesOptions.cs

```
using System;
using System.Collections.Generic;
using Platform.Interfaces;
using Platform.Collections.Stacks;
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.CreteriaMatchers;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Data.Doublets.Sequences.Indexes;

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

namespace Platform.Data.Doublets.Sequences
{
    public class SequencesOptions<TLink> // TODO: To use type parameter <TLink> the ILinks<TLink> must contain GetConstants function.
    {
        private static readonly EqualityComparer<TLink> _equalityComparer = EqualityComparer<TLink>.Default;

        public TLink SequenceMarkerLink { get; set; }
        public bool UseCascadeUpdate { get; set; }
        public bool UseCascadeDelete { get; set; }
        public bool UseIndex { get; set; } // TODO: Update Index on sequence update/delete.
        public bool UseSequenceMarker { get; set; }
        public bool UseCompression { get; set; }
        public bool UseGarbageCollection { get; set; }
        public bool EnforceSingleSequenceVersionOnWriteBasedOnExisting { get; set; }
        public bool EnforceSingleSequenceVersionOnWriteBasedOnNew { get; set; }

        public MarkedSequenceCriterionMatcher<TLink> MarkedSequenceMatcher { get; set; }
        public IConverter<IList<TLink>, TLink> LinksToSequenceConverter { get; set; }
        public ISequenceIndex<TLink> Index { get; set; }
        public ISequenceWalker<TLink> Walker { get; set; }
        public bool ReadFullSequence { get; set; }

        // TODO: Реализовать компактификацию при чтении
        //public bool EnforceSingleSequenceVersionOnRead { get; set; }
        //public bool UseRequestMarker { get; set; }
        //public bool StoreRequestResults { get; set; }

        public void InitOptions(ISynchronizedLinks<TLink> links)
        {
            if (UseSequenceMarker)
            {
                if (_equalityComparer.Equals(SequenceMarkerLink, links.Constants.Null))
                {
                    SequenceMarkerLink = links.CreatePoint();
                }
                else
                {
                    if (!links.Exists(SequenceMarkerLink))
                    {
                        var link = links.CreatePoint();
                        if (!_equalityComparer.Equals(link, SequenceMarkerLink))
                        {
                            throw new InvalidOperationException("Cannot recreate sequence marker link.");
                        }
                    }
                }
                if (MarkedSequenceMatcher == null)
                {
                    MarkedSequenceMatcher = new MarkedSequenceCriterionMatcher<TLink>(links, SequenceMarkerLink);
                }
            }
            var balancedVariantConverter = new BalancedVariantConverter<TLink>(links);
            if (UseCompression)
            {
                if (LinksToSequenceConverter == null)
                {
```

```
                    ICounter<TLink, TLink> totalSequenceSymbolFrequencyCounter;
                    if (UseSequenceMarker)
                    {
                        totalSequenceSymbolFrequencyCounter = new
                        ↪  TotalMarkedSequenceSymbolFrequencyCounter<TLink>(links,
                        ↪  MarkedSequenceMatcher);
                    }
                    else
                    {
                        totalSequenceSymbolFrequencyCounter = new
                        ↪  TotalSequenceSymbolFrequencyCounter<TLink>(links);
                    }
                    var doubletFrequenciesCache = new LinkFrequenciesCache<TLink>(links,
                    ↪  totalSequenceSymbolFrequencyCounter);
                    var compressingConverter = new CompressingConverter<TLink>(links,
                    ↪  balancedVariantConverter, doubletFrequenciesCache);
                    LinksToSequenceConverter = compressingConverter;
                }
            }
            else
            {
                if (LinksToSequenceConverter == null)
                {
                    LinksToSequenceConverter = balancedVariantConverter;
                }
            }
            if (UseIndex && Index == null)
            {
                Index = new SequenceIndex<TLink>(links);
            }
            if (Walker == null)
            {
                Walker = new RightSequenceWalker<TLink>(links, new DefaultStack<TLink>());
            }
        }

        public void ValidateOptions()
        {
            if (UseGarbageCollection && !UseSequenceMarker)
            {
                throw new NotSupportedException("To use garbage collection UseSequenceMarker
                ↪  option must be on.");
            }
        }
    }
}
```

./Platform.Data.Doublets/Sequences/SetFiller.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
{
    public class SetFiller<TElement, TReturnConstant>
    {
        protected readonly ISet<TElement> _set;
        protected readonly TReturnConstant _returnConstant;

        public SetFiller(ISet<TElement> set, TReturnConstant returnConstant)
        {
            _set = set;
            _returnConstant = returnConstant;
        }

        public SetFiller(ISet<TElement> set) : this(set, default) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Add(TElement element) => _set.Add(element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool AddAndReturnTrue(TElement element)
        {
            _set.Add(element);
            return true;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
        public bool AddFirstAndReturnTrue(IList<TElement> collection)
        {
            _set.Add(collection[0]);
            return true;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TReturnConstant AddAndReturnConstant(TElement element)
        {
            _set.Add(element);
            return _returnConstant;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TReturnConstant AddFirstAndReturnConstant(IList<TElement> collection)
        {
            _set.Add(collection[0]);
            return _returnConstant;
        }
    }
}
```

./Platform.Data.Doublets/Sequences/Walkers/ISequenceWalker.cs

```
using System.Collections.Generic;

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

namespace Platform.Data.Doublets.Sequences.Walkers
{
    public interface ISequenceWalker<TLink>
    {
        IEnumerable<TLink> Walk(TLink sequence);
    }
}
```

./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>
    {
        public LeftSequenceWalker(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
        ↪  isElement) : base(links, stack, isElement) { }

        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 parts = Links.GetLink(element);
            var start = Links.Constants.IndexPart + 1;
            for (var i = parts.Count - 1; i >= start; i--)
            {
                var part = parts[i];
                if (IsElement(part))
                {
                    yield return part;
                }
            }
        }
    }
}
```

./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;

        public LeveledSequenceWalker(ILinks<TLink> links, Func<TLink, bool> isElement) :
        ↪  base(links) => _isElement = isElement;

        public LeveledSequenceWalker(ILinks<TLink> links) : base(links) => _isElement =
        ↪  Links.IsPartialPoint;

        public IEnumerable<TLink> Walk(TLink sequence) => ToArray(sequence);

        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 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;
        }
    }
}
```

./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>
    {
        public RightSequenceWalker(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
        ↪  isElement) : base(links, stack, isElement) { }

        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.IndexPart + 1; i < parts.Count; i++)
            {
```

```
                var part = parts[i];
                if (IsElement(part))
                {
                    yield return part;
                }
            }
        }
    }
}
```

./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;

        protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
        ↪ isElement) : base(links)
        {
            _stack = stack;
            _isElement = isElement;
        }

        protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack) : this(links,
        ↪ stack, links.IsPartialPoint)
        {
        }

        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);
    }
}
```

./Platform.Data.Doublets/Stacks/Stack.cs

```
using System.Collections.Generic;
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> : IStack<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly ILinks<TLink> _links;
        private readonly TLink _stack;

        public bool IsEmpty => _equalityComparer.Equals(Peek(), _stack);

        public Stack(ILinks<TLink> links, TLink stack)
        {
            _links = links;
            _stack = stack;
        }

        private TLink GetStackMarker() => _links.GetSource(_stack);

        private TLink GetTop() => _links.GetTarget(_stack);

        public TLink Peek() => _links.GetTarget(GetTop());

        public TLink Pop()
        {
            var element = Peek();
            if (!_equalityComparer.Equals(element, _stack))
            {
                var top = GetTop();
                var previousTop = _links.GetSource(top);
                _links.Update(_stack, GetStackMarker(), previousTop);
                _links.Delete(top);
            }
            return element;
        }

        public void Push(TLink element) => _links.Update(_stack, GetStackMarker(),
        ↪  _links.GetOrCreate(GetTop(), element));
    }
}
```

./Platform.Data.Doublets/Stacks/StackExtensions.cs

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

namespace Platform.Data.Doublets.Stacks
{
    public static class StackExtensions
    {
        public static TLink CreateStack<TLink>(this ILinks<TLink> links, TLink stackMarker)
        {
            var stackPoint = links.CreatePoint();
            var stack = links.Update(stackPoint, stackMarker, stackPoint);
            return stack;
        }
    }
}
```

./Platform.Data.Doublets/SynchronizedLinks.cs

```
using System;
using System.Collections.Generic;
using Platform.Data.Doublets;
using Platform.Threading.Synchronization;

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

namespace Platform.Data.Doublets
```

```
{
    /// <remarks>
    /// TODO: Autogeneration of synchronized wrapper (decorator).
    /// TODO: Try to unfold code of each method using IL generation for performance improvements.
    /// TODO: Or even to unfold multiple layers of implementations.
    /// </remarks>
    public class SynchronizedLinks<TLinkAddress> : ISynchronizedLinks<TLinkAddress>
    {
        public LinksConstants<TLinkAddress> Constants { get; }
        public ISynchronization SyncRoot { get; }
        public ILinks<TLinkAddress> Sync { get; }
        public ILinks<TLinkAddress> Unsync { get; }

        public SynchronizedLinks(ILinks<TLinkAddress> links) : this(new ReaderWriterLockSynchronization(), links) { }

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

        public TLinkAddress Count(IList<TLinkAddress> restriction) => SyncRoot.ExecuteReadOperation(restriction, Unsync.Count);
        public TLinkAddress Each(Func<IList<TLinkAddress>, TLinkAddress> handler, IList<TLinkAddress> restrictions) => SyncRoot.ExecuteReadOperation(handler, restrictions, (handler1, restrictions1) => Unsync.Each(handler1, restrictions1));
        public TLinkAddress Create(IList<TLinkAddress> restrictions) => SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Create);
        public TLinkAddress Update(IList<TLinkAddress> restrictions, IList<TLinkAddress> substitution) => SyncRoot.ExecuteWriteOperation(restrictions, substitution, Unsync.Update);
        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);
        //}
    }
}
```

./Platform.Data.Doublets/UInt64LinksExtensions.cs

```
using System;
using System.Text;
using System.Collections.Generic;
using Platform.Singletons;
using Platform.Data.Exceptions;
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;

        public static void UseUnicode(this ILinks<ulong> links) => UnicodeMap.InitNew(links);

        public static void EnsureEachLinkExists(this ILinks<ulong> links, IList<ulong> sequence)
        {
            if (sequence == null)
            {
                return;
            }
            for (var i = 0; i < sequence.Count; i++)
            {
                if (!links.Exists(sequence[i]))
```

```
27                  {
28                      throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
                        ↪  $"sequence[{i}]");
29                  }
30              }
31          }
32
33          public static void EnsureEachLinkIsAnyOrExists(this ILinks<ulong> links, IList<ulong>
            ↪  sequence)
34          {
35              if (sequence == null)
36              {
37                  return;
38              }
39              for (var i = 0; i < sequence.Count; i++)
40              {
41                  if (sequence[i] != Constants.Any && !links.Exists(sequence[i]))
42                  {
43                      throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
                        ↪  $"sequence[{i}]");
44                  }
45              }
46          }
47
48          public static bool AnyLinkIsAny(this ILinks<ulong> links, params ulong[] sequence)
49          {
50              if (sequence == null)
51              {
52                  return false;
53              }
54              var constants = links.Constants;
55              for (var i = 0; i < sequence.Length; i++)
56              {
57                  if (sequence[i] == constants.Any)
58                  {
59                      return true;
60                  }
61              }
62              return false;
63          }
64
65          public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
            ↪  Func<Link<ulong>, bool> isElement, bool renderIndex = false, bool renderDebug =
            ↪  false)
66          {
67              var sb = new StringBuilder();
68              var visited = new HashSet<ulong>();
69              links.AppendStructure(sb, visited, linkIndex, isElement, (innerSb, link) =>
                ↪  innerSb.Append(link.Index), renderIndex, renderDebug);
70              return sb.ToString();
71          }
72
73          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)
74          {
75              var sb = new StringBuilder();
76              var visited = new HashSet<ulong>();
77              links.AppendStructure(sb, visited, linkIndex, isElement, appendElement, renderIndex,
                ↪  renderDebug);
78              return sb.ToString();
79          }
80
81          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)
82          {
83              if (sb == null)
84              {
85                  throw new ArgumentNullException(nameof(sb));
86              }
87              if (linkIndex == Constants.Null || linkIndex == Constants.Any || linkIndex ==
                ↪  Constants.Itself)
88              {
89                  return;
90              }
91              if (links.Exists(linkIndex))
```

```
            {
                if (visited.Add(linkIndex))
                {
                    sb.Append('(');
                    var link = new Link<ulong>(links.GetLink(linkIndex));
                    if (renderIndex)
                    {
                        sb.Append(link.Index);
                        sb.Append(':');
                    }
                    if (link.Source == link.Index)
                    {
                        sb.Append(link.Index);
                    }
                    else
                    {
                        var source = new Link<ulong>(links.GetLink(link.Source));
                        if (isElement(source))
                        {
                            appendElement(sb, source);
                        }
                        else
                        {
                            links.AppendStructure(sb, visited, source.Index, isElement,
                            ↪  appendElement, renderIndex);
                        }
                    }
                    sb.Append(' ');
                    if (link.Target == link.Index)
                    {
                        sb.Append(link.Index);
                    }
                    else
                    {
                        var target = new Link<ulong>(links.GetLink(link.Target));
                        if (isElement(target))
                        {
                            appendElement(sb, target);
                        }
                        else
                        {
                            links.AppendStructure(sb, visited, target.Index, isElement,
                            ↪  appendElement, renderIndex);
                        }
                    }
                    sb.Append(')');
                }
                else
                {
                    if (renderDebug)
                    {
                        sb.Append('*');
                    }
                    sb.Append(linkIndex);
                }
            }
            else
            {
                if (renderDebug)
                {
                    sb.Append('~');
                }
                sb.Append(linkIndex);
            }
        }
    }
}
```

./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
        {
            public static readonly long Size = Structure<Transition>.Size;

```

```
89              public readonly ulong TransactionId;
90              public readonly Link<ulong> Before;
91              public readonly Link<ulong> After;
92              public readonly Timestamp Timestamp;
93
94              public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
                ↪  transactionId, Link<ulong> before, Link<ulong> after)
95              {
96                  TransactionId = transactionId;
97                  Before = before;
98                  After = after;
99                  Timestamp = uniqueTimestampFactory.Create();
100             }
101
102             public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
                ↪  transactionId, Link<ulong> before)
103                 : this(uniqueTimestampFactory, transactionId, before, default)
104             {
105             }
106
107             public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong transactionId)
108                 : this(uniqueTimestampFactory, transactionId, default, default)
109             {
110             }
111
112             public override string ToString() => $"{Timestamp} {TransactionId}: {Before} =>
                ↪  {After}";
113         }
114
115         /// <remarks>
116         /// Другие варианты реализации транзакций (атомарности):
117         ///     1. Разделение хранения значения связи ((Source Target) или (Source Linker
                ↪  Target)) и индексов.
118         ///     2. Хранение трансформаций/операций в отдельном хранилище Links, но дополнительно
                ↪  потребуется решить вопрос
119         ///        со ссылками на внешние идентификаторы, или как-то иначе решить вопрос с
                ↪  пересечениями идентификаторов.
120         ///
121         /// Где хранить промежуточный список транзакций?
122         ///
123         /// В оперативной памяти:
124         ///  Минусы:
125         ///     1. Может усложнить систему, если она будет функционировать самостоятельно,
126         ///     так как нужно отдельно выделять память под список трансформаций.
127         ///     2. Выделенной оперативной памяти может не хватить, в том случае,
128         ///     если транзакция использует слишком много трансформаций.
129         ///         -> Можно использовать жёсткий диск для слишком длинных транзакций.
130         ///         -> Максимальный размер списка трансформаций можно ограничить / задать
                ↪  константой.
131         ///     3. При подтверждении транзакции (Commit) все трансформации записываются разом
                ↪  создавая задержку.
132         ///
133         /// На жёстком диске:
134         ///  Минусы:
135         ///     1. Длительный отклик, на запись каждой трансформации.
136         ///     2. Лог транзакций дополнительно наполняется отменёнными транзакциями.
137         ///         -> Это может решаться упаковкой/исключением дублирующих операций.
138         ///         -> Также это может решаться тем, что короткие транзакции вообще
139         ///            не будут записываться в случае отката.
140         ///     3. Перед тем как выполнять отмену операций транзакции нужно дождаться пока все
                ↪  операции (трансформации)
141         ///        будут записаны в лог.
142         ///
143         /// </remarks>
144         public class Transaction : DisposableBase
145         {
146             private readonly Queue<Transition> _transitions;
147             private readonly UInt64LinksTransactionsLayer _layer;
148             public bool IsCommitted { get; private set; }
149             public bool IsReverted { get; private set; }
150
151             public Transaction(UInt64LinksTransactionsLayer layer)
152             {
153                 _layer = layer;
154                 if (_layer._currentTransactionId != 0)
155                 {
156                     throw new NotSupportedException("Nested transactions not supported.");
157                 }
158                 IsCommitted = false;
```

```
            IsReverted = false;
            _transitions = new Queue<Transition>();
            SetCurrentTransaction(layer, this);
        }

        public void Commit()
        {
            EnsureTransactionAllowsWriteOperations(this);
            while (_transitions.Count > 0)
            {
                var transition = _transitions.Dequeue();
                _layer._transitions.Enqueue(transition);
            }
            _layer._lastCommitedTransactionId = _layer._currentTransactionId;
            IsCommitted = true;
        }

        private void Revert()
        {
            EnsureTransactionAllowsWriteOperations(this);
            var transitionsToRevert = new Transition[_transitions.Count];
            _transitions.CopyTo(transitionsToRevert, 0);
            for (var i = transitionsToRevert.Length - 1; i >= 0; i--)
            {
                _layer.RevertTransition(transitionsToRevert[i]);
            }
            IsReverted = true;
        }

        public static void SetCurrentTransaction(UInt64LinksTransactionsLayer layer,
        ↪  Transaction transaction)
        {
            layer._currentTransactionId = layer._lastCommitedTransactionId + 1;
            layer._currentTransactionTransitions = transaction._transitions;
            layer._currentTransaction = transaction;
        }

        public static void EnsureTransactionAllowsWriteOperations(Transaction transaction)
        {
            if (transaction.IsReverted)
            {
                throw new InvalidOperationException("Transation is reverted.");
            }
            if (transaction.IsCommitted)
            {
                throw new InvalidOperationException("Transation is commited.");
            }
        }

        protected override void Dispose(bool manual, bool wasDisposed)
        {
            if (!wasDisposed && _layer != null && !_layer.IsDisposed)
            {
                if (!IsCommitted && !IsReverted)
                {
                    Revert();
                }
                _layer.ResetCurrentTransation();
            }
        }
    }

    public static readonly TimeSpan DefaultPushDelay = TimeSpan.FromSeconds(0.1);

    private readonly string _logAddress;
    private readonly FileStream _log;
    private readonly Queue<Transition> _transitions;
    private readonly UniqueTimestampFactory _uniqueTimestampFactory;
    private Task _transitionsPusher;
    private Transition _lastCommitedTransition;
    private ulong _currentTransactionId;
    private Queue<Transition> _currentTransactionTransitions;
    private Transaction _currentTransaction;
    private ulong _lastCommitedTransactionId;

    public UInt64LinksTransactionsLayer(ILinks<ulong> links, string logAddress)
        : base(links)
    {
        if (string.IsNullOrWhiteSpace(logAddress))
        {
```

```
238                 throw new ArgumentNullException(nameof(logAddress));
239             }
240             // В первой строке файла хранится последняя закоммиченную транзакцию.
241             // При запуске это используется для проверки удачного закрытия файла лога.
242             // In the first line of the file the last committed transaction is stored.
243             // On startup, this is used to check that the log file is successfully closed.
244             var lastCommitedTransition = FileHelpers.ReadFirstOrDefault<Transition>(logAddress);
245             var lastWrittenTransition = FileHelpers.ReadLastOrDefault<Transition>(logAddress);
246             if (!lastCommitedTransition.Equals(lastWrittenTransition))
247             {
248                 Dispose();
249                 throw new NotSupportedException("Database is damaged, autorecovery is not
                    ↪  supported yet.");
250             }
251             if (lastCommitedTransition.Equals(default(Transition)))
252             {
253                 FileHelpers.WriteFirst(logAddress, lastCommitedTransition);
254             }
255             _lastCommitedTransition = lastCommitedTransition;
256             // TODO: Think about a better way to calculate or store this value
257             var allTransitions = FileHelpers.ReadAll<Transition>(logAddress);
258             _lastCommitedTransactionId = allTransitions.Max(x => x.TransactionId);
259             _uniqueTimestampFactory = new UniqueTimestampFactory();
260             _logAddress = logAddress;
261             _log = FileHelpers.Append(logAddress);
262             _transitions = new Queue<Transition>();
263             _transitionsPusher = new Task(TransitionsPusher);
264             _transitionsPusher.Start();
265         }
266 
267         public IList<ulong> GetLinkValue(ulong link) => Links.GetLink(link);
268 
269         public override ulong Create(IList<ulong> restrictions)
270         {
271             var createdLinkIndex = Links.Create();
272             var createdLink = new Link<ulong>(Links.GetLink(createdLinkIndex));
273             CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
                ↪  default, createdLink));
274             return createdLinkIndex;
275         }
276 
277         public override ulong Update(IList<ulong> restrictions, IList<ulong> substitution)
278         {
279             var linkIndex = restrictions[Constants.IndexPart];
280             var beforeLink = new Link<ulong>(Links.GetLink(linkIndex));
281             linkIndex = Links.Update(restrictions, substitution);
282             var afterLink = new Link<ulong>(Links.GetLink(linkIndex));
283             CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
                ↪  beforeLink, afterLink));
284             return linkIndex;
285         }
286 
287         public override void Delete(IList<ulong> restrictions)
288         {
289             var link = restrictions[Constants.IndexPart];
290             var deletedLink = new Link<ulong>(Links.GetLink(link));
291             Links.Delete(link);
292             CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
                ↪  deletedLink, default));
293         }
294 
295         [MethodImpl(MethodImplOptions.AggressiveInlining)]
296         private Queue<Transition> GetCurrentTransitions() => _currentTransactionTransitions ??
            ↪  _transitions;
297 
298         private void CommitTransition(Transition transition)
299         {
300             if (_currentTransaction != null)
301             {
302                 Transaction.EnsureTransactionAllowsWriteOperations(_currentTransaction);
303             }
304             var transitions = GetCurrentTransitions();
305             transitions.Enqueue(transition);
306         }
307 
308         private void RevertTransition(Transition transition)
309         {
310             if (transition.After.IsNull()) // Revert Deletion with Creation
```

```
311             {
312                 Links.Create();
313             }
314             else if (transition.Before.IsNull()) // Revert Creation with Deletion
315             {
316                 Links.Delete(transition.After.Index);
317             }
318             else // Revert Update
319             {
320                 Links.Update(new[] { transition.After.Index, transition.Before.Source,
                    ↪  transition.Before.Target });
321             }
322         }
323 
324         private void ResetCurrentTransation()
325         {
326             _currentTransactionId = 0;
327             _currentTransactionTransitions = null;
328             _currentTransaction = null;
329         }
330 
331         private void PushTransitions()
332         {
333             if (_log == null || _transitions == null)
334             {
335                 return;
336             }
337             for (var i = 0; i < _transitions.Count; i++)
338             {
339                 var transition = _transitions.Dequeue();
340 
341                 _log.Write(transition);
342                 _lastCommitedTransition = transition;
343             }
344         }
345 
346         private void TransitionsPusher()
347         {
348             while (!IsDisposed && _transitionsPusher != null)
349             {
350                 Thread.Sleep(DefaultPushDelay);
351                 PushTransitions();
352             }
353         }
354 
355         public Transaction BeginTransaction() => new Transaction(this);
356 
357         private void DisposeTransitions()
358         {
359             try
360             {
361                 var pusher = _transitionsPusher;
362                 if (pusher != null)
363                 {
364                     _transitionsPusher = null;
365                     pusher.Wait();
366                 }
367                 if (_transitions != null)
368                 {
369                     PushTransitions();
370                 }
371                 _log.DisposeIfPossible();
372                 FileHelpers.WriteFirst(_logAddress, _lastCommitedTransition);
373             }
374             catch (Exception ex)
375             {
376                 ex.Ignore();
377             }
378         }
379 
380         #region DisposalBase
381 
382         protected override void Dispose(bool manual, bool wasDisposed)
383         {
384             if (!wasDisposed)
385             {
386                 DisposeTransitions();
387             }
388             base.Dispose(manual, wasDisposed);
```

```
        }

        #endregion
    }
}
```

./Platform.Data.Doublets/Unicode/CharToUnicodeSymbolConverter.cs

```
using Platform.Interfaces;
using Platform.Numbers;

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

        public CharToUnicodeSymbolConverter(ILinks<TLink> links, IConverter<TLink>
        ↪ addressToNumberConverter, TLink unicodeSymbolMarker) : base(links)
        {
            _addressToNumberConverter = addressToNumberConverter;
            _unicodeSymbolMarker = unicodeSymbolMarker;
        }

        public TLink Convert(char source)
        {
            var unaryNumber = _addressToNumberConverter.Convert((Integer<TLink>)source);
            return Links.GetOrCreate(unaryNumber, _unicodeSymbolMarker);
        }
    }
}
```

./Platform.Data.Doublets/Unicode/StringToUnicodeSequenceConverter.cs

```
using Platform.Data.Doublets.Sequences.Indexes;
using Platform.Interfaces;
using System.Collections.Generic;

#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<char, TLink> _charToUnicodeSymbolConverter;
        private readonly ISequenceIndex<TLink> _index;
        private readonly IConverter<IList<TLink>, TLink> _listToSequenceLinkConverter;
        private readonly TLink _unicodeSequenceMarker;

        public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<char, TLink>
        ↪ charToUnicodeSymbolConverter, ISequenceIndex<TLink> index, IConverter<IList<TLink>,
        ↪ TLink> listToSequenceLinkConverter, TLink unicodeSequenceMarker) : base(links)
        {
            _charToUnicodeSymbolConverter = charToUnicodeSymbolConverter;
            _index = index;
            _listToSequenceLinkConverter = listToSequenceLinkConverter;
            _unicodeSequenceMarker = unicodeSequenceMarker;
        }

        public TLink Convert(string source)
        {
            var elements = new TLink[source.Length];
            for (int i = 0; i < source.Length; i++)
            {
                elements[i] = _charToUnicodeSymbolConverter.Convert(source[i]);
            }
            _index.Add(elements);
            var sequence = _listToSequenceLinkConverter.Convert(elements);
            return Links.GetOrCreate(sequence, _unicodeSequenceMarker);
        }
    }
}
```

./Platform.Data.Doublets/Unicode/UnicodeMap.cs

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

```
using System.Runtime.CompilerServices;
using System.Text;
using Platform.Data.Sequences;

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

namespace Platform.Data.Doublets.Unicode
{
    public class UnicodeMap
    {
        public static readonly ulong FirstCharLink = 1;
        public static readonly ulong LastCharLink = FirstCharLink + char.MaxValue;
        public static readonly ulong MapSize = 1 + char.MaxValue;

        private readonly ILinks<ulong> _links;
        private bool _initialized;

        public UnicodeMap(ILinks<ulong> links) => _links = links;

        public static UnicodeMap InitNew(ILinks<ulong> links)
        {
            var map = new UnicodeMap(links);
            map.Init();
            return map;
        }

        public void Init()
        {
            if (_initialized)
            {
                return;
            }
            _initialized = true;
            var firstLink = _links.CreatePoint();
            if (firstLink != FirstCharLink)
            {
                _links.Delete(firstLink);
            }
            else
            {
                for (var i = FirstCharLink + 1; i <= LastCharLink; i++)
                {
                    // From NIL to It (NIL -> Character) transformation meaning, (or infinite amount of NIL characters before actual Character)
                    var createdLink = _links.CreatePoint();
                    _links.Update(createdLink, firstLink, createdLink);
                    if (createdLink != i)
                    {
                        throw new InvalidOperationException("Unable to initialize UTF 16 table.");
                    }
                }
            }
        }

        // 0 - null link
        // 1 - nil character (0 character)
        // ...
        // 65536 (0(1) + 65535 = 65536 possible values)

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static ulong FromCharToLink(char character) => (ulong)character + 1;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static char FromLinkToChar(ulong link) => (char)(link - 1);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool IsCharLink(ulong link) => link <= MapSize;

        public static string FromLinksToString(IList<ulong> linksList)
        {
            var sb = new StringBuilder();
            for (int i = 0; i < linksList.Count; i++)
            {
                sb.Append(FromLinkToChar(linksList[i]));
            }
            return sb.ToString();
        }

        public static string FromSequenceLinkToString(ulong link, ILinks<ulong> links)
```

```
        {
            var sb = new StringBuilder();
            if (links.Exists(link))
            {
                StopableSequenceWalker.WalkRight(link, links.GetSource, links.GetTarget,
                    x => x <= MapSize || links.GetSource(x) == x || links.GetTarget(x) == x,
                    element =>
                    {
                        sb.Append(FromLinkToChar(element));
                        return true;
                    });
            }
            return sb.ToString();
        }

        public static ulong[] FromCharsToLinkArray(char[] chars) => FromCharsToLinkArray(chars,
        chars.Length);

        public static ulong[] FromCharsToLinkArray(char[] chars, int count)
        {
            // char array to ulong array
            var linksSequence = new ulong[count];
            for (var i = 0; i < count; i++)
            {
                linksSequence[i] = FromCharToLink(chars[i]);
            }
            return linksSequence;
        }

        public static ulong[] FromStringToLinkArray(string sequence)
        {
            // char array to ulong array
            var linksSequence = new ulong[sequence.Length];
            for (var i = 0; i < sequence.Length; i++)
            {
                linksSequence[i] = FromCharToLink(sequence[i]);
            }
            return linksSequence;
        }

        public static List<ulong[]> FromStringToLinkArrayGroups(string sequence)
        {
            var result = new List<ulong[]>();
            var offset = 0;
            while (offset < sequence.Length)
            {
                var currentCategory = CharUnicodeInfo.GetUnicodeCategory(sequence[offset]);
                var relativeLength = 1;
                var absoluteLength = offset + relativeLength;
                while (absoluteLength < sequence.Length &&
                       currentCategory ==
                       CharUnicodeInfo.GetUnicodeCategory(sequence[absoluteLength]))
                {
                    relativeLength++;
                    absoluteLength++;
                }
                // char array to ulong array
                var innerSequence = new ulong[relativeLength];
                var maxLength = offset + relativeLength;
                for (var i = offset; i < maxLength; i++)
                {
                    innerSequence[i - offset] = FromCharToLink(sequence[i]);
                }
                result.Add(innerSequence);
                offset += relativeLength;
            }
            return result;
        }

        public static List<ulong[]> FromLinkArrayToLinkArrayGroups(ulong[] array)
        {
            var result = new List<ulong[]>();
            var offset = 0;
            while (offset < array.Length)
            {
                var relativeLength = 1;
                if (array[offset] <= LastCharLink)
                {
```

```
                    var currentCategory =
                    ↪  CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(array[offset]));
                    var absoluteLength = offset + relativeLength;
                    while (absoluteLength < array.Length &&
                           array[absoluteLength] <= LastCharLink &&
                           currentCategory == CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(
                           ↪  array[absoluteLength])))
                    {
                        relativeLength++;
                        absoluteLength++;
                    }
                }
                else
                {
                    var absoluteLength = offset + relativeLength;
                    while (absoluteLength < array.Length && array[absoluteLength] > LastCharLink)
                    {
                        relativeLength++;
                        absoluteLength++;
                    }
                }
                // copy array
                var innerSequence = new ulong[relativeLength];
                var maxLength = offset + relativeLength;
                for (var i = offset; i < maxLength; i++)
                {
                    innerSequence[i - offset] = array[i];
                }
                result.Add(innerSequence);
                offset += relativeLength;
            }
            return result;
        }
    }
}
```

./Platform.Data.Doublets/Unicode/UnicodeSequenceCriterionMatcher.cs

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

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

namespace Platform.Data.Doublets.Unicode
{
    public class UnicodeSequenceCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
    ↪  ICriterionMatcher<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;
        private readonly TLink _unicodeSequenceMarker;
        public UnicodeSequenceCriterionMatcher(ILinks<TLink> links, TLink unicodeSequenceMarker)
        ↪  : base(links) => _unicodeSequenceMarker = unicodeSequenceMarker;
        public bool IsMatched(TLink link) => _equalityComparer.Equals(Links.GetTarget(link),
        ↪  _unicodeSequenceMarker);
    }
}
```

./Platform.Data.Doublets/Unicode/UnicodeSequenceToStringConverter.cs

```
using System;
using System.Linq;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Interfaces;

#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;

        public UnicodeSequenceToStringConverter(ILinks<TLink> links, ICriterionMatcher<TLink>
        ↪  unicodeSequenceCriterionMatcher, ISequenceWalker<TLink> sequenceWalker,
        ↪  IConverter<TLink, char> unicodeSymbolToCharConverter) : base(links)
        {
            _unicodeSequenceCriterionMatcher = unicodeSequenceCriterionMatcher;
            _sequenceWalker = sequenceWalker;
```

```
            _unicodeSymbolToCharConverter = unicodeSymbolToCharConverter;
        }

        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);
        }
    }
}
```

./Platform.Data.Doublets/Unicode/UnicodeSymbolCriterionMatcher.cs

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

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

namespace Platform.Data.Doublets.Unicode
{
    public class UnicodeSymbolCriterionMatcher<TLink> : LinksOperatorBase<TLink>, ICriterionMatcher<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer = EqualityComparer<TLink>.Default;
        private readonly TLink _unicodeSymbolMarker;
        public UnicodeSymbolCriterionMatcher(ILinks<TLink> links, TLink unicodeSymbolMarker) : base(links) => _unicodeSymbolMarker = unicodeSymbolMarker;
        public bool IsMatched(TLink link) => _equalityComparer.Equals(Links.GetTarget(link), _unicodeSymbolMarker);
    }
}
```

./Platform.Data.Doublets/Unicode/UnicodeSymbolToCharConverter.cs

```
using System;
using Platform.Interfaces;
using Platform.Numbers;

#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 readonly IConverter<TLink> _numberToAddressConverter;
        private readonly ICriterionMatcher<TLink> _unicodeSymbolCriterionMatcher;

        public UnicodeSymbolToCharConverter(ILinks<TLink> links, IConverter<TLink> numberToAddressConverter, ICriterionMatcher<TLink> unicodeSymbolCriterionMatcher) : base(links)
        {
            _numberToAddressConverter = numberToAddressConverter;
            _unicodeSymbolCriterionMatcher = unicodeSymbolCriterionMatcher;
        }

        public char Convert(TLink source)
        {
            if (!_unicodeSymbolCriterionMatcher.IsMatched(source))
            {
                throw new ArgumentOutOfRangeException(nameof(source), source, "Specified link is not a unicode symbol.");
            }
            return (char)(ushort)(Integer<TLink>)_numberToAddressConverter.Convert(Links.GetSource(source));
        }
    }
}
```

./Platform.Data.Doublets.Tests/ComparisonTests.cs

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

```
using Xunit;
using Platform.Diagnostics;

namespace Platform.Data.Doublets.Tests
{
    public static class ComparisonTests
    {
        private class UInt64Comparer : IComparer<ulong>
        {
            public int Compare(ulong x, ulong y) => x.CompareTo(y);
        }

        private static int Compare(ulong x, ulong y) => x.CompareTo(y);

        [Fact]
        public static void GreaterOrEqualPerfomanceTest()
        {
            const int N = 1000000;

            ulong x = 10;
            ulong y = 500;

            bool result = false;

            var ts1 = Performance.Measure(() =>
            {
                for (int i = 0; i < N; i++)
                {
                    result = Compare(x, y) >= 0;
                }
            });

            var comparer1 = Comparer<ulong>.Default;

            var ts2 = Performance.Measure(() =>
            {
                for (int i = 0; i < N; i++)
                {
                    result = comparer1.Compare(x, y) >= 0;
                }
            });

            Func<ulong, ulong, int> compareReference = comparer1.Compare;

            var ts3 = Performance.Measure(() =>
            {
                for (int i = 0; i < N; i++)
                {
                    result = compareReference(x, y) >= 0;
                }
            });

            var comparer2 = new UInt64Comparer();

            var ts4 = Performance.Measure(() =>
            {
                for (int i = 0; i < N; i++)
                {
                    result = comparer2.Compare(x, y) >= 0;
                }
            });

            Console.WriteLine($"{ts1} {ts2} {ts3} {ts4} {result}");
        }
    }
}
```

./Platform.Data.Doublets.Tests/EqualityTests.cs

```
using System;
using System.Collections.Generic;
using Xunit;
using Platform.Diagnostics;

namespace Platform.Data.Doublets.Tests
{
    public static class EqualityTests
    {
        protected class UInt64EqualityComparer : IEqualityComparer<ulong>
        {
            public bool Equals(ulong x, ulong y) => x == y;
```

```
        public int GetHashCode(ulong obj) => obj.GetHashCode();
    }

    private static bool Equals1<T>(T x, T y) => Equals(x, y);

    private static bool Equals2<T>(T x, T y) => x.Equals(y);

    private static bool Equals3(ulong x, ulong y) => x == y;

    [Fact]
    public static void EqualsPerfomanceTest()
    {
        const int N = 1000000;

        ulong x = 10;
        ulong y = 500;

        bool result = false;

        var ts1 = Performance.Measure(() =>
        {
            for (int i = 0; i < N; i++)
            {
                result = Equals1(x, y);
            }
        });

        var ts2 = Performance.Measure(() =>
        {
            for (int i = 0; i < N; i++)
            {
                result = Equals2(x, y);
            }
        });

        var ts3 = Performance.Measure(() =>
        {
            for (int i = 0; i < N; i++)
            {
                result = Equals3(x, y);
            }
        });

        var equalityComparer1 = EqualityComparer<ulong>.Default;

        var ts4 = Performance.Measure(() =>
        {
            for (int i = 0; i < N; i++)
            {
                result = equalityComparer1.Equals(x, y);
            }
        });

        var equalityComparer2 = new UInt64EqualityComparer();

        var ts5 = Performance.Measure(() =>
        {
            for (int i = 0; i < N; i++)
            {
                result = equalityComparer2.Equals(x, y);
            }
        });

        Func<ulong, ulong, bool> equalityComparer3 = equalityComparer2.Equals;

        var ts6 = Performance.Measure(() =>
        {
            for (int i = 0; i < N; i++)
            {
                result = equalityComparer3(x, y);
            }
        });

        var comparer = Comparer<ulong>.Default;

        var ts7 = Performance.Measure(() =>
        {
            for (int i = 0; i < N; i++)
            {
```

```
                    result = comparer.Compare(x, y) == 0;
                }
            });

            Assert.True(ts2 < ts1);
            Assert.True(ts3 < ts2);
            Assert.True(ts5 < ts4);
            Assert.True(ts5 < ts6);

            Console.WriteLine($"{ts1} {ts2} {ts3} {ts4} {ts5} {ts6} {ts7} {result}");
        }
    }
}
```

./Platform.Data.Doublets.Tests/GenericLinksTests.cs

```
using System;
using Xunit;
using Platform.Reflection;
using Platform.Memory;
using Platform.Scopes;
using Platform.Data.Doublets.ResizableDirectMemory;

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,
            ↪  ResizableDirectMemoryLinks<TLink>>>())
            {
                action(scope.Use<ILinks<TLink>>());
            }
        }
    }
}
```

./Platform.Data.Doublets.Tests/OptimalVariantSequenceTests.cs

```
using System;
using System.Linq;
using System.Collections.Generic;
using Xunit;
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;
```

```
10  using Platform.Data.Doublets.Incrementers;
11  using Platform.Data.Doublets.Sequences.Walkers;
12  using Platform.Data.Doublets.Sequences.Indexes;
13  using Platform.Data.Doublets.Unicode;
14  using Platform.Data.Doublets.Numbers.Unary;
15
16  namespace Platform.Data.Doublets.Tests
17  {
18      public static class OptimalVariantSequenceTests
19      {
20          private const string SequenceExample = "зеленела зелёная зелень";
21
22          [Fact]
23          public static void LinksBasedFrequencyStoredOptimalVariantSequenceTest()
24          {
25              using (var scope = new TempLinksTestScope(useSequences: false))
26              {
27                  var links = scope.Links;
28                  var constants = links.Constants;
29
30                  links.UseUnicode();
31
32                  var sequence = UnicodeMap.FromStringToLinkArray(SequenceExample);
33
34                  var meaningRoot = links.CreatePoint();
35                  var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
36                  var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
37                  var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
                    ↪  constants.Itself);
38
39                  var unaryNumberToAddressConverter = new
                    ↪  UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
40                  var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
41                  var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
                    ↪  frequencyMarker, unaryOne, unaryNumberIncrementer);
42                  var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
                    ↪  frequencyPropertyMarker, frequencyMarker);
43                  var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
                    ↪  frequencyPropertyOperator, frequencyIncrementer);
44                  var linkToItsFrequencyNumberConverter = new
                    ↪  LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
                    ↪  unaryNumberToAddressConverter);
45                  var sequenceToItsLocalElementLevelsConverter = new
                    ↪  SequenceToItsLocalElementLevelsConverter<ulong>(links,
                    ↪  linkToItsFrequencyNumberConverter);
46                  var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                    ↪  sequenceToItsLocalElementLevelsConverter);
47
48                  var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
                    ↪  Walker = new LeveledSequenceWalker<ulong>(links) });
49
50                  ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
                    ↪  index, optimalVariantConverter);
51              }
52          }
53
54          [Fact]
55          public static void DictionaryBasedFrequencyStoredOptimalVariantSequenceTest()
56          {
57              using (var scope = new TempLinksTestScope(useSequences: false))
58              {
59                  var links = scope.Links;
60
61                  links.UseUnicode();
62
63                  var sequence = UnicodeMap.FromStringToLinkArray(SequenceExample);
64
65                  var linksToFrequencies = new Dictionary<ulong, ulong>();
66
67                  var totalSequenceSymbolFrequencyCounter = new
                    ↪  TotalSequenceSymbolFrequencyCounter<ulong>(links);
68
69                  var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
                    ↪  totalSequenceSymbolFrequencyCounter);
70
71                  var index = new
                    ↪  CachedFrequencyIncrementingSequenceIndex<ulong>(linkFrequenciesCache);
72                  var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFreque
                    ↪  ncyNumberConverter<ulong>(linkFrequenciesCache);
```

```
73
74                  var sequenceToItsLocalElementLevelsConverter = new
                    ↪  SequenceToItsLocalElementLevelsConverter<ulong>(links,
                    ↪  linkToItsFrequencyNumberConverter);
75                  var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                    ↪  sequenceToItsLocalElementLevelsConverter);
76
77                  var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
                    ↪  Walker = new LeveledSequenceWalker<ulong>(links) });
78
79                  ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
                    ↪  index, optimalVariantConverter);
80              }
81          }
82
83          private static void ExecuteTest(Sequences.Sequences sequences, ulong[] sequence,
            ↪  SequenceToItsLocalElementLevelsConverter<ulong>
            ↪  sequenceToItsLocalElementLevelsConverter, ISequenceIndex<ulong> index,
            ↪  OptimalVariantConverter<ulong> optimalVariantConverter)
84          {
85              index.Add(sequence);
86
87              var optimalVariant = optimalVariantConverter.Convert(sequence);
88
89              var readSequence1 = sequences.ToList(optimalVariant);
90
91              Assert.True(sequence.SequenceEqual(readSequence1));
92          }
93      }
94  }
```

./Platform.Data.Doublets.Tests/ReadSequenceTests.cs

```
1   using System;
2   using System.Collections.Generic;
3   using System.Diagnostics;
4   using System.Linq;
5   using Xunit;
6   using Platform.Data.Sequences;
7   using Platform.Data.Doublets.Sequences.Converters;
8   using Platform.Data.Doublets.Sequences.Walkers;
9   using Platform.Data.Doublets.Sequences;
10
11  namespace Platform.Data.Doublets.Tests
12  {
13      public static class ReadSequenceTests
14      {
15          [Fact]
16          public static void ReadSequenceTest()
17          {
18              const long sequenceLength = 2000;
19
20              using (var scope = new TempLinksTestScope(useSequences: false))
21              {
22                  var links = scope.Links;
23                  var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong> {
                    ↪  Walker = new LeveledSequenceWalker<ulong>(links) });
24
25                  var sequence = new ulong[sequenceLength];
26                  for (var i = 0; i < sequenceLength; i++)
27                  {
28                      sequence[i] = links.Create();
29                  }
30
31                  var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
32
33                  var sw1 = Stopwatch.StartNew();
34                  var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();
35
36                  var sw2 = Stopwatch.StartNew();
37                  var readSequence1 = sequences.ToList(balancedVariant); sw2.Stop();
38
39                  var sw3 = Stopwatch.StartNew();
40                  var readSequence2 = new List<ulong>();
41                  SequenceWalker.WalkRight(balancedVariant,
42                                           links.GetSource,
43                                           links.GetTarget,
44                                           links.IsPartialPoint,
45                                           readSequence2.Add);
46                  sw3.Stop();
47
```

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

./Platform.Data.Doublets.Tests/ResizableDirectMemoryLinksTests.cs

```
using System.IO;
using Xunit;
using Platform.Singletons;
using Platform.Memory;
using Platform.Data.Doublets.ResizableDirectMemory;

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 UInt64ResizableDirectMemoryLinks(tempFilename))
            {
                memoryAdapter.TestBasicMemoryOperations();
            }
            File.Delete(tempFilename);
        }

        [Fact]
        public static void BasicHeapMemoryTest()
        {
            using (var memory = new HeapResizableDirectMemory(UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep))
            using (var memoryAdapter = new UInt64ResizableDirectMemoryLinks(memory, UInt64ResizableDirectMemoryLinks.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(UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep))
            using (var memoryAdapter = new UInt64ResizableDirectMemoryLinks(memory, UInt64ResizableDirectMemoryLinks.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);
        }
    }
}
```

./Platform.Data.Doublets.Tests/ScopeTests.cs

```
using Xunit;
using Platform.Scopes;
using Platform.Memory;
using Platform.Data.Doublets.ResizableDirectMemory;
using Platform.Data.Doublets.Decorators;
using Platform.Reflection;

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<UInt64ResizableDirectMemoryLinks>();
                var instance = scope.Use<ILinks<ulong>>();
                Assert.IsType<UInt64ResizableDirectMemoryLinks>(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,
            ↪ ResizableDirectMemoryLinks<ulong>>>())
            {
                var links = scope.Use<ILinks<ulong>>();
                Assert.IsType<ResizableDirectMemoryLinks<ulong>>(links);
            }
        }
    }
}
```

./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.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();

        //    const long sequenceLength = 8;

        //    const ulong itself = LinksConstants.Itself;

        //    using (var memoryAdapter = new ResizableDirectMemoryLinks(tempFilename,
        //    ↪ DefaultLinksSizeStep))
        //    using (var links = new Links(memoryAdapter))
        //    {
        //        var sequence = new ulong[sequenceLength];
        //        for (var i = 0; i < sequenceLength; i++)
        //            sequence[i] = links.Create(itself, itself);

        //        SequencesOptions o = new SequencesOptions();

        // TODO: Из числа в bool значения o.UseSequenceMarker = ((value & 1) != 0)
        //        o.

        //        var sequences = new Sequences(links);

        //        var sw1 = Stopwatch.StartNew();
        //        var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();

```

```
88          //        var sw2 = Stopwatch.StartNew();
89          //        var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();
90
91          //        Assert.True(results1.Count > results2.Length);
92          //        Assert.True(sw1.Elapsed > sw2.Elapsed);
93
94          //        for (var i = 0; i < sequenceLength; i++)
95          //            links.Delete(sequence[i]);
96          //    }
97
98          //    File.Delete(tempFilename);
99          //}
100
101         [Fact]
102         public static void AllVariantsSearchTest()
103         {
104             const long sequenceLength = 8;
105
106             using (var scope = new TempLinksTestScope(useSequences: true))
107             {
108                 var links = scope.Links;
109                 var sequences = scope.Sequences;
110
111                 var sequence = new ulong[sequenceLength];
112                 for (var i = 0; i < sequenceLength; i++)
113                 {
114                     sequence[i] = links.Create();
115                 }
116
117                 var createResults = sequences.CreateAllVariants2(sequence).Distinct().ToArray();
118
119                 //for (int i = 0; i < createResults.Length; i++)
120                 //    sequences.Create(createResults[i]);
121
122                 var sw0 = Stopwatch.StartNew();
123                 var searchResults0 = sequences.GetAllMatchingSequences0(sequence); sw0.Stop();
124
125                 var sw1 = Stopwatch.StartNew();
126                 var searchResults1 = sequences.GetAllMatchingSequences1(sequence); sw1.Stop();
127
128                 var sw2 = Stopwatch.StartNew();
129                 var searchResults2 = sequences.Each1(sequence); sw2.Stop();
130
131                 var sw3 = Stopwatch.StartNew();
132                 var searchResults3 = sequences.Each(sequence.ConvertToRestrictionsValues());
                    ↪ sw3.Stop();
133
134                 var intersection0 = createResults.Intersect(searchResults0).ToList();
135                 Assert.True(intersection0.Count == searchResults0.Count);
136                 Assert.True(intersection0.Count == createResults.Length);
137
138                 var intersection1 = createResults.Intersect(searchResults1).ToList();
139                 Assert.True(intersection1.Count == searchResults1.Count);
140                 Assert.True(intersection1.Count == createResults.Length);
141
142                 var intersection2 = createResults.Intersect(searchResults2).ToList();
143                 Assert.True(intersection2.Count == searchResults2.Count);
144                 Assert.True(intersection2.Count == createResults.Length);
145
146                 var intersection3 = createResults.Intersect(searchResults3).ToList();
147                 Assert.True(intersection3.Count == searchResults3.Count);
148                 Assert.True(intersection3.Count == createResults.Length);
149
150                 for (var i = 0; i < sequenceLength; i++)
151                 {
152                     links.Delete(sequence[i]);
153                 }
154             }
155         }
156
157         [Fact]
158         public static void BalancedVariantSearchTest()
159         {
160             const long sequenceLength = 200;
161
162             using (var scope = new TempLinksTestScope(useSequences: true))
163             {
164                 var links = scope.Links;
165                 var sequences = scope.Sequences;
166
```

```
            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];

            Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);

            var sw1 = Stopwatch.StartNew();
            var searchResults1 =
            ↪  sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();

            var sw2 = Stopwatch.StartNew();
            var searchResults2 =
            ↪  sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();

            //var sw3 = Stopwatch.StartNew();
            //var searchResults3 =
            ↪  sequences.GetAllPartiallyMatchingSequences2(partialSequence); sw3.Stop();

            var sw4 = Stopwatch.StartNew();
            var searchResults4 =
            ↪  sequences.GetAllPartiallyMatchingSequences3(partialSequence); sw4.Stop();

            //Global.Trash = searchResults3;

```

```
240                 //var searchResults1Strings = searchResults1.Select(x => x + ": " +
                    ↪  sequences.FormatSequence(x)).ToList();
241                 //Global.Trash = searchResults1Strings;
242
243                 var intersection1 = createResults.Intersect(searchResults1).ToList();
244                 Assert.True(intersection1.Count == createResults.Length);
245
246                 var intersection2 = createResults.Intersect(searchResults2).ToList();
247                 Assert.True(intersection2.Count == createResults.Length);
248
249                 var intersection4 = createResults.Intersect(searchResults4).ToList();
250                 Assert.True(intersection4.Count == createResults.Length);
251
252                 for (var i = 0; i < sequenceLength; i++)
253                 {
254                     links.Delete(sequence[i]);
255                 }
256             }
257         }
258
259         [Fact]
260         public static void BalancedPartialVariantsSearchTest()
261         {
262             const long sequenceLength = 200;
263
264             using (var scope = new TempLinksTestScope(useSequences: true))
265             {
266                 var links = scope.Links;
267                 var sequences = scope.Sequences;
268
269                 var sequence = new ulong[sequenceLength];
270                 for (var i = 0; i < sequenceLength; i++)
271                 {
272                     sequence[i] = links.Create();
273                 }
274
275                 var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
276
277                 var balancedVariant = balancedVariantConverter.Convert(sequence);
278
279                 var partialSequence = new ulong[sequenceLength - 2];
280
281                 Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
282
283                 var sw1 = Stopwatch.StartNew();
284                 var searchResults1 =
                    ↪  sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
285
286                 var sw2 = Stopwatch.StartNew();
287                 var searchResults2 =
                    ↪  sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
288
289                 Assert.True(searchResults1.Count == 1 && balancedVariant == searchResults1[0]);
290
291                 Assert.True(searchResults2.Count == 1 && balancedVariant ==
                    ↪  searchResults2.First());
292
293                 for (var i = 0; i < sequenceLength; i++)
294                 {
295                     links.Delete(sequence[i]);
296                 }
297             }
298         }
299
300         [Fact(Skip = "Correct implementation is pending")]
301         public static void PatternMatchTest()
302         {
303             var zeroOrMany = Sequences.Sequences.ZeroOrMany;
304
305             using (var scope = new TempLinksTestScope(useSequences: true))
306             {
307                 var links = scope.Links;
308                 var sequences = scope.Sequences;
309
310                 var e1 = links.Create();
311                 var e2 = links.Create();
312
313                 var sequence = new[]
314                 {
315                     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?

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] }
                };

                var balancedVariantConverter = new BalancedVariantConverter<ulong>(links.Unsync);
                var totalSequenceSymbolFrequencyCounter = new TotalSequenceSymbolFrequencyCounter<ulong>(links.Unsync);
                var doubletFrequenciesCache = new LinkFrequenciesCache<ulong>(links.Unsync, totalSequenceSymbolFrequencyCounter);
                var compressingConverter = new CompressingConverter<ulong>(links.Unsync, balancedVariantConverter, doubletFrequenciesCache);

                var compressedVariant = compressingConverter.Convert(sequence);

                // 1: [1]       (1->1) point
                // 2: [2]       (2->2) point
                // 3: [1,2]     (1->2) doublet
                // 4: [1,2,1,2] (3->3) doublet

                Assert.True(links.GetSource(links.GetSource(compressedVariant)) == sequence[0]);
                Assert.True(links.GetTarget(links.GetSource(compressedVariant)) == sequence[1]);
                Assert.True(links.GetSource(links.GetTarget(compressedVariant)) == sequence[2]);
                Assert.True(links.GetTarget(links.GetTarget(compressedVariant)) == sequence[3]);

                var source = _constants.SourcePart;
                var target = _constants.TargetPart;
```

```
473
474                 Assert.True(links.GetByKeys(compressedVariant, source, source) == sequence[0]);
475                 Assert.True(links.GetByKeys(compressedVariant, source, target) == sequence[1]);
476                 Assert.True(links.GetByKeys(compressedVariant, target, source) == sequence[2]);
477                 Assert.True(links.GetByKeys(compressedVariant, target, target) == sequence[3]);
478
479                 // 4 - length of sequence
480                 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 0)
                    ↪  == sequence[0]);
481                 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 1)
                    ↪  == sequence[1]);
482                 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 2)
                    ↪  == sequence[2]);
483                 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 3)
                    ↪  == sequence[3]);
484             }
485         }
486
487         [Fact]
488         public static void CompressionEfficiencyTest()
489         {
490             var strings = _exampleLoremIpsumText.Split(new[] { '\n', '\r' },
                ↪  StringSplitOptions.RemoveEmptyEntries);
491             var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
492             var totalCharacters = arrays.Select(x => x.Length).Sum();
493
494             using (var scope1 = new TempLinksTestScope(useSequences: true))
495             using (var scope2 = new TempLinksTestScope(useSequences: true))
496             using (var scope3 = new TempLinksTestScope(useSequences: true))
497             {
498                 scope1.Links.Unsync.UseUnicode();
499                 scope2.Links.Unsync.UseUnicode();
500                 scope3.Links.Unsync.UseUnicode();
501
502                 var balancedVariantConverter1 = new
                    ↪  BalancedVariantConverter<ulong>(scope1.Links.Unsync);
503                 var totalSequenceSymbolFrequencyCounter = new
                    ↪  TotalSequenceSymbolFrequencyCounter<ulong>(scope1.Links.Unsync);
504                 var linkFrequenciesCache1 = new LinkFrequenciesCache<ulong>(scope1.Links.Unsync,
                    ↪  totalSequenceSymbolFrequencyCounter);
505                 var compressor1 = new CompressingConverter<ulong>(scope1.Links.Unsync,
                    ↪  balancedVariantConverter1, linkFrequenciesCache1,
                    ↪  doInitialFrequenciesIncrement: false);
506
507                 //var compressor2 = scope2.Sequences;
508                 var compressor3 = scope3.Sequences;
509
510                 var constants = Default<LinksConstants<ulong>>.Instance;
511
512                 var sequences = compressor3;
513                 //var meaningRoot = links.CreatePoint();
514                 //var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
515                 //var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
516                 //var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
                    ↪  constants.Itself);
517
518                 //var unaryNumberToAddressConverter = new
                    ↪  UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
519                 //var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links,
                    ↪  unaryOne);
520                 //var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
                    ↪  frequencyMarker, unaryOne, unaryNumberIncrementer);
521                 //var frequencyPropertyOperator = new FrequencyPropertyOperator<ulong>(links,
                    ↪  frequencyPropertyMarker, frequencyMarker);
522                 //var linkFrequencyIncrementer = new LinkFrequencyIncrementer<ulong>(links,
                    ↪  frequencyPropertyOperator, frequencyIncrementer);
523                 //var linkToItsFrequencyNumberConverter = new
                    ↪  LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
                    ↪  unaryNumberToAddressConverter);
524
525                 var linkFrequenciesCache3 = new LinkFrequenciesCache<ulong>(scope3.Links.Unsync,
                    ↪  totalSequenceSymbolFrequencyCounter);
526
527                 var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFreque
                    ↪  ncyNumberConverter<ulong>(linkFrequenciesCache3);
528
```

```
529                 var sequenceToItsLocalElementLevelsConverter = new
                    ↪  SequenceToItsLocalElementLevelsConverter<ulong>(scope3.Links.Unsync,
                    ↪  linkToItsFrequencyNumberConverter);
530                 var optimalVariantConverter = new
                    ↪  OptimalVariantConverter<ulong>(scope3.Links.Unsync,
                    ↪  sequenceToItsLocalElementLevelsConverter);
531
532                 var compressed1 = new ulong[arrays.Length];
533                 var compressed2 = new ulong[arrays.Length];
534                 var compressed3 = new ulong[arrays.Length];
535
536                 var START = 0;
537                 var END = arrays.Length;
538
539                 //for (int i = START; i < END; i++)
540                 //    linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
541
542                 var initialCount1 = scope2.Links.Unsync.Count();
543
544                 var sw1 = Stopwatch.StartNew();
545
546                 for (int i = START; i < END; i++)
547                 {
548                     linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
549                     compressed1[i] = compressor1.Convert(arrays[i]);
550                 }
551
552                 var elapsed1 = sw1.Elapsed;
553
554                 var balancedVariantConverter2 = new
                    ↪  BalancedVariantConverter<ulong>(scope2.Links.Unsync);
555
556                 var initialCount2 = scope2.Links.Unsync.Count();
557
558                 var sw2 = Stopwatch.StartNew();
559
560                 for (int i = START; i < END; i++)
561                 {
562                     compressed2[i] = balancedVariantConverter2.Convert(arrays[i]);
563                 }
564
565                 var elapsed2 = sw2.Elapsed;
566
567                 for (int i = START; i < END; i++)
568                 {
569                     linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
570                 }
571
572                 var initialCount3 = scope3.Links.Unsync.Count();
573
574                 var sw3 = Stopwatch.StartNew();
575
576                 for (int i = START; i < END; i++)
577                 {
578                     //linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
579                     compressed3[i] = optimalVariantConverter.Convert(arrays[i]);
580                 }
581
582                 var elapsed3 = sw3.Elapsed;
583
584                 Console.WriteLine($"Compressor: {elapsed1}, Balanced variant: {elapsed2},
                    ↪  Optimal variant: {elapsed3}");
585
586                 // Assert.True(elapsed1 > elapsed2);
587
588                 // Checks
589                 for (int i = START; i < END; i++)
590                 {
591                     var sequence1 = compressed1[i];
592                     var sequence2 = compressed2[i];
593                     var sequence3 = compressed3[i];
594
595                     var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
                        ↪  scope1.Links.Unsync);
596
597                     var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
                        ↪  scope2.Links.Unsync);
598
599                     var decompress3 = UnicodeMap.FromSequenceLinkToString(sequence3,
                        ↪  scope3.Links.Unsync);
```

```
600
601                     var structure1 = scope1.Links.Unsync.FormatStructure(sequence1, link =>
                        ↪  link.IsPartialPoint());
602                     var structure2 = scope2.Links.Unsync.FormatStructure(sequence2, link =>
                        ↪  link.IsPartialPoint());
603                     var structure3 = scope3.Links.Unsync.FormatStructure(sequence3, link =>
                        ↪  link.IsPartialPoint());
604
605                     //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
                        ↪  arrays[i].Length > 3)
606                     //    Assert.False(structure1 == structure2);
607                     //if (sequence3 != Constants.Null && sequence2 != Constants.Null &&
                        ↪  arrays[i].Length > 3)
608                     //    Assert.False(structure3 == structure2);
609
610                     Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
611                     Assert.True(strings[i] == decompress3 && decompress3 == decompress2);
612                 }
613
614                 Assert.True((int)(scope1.Links.Unsync.Count() - initialCount1) <
                    ↪  totalCharacters);
615                 Assert.True((int)(scope2.Links.Unsync.Count() - initialCount2) <
                    ↪  totalCharacters);
616                 Assert.True((int)(scope3.Links.Unsync.Count() - initialCount3) <
                    ↪  totalCharacters);
617
618                 Console.WriteLine($"{(double)(scope1.Links.Unsync.Count() - initialCount1) /
                    ↪  totalCharacters} | {(double)(scope2.Links.Unsync.Count() - initialCount2) /
                    ↪  totalCharacters} | {(double)(scope3.Links.Unsync.Count() - initialCount3) /
                    ↪  totalCharacters}");
619
620                 Assert.True(scope1.Links.Unsync.Count() - initialCount1 <
                    ↪  scope2.Links.Unsync.Count() - initialCount2);
621                 Assert.True(scope3.Links.Unsync.Count() - initialCount3 <
                    ↪  scope2.Links.Unsync.Count() - initialCount2);
622
623                 var duplicateProvider1 = new
                    ↪  DuplicateSegmentsProvider<ulong>(scope1.Links.Unsync, scope1.Sequences);
624                 var duplicateProvider2 = new
                    ↪  DuplicateSegmentsProvider<ulong>(scope2.Links.Unsync, scope2.Sequences);
625                 var duplicateProvider3 = new
                    ↪  DuplicateSegmentsProvider<ulong>(scope3.Links.Unsync, scope3.Sequences);
626
627                 var duplicateCounter1 = new DuplicateSegmentsCounter<ulong>(duplicateProvider1);
628                 var duplicateCounter2 = new DuplicateSegmentsCounter<ulong>(duplicateProvider2);
629                 var duplicateCounter3 = new DuplicateSegmentsCounter<ulong>(duplicateProvider3);
630
631                 var duplicates1 = duplicateCounter1.Count();
632
633                 ConsoleHelpers.Debug("------");
634
635                 var duplicates2 = duplicateCounter2.Count();
636
637                 ConsoleHelpers.Debug("------");
638
639                 var duplicates3 = duplicateCounter3.Count();
640
641                 Console.WriteLine($"{duplicates1} | {duplicates2} | {duplicates3}");
642
643                 linkFrequenciesCache1.ValidateFrequencies();
644                 linkFrequenciesCache3.ValidateFrequencies();
645             }
646         }
647
648         [Fact]
649         public static void CompressionStabilityTest()
650         {
651             // TODO: Fix bug (do a separate test)
652             //const ulong minNumbers = 0;
653             //const ulong maxNumbers = 1000;
654
655             const ulong minNumbers = 10000;
656             const ulong maxNumbers = 12500;
657
658             var strings = new List<string>();
659
660             for (ulong i = minNumbers; i < maxNumbers; i++)
661             {
```

```
662                 strings.Add(i.ToString());
663             }
664
665             var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
666             var totalCharacters = arrays.Select(x => x.Length).Sum();
667
668             using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
                ↪  SequencesOptions<ulong> { UseCompression = true,
                ↪  EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
669             using (var scope2 = new TempLinksTestScope(useSequences: true))
670             {
671                 scope1.Links.UseUnicode();
672                 scope2.Links.UseUnicode();
673
674                 //var compressor1 = new Compressor(scope1.Links.Unsync, scope1.Sequences);
675                 var compressor1 = scope1.Sequences;
676                 var compressor2 = scope2.Sequences;
677
678                 var compressed1 = new ulong[arrays.Length];
679                 var compressed2 = new ulong[arrays.Length];
680
681                 var sw1 = Stopwatch.StartNew();
682
683                 var START = 0;
684                 var END = arrays.Length;
685
686                 // Collisions proved (cannot be solved by max doublet comparison, no stable rule)
687                 // Stability issue starts at 10001 or 11000
688                 //for (int i = START; i < END; i++)
689                 //{
690                 //    var first = compressor1.Compress(arrays[i]);
691                 //    var second = compressor1.Compress(arrays[i]);
692
693                 //    if (first == second)
694                 //        compressed1[i] = first;
695                 //    else
696                 //    {
697                 //        // TODO: Find a solution for this case
698                 //    }
699                 //}
700
701                 for (int i = START; i < END; i++)
702                 {
703                     var first = compressor1.Create(arrays[i].ConvertToRestrictionsValues());
704                     var second = compressor1.Create(arrays[i].ConvertToRestrictionsValues());
705
706                     if (first == second)
707                     {
708                         compressed1[i] = first;
709                     }
710                     else
711                     {
712                         // TODO: Find a solution for this case
713                     }
714                 }
715
716                 var elapsed1 = sw1.Elapsed;
717
718                 var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
719
720                 var sw2 = Stopwatch.StartNew();
721
722                 for (int i = START; i < END; i++)
723                 {
724                     var first = balancedVariantConverter.Convert(arrays[i]);
725                     var second = balancedVariantConverter.Convert(arrays[i]);
726
727                     if (first == second)
728                     {
729                         compressed2[i] = first;
730                     }
731                 }
732
733                 var elapsed2 = sw2.Elapsed;
734
735                 Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
                    ↪  {elapsed2}");
736
737                 Assert.True(elapsed1 > elapsed2);
738
```

```
739                 // Checks
740                 for (int i = START; i < END; i++)
741                 {
742                     var sequence1 = compressed1[i];
743                     var sequence2 = compressed2[i];
744
745                     if (sequence1 != _constants.Null && sequence2 != _constants.Null)
746                     {
747                         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
                            ↪ scope1.Links);
748
749                         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
                            ↪ scope2.Links);
750
751                         //var structure1 = scope1.Links.FormatStructure(sequence1, link =>
                            ↪ link.IsPartialPoint());
752                         //var structure2 = scope2.Links.FormatStructure(sequence2, link =>
                            ↪ link.IsPartialPoint());
753
754                         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
                            ↪ arrays[i].Length > 3)
755                         //    Assert.False(structure1 == structure2);
756
757                         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
758                     }
759                 }
760
761                 Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
762                 Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
763
764                 Debug.WriteLine($"{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
                    ↪ totalCharacters} | {(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
                    ↪ totalCharacters}");
765
766                 Assert.True(scope1.Links.Count() <= scope2.Links.Count());
767
768                 //compressor1.ValidateFrequencies();
769             }
770         }
771
772         [Fact]
773         public static void RundomNumbersCompressionQualityTest()
774         {
775             const ulong N = 500;
776
777             //const ulong minNumbers = 10000;
778             //const ulong maxNumbers = 20000;
779
780             //var strings = new List<string>();
781
782             //for (ulong i = 0; i < N; i++)
783             //    strings.Add(RandomHelpers.DefaultFactory.NextUInt64(minNumbers,
                ↪ maxNumbers).ToString());
784
785             var strings = new List<string>();
786
787             for (ulong i = 0; i < N; i++)
788             {
789                 strings.Add(RandomHelpers.Default.NextUInt64().ToString());
790             }
791
792             strings = strings.Distinct().ToList();
793
794             var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
795             var totalCharacters = arrays.Select(x => x.Length).Sum();
796
797             using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
                ↪ SequencesOptions<ulong> { UseCompression = true,
                ↪ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
798             using (var scope2 = new TempLinksTestScope(useSequences: true))
799             {
800                 scope1.Links.UseUnicode();
801                 scope2.Links.UseUnicode();
802
803                 var compressor1 = scope1.Sequences;
804                 var compressor2 = scope2.Sequences;
805
806                 var compressed1 = new ulong[arrays.Length];
807                 var compressed2 = new ulong[arrays.Length];
```

```
808
809                 var sw1 = Stopwatch.StartNew();
810
811                 var START = 0;
812                 var END = arrays.Length;
813
814                 for (int i = START; i < END; i++)
815                 {
816                     compressed1[i] = compressor1.Create(arrays[i].ConvertToRestrictionsValues());
817                 }
818
819                 var elapsed1 = sw1.Elapsed;
820
821                 var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
822
823                 var sw2 = Stopwatch.StartNew();
824
825                 for (int i = START; i < END; i++)
826                 {
827                     compressed2[i] = balancedVariantConverter.Convert(arrays[i]);
828                 }
829
830                 var elapsed2 = sw2.Elapsed;
831
832                 Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
                    ↪ {elapsed2}");
833
834                 Assert.True(elapsed1 > elapsed2);
835
836                 // Checks
837                 for (int i = START; i < END; i++)
838                 {
839                     var sequence1 = compressed1[i];
840                     var sequence2 = compressed2[i];
841
842                     if (sequence1 != _constants.Null && sequence2 != _constants.Null)
843                     {
844                         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
                            ↪ scope1.Links);
845
846                         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
                            ↪ scope2.Links);
847
848                         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
849                     }
850                 }
851
852                 Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
853                 Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
854
855                 Debug.WriteLine($"{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
                    ↪ totalCharacters} | {(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
                    ↪ totalCharacters}");
856
857                 // Can be worse than balanced variant
858                 //Assert.True(scope1.Links.Count() <= scope2.Links.Count());
859
860                 //compressor1.ValidateFrequencies();
861             }
862         }
863
864         [Fact]
865         public static void AllTreeBreakDownAtSequencesCreationBugTest()
866         {
867             // Made out of AllPossibleConnectionsTest test.
868
869             //const long sequenceLength = 5; //100% bug
870             const long sequenceLength = 4; //100% bug
871             //const long sequenceLength = 3; //100% _no_bug (ok)
872
873             using (var scope = new TempLinksTestScope(useSequences: true))
874             {
875                 var links = scope.Links;
876                 var sequences = scope.Sequences;
877
878                 var sequence = new ulong[sequenceLength];
879                 for (var i = 0; i < sequenceLength; i++)
880                 {
881                     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]);
                }
            }
        }
    }
}
```

./Platform.Data.Doublets.Tests/TempLinksTestScope.cs

```
using System.IO;
using Platform.Disposables;
using Platform.Data.Doublets.ResizableDirectMemory;
using Platform.Data.Doublets.Sequences;
using Platform.Data.Doublets.Decorators;

namespace Platform.Data.Doublets.Tests
{
    public class TempLinksTestScope : DisposableBase
    {
        public ILinks<ulong> MemoryAdapter { get; }
        public SynchronizedLinks<ulong> Links { get; }
        public Sequences.Sequences Sequences { get; }
        public string TempFilename { get; }
        public string TempTransactionLogFilename { get; }
        private readonly bool _deleteFiles;

        public TempLinksTestScope(bool deleteFiles = true, bool useSequences = false, bool
        ↪  useLog = false) : this(new SequencesOptions<ulong>(), deleteFiles, useSequences,
        ↪  useLog) { }

        public TempLinksTestScope(SequencesOptions<ulong> sequencesOptions, bool deleteFiles =
        ↪  true, bool useSequences = false, bool useLog = false)
        {
            _deleteFiles = deleteFiles;
            TempFilename = Path.GetTempFileName();
            TempTransactionLogFilename = Path.GetTempFileName();
            var coreMemoryAdapter = new UInt64ResizableDirectMemoryLinks(TempFilename);
            MemoryAdapter = useLog ? (ILinks<ulong>)new
            ↪  UInt64LinksTransactionsLayer(coreMemoryAdapter, TempTransactionLogFilename) :
            ↪  coreMemoryAdapter;
            Links = new SynchronizedLinks<ulong>(new UInt64Links(MemoryAdapter));
            if (useSequences)
            {
                Sequences = new Sequences.Sequences(Links, sequencesOptions);
            }
        }

        protected override void Dispose(bool manual, bool wasDisposed)
        {
            if (!wasDisposed)
            {
```

```
                Links.Unsync.DisposeIfPossible();
                if (_deleteFiles)
                {
                    DeleteFiles();
                }
            }
        }

        public void DeleteFiles()
        {
            File.Delete(TempFilename);
            File.Delete(TempTransactionLogFilename);
        }
    }
}
```

./Platform.Data.Doublets.Tests/TestExtensions.cs

```
using System.Collections.Generic;
using Xunit;
using Platform.Ranges;
using Platform.Numbers;
using Platform.Random;
using Platform.Setters;

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;

            // Create Link
            Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.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(), Integer<T>.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);

```

```
64              Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.Zero));
65
66              setter = new Setter<T>(constants.Null);
67              links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);
68
69              Assert.True(equalityComparer.Equals(setter.Result, constants.Null));
70          }
71
72          public static void TestRawNumbersCRUDOperations<T>(this ILinks<T> links)
73          {
74              // Constants
75              var constants = links.Constants;
76              var equalityComparer = EqualityComparer<T>.Default;
77
78              var h106E = new Hybrid<T>(106L, isExternal: true);
79              var h107E = new Hybrid<T>(-char.ConvertFromUtf32(107)[0]);
80              var h108E = new Hybrid<T>(-108L);
81
82              Assert.Equal(106L, h106E.AbsoluteValue);
83              Assert.Equal(107L, h107E.AbsoluteValue);
84              Assert.Equal(108L, h108E.AbsoluteValue);
85
86              // Create Link (External -> External)
87              var linkAddress1 = links.Create();
88
89              links.Update(linkAddress1, h106E, h108E);
90
91              var link1 = new Link<T>(links.GetLink(linkAddress1));
92
93              Assert.True(equalityComparer.Equals(link1.Source, h106E));
94              Assert.True(equalityComparer.Equals(link1.Target, h108E));
95
96              // Create Link (Internal -> External)
97              var linkAddress2 = links.Create();
98
99              links.Update(linkAddress2, linkAddress1, h108E);
100
101             var link2 = new Link<T>(links.GetLink(linkAddress2));
102
103             Assert.True(equalityComparer.Equals(link2.Source, linkAddress1));
104             Assert.True(equalityComparer.Equals(link2.Target, h108E));
105
106             // Create Link (Internal -> Internal)
107             var linkAddress3 = links.Create();
108
109             links.Update(linkAddress3, linkAddress1, linkAddress2);
110
111             var link3 = new Link<T>(links.GetLink(linkAddress3));
112
113             Assert.True(equalityComparer.Equals(link3.Source, linkAddress1));
114             Assert.True(equalityComparer.Equals(link3.Target, linkAddress2));
115
116             // Search for created link
117             var setter1 = new Setter<T>(constants.Null);
118             links.Each(h106E, h108E, setter1.SetAndReturnFalse);
119
120             Assert.True(equalityComparer.Equals(setter1.Result, linkAddress1));
121
122             // Search for nonexistent link
123             var setter2 = new Setter<T>(constants.Null);
124             links.Each(h106E, h107E, setter2.SetAndReturnFalse);
125
126             Assert.True(equalityComparer.Equals(setter2.Result, constants.Null));
127
128             // Update link to reference null (prepare for delete)
129             var updated = links.Update(linkAddress3, constants.Null, constants.Null);
130
131             Assert.True(equalityComparer.Equals(updated, linkAddress3));
132
133             link3 = new Link<T>(links.GetLink(linkAddress3));
134
135             Assert.True(equalityComparer.Equals(link3.Source, constants.Null));
136             Assert.True(equalityComparer.Equals(link3.Target, constants.Null));
137
138             // Delete link
139             links.Delete(linkAddress3);
140
141             Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.Two));
142
143             var setter3 = new Setter<T>(constants.Null);
```

```
            links.Each(constants.Any, constants.Any, setter3.SetAndReturnTrue);

            Assert.True(equalityComparer.Equals(setter3.Result, linkAddress2));
        }

        public static void TestMultipleRandomCreationsAndDeletions<TLink>(this ILinks<TLink>
        ↪  links, int maximumOperationsPerCycle)
        {
            var comparer = Comparer<TLink>.Default;
            for (var N = 1; N < maximumOperationsPerCycle; N++)
            {
                var random = new System.Random(N);
                var created = 0;
                var deleted = 0;
                for (var i = 0; i < N; i++)
                {
                    long linksCount = (Integer<TLink>)links.Count();
                    var createPoint = random.NextBoolean();
                    if (linksCount > 2 && createPoint)
                    {
                        var linksAddressRange = new Range<ulong>(1, (ulong)linksCount);
                        TLink source = (Integer<TLink>)random.NextUInt64(linksAddressRange);
                        TLink target = (Integer<TLink>)random.NextUInt64(linksAddressRange);
                        ↪  //-V3086
                        var resultLink = links.CreateAndUpdate(source, target);
                        if (comparer.Compare(resultLink, (Integer<TLink>)linksCount) > 0)
                        {
                            created++;
                        }
                    }
                    else
                    {
                        links.Create();
                        created++;
                    }
                }
                Assert.True(created == (Integer<TLink>)links.Count());
                for (var i = 0; i < N; i++)
                {
                    TLink link = (Integer<TLink>)(i + 1);
                    if (links.Exists(link))
                    {
                        links.Delete(link);
                        deleted++;
                    }
                }
                Assert.True((Integer<TLink>)links.Count() == 0);
            }
        }
    }
}
```

./Platform.Data.Doublets.Tests/UInt64LinksTests.cs

```
using System;
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.IO;
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.Memory;
using Platform.Data.Doublets.ResizableDirectMemory;
using Platform.Data.Doublets.Decorators;

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

```
28
29          private const long Iterations = 10 * 1024;
30
31          #region Concept
32
33          [Fact]
34          public static void MultipleCreateAndDeleteTest()
35          {
36              using (var scope = new Scope<Types<HeapResizableDirectMemory,
                ↪  UInt64ResizableDirectMemoryLinks>>())
37              {
38                  new UInt64Links(scope.Use<ILinks<ulong>>()).TestMultipleRandomCreationsAndDeleti
                    ↪  ons(100);
39              }
40          }
41
42          [Fact]
43          public static void CascadeUpdateTest()
44          {
45              var itself = _constants.Itself;
46
47              using (var scope = new TempLinksTestScope(useLog: true))
48              {
49                  var links = scope.Links;
50
51                  var l1 = links.Create();
52                  var l2 = links.Create();
53
54                  l2 = links.Update(l2, l2, l1, l2);
55
56                  links.CreateAndUpdate(l2, itself);
57                  links.CreateAndUpdate(l2, itself);
58
59                  l2 = links.Update(l2, l1);
60
61                  links.Delete(l2);
62
63                  Global.Trash = links.Count();
64
65                  links.Unsync.DisposeIfPossible(); // Close links to access log
66
67                  Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scop
                    ↪  e.TempTransactionLogFilename);
68              }
69          }
70
71          [Fact]
72          public static void BasicTransactionLogTest()
73          {
74              using (var scope = new TempLinksTestScope(useLog: true))
75              {
76                  var links = scope.Links;
77                  var l1 = links.Create();
78                  var l2 = links.Create();
79
80                  Global.Trash = links.Update(l2, l2, l1, l2);
81
82                  links.Delete(l1);
83
84                  links.Unsync.DisposeIfPossible(); // Close links to access log
85
86                  Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scop
                    ↪  e.TempTransactionLogFilename);
87              }
88          }
89
90          [Fact]
91          public static void TransactionAutoRevertedTest()
92          {
93              // Auto Reverted (Because no commit at transaction)
94              using (var scope = new TempLinksTestScope(useLog: true))
95              {
96                  var links = scope.Links;
97                  var transactionsLayer = (UInt64LinksTransactionsLayer)scope.MemoryAdapter;
98                  using (var transaction = transactionsLayer.BeginTransaction())
99                  {
100                     var l1 = links.Create();
101                     var l2 = links.Create();
102
```

```
                links.Update(l2, l2, l1, l2);
            }

            Assert.Equal(OUL, links.Count());

            links.Unsync.DisposeIfPossible();

            var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(s
            ↪  cope.TempTransactionLogFilename);
            Assert.Single(transitions);
        }
    }

    [Fact]
    public static void TransactionUserCodeErrorNoDataSavedTest()
    {
        // User Code Error (Autoreverted), no data saved
        var itself = _constants.Itself;

        TempLinksTestScope lastScope = null;
        try
        {
            using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
            ↪  useLog: true))
            {
                var links = scope.Links;
                var transactionsLayer = (UInt64LinksTransactionsLayer)((LinksDisposableDecor
                ↪  atorBase<ulong>)links.Unsync).Links;
                using (var transaction = transactionsLayer.BeginTransaction())
                {
                    var l1 = links.CreateAndUpdate(itself, itself);
                    var 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.Transi
                    ↪  tion>(scope.TempTransactionLogFilename);

                    l2 = links.Update(l2, l1);

                    links.Delete(l2);

                    ExceptionThrower();

                    transaction.Commit();
                }

                Global.Trash = links.Count();
            }
        }
        catch
        {
            Assert.False(lastScope == null);

            var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(l
            ↪  astScope.TempTransactionLogFilename);

            Assert.True(transitions.Length == 1 && transitions[0].Before.IsNull() &&
            ↪  transitions[0].After.IsNull());

            lastScope.DeleteFiles();
        }
    }

    [Fact]
    public static void TransactionUserCodeErrorSomeDataSavedTest()
    {
        // User Code Error (Autoreverted), some data saved
        var itself = _constants.Itself;

        TempLinksTestScope lastScope = null;
        try
        {
            ulong l1;
            ulong l2;

            using (var scope = new TempLinksTestScope(useLog: true))
```

```
            {
                var links = scope.Links;
                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);

                links.Unsync.DisposeIfPossible();

                Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(
                    scope.TempTransactionLogFilename);
            }

            using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
            useLog: true))
            {
                var links = scope.Links;
                var transactionsLayer = (UInt64LinksTransactionsLayer)links.Unsync;
                using (var transaction = transactionsLayer.BeginTransaction())
                {
                    l2 = links.Update(l2, l1);

                    links.Delete(l2);

                    ExceptionThrower();

                    transaction.Commit();
                }

                Global.Trash = links.Count();
            }
        }
        catch
        {
            Assert.False(lastScope == null);

            Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(last
            Scope.TempTransactionLogFilename);

            lastScope.DeleteFiles();
        }
    }

    [Fact]
    public static void TransactionCommit()
    {
        var itself = _constants.Itself;

        var tempDatabaseFilename = Path.GetTempFileName();
        var tempTransactionLogFilename = Path.GetTempFileName();

        // Commit
        using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
        UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
        tempTransactionLogFilename))
        using (var links = new UInt64Links(memoryAdapter))
        {
            using (var transaction = memoryAdapter.BeginTransaction())
            {
                var l1 = links.CreateAndUpdate(itself, itself);
                var l2 = links.CreateAndUpdate(itself, itself);

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

                links.Delete(l1);

                transaction.Commit();
            }

            Global.Trash = links.Count();
        }

        Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
        sactionLogFilename);
    }

```

```
250         [Fact]
251         public static void TransactionDamage()
252         {
253             var itself = _constants.Itself;
254
255             var tempDatabaseFilename = Path.GetTempFileName();
256             var tempTransactionLogFilename = Path.GetTempFileName();
257
258             // Commit
259             using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
                ↪  UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
                ↪  tempTransactionLogFilename))
260             using (var links = new UInt64Links(memoryAdapter))
261             {
262                 using (var transaction = memoryAdapter.BeginTransaction())
263                 {
264                     var l1 = links.CreateAndUpdate(itself, itself);
265                     var l2 = links.CreateAndUpdate(itself, itself);
266
267                     Global.Trash = links.Update(l2, l2, l1, l2);
268
269                     links.Delete(l1);
270
271                     transaction.Commit();
272                 }
273
274                 Global.Trash = links.Count();
275             }
276
277             Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
                ↪  sactionLogFilename);
278
279             // Damage database
280
281             FileHelpers.WriteFirst(tempTransactionLogFilename, new
                ↪  UInt64LinksTransactionsLayer.Transition(new UniqueTimestampFactory(), 555));
282
283             // Try load damaged database
284             try
285             {
286                 // TODO: Fix
287                 using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
                    ↪  UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
                    ↪  tempTransactionLogFilename))
288                 using (var links = new UInt64Links(memoryAdapter))
289                 {
290                     Global.Trash = links.Count();
291                 }
292             }
293             catch (NotSupportedException ex)
294             {
295                 Assert.True(ex.Message == "Database is damaged, autorecovery is not supported
                    ↪  yet.");
296             }
297
298             Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
                ↪  sactionLogFilename);
299
300             File.Delete(tempDatabaseFilename);
301             File.Delete(tempTransactionLogFilename);
302         }
303
304         [Fact]
305         public static void Bug1Test()
306         {
307             var tempDatabaseFilename = Path.GetTempFileName();
308             var tempTransactionLogFilename = Path.GetTempFileName();
309
310             var itself = _constants.Itself;
311
312             // User Code Error (Autoreverted), some data saved
313             try
314             {
315                 ulong l1;
316                 ulong l2;
317
318                 using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
                    ↪  UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
                    ↪  tempTransactionLogFilename))
```

```
319                 using (var links = new UInt64Links(memoryAdapter))
320                 {
321                     l1 = links.CreateAndUpdate(itself, itself);
322                     l2 = links.CreateAndUpdate(itself, itself);
323 
324                     l2 = links.Update(l2, l2, l1, l2);
325 
326                     links.CreateAndUpdate(l2, itself);
327                     links.CreateAndUpdate(l2, itself);
328                 }
329 
330                 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
                    ↪ TransactionLogFilename);
331 
332                 using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
                    ↪ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
                    ↪ tempTransactionLogFilename))
333                 using (var links = new UInt64Links(memoryAdapter))
334                 {
335                     using (var transaction = memoryAdapter.BeginTransaction())
336                     {
337                         l2 = links.Update(l2, l1);
338 
339                         links.Delete(l2);
340 
341                         ExceptionThrower();
342 
343                         transaction.Commit();
344                     }
345 
346                     Global.Trash = links.Count();
347                 }
348             }
349             catch
350             {
351                 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
                    ↪ TransactionLogFilename);
352             }
353 
354             File.Delete(tempDatabaseFilename);
355             File.Delete(tempTransactionLogFilename);
356         }
357 
358         private static void ExceptionThrower() => throw new InvalidOperationException();
359 
360         [Fact]
361         public static void PathsTest()
362         {
363             var source = _constants.SourcePart;
364             var target = _constants.TargetPart;
365 
366             using (var scope = new TempLinksTestScope())
367             {
368                 var links = scope.Links;
369                 var l1 = links.CreatePoint();
370                 var l2 = links.CreatePoint();
371 
372                 var r1 = links.GetByKeys(l1, source, target, source);
373                 var r2 = links.CheckPathExistance(l2, l2, l2, l2);
374             }
375         }
376 
377         [Fact]
378         public static void RecursiveStringFormattingTest()
379         {
380             using (var scope = new TempLinksTestScope(useSequences: true))
381             {
382                 var links = scope.Links;
383                 var sequences = scope.Sequences; // TODO: Auto use sequences on Sequences getter.
384 
385                 var a = links.CreatePoint();
386                 var b = links.CreatePoint();
387                 var c = links.CreatePoint();
388 
389                 var ab = links.CreateAndUpdate(a, b);
390                 var cb = links.CreateAndUpdate(c, b);
391                 var ac = links.CreateAndUpdate(a, c);
392 
393                 a = links.Update(a, c, b);
```

```
394                 b = links.Update(b, a, c);
395                 c = links.Update(c, a, b);
396
397                 Debug.WriteLine(links.FormatStructure(ab, link => link.IsFullPoint(), true));
398                 Debug.WriteLine(links.FormatStructure(cb, link => link.IsFullPoint(), true));
399                 Debug.WriteLine(links.FormatStructure(ac, link => link.IsFullPoint(), true));
400
401                 Assert.True(links.FormatStructure(cb, link => link.IsFullPoint(), true) ==
                    ↪  "(5:(4:5 (6:5 4)) 6)");
402                 Assert.True(links.FormatStructure(ac, link => link.IsFullPoint(), true) ==
                    ↪  "(6:(5:(4:5 6) 6) 4)");
403                 Assert.True(links.FormatStructure(ab, link => link.IsFullPoint(), true) ==
                    ↪  "(4:(5:4 (6:5 4)) 6)");
404
405                 // 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)"
406
407                 Assert.True(sequences.SafeFormatSequence(cb, DefaultFormatter, false) ==
                    ↪  "{{5}{5}{4}{6}}");
408                 Assert.True(sequences.SafeFormatSequence(ac, DefaultFormatter, false) ==
                    ↪  "{{5}{6}{6}{4}}");
409                 Assert.True(sequences.SafeFormatSequence(ab, DefaultFormatter, false) ==
                    ↪  "{{4}{5}{4}{6}}");
410             }
411         }
412
413         private static void DefaultFormatter(StringBuilder sb, ulong link)
414         {
415             sb.Append(link.ToString());
416         }
417
418         #endregion
419
420         #region Performance
421
422         /*
423         public static void RunAllPerformanceTests()
424         {
425             try
426             {
427                 links.TestLinksInSteps();
428             }
429             catch (Exception ex)
430             {
431                 ex.WriteToConsole();
432             }
433
434             return;
435
436             try
437             {
438                 //ThreadPool.SetMaxThreads(2, 2);
439
440                 // Запускаем все тесты дважды, чтобы первоначальная инициализация не повлияла на
    ↪  результат
441                 // Также это дополнительно помогает в отладке
442                 // Увеличивает вероятность попадания информации в кэши
443                 for (var i = 0; i < 10; i++)
444                 {
445                     //0 - 10 ГБ
446                     //Каждые 100 МБ срез цифр
447
448                     //links.TestGetSourceFunction();
449                     //links.TestGetSourceFunctionInParallel();
450                     //links.TestGetTargetFunction();
451                     //links.TestGetTargetFunctionInParallel();
452                     links.Create64BillionLinks();
453
454                     links.TestRandomSearchFixed();
455                     //links.Create64BillionLinksInParallel();
456                     links.TestEachFunction();
457                     //links.TestForeach();
458                     //links.TestParallelForeach();
459                 }
460
461                 links.TestDeletionOfAllLinks();
462
463             }
464             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);

```

```
615                 ConsoleHelpers.Debug(
616                     "{0} Iterations of GetSource function done in {1} ({2} Iterations per
                        ↪  second), counter result: {3}",
617                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
618             }
619         }
620
621         [Fact(Skip = "performance test")]
622         public static void TestGetTarget()
623         {
624             using (var scope = new TempLinksTestScope())
625             {
626                 var links = scope.Links;
627                 ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations.",
                    ↪  Iterations);
628
629                 ulong counter = 0;
630
631                 //var firstLink = links.First();
632                 var firstLink = links.Create();
633
634                 var sw = Stopwatch.StartNew();
635
636                 for (ulong i = 0; i < Iterations; i++)
637                 {
638                     counter += links.GetTarget(firstLink);
639                 }
640
641                 var elapsedTime = sw.Elapsed;
642
643                 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
644
645                 links.Delete(firstLink);
646
647                 ConsoleHelpers.Debug(
648                     "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
                        ↪  second), counter result: {3}",
649                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
650             }
651         }
652
653         [Fact(Skip = "performance test")]
654         public static void TestGetTargetInParallel()
655         {
656             using (var scope = new TempLinksTestScope())
657             {
658                 var links = scope.Links;
659                 ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations in
                    ↪  parallel.", Iterations);
660
661                 long counter = 0;
662
663                 //var firstLink = links.First();
664                 var firstLink = links.Create();
665
666                 var sw = Stopwatch.StartNew();
667
668                 Parallel.For(0, Iterations, x =>
669                 {
670                     Interlocked.Add(ref counter, (long)links.GetTarget(firstLink));
671                     //Interlocked.Increment(ref counter);
672                 });
673
674                 var elapsedTime = sw.Elapsed;
675
676                 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
677
678                 links.Delete(firstLink);
679
680                 ConsoleHelpers.Debug(
681                     "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
                        ↪  second), counter result: {3}",
682                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
683             }
684         }
685
686         // TODO: Заполнить базу данных перед тестом
687         /*
688         [Fact]
```

```
689         public void TestRandomSearchFixed()
690         {
691             var tempFilename = Path.GetTempFileName();
692 
693             using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
    ↪  DefaultLinksSizeStep))
694             {
695                 long iterations = 64 * 1024 * 1024 /
    ↪  Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
696 
697                 ulong counter = 0;
698                 var maxLink = links.Total;
699 
700                 ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.", iterations);
701 
702                 var sw = Stopwatch.StartNew();
703 
704                 for (var i = iterations; i > 0; i--)
705                 {
706                     var source =
    ↪  RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
707                     var target =
    ↪  RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
708 
709                     counter += links.Search(source, target);
710                 }
711 
712                 var elapsedTime = sw.Elapsed;
713 
714                 var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
715 
716                 ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
    ↪  Iterations per second), c: {3}", iterations, elapsedTime, (long)iterationsPerSecond,
    ↪  counter);
717             }
718 
719             File.Delete(tempFilename);
720         }*/
721 
722         [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
723         public static void TestRandomSearchAll()
724         {
725             using (var scope = new TempLinksTestScope())
726             {
727                 var links = scope.Links;
728                 ulong counter = 0;
729 
730                 var maxLink = links.Count();
731 
732                 var iterations = links.Count();
733 
734                 ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.",
                    ↪  links.Count());
735 
736                 var sw = Stopwatch.StartNew();
737 
738                 for (var i = iterations; i > 0; i--)
739                 {
740                     var linksAddressRange = new
                        ↪  Range<ulong>(_constants.PossibleInnerReferencesRange.Minimum, maxLink);
741 
742                     var source = RandomHelpers.Default.NextUInt64(linksAddressRange);
743                     var target = RandomHelpers.Default.NextUInt64(linksAddressRange);
744 
745                     counter += links.SearchOrDefault(source, target);
746                 }
747 
748                 var elapsedTime = sw.Elapsed;
749 
750                 var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
751 
752                 ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
                    ↪  Iterations per second), c: {3}",
753                     iterations, elapsedTime, (long)iterationsPerSecond, counter);
754             }
755         }
756 
757         [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
758         public static void TestEach()
759         {
```

```
760             using (var scope = new TempLinksTestScope())
761             {
762                 var links = scope.Links;
763 
764                 var counter = new Counter<IList<ulong>, ulong>(links.Constants.Continue);
765 
766                 ConsoleHelpers.Debug("Testing Each function.");
767 
768                 var sw = Stopwatch.StartNew();
769 
770                 links.Each(counter.IncrementAndReturnTrue);
771 
772                 var elapsedTime = sw.Elapsed;
773 
774                 var linksPerSecond = counter.Count / elapsedTime.TotalSeconds;
775 
776                 ConsoleHelpers.Debug("{0} Iterations of Each's handler function done in {1} ({2}
                    ↪  links per second)",
777                     counter, elapsedTime, (long)linksPerSecond);
778             }
779         }
780 
781         /*
782         [Fact]
783         public static void TestForeach()
784         {
785             var tempFilename = Path.GetTempFileName();
786 
787             using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
    ↪  DefaultLinksSizeStep))
788             {
789                 ulong counter = 0;
790 
791                 ConsoleHelpers.Debug("Testing foreach through links.");
792 
793                 var sw = Stopwatch.StartNew();
794 
795                 //foreach (var link in links)
796                 //{
797                 //    counter++;
798                 //}
799 
800                 var elapsedTime = sw.Elapsed;
801 
802                 var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
803 
804                 ConsoleHelpers.Debug("{0} Iterations of Foreach's handler block done in {1} ({2}
    ↪  links per second)", counter, elapsedTime, (long)linksPerSecond);
805             }
806 
807             File.Delete(tempFilename);
808         }
809         */
810 
811         /*
812         [Fact]
813         public static void TestParallelForeach()
814         {
815             var tempFilename = Path.GetTempFileName();
816 
817             using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
    ↪  DefaultLinksSizeStep))
818             {
819 
820                 long counter = 0;
821 
822                 ConsoleHelpers.Debug("Testing parallel foreach through links.");
823 
824                 var sw = Stopwatch.StartNew();
825 
826                 //Parallel.ForEach((IEnumerable<ulong>)links, x =>
827                 //{
828                 //    Interlocked.Increment(ref counter);
829                 //});
830 
831                 var elapsedTime = sw.Elapsed;
832 
833                 var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
834 
```

```
835                 ConsoleHelpers.Debug("{0} Iterations of Parallel Foreach's handler block done in
    ↪  {1} ({2} links per second)", counter, elapsedTime, (long)linksPerSecond);
836             }
837
838             File.Delete(tempFilename);
839         }
840         */
841
842         [Fact(Skip = "performance test")]
843         public static void Create64BillionLinks()
844         {
845             using (var scope = new TempLinksTestScope())
846             {
847                 var links = scope.Links;
848                 var linksBeforeTest = links.Count();
849
850                 long linksToCreate = 64 * 1024 * 1024 /
                    ↪  UInt64ResizableDirectMemoryLinks.LinkSizeInBytes;
851
852                 ConsoleHelpers.Debug("Creating {0} links.", linksToCreate);
853
854                 var elapsedTime = Performance.Measure(() =>
855                 {
856                     for (long i = 0; i < linksToCreate; i++)
857                     {
858                         links.Create();
859                     }
860                 });
861
862                 var linksCreated = links.Count() - linksBeforeTest;
863                 var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
864
865                 ConsoleHelpers.Debug("Current links count: {0}.", links.Count());
866
867                 ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
                    ↪  linksCreated, elapsedTime,
868                     (long)linksPerSecond);
869             }
870         }
871
872         [Fact(Skip = "performance test")]
873         public static void Create64BillionLinksInParallel()
874         {
875             using (var scope = new TempLinksTestScope())
876             {
877                 var links = scope.Links;
878                 var linksBeforeTest = links.Count();
879
880                 var sw = Stopwatch.StartNew();
881
882                 long linksToCreate = 64 * 1024 * 1024 /
                    ↪  UInt64ResizableDirectMemoryLinks.LinkSizeInBytes;
883
884                 ConsoleHelpers.Debug("Creating {0} links in parallel.", linksToCreate);
885
886                 Parallel.For(0, linksToCreate, x => links.Create());
887
888                 var elapsedTime = sw.Elapsed;
889
890                 var linksCreated = links.Count() - linksBeforeTest;
891                 var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
892
893                 ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
                    ↪  linksCreated, elapsedTime,
894                     (long)linksPerSecond);
895             }
896         }
897
898         [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
899         public static void TestDeletionOfAllLinks()
900         {
901             using (var scope = new TempLinksTestScope())
902             {
903                 var links = scope.Links;
904                 var linksBeforeTest = links.Count();
905
906                 ConsoleHelpers.Debug("Deleting all links");
907
908                 var elapsedTime = Performance.Measure(links.DeleteAll);
909
```

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

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

        #endregion
    }
}
```

./Platform.Data.Doublets.Tests/UnaryNumberConvertersTests.cs

```
using Xunit;
using Platform.Random;
using Platform.Data.Doublets.Numbers.Unary;

namespace Platform.Data.Doublets.Tests
{
    public static class UnaryNumberConvertersTests
    {
        [Fact]
        public static void ConvertersTest()
        {
            using (var scope = new TempLinksTestScope())
            {
                const int N = 10;
                var links = scope.Links;
                var meaningRoot = links.CreatePoint();
                var one = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
                var powerOf2ToUnaryNumberConverter = new
                ↪  PowerOf2ToUnaryNumberConverter<ulong>(links, one);
                var toUnaryNumberConverter = new AddressToUnaryNumberConverter<ulong>(links,
                ↪  powerOf2ToUnaryNumberConverter);
                var random = new System.Random(0);
                ulong[] numbers = new ulong[N];
                ulong[] unaryNumbers = new ulong[N];
                for (int i = 0; i < N; i++)
                {
                    numbers[i] = random.NextUInt64();
                    unaryNumbers[i] = toUnaryNumberConverter.Convert(numbers[i]);
                }
                var fromUnaryNumberConverterUsingOrOperation = new
                ↪  UnaryNumberToAddressOrOperationConverter<ulong>(links,
                ↪  powerOf2ToUnaryNumberConverter);
                var fromUnaryNumberConverterUsingAddOperation = new
                ↪  UnaryNumberToAddressAddOperationConverter<ulong>(links, one);
                for (int i = 0; i < N; i++)
                {
                    Assert.Equal(numbers[i],
                    ↪  fromUnaryNumberConverterUsingOrOperation.Convert(unaryNumbers[i]));
                    Assert.Equal(numbers[i],
                    ↪  fromUnaryNumberConverterUsingAddOperation.Convert(unaryNumbers[i]));
                }
            }
        }
    }
}
```

./Platform.Data.Doublets.Tests/UnicodeConvertersTests.cs

```
using Xunit;
using Platform.Interfaces;
using Platform.Memory;
using Platform.Reflection;
using Platform.Scopes;
using Platform.Data.Doublets.Incrementers;
using Platform.Data.Doublets.Numbers.Raw;
using Platform.Data.Doublets.Numbers.Unary;
using Platform.Data.Doublets.PropertyOperators;
using Platform.Data.Doublets.ResizableDirectMemory;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Doublets.Sequences.Indexes;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Data.Doublets.Unicode;

namespace Platform.Data.Doublets.Tests
{
    public static class UnicodeConvertersTests
```

```
19      {
20          [Fact]
21          public static void CharAndUnaryNumberUnicodeSymbolConvertersTest()
22          {
23              using (var scope = new TempLinksTestScope())
24              {
25                  var links = scope.Links;
26                  var meaningRoot = links.CreatePoint();
27                  var one = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
28                  var powerOf2ToUnaryNumberConverter = new
                    ↪  PowerOf2ToUnaryNumberConverter<ulong>(links, one);
29                  var addressToUnaryNumberConverter = new
                    ↪  AddressToUnaryNumberConverter<ulong>(links, powerOf2ToUnaryNumberConverter);
30                  var unaryNumberToAddressConverter = new
                    ↪  UnaryNumberToAddressOrOperationConverter<ulong>(links,
                    ↪  powerOf2ToUnaryNumberConverter);
31                  TestCharAndUnicodeSymbolConverters(links, meaningRoot,
                    ↪  addressToUnaryNumberConverter, unaryNumberToAddressConverter);
32              }
33          }
34
35          [Fact]
36          public static void CharAndRawNumberUnicodeSymbolConvertersTest()
37          {
38              using (var scope = new Scope<Types<HeapResizableDirectMemory,
                    ↪  ResizableDirectMemoryLinks<ulong>>>())
39              {
40                  var links = scope.Use<ILinks<ulong>>();
41                  var meaningRoot = links.CreatePoint();
42                  var addressToRawNumberConverter = new AddressToRawNumberConverter<ulong>();
43                  var rawNumberToAddressConverter = new RawNumberToAddressConverter<ulong>();
44                  TestCharAndUnicodeSymbolConverters(links, meaningRoot,
                    ↪  addressToRawNumberConverter, rawNumberToAddressConverter);
45              }
46          }
47
48          private static void TestCharAndUnicodeSymbolConverters(ILinks<ulong> links, ulong
            ↪  meaningRoot, IConverter<ulong> addressToNumberConverter, IConverter<ulong>
            ↪  numberToAddressConverter)
49          {
50              var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
51              var charToUnicodeSymbolConverter = new CharToUnicodeSymbolConverter<ulong>(links,
                ↪  addressToNumberConverter, unicodeSymbolMarker);
52              var originalCharacter = 'H';
53              var characterLink = charToUnicodeSymbolConverter.Convert(originalCharacter);
54              var unicodeSymbolCriterionMatcher = new UnicodeSymbolCriterionMatcher<ulong>(links,
                ↪  unicodeSymbolMarker);
55              var unicodeSymbolToCharConverter = new UnicodeSymbolToCharConverter<ulong>(links,
                ↪  numberToAddressConverter, unicodeSymbolCriterionMatcher);
56              var resultingCharacter = unicodeSymbolToCharConverter.Convert(characterLink);
57              Assert.Equal(originalCharacter, resultingCharacter);
58          }
59
60          [Fact]
61          public static void StringAndUnicodeSequenceConvertersTest()
62          {
63              using (var scope = new TempLinksTestScope())
64              {
65                  var links = scope.Links;
66
67                  var itself = links.Constants.Itself;
68
69                  var meaningRoot = links.CreatePoint();
70                  var unaryOne = links.CreateAndUpdate(meaningRoot, itself);
71                  var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, itself);
72                  var unicodeSequenceMarker = links.CreateAndUpdate(meaningRoot, itself);
73                  var frequencyMarker = links.CreateAndUpdate(meaningRoot, itself);
74                  var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot, itself);
75
76                  var powerOf2ToUnaryNumberConverter = new
                    ↪  PowerOf2ToUnaryNumberConverter<ulong>(links, unaryOne);
77                  var addressToUnaryNumberConverter = new
                    ↪  AddressToUnaryNumberConverter<ulong>(links, powerOf2ToUnaryNumberConverter);
78                  var charToUnicodeSymbolConverter = new
                    ↪  CharToUnicodeSymbolConverter<ulong>(links, addressToUnaryNumberConverter,
                    ↪  unicodeSymbolMarker);
79
```

```
80                  var unaryNumberToAddressConverter = new
                    ↪  UnaryNumberToAddressOrOperationConverter<ulong>(links,
                    ↪  powerOf2ToUnaryNumberConverter);
81                  var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
82                  var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
                    ↪  frequencyMarker, unaryOne, unaryNumberIncrementer);
83                  var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
                    ↪  frequencyPropertyMarker, frequencyMarker);
84                  var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
                    ↪  frequencyPropertyOperator, frequencyIncrementer);
85                  var linkToItsFrequencyNumberConverter = new
                    ↪  LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
                    ↪  unaryNumberToAddressConverter);
86                  var sequenceToItsLocalElementLevelsConverter = new
                    ↪  SequenceToItsLocalElementLevelsConverter<ulong>(links,
                    ↪  linkToItsFrequencyNumberConverter);
87                  var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                    ↪  sequenceToItsLocalElementLevelsConverter);
88
89                  var stringToUnicodeSequenceConverter = new
                    ↪  StringToUnicodeSequenceConverter<ulong>(links, charToUnicodeSymbolConverter,
                    ↪  index, optimalVariantConverter, unicodeSequenceMarker);
90
91                  var originalString = "Hello";
92
93                  var unicodeSequenceLink =
                    ↪  stringToUnicodeSequenceConverter.Convert(originalString);
94
95                  var unicodeSymbolCriterionMatcher = new
                    ↪  UnicodeSymbolCriterionMatcher<ulong>(links, unicodeSymbolMarker);
96                  var unicodeSymbolToCharConverter = new
                    ↪  UnicodeSymbolToCharConverter<ulong>(links, unaryNumberToAddressConverter,
                    ↪  unicodeSymbolCriterionMatcher);
97
98                  var unicodeSequenceCriterionMatcher = new
                    ↪  UnicodeSequenceCriterionMatcher<ulong>(links, unicodeSequenceMarker);
99
100                 var sequenceWalker = new LeveledSequenceWalker<ulong>(links,
                    ↪  unicodeSymbolCriterionMatcher.IsMatched);
101
102                 var unicodeSequenceToStringConverter = new
                    ↪  UnicodeSequenceToStringConverter<ulong>(links,
                    ↪  unicodeSequenceCriterionMatcher, sequenceWalker,
                    ↪  unicodeSymbolToCharConverter);
103
104                 var resultingString =
                    ↪  unicodeSequenceToStringConverter.Convert(unicodeSequenceLink);
105
106                 Assert.Equal(originalString, resultingString);
107             }
108         }
109     }
110 }
```

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