

# LinksPlatform's Platform.Data.Doublets Class Library

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

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  using System.Runtime.CompilerServices;
4
5  namespace Platform.Data.Doublets.Decorators
6  {
7      public class LinksCascadeUniquenessAndUsagesResolver<TLink> : LinksUniquenessResolver<TLink>
8      {
9          [MethodImpl(MethodImplOptions.AggressiveInlining)]
10         public LinksCascadeUniquenessAndUsagesResolver(ILinks<TLink> links) : base(links) { }
11
12         [MethodImpl(MethodImplOptions.AggressiveInlining)]
13         protected override TLink ResolveAddressChangeConflict(TLink oldLinkAddress, TLink
14             ↪ newLinkAddress)
15         {
16             // Use Facade (the last decorator) to ensure recursion working correctly
17             Facade.MergeUsages(oldLinkAddress, newLinkAddress);
18             return base.ResolveAddressChangeConflict(oldLinkAddress, newLinkAddress);
19         }
20     }

```

## ./Platform.Data.Doublets/Decorators/LinksCascadeUsagesResolver.cs

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Decorators
7  {
8      /// <remarks>
9      /// <para>Must be used in conjunction with NonNullContentsLinkDeletionResolver.</para>
10     /// <para>Должен использоваться вместе с NonNullContentsLinkDeletionResolver.</para>
11     /// </remarks>
12     public class LinksCascadeUsagesResolver<TLink> : LinksDecoratorBase<TLink>
13     {
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         public LinksCascadeUsagesResolver(ILinks<TLink> links) : base(links) { }
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         public override void Delete(ICollection<TLink> restrictions)
19         {
20             var linkIndex = restrictions[Constants.IndexPart];
21             // Use Facade (the last decorator) to ensure recursion working correctly
22             Facade.DeleteAllUsages(linkIndex);
23             Links.Delete(linkIndex);
24         }
25     }
26 }

```

## ./Platform.Data.Doublets/Decorators/LinksDecoratorBase.cs

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Decorators
8  {
9      public abstract class LinksDecoratorBase<TLink> : LinksOperatorBase<TLink>, ILinks<TLink>
10     {
11         private ILinks<TLink> _facade;
12
13         public LinksConstants<TLink> Constants { get; }
14
15         public ILinks<TLink> Facade
16         {
17             get => _facade;
18             set
19             {
20                 _facade = value;
21                 if (Links is LinksDecoratorBase<TLink> decorator)
22                 {
23                     decorator.Facade = value;
24                 }
25                 else if (Links is LinksDisposableDecoratorBase<TLink> disposableDecorator)
26                 {

```

```

27         disposableDecorator.Facade = value;
28     }
29 }
30
31 [MethodImpl(MethodImplOptions.AggressiveInlining)]
32 protected LinksDecoratorBase(ILinks<TLink> links) : base(links)
33 {
34     Constants = links.Constants;
35     Facade = this;
36 }
37
38 [MethodImpl(MethodImplOptions.AggressiveInlining)]
39 public virtual TLink Count(IList<TLink> restrictions) => Links.Count(restrictions);
40
41 [MethodImpl(MethodImplOptions.AggressiveInlining)]
42 public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
43     => Links.Each(handler, restrictions);
44
45 [MethodImpl(MethodImplOptions.AggressiveInlining)]
46 public virtual TLink Create(IList<TLink> restrictions) => Links.Create(restrictions);
47
48 [MethodImpl(MethodImplOptions.AggressiveInlining)]
49 public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution) =>
50     Links.Update(restrictions, substitution);
51
52 [MethodImpl(MethodImplOptions.AggressiveInlining)]
53 public virtual void Delete(IList<TLink> restrictions) => Links.Delete(restrictions);
54 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Disposables;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Decorators
9  {
10     public abstract class LinksDisposableDecoratorBase<TLink> : DisposableBase, ILinks<TLink>
11     {
12         private ILinks<TLink> _facade;
13
14         public LinksConstants<TLink> Constants { get; }
15
16         public ILinks<TLink> Links { get; }
17
18         public ILinks<TLink> Facade
19         {
20             get => _facade;
21             set
22             {
23                 _facade = value;
24                 if (Links is LinksDecoratorBase<TLink> decorator)
25                 {
26                     decorator.Facade = value;
27                 }
28                 else if (Links is LinksDisposableDecoratorBase<TLink> disposableDecorator)
29                 {
30                     disposableDecorator.Facade = value;
31                 }
32             }
33         }
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected LinksDisposableDecoratorBase(ILinks<TLink> links)
37         {
38             Links = links;
39             Constants = links.Constants;
40             Facade = this;
41         }
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         public virtual TLink Count(IList<TLink> restrictions) => Links.Count(restrictions);
45
46         [MethodImpl(MethodImplOptions.AggressiveInlining)]
47         public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
48             => Links.Each(handler, restrictions);

```

```

48     [MethodImpl(MethodImplOptions.AggressiveInlining)]
49     public virtual TLink Create(IList<TLink> restrictions) => Links.Create(restrictions);
50
51     [MethodImpl(MethodImplOptions.AggressiveInlining)]
52     public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution) =>
53         ↳ Links.Update(restrictions, substitution);
54
55     [MethodImpl(MethodImplOptions.AggressiveInlining)]
56     public virtual void Delete(IList<TLink> restrictions) => Links.Delete(restrictions);
57
58     protected override bool AllowMultipleDisposeCalls => true;
59
60     protected override void Dispose(bool manual, bool wasDisposed)
61     {
62         if (!wasDisposed)
63         {
64             Links.DisposeIfPossible();
65         }
66     }
67 }
68 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Decorators
8  {
9      // TODO: Make LinksExternalReferenceValidator. A layer that checks each link to exist or to
10     ↳ be external (hybrid link's raw number).
11     public class LinksInnerReferenceExistenceValidator<TLink> : LinksDecoratorBase<TLink>
12     {
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public LinksInnerReferenceExistenceValidator(ILinks<TLink> links) : base(links) { }
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         public override TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
18         {
19             Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
20             return Links.Each(handler, restrictions);
21         }
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
25         {
26             // TODO: Possible values: null, ExistentLink or NonExistentHybrid(ExternalReference)
27             Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
28             Links.EnsureInnerReferenceExists(substitution, nameof(substitution));
29             return Links.Update(restrictions, substitution);
30         }
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         public override void Delete(IList<TLink> restrictions)
34         {
35             var link = restrictions[Constants.IndexPart];
36             Links.EnsureLinkExists(link, nameof(link));
37             Links.Delete(link);
38         }
39     }
40 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Decorators
8  {
9      public class LinksItselfConstantToSelfReferenceResolver<TLink> : LinksDecoratorBase<TLink>
10     {
11         private static readonly EqualityComparer<TLink> _equalityComparer =
12             ↳ EqualityComparer<TLink>.Default;

```

```

13     [MethodImpl(MethodImplOptions.AggressiveInlining)]
14     public LinksItselfConstantToSelfReferenceResolver(ILinks<TLink> links) : base(links) { }
15
16     [MethodImpl(MethodImplOptions.AggressiveInlining)]
17     public override TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
18     {
19         var constants = Constants;
20         var itselfConstant = constants.Itself;
21         var indexPartConstant = constants.IndexPart;
22         var sourcePartConstant = constants.SourcePart;
23         var targetPartConstant = constants.TargetPart;
24         var restrictionsCount = restrictions.Count;
25         if (!_equalityComparer.Equals(constants.Any, itselfConstant)
26             && (((restrictionsCount > indexPartConstant) &&
27                 ↪ _equalityComparer.Equals(restrictions[indexPartConstant], itselfConstant))
28                 || ((restrictionsCount > sourcePartConstant) &&
29                     ↪ _equalityComparer.Equals(restrictions[sourcePartConstant], itselfConstant))
30                 || ((restrictionsCount > targetPartConstant) &&
31                     ↪ _equalityComparer.Equals(restrictions[targetPartConstant], itselfConstant))))
32         {
33             // Itself constant is not supported for Each method right now, skipping execution
34             return constants.Continue;
35         }
36         return Links.Each(handler, restrictions);
37     }
38
39     [MethodImpl(MethodImplOptions.AggressiveInlining)]
40     public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution) =>
41     ↪ Links.Update(restrictions, Links.ResolveConstantAsSelfReference(Constants.Itself,
42     ↪ restrictions, substitution));
43 }

```

#### ./Platform.Data.Doublets/Decorators/LinksNonExistentDependenciesCreator.cs

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Decorators
7  {
8      /// <remarks>
9      /// Not practical if newSource and newTarget are too big.
10     /// To be able to use practical version we should allow to create link at any specific
11     ↪ location inside ResizableDirectMemoryLinks.
12     /// This in turn will require to implement not a list of empty links, but a list of ranges
13     ↪ to store it more efficiently.
14     /// </remarks>
15     public class LinksNonExistentDependenciesCreator<TLink> : LinksDecoratorBase<TLink>
16     {
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         public LinksNonExistentDependenciesCreator(ILinks<TLink> links) : base(links) { }
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
22         {
23             var constants = Constants;
24             Links.EnsureCreated(substitution[constants.SourcePart],
25             ↪ substitution[constants.TargetPart]);
26             return Links.Update(restrictions, substitution);
27         }
28     }
29 }

```

#### ./Platform.Data.Doublets/Decorators/LinksNullConstantToSelfReferenceResolver.cs

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Decorators
7  {
8     public class LinksNullConstantToSelfReferenceResolver<TLink> : LinksDecoratorBase<TLink>
9     {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public LinksNullConstantToSelfReferenceResolver(ILinks<TLink> links) : base(links) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public override TLink Create(IList<TLink> restrictions)

```

```

15     {
16         var link = Links.Create();
17         return Links.Update(link, link, link);
18     }
19
20     [MethodImpl(MethodImplOptions.AggressiveInlining)]
21     public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution) =>
22     ↪ Links.Update(restrictions, Links.ResolveConstantAsSelfReference(Constants.Null,
23     ↪ restrictions, substitution));
24 }

```

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

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Decorators
7  {
8      public class LinksUniquenessResolver<TLink> : LinksDecoratorBase<TLink>
9      {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11         ↪ EqualityComparer<TLink>.Default;
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public LinksUniquenessResolver(ILinks<TLink> links) : base(links) { }
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
18         {
19             var newLinkAddress = Links.SearchOrDefault(substitution[Constants.SourcePart],
20             ↪ substitution[Constants.TargetPart]);
21             if (_equalityComparer.Equals(newLinkAddress, default))
22             {
23                 return Links.Update(restrictions, substitution);
24             }
25             return ResolveAddressChangeConflict(restrictions[Constants.IndexPart],
26             ↪ newLinkAddress);
27         }
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         protected virtual TLink ResolveAddressChangeConflict(TLink oldLinkAddress, TLink
31         ↪ newLinkAddress)
32         {
33             if (!_equalityComparer.Equals(oldLinkAddress, newLinkAddress) &&
34             ↪ Links.Exists(oldLinkAddress))
35             {
36                 Facade.Delete(oldLinkAddress);
37             }
38             return newLinkAddress;
39         }
40     }
41 }

```

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

```

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

```

## ./Platform.Data.Doublets/Decorators/LinksUsagesValidator.cs

```
1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Decorators
7 {
8     public class LinksUsagesValidator<TLink> : LinksDecoratorBase<TLink>
9     {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public LinksUsagesValidator(ILinks<TLink> links) : base(links) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
15         {
16             Links.EnsureNoUsages(restrictions[Constants.IndexPart]);
17             return Links.Update(restrictions, substitution);
18         }
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         public override void Delete(IList<TLink> restrictions)
22         {
23             var link = restrictions[Constants.IndexPart];
24             Links.EnsureNoUsages(link);
25             Links.Delete(link);
26         }
27     }
28 }
```

## ./Platform.Data.Doublets/Decorators/NonNullContentsLinkDeletionResolver.cs

```
1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Decorators
7 {
8     public class NonNullContentsLinkDeletionResolver<TLink> : LinksDecoratorBase<TLink>
9     {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public NonNullContentsLinkDeletionResolver(ILinks<TLink> links) : base(links) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public override void Delete(IList<TLink> restrictions)
15         {
16             var linkIndex = restrictions[Constants.IndexPart];
17             Links.EnforceResetValues(linkIndex);
18             Links.Delete(linkIndex);
19         }
20     }
21 }
```

## ./Platform.Data.Doublets/Decorators/UInt64Links.cs

```
1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Decorators
7 {
8     /// <summary>
9     /// Представляет объект для работы с базой данных (файлом) в формате Links (массива связей).
10     /// </summary>
11     /// <remarks>
12     /// Возможные оптимизации:
13     /// Объединение в одном поле Source и Target с уменьшением до 32 бит.
14     ///     + меньше объём БД
15     ///     - меньше производительность
16     ///     - больше ограничение на количество связей в БД)
17     /// Ленивое хранение размеров поддеревьев (расчитываемое по мере использования БД)
18     ///     + меньше объём БД
19     ///     - больше сложность
20     ///
21     /// Текущее теоретическое ограничение на индекс связи, из-за использования 5 бит в размере
22     ///     ↳ поддеревьев для AVL баланса и флагов нитей: 2 в степени(64 минус 5 равно 59 ) равно 576
23     ///     ↳ 460 752 303 423 488
24     /// Желательно реализовать поддержку переключения между деревьями и битовыми индексами
25     ///     ↳ (битовыми строками) - вариант матрицы (выстраиваемой 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 =
22          ↳ EqualityComparer<TLink>.Default;
23
24      public UniLinks(ILinks<TLink> links) : base(links) { }
25
26      private struct Transition
27      {
28          public IList<TLink> Before;
29          public IList<TLink> After;
30
31          public Transition(IList<TLink> before, IList<TLink> after)
32          {
33              Before = before;
34              After = after;
35          }
36      }
37
38      //public static readonly TLink NullConstant = Use<LinksConstants<TLink>>.Single.Null;
39      //public static readonly IReadOnlyList<TLink> NullLink = new
40      ↳ ReadOnlyCollection<TLink>(new List<TLink> { NullConstant, NullConstant, NullConstant
41      ↳ });
42
43      // TODO: Подумать о том, как реализовать древовидный Restriction и Substitution
44      ↳ (Links-Expression)
45      public TLink Trigger(IList<TLink> restriction, Func<IList<TLink>, IList<TLink>, TLink>
46      ↳ matchedHandler, IList<TLink> substitution, Func<IList<TLink>, IList<TLink>, TLink>
47      ↳ substitutedHandler)
48      {
49          ///List<Transition> transitions = null;
50          ///if (!restriction.IsNullOrEmpty())
51          ///{
52          ///    // Есть причина делать проход (чтение)
53          ///    if (matchedHandler != null)
54          ///    {
55          ///        if (!substitution.IsNullOrEmpty())
56          ///        {
57          ///            // restriction => { 0, 0, 0 } | { 0 } // Create
58          ///            // substitution => { itself, 0, 0 } | { itself, itself, itself } //
59          ↳ Create / Update
60          ///            // substitution => { 0, 0, 0 } | { 0 } // Delete
61          ///            transitions = new List<Transition>();
62          ///            if (Equals(substitution[Constants.IndexPart], Constants.Null))
63          ///            {
64          ///                // If index is Null, that means we always ignore every other
65          ↳ value (they are also Null by definition)
66          ///                var matchDecision = matchedHandler(, NullLink);
67          ///                if (Equals(matchDecision, Constants.Break))
68          ///                    return false;
69          ///                if (!Equals(matchDecision, Constants.Skip))
70          ///                    transitions.Add(new Transition(matchedLink, newValue));
71          ///            }
72          ///            else
73          ///            {
74          ///                Func<T, bool> handler;
75          ///                handler = link =>
76          ///                {
77          ///                    var matchedLink = Memory.GetLinkValue(link);
78          ///                    var newValue = Memory.GetLinkValue(link);
79          ///                    newValue[Constants.IndexPart] = Constants.Itself;
80          ///                    newValue[Constants.SourcePart] =
81          ↳ Equals(substitution[Constants.SourcePart], Constants.Itself) ?
82          ↳ matchedLink[Constants.IndexPart] : substitution[Constants.SourcePart];
83          ///                    newValue[Constants.TargetPart] =
84          ↳ Equals(substitution[Constants.TargetPart], Constants.Itself) ?
85          ↳ matchedLink[Constants.IndexPart] : substitution[Constants.TargetPart];
86          ///                    var matchDecision = matchedHandler(matchedLink, newValue);
87          ///                    if (Equals(matchDecision, Constants.Break))
88          ///                        return false;
89          ///                    if (!Equals(matchDecision, Constants.Skip))
90          ///                        transitions.Add(new Transition(matchedLink, newValue));
91          ///                    return true;
92          ///                };
93          ///            }
94          ///            if (!Memory.Each(handler, restriction))
95          ///                return Constants.Break;
96          ///        }
97      }

```



```

84         ////    }
85         ////    else
86         ////    {
87         ////        Func<T, bool> handler = link =>
88         ////        {
89         ////            var matchedLink = Memory.GetLinkValue(link);
90         ////            var matchDecision = matchedHandler(matchedLink, matchedLink);
91         ////            return !Equals(matchDecision, Constants.Break);
92         ////        };
93         ////        if (!Memory.Each(handler, restriction))
94         ////            return Constants.Break;
95         ////    }
96         ////    }
97         ////    else
98         ////    {
99         ////        if (substitution != null)
100        ////        {
101        ////            transitions = new List<IList<T>>();
102        ////            Func<T, bool> handler = link =>
103        ////            {
104        ////                var matchedLink = Memory.GetLinkValue(link);
105        ////                transitions.Add(matchedLink);
106        ////                return true;
107        ////            };
108        ////            if (!Memory.Each(handler, restriction))
109        ////                return Constants.Break;
110        ////        }
111        ////        else
112        ////        {
113        ////            return Constants.Continue;
114        ////        }
115        ////    }
116        ////}
117        ////if (substitution != null)
118        ////{
119        ////    // Есть причина делать замену (запись)
120        ////    if (substitutedHandler != null)
121        ////    {
122        ////    }
123        ////    else
124        ////    {
125        ////    }
126        ////}
127        ////return Constants.Continue;
128
129        //if (restriction.IsNullOrEmpty()) // Create
130        //{
131        //    substitution[Constants.IndexPart] = Memory.AllocateLink();
132        //    Memory.SetLinkValue(substitution);
133        //}
134        //else if (substitution.IsNullOrEmpty()) // Delete
135        //{
136        //    Memory.FreeLink(restriction[Constants.IndexPart]);
137        //}
138        //else if (restriction.EqualTo(substitution)) // Read or ("repeat" the state) // Each
139        //{
140        //    // No need to collect links to list
141        //    // Skip == Continue
142        //    // No need to check substitutedHandler
143        //    if (!Memory.Each(link => !Equals(matchedHandler(Memory.GetLinkValue(link)),
144        //        ↪ Constants.Break), restriction))
145        //        return Constants.Break;
146        //}
147        //else // Update
148        //{
149        //    //List<IList<T>> matchedLinks = null;
150        //    if (matchedHandler != null)
151        //    {
152        //        matchedLinks = new List<IList<T>>();
153        //        Func<T, bool> handler = link =>
154        //        {
155        //            var matchedLink = Memory.GetLinkValue(link);
156        //            var matchDecision = matchedHandler(matchedLink);
157        //            if (Equals(matchDecision, Constants.Break))
158        //                return false;
159        //            if (!Equals(matchDecision, Constants.Skip))
160        //                matchedLinks.Add(matchedLink);
161        //            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
175         //             substitution handling.
176         //             var substitutedDecision = substitutedHandler(matchedLink,
177         //             ↪ newValue);
178         //             if (Equals(substitutedDecision, Constants.Break))
179         //                 return Constants.Break;
180         //             if (Equals(substitutedDecision, Constants.Continue))
181         //             {
182         //                 // Actual update here
183         //                 Memory.SetLinkValue(newValue);
184         //             }
185         //             if (Equals(substitutedDecision, Constants.Skip))
186         //             {
187         //                 // Cancel the update. TODO: decide use separate Cancel
188         //                 ↪ constant or Skip is enough?
189         //             }
190         //         }
191         //     }
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1000        // }

```

```

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),
244                 ↪ Constants.Break))
245             {
246                 return Constants.Break;
247             }
248             var after = ArrayPool<TLink>.Empty;
249             Links.Update(linkToDelete, Constants.Null, Constants.Null);
250             Links.Delete(linkToDelete);
251             if (matchHandler != null)
252             {
253                 return substitutionHandler(before, after);
254             }
255             return Constants.Continue;
256         }
257         else
258         {
259             throw new NotSupportedException();
260         }
261     }
262     else // Replace / Update
263     {
264         if (patternOrCondition.Count == 1) //-V3125
265         {
266             var linkToUpdate = patternOrCondition[0];
267             var before = Links.GetLink(linkToUpdate);
268             if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
269                 ↪ Constants.Break))
270             {
271                 return Constants.Break;
272             }
273             var after = (IList<TLink>)substitution.ToArray(); //-V3125
274             if (_equalityComparer.Equals(after[0], default))
275             {
276                 after[0] = linkToUpdate;
277             }
278             if (substitution.Count == 1)
279             {
280                 if (!_equalityComparer.Equals(substitution[0], linkToUpdate))
281                 {
282                     after = Links.GetLink(substitution[0]);
283                     Links.Update(linkToUpdate, Constants.Null, Constants.Null);
284                     Links.Delete(linkToUpdate);
285                 }
286             }
287             else if (substitution.Count == 3)
288             {
289                 //Links.Update(after);
290             }
291             else
292             {
293                 throw new NotSupportedException();
294             }
295             if (matchHandler != null)
296             {
297                 return substitutionHandler(before, after);
298             }
299             return Constants.Continue;
300         }
301         else
302         {
303             throw new NotSupportedException();
304         }
305     }
306 }

```

/// <remarks>

```

307     /// IList[IList[IList[T]]]
308     /// |         |         |         |
309     /// |         |         |-----|
310     /// |         |         |   link   |
311     /// |         |         |-----|
312     /// |         |         |   change  |
313     /// |         |         |-----|
314     /// |         |         |   changes  |
315     /// </remarks>
316     public IList<IList<IList<TLink>>> Trigger(IList<TLink> condition, IList<TLink>
    ↪ substitution)
317     {
318         var changes = new List<IList<IList<TLink>>>();
319         Trigger(condition, AlwaysContinue, substitution, (before, after) =>
320         {
321             var change = new[] { before, after };
322             changes.Add(change);
323             return Constants.Continue;
324         });
325         return changes;
326     }
327
328     private TLink AlwaysContinue(IList<TLink> linkToMatch) => Constants.Continue;
329 }
330 }

```

#### ./Platform.Data.Doublets/DoubletComparer.cs

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets
7  {
8      /// <remarks>
9      /// TODO: Может стоит попробовать ref во всех методах (IRefEqualityComparer)
10     /// 2x faster with comparer
11     /// </remarks>
12     public class DoubletComparer<T> : IEqualityComparer<Doublet<T>>
13     {
14         public static readonly DoubletComparer<T> Default = new DoubletComparer<T>();
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         public bool Equals(Doublet<T> x, Doublet<T> y) => x.Equals(y);
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         public int GetHashCode(Doublet<T> obj) => obj.GetHashCode();
21     }
22 }

```

#### ./Platform.Data.Doublets/Doublet.cs

```

1  using System;
2  using System.Collections.Generic;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets
7  {
8      public struct Doublet<T> : IEquatable<Doublet<T>>
9      {
10         private static readonly EqualityComparer<T> _equalityComparer =
    ↪ EqualityComparer<T>.Default;
11
12         public T Source { get; set; }
13         public T Target { get; set; }
14
15         public Doublet(T source, T target)
16         {
17             Source = source;
18             Target = target;
19         }
20
21         public override string ToString() => $"{Source}->{Target}";
22
23         public bool Equals(Doublet<T> other) => _equalityComparer.Equals(Source, other.Source)
    ↪ && _equalityComparer.Equals(Target, other.Target);
24
25         public override bool Equals(object obj) => obj is Doublet<T> doublet ?
    ↪ base.Equals(doublet) : false;

```

```

26
27     public override int GetHashCode() => (Source, Target).GetHashCode();
28 }
29 }

```

# ./Platform.Data.Doublets/Hybrid.cs

```

1  using System;
2  using System.Reflection;
3  using System.Reflection.Emit;
4  using Platform.Reflection;
5  using Platform.Converters;
6  using Platform.Exceptions;
7
8  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets
11 {
12     public struct Hybrid<T>
13     {
14         private static readonly Func<object, T> _absAndConvert;
15         private static readonly Func<object, T> _absAndNegateAndConvert;
16
17         static Hybrid()
18         {
19             _absAndConvert = DelegateHelpers.Compile<Func<object, T>>(emitter =>
20             {
21                 Ensure.Always.IsUnsignedInteger<T>();
22                 emitter.LoadArgument(0);
23                 var signedVersion = NumericType<T>.SignedVersion;
24                 var signedVersionField =
25                     ↳ typeof(NumericType<T>).GetTypeInfo().GetField("SignedVersion",
26                     ↳ BindingFlags.Static | BindingFlags.Public);
27                 //emitter.LoadField(signedVersionField);
28                 emitter.Emit(OpCodes.Ldsfld, signedVersionField);
29                 var changeTypeMethod = typeof(Convert).GetTypeInfo().GetMethod("ChangeType",
30                     ↳ Types<object, Type>.Array);
31                 emitter.Call(changeTypeMethod);
32                 emitter.UnboxValue(signedVersion);
33                 var absMethod = typeof(Math).GetTypeInfo().GetMethod("Abs", new[] {
34                     ↳ signedVersion });
35                 emitter.Call(absMethod);
36                 var unsignedMethod = typeof(To).GetTypeInfo().GetMethod("Unsigned", new[] {
37                     ↳ signedVersion });
38                 emitter.Call(unsignedMethod);
39                 emitter.Return();
40             });
41             _absAndNegateAndConvert = DelegateHelpers.Compile<Func<object, T>>(emitter =>
42             {
43                 Ensure.Always.IsUnsignedInteger<T>();
44                 emitter.LoadArgument(0);
45                 var signedVersion = NumericType<T>.SignedVersion;
46                 var signedVersionField =
47                     ↳ typeof(NumericType<T>).GetTypeInfo().GetField("SignedVersion",
48                     ↳ BindingFlags.Static | BindingFlags.Public);
49                 //emitter.LoadField(signedVersionField);
50                 emitter.Emit(OpCodes.Ldsfld, signedVersionField);
51                 var changeTypeMethod = typeof(Convert).GetTypeInfo().GetMethod("ChangeType",
52                     ↳ Types<object, Type>.Array);
53                 emitter.Call(changeTypeMethod);
54                 emitter.UnboxValue(signedVersion);
55                 var absMethod = typeof(Math).GetTypeInfo().GetMethod("Abs", new[] {
56                     ↳ signedVersion });
57                 emitter.Call(absMethod);
58                 var negateMethod = typeof(Platform.Numbers.Math).GetTypeInfo().GetMethod("Negate",
59                     ↳ ").MakeGenericMethod(signedVersion);
60                 emitter.Call(negateMethod);
61                 var unsignedMethod = typeof(To).GetTypeInfo().GetMethod("Unsigned", new[] {
62                     ↳ signedVersion });
63                 emitter.Call(unsignedMethod);
64                 emitter.Return();
65             });
66         }
67
68         public readonly T Value;
69         public bool IsNothing => Convert.ToInt64(To.Signed(Value)) == 0;
70         public bool IsInternal => Convert.ToInt64(To.Signed(Value)) > 0;
71         public bool IsExternal => Convert.ToInt64(To.Signed(Value)) < 0;
72         public long AbsoluteValue =>
73             ↳ Platform.Numbers.Math.Abs(Convert.ToInt64(To.Signed(Value)));
74     }
75 }

```

```

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

```
1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  using System.Collections.Generic;
4
5  namespace Platform.Data.Doublets
6  {
7      public interface ILinks<TLink> : ILinks<TLink, LinksConstants<TLink>>
8      {
9      }
10 }
```

./Platform.Data.Doublets/ILinksExtensions.cs

```
1  using System;
2  using System.Collections;
3  using System.Collections.Generic;
4  using System.Linq;
5  using System.Runtime.CompilerServices;
6  using Platform.Ranges;
7  using Platform.Collections.Arrays;
8  using Platform.Numbers;
9  using Platform.Random;
10 using Platform.Setters;
11 using Platform.Data.Exceptions;
12 using Platform.Data.Doublets.Decorators;
13
14 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
15
16 namespace Platform.Data.Doublets
17 {
18     public static class ILinksExtensions
19     {
20         public static void RunRandomCreations<TLink>(this ILinks<TLink> links, long
21             ↳ amountOfCreations)
22         {
23             for (long i = 0; i < amountOfCreations; i++)
24             {
25                 var linksAddressRange = new Range<ulong>(0, (Integer<TLink>)links.Count());
26                 Integer<TLink> source = RandomHelpers.Default.NextUInt64(linksAddressRange);
27                 Integer<TLink> target = RandomHelpers.Default.NextUInt64(linksAddressRange);
28                 links.CreateAndUpdate(source, target);
29             }
30
31             public static void RunRandomSearches<TLink>(this ILinks<TLink> links, long
32                 ↳ amountOfSearches)
33             {
34                 for (long i = 0; i < amountOfSearches; i++)
35                 {
36                     var linkAddressRange = new Range<ulong>(1, (Integer<TLink>)links.Count());
37                     Integer<TLink> source = RandomHelpers.Default.NextUInt64(linkAddressRange);
38                     Integer<TLink> target = RandomHelpers.Default.NextUInt64(linkAddressRange);
39                     links.SearchOrDefault(source, target);
40                 }
41
42                 public static void RunRandomDeletions<TLink>(this ILinks<TLink> links, long
43                     ↳ amountOfDeletions)
44                 {
45                     var min = (ulong)amountOfDeletions > (Integer<TLink>)links.Count() ? 1 :
46                         ↳ (Integer<TLink>)links.Count() - (ulong)amountOfDeletions;
47                     for (long i = 0; i < amountOfDeletions; i++)
48                     {
49                         var linksAddressRange = new Range<ulong>(min, (Integer<TLink>)links.Count());
50                         Integer<TLink> link = RandomHelpers.Default.NextUInt64(linksAddressRange);
51                         links.Delete(link);
52                         if ((Integer<TLink>)links.Count() < min)
53                         {
54                             break;
55                         }
56                     }
57
58                     public static void Delete<TLink>(this ILinks<TLink> links, TLink linkToDelete) =>
59                         ↳ links.Delete(new LinkAddress<TLink>(linkToDelete));
60
61                     /// <remarks>
62                     /// TODO: Возможно есть очень простой способ это сделать.
63                     /// (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));

```



```

132         return false;
133     }
134     current = next;
135 }
136 return true;
137 }
138
139 /// <remarks>
140 /// Может потребовать дополнительного стека для PathElement's при использовании
141   ↳ SequenceWalker.
142 /// </remarks>
143 public static TLink GetByKeyes<TLink>(this ILinks<TLink> links, TLink root, params int[]
144   ↳ path)
145 {
146     links.EnsureLinkExists(root, "root");
147     var currentLink = root;
148     for (var i = 0; i < path.Length; i++)
149     {
150         currentLink = links.GetLink(currentLink)[path[i]];
151     }
152     return currentLink;
153 }
154
155 public static TLink GetSquareMatrixSequenceElementByIndex<TLink>(this ILinks<TLink>
156   ↳ links, TLink root, ulong size, ulong index)
157 {
158     var constants = links.Constants;
159     var source = constants.SourcePart;
160     var target = constants.TargetPart;
161     if (!Platform.Numbers.Math.IsPowerOfTwo(size))
162     {
163         throw new ArgumentOutOfRangeException(nameof(size), "Sequences with sizes other
164           ↳ than powers of two are not supported.");
165     }
166     var path = new BitArray(BitConverter.GetBytes(index));
167     var length = Bit.GetLowestPosition(size);
168     links.EnsureLinkExists(root, "root");
169     var currentLink = root;
170     for (var i = length - 1; i >= 0; i--)
171     {
172         currentLink = links.GetLink(currentLink)[path[i] ? target : source];
173     }
174     return currentLink;
175 }
176
177 #endregion
178
179 /// <summary>
180 /// Возвращает индекс указанной связи.
181 /// </summary>
182 /// <param name="links">Хранилище связей.</param>
183 /// <param name="link">Связь представленная списком, состоящим из её адреса и
184   ↳ содержимого.</param>
185 /// <returns>Индекс начальной связи для указанной связи.</returns>
186 [MethodImpl(MethodImplOptions.AggressiveInlining)]
187 public static TLink GetIndex<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
188   ↳ link[links.Constants.IndexPart];
189
190 /// <summary>
191 /// Возвращает индекс начальной (Source) связи для указанной связи.
192 /// </summary>
193 /// <param name="links">Хранилище связей.</param>
194 /// <param name="link">Индекс связи.</param>
195 /// <returns>Индекс начальной связи для указанной связи.</returns>
196 [MethodImpl(MethodImplOptions.AggressiveInlining)]
197 public static TLink GetSource<TLink>(this ILinks<TLink> links, TLink link) =>
198   ↳ links.GetLink(link)[links.Constants.SourcePart];
199
200 /// <summary>
201 /// Возвращает индекс начальной (Source) связи для указанной связи.
202 /// </summary>
203 /// <param name="links">Хранилище связей.</param>
204 /// <param name="link">Связь представленная списком, состоящим из её адреса и
205   ↳ содержимого.</param>
206 /// <returns>Индекс начальной связи для указанной связи.</returns>
207 [MethodImpl(MethodImplOptions.AggressiveInlining)]
208 public static TLink GetSource<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
209   ↳ 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) =>
210     ↪ links.GetLink(link)[links.Constants.TargetPart];
211
212 /// <summary>
213 /// Возвращает индекс конечной (Target) связи для указанной связи.
214 /// </summary>
215 /// <param name="links">Хранилище связей.</param>
216 /// <param name="link">Связь представленная списком, состоящим из её адреса и
217     ↪ содержимого.</param>
218 /// <returns>Индекс конечной связи для указанной связи.</returns>
219 [MethodImpl(MethodImplOptions.AggressiveInlining)]
220 public static TLink GetTarget<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
221     ↪ link[links.Constants.TargetPart];
222
223 /// <summary>
224 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
225     ↪ (handler) для каждой подходящей связи.
226 /// </summary>
227 /// <param name="links">Хранилище связей.</param>
228 /// <param name="handler">Обработчик каждой подходящей связи.</param>
229 /// <param name="restrictions">Ограничения на содержимое связей. Каждое ограничение
230     ↪ может иметь значения: Constants.Null - 0-я связь, обозначающая ссылку на пустоту,
231     ↪ Any - отсутствие ограничения, 1..∞ конкретный адрес связи.</param>
232 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
233     ↪ случае.</returns>
234 [MethodImpl(MethodImplOptions.AggressiveInlining)]
235 public static bool Each<TLink>(this ILinks<TLink> links, Func<IList<TLink>, TLink>
236     ↪ handler, params TLink[] restrictions)
237     => EqualityComparer<TLink>.Default.Equals(links.Each(handler, restrictions),
238     ↪ links.Constants.Continue);
239
240 /// <summary>
241 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
242     ↪ (handler) для каждой подходящей связи.
243 /// </summary>
244 /// <param name="links">Хранилище связей.</param>
245 /// <param name="source">Значение, определяющее соответствующие шаблону связи.
246     ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве начала,
247     ↪ Constants.Any - любое начало, 1..∞ конкретное начало)</param>
248 /// <param name="target">Значение, определяющее соответствующие шаблону связи.
249     ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве конца,
250     ↪ Constants.Any - любой конец, 1..∞ конкретный конец)</param>
251 /// <param name="handler">Обработчик каждой подходящей связи.</param>
252 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
253     ↪ случае.</returns>
254 [MethodImpl(MethodImplOptions.AggressiveInlining)]
255 public static bool Each<TLink>(this ILinks<TLink> links, TLink source, TLink target,
256     ↪ Func<TLink, bool> handler)
257 {
258     var constants = links.Constants;
259     return links.Each(link => handler(link[constants.IndexPart]) ? constants.Continue :
260     ↪ constants.Break, constants.Any, source, target);
261 }
262
263 /// <summary>
264 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
265     ↪ (handler) для каждой подходящей связи.
266 /// </summary>
267 /// <param name="links">Хранилище связей.</param>
268 /// <param name="source">Значение, определяющее соответствующие шаблону связи.
269     ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве начала,
270     ↪ Constants.Any - любое начало, 1..∞ конкретное начало)</param>
271 /// <param name="target">Значение, определяющее соответствующие шаблону связи.
272     ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве конца,
273     ↪ Constants.Any - любой конец, 1..∞ конкретный конец)</param>
274 /// <param name="handler">Обработчик каждой подходящей связи.</param>
275 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
276     ↪ 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 EnsureLinkExists<TLink>(this ILinks<TLink> links, IList<TLink>
    ↳ restrictions)
302 {
303     for (var i = 0; i < restrictions.Count; i++)
304     {
305         if (!links.Exists(restrictions[i]))
306         {
307             throw new ArgumentLinkDoesNotExistsException<TLink>(restrictions[i],
                ↳ $"sequence[{i}]");
308         }
309     }
310 }
311
312 [MethodImpl(MethodImplOptions.AggressiveInlining)]
313 public static void EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links, TLink
    ↳ reference, string argumentName)
314 {
315     if (links.Constants.IsInnerReference(reference) && !links.Exists(reference))
316     {
317         throw new ArgumentLinkDoesNotExistsException<TLink>(reference, argumentName);
318     }
319 }
320
321 [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

322 public static void EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links,
    ↳ IList<TLink> restrictions, string argumentName)
323 {
324     for (int i = 0; i < restrictions.Count; i++)
325     {
326         links.EnsureInnerReferenceExists(restrictions[i], argumentName);
327     }
328 }
329
330 [MethodImpl(MethodImplOptions.AggressiveInlining)]
331 public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, IList<TLink>
    ↳ restrictions)
332 {
333     var equalityComparer = EqualityComparer<TLink>.Default;
334     var any = links.Constants.Any;
335     for (var i = 0; i < restrictions.Count; i++)
336     {
337         if (!equalityComparer.Equals(restrictions[i], any) &&
            ↳ !links.Exists(restrictions[i]))
338         {
339             throw new ArgumentLinkDoesNotExistsException<TLink>(restrictions[i],
                ↳ $"{sequence[{i}]"}");
340         }
341     }
342 }
343
344 [MethodImpl(MethodImplOptions.AggressiveInlining)]
345 public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, TLink link,
    ↳ string argumentName)
346 {
347     var equalityComparer = EqualityComparer<TLink>.Default;
348     if (!equalityComparer.Equals(link, links.Constants.Any) && !links.Exists(link))
349     {
350         throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
351     }
352 }
353
354 [MethodImpl(MethodImplOptions.AggressiveInlining)]
355 public static void EnsureLinkIsItselfOrExists<TLink>(this ILinks<TLink> links, TLink
    ↳ link, string argumentName)
356 {
357     var equalityComparer = EqualityComparer<TLink>.Default;
358     if (!equalityComparer.Equals(link, links.Constants.Itself) && !links.Exists(link))
359     {
360         throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
361     }
362 }
363
364 /// <param name="links">Хранилище связей.</param>
365 [MethodImpl(MethodImplOptions.AggressiveInlining)]
366 public static void EnsureDoesNotExists<TLink>(this ILinks<TLink> links, TLink source,
    ↳ TLink target)
367 {
368     if (links.Exists(source, target))
369     {
370         throw new LinkWithSameValueAlreadyExistsException();
371     }
372 }
373
374 /// <param name="links">Хранилище связей.</param>
375 public static void EnsureNoUsages<TLink>(this ILinks<TLink> links, TLink link)
376 {
377     if (links.HasUsages(link))
378     {
379         throw new ArgumentLinkHasDependenciesException<TLink>(link);
380     }
381 }
382
383 /// <param name="links">Хранилище связей.</param>
384 public static void EnsureCreated<TLink>(this ILinks<TLink> links, params TLink[]
    ↳ addresses) => links.EnsureCreated(links.Create, addresses);
385
386 /// <param name="links">Хранилище связей.</param>
387 public static void EnsurePointsCreated<TLink>(this ILinks<TLink> links, params TLink[]
    ↳ addresses) => links.EnsureCreated(links.CreatePoint, addresses);
388
389 /// <param name="links">Хранилище связей.</param>

```

```

390 public static void EnsureCreated<TLink>(this ILinks<TLink> links, Func<TLink> creator,
391 ↪ params TLink[] addresses)
392 {
393     var constants = links.Constants;
394
395     var nonExistentAddresses = new HashSet<TLink>(addresses.Where(x =>
396 ↪ !links.Exists(x)));
397     if (nonExistentAddresses.Count > 0)
398     {
399         var max = nonExistentAddresses.Max();
400         max = (Integer<TLink>)System.Math.Min((ulong)(Integer<TLink>)max,
401 ↪ (ulong)(Integer<TLink>)constants.PossibleInnerReferencesRange.Maximum);
402         var createdLinks = new List<TLink>();
403         var equalityComparer = EqualityComparer<TLink>.Default;
404         TLink createdLink = creator();
405         while (!equalityComparer.Equals(createdLink, max))
406         {
407             createdLinks.Add(createdLink);
408         }
409         for (var i = 0; i < createdLinks.Count; i++)
410         {
411             if (!nonExistentAddresses.Contains(createdLinks[i]))
412             {
413                 links.Delete(createdLinks[i]);
414             }
415         }
416     }
417 }
418
419 #endregion
420
421 /// <param name="links">Хранилище связей.</param>
422 public static TLink CountUsages<TLink>(this ILinks<TLink> links, TLink link)
423 {
424     var constants = links.Constants;
425     var values = links.GetLink(link);
426     TLink usagesAsSource = links.Count(new Link<TLink>(constants.Any, link,
427 ↪ constants.Any));
428     var equalityComparer = EqualityComparer<TLink>.Default;
429     if (equalityComparer.Equals(values[constants.SourcePart], link))
430     {
431         usagesAsSource = Arithmetic<TLink>.Decrement(usagesAsSource);
432     }
433     TLink usagesAsTarget = links.Count(new Link<TLink>(constants.Any, constants.Any,
434 ↪ link));
435     if (equalityComparer.Equals(values[constants.TargetPart], link))
436     {
437         usagesAsTarget = Arithmetic<TLink>.Decrement(usagesAsTarget);
438     }
439     return Arithmetic<TLink>.Add(usagesAsSource, usagesAsTarget);
440 }
441
442 /// <param name="links">Хранилище связей.</param>
443 [MethodImpl(MethodImplOptions.AggressiveInlining)]
444 public static bool HasUsages<TLink>(this ILinks<TLink> links, TLink link) =>
445 ↪ Comparer<TLink>.Default.Compare(links.CountUsages(link), Integer<TLink>.Zero) > 0;
446
447 /// <param name="links">Хранилище связей.</param>
448 [MethodImpl(MethodImplOptions.AggressiveInlining)]
449 public static bool Equals<TLink>(this ILinks<TLink> links, TLink link, TLink source,
450 ↪ TLink target)
451 {
452     var constants = links.Constants;
453     var values = links.GetLink(link);
454     var equalityComparer = EqualityComparer<TLink>.Default;
455     return equalityComparer.Equals(values[constants.SourcePart], source) &&
456 ↪ equalityComparer.Equals(values[constants.TargetPart], target);
457 }
458
459 /// <summary>
460 /// Выполняет поиск связи с указанными Source (началом) и Target (концом).
461 /// </summary>
462 /// <param name="links">Хранилище связей.</param>
463 /// <param name="source">Индекс связи, которая является началом для искомой
464 ↪ связи.</param>
465 /// <param name="target">Индекс связи, которая является концом для искомой связи.</param>
466 /// <returns>Индекс искомой связи с указанными Source (началом) и Target
467 ↪ (концом).</returns>

```

```

458 [MethodImpl(MethodImplOptions.AggressiveInlining)]
459 public static TLink SearchOrDefault<TLink>(this ILinks<TLink> links, TLink source, TLink
    ↪ target)
460 {
461     var constants = links.Constants;
462     var setter = new Setter<TLink, TLink>(constants.Continue, constants.Break, default);
463     links.Each(setter.SetFirstAndReturnFalse, constants.Any, source, target);
464     return setter.Result;
465 }
466
467 /// <param name="links">Хранилище связей.</param>
468 [MethodImpl(MethodImplOptions.AggressiveInlining)]
469 public static TLink Create<TLink>(this ILinks<TLink> links) => links.Create(null);
470
471 /// <param name="links">Хранилище связей.</param>
472 [MethodImpl(MethodImplOptions.AggressiveInlining)]
473 public static TLink CreatePoint<TLink>(this ILinks<TLink> links)
474 {
475     var link = links.Create();
476     return links.Update(link, link, link);
477 }
478
479 /// <param name="links">Хранилище связей.</param>
480 [MethodImpl(MethodImplOptions.AggressiveInlining)]
481 public static TLink CreateAndUpdate<TLink>(this ILinks<TLink> links, TLink source, TLink
    ↪ target) => links.Update(links.Create(), source, target);
482
483 /// <summary>
484 /// Обновляет связь с указанными началом (Source) и концом (Target)
485 /// на связь с указанными началом (NewSource) и концом (NewTarget).
486 /// </summary>
487 /// <param name="links">Хранилище связей.</param>
488 /// <param name="link">Индекс обновляемой связи.</param>
489 /// <param name="newSource">Индекс связи, которая является началом связи, на которую
    ↪ выполняется обновление.</param>
490 /// <param name="newTarget">Индекс связи, которая является концом связи, на которую
    ↪ выполняется обновление.</param>
491 /// <returns>Индекс обновлённой связи.</returns>
492 [MethodImpl(MethodImplOptions.AggressiveInlining)]
493 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));
494
495 /// <summary>
496 /// Обновляет связь с указанными началом (Source) и концом (Target)
497 /// на связь с указанными началом (NewSource) и концом (NewTarget).
498 /// </summary>
499 /// <param name="links">Хранилище связей.</param>
500 /// <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>
501 /// <returns>Индекс обновлённой связи.</returns>
502 [MethodImpl(MethodImplOptions.AggressiveInlining)]
503 public static TLink Update<TLink>(this ILinks<TLink> links, params TLink[] restrictions)
504 {
505     if (restrictions.Length == 2)
506     {
507         return links.MergeAndDelete(restrictions[0], restrictions[1]);
508     }
509     if (restrictions.Length == 4)
510     {
511         return links.UpdateOrCreateOrGet(restrictions[0], restrictions[1],
            ↪ restrictions[2], restrictions[3]);
512     }
513     else
514     {
515         return links.Update(new LinkAddress<TLink>(restrictions[0]), restrictions);
516     }
517 }
518
519 [MethodImpl(MethodImplOptions.AggressiveInlining)]
520 public static IList<TLink> ResolveConstantAsSelfReference<TLink>(this ILinks<TLink>
    ↪ links, TLink constant, IList<TLink> restrictions, IList<TLink> substitution)
521 {
522     var equalityComparer = EqualityComparer<TLink>.Default;
523     var constants = links.Constants;
524     var restrictionsIndex = restrictions[constants.IndexPart];

```

```

525     var substitutionIndex = substitution[constants.IndexPart];
526     if (equalityComparer.Equals(substitutionIndex, default))
527     {
528         substitutionIndex = restrictionsIndex;
529     }
530     var source = substitution[constants.SourcePart];
531     var target = substitution[constants.TargetPart];
532     source = equalityComparer.Equals(source, constant) ? substitutionIndex : source;
533     target = equalityComparer.Equals(target, constant) ? substitutionIndex : target;
534     return new Link<TLink>(substitutionIndex, source, target);
535 }
536
537 /// <summary>
538 /// Создаёт связь (если она не существовала), либо возвращает индекс существующей связи
539   ↳ с указанными Source (началом) и Target (концом).
540 /// </summary>
541 /// <param name="links">Хранилище связей.</param>
542 /// <param name="source">Индекс связи, которая является началом на создаваемой
543   ↳ связи.</param>
544 /// <param name="target">Индекс связи, которая является концом для создаваемой
545   ↳ связи.</param>
546 /// <returns>Индекс связи, с указанным Source (началом) и Target (концом)</returns>
547 [MethodImpl(MethodImplOptions.AggressiveInlining)]
548 public static TLink GetOrCreate<TLink>(this ILinks<TLink> links, TLink source, TLink
549   ↳ target)
550 {
551     var link = links.SearchOrDefault(source, target);
552     if (EqualityComparer<TLink>.Default.Equals(link, default))
553     {
554         link = links.CreateAndUpdate(source, target);
555     }
556     return link;
557 }
558
559 /// <summary>
560 /// Обновляет связь с указанными началом (Source) и концом (Target)
561   ↳ на связь с указанными началом (NewSource) и концом (NewTarget).
562 /// </summary>
563 /// <param name="links">Хранилище связей.</param>
564 /// <param name="source">Индекс связи, которая является началом обновляемой
565   ↳ связи.</param>
566 /// <param name="target">Индекс связи, которая является концом обновляемой связи.</param>
567 /// <param name="newSource">Индекс связи, которая является началом связи, на которую
568   ↳ выполняется обновление.</param>
569 /// <param name="newTarget">Индекс связи, которая является концом связи, на которую
570   ↳ выполняется обновление.</param>
571 /// <returns>Индекс обновлённой связи.</returns>
572 [MethodImpl(MethodImplOptions.AggressiveInlining)]
573 public static TLink UpdateOrCreateOrGet<TLink>(this ILinks<TLink> links, TLink source,
574   ↳ TLink target, TLink newSource, TLink newTarget)
575 {
576     var equalityComparer = EqualityComparer<TLink>.Default;
577     var link = links.SearchOrDefault(source, target);
578     if (equalityComparer.Equals(link, default))
579     {
580         return links.CreateAndUpdate(newSource, newTarget);
581     }
582     if (equalityComparer.Equals(newSource, source) && equalityComparer.Equals(newTarget,
583   ↳ target))
584     {
585         return link;
586     }
587     return links.Update(link, newSource, newTarget);
588 }
589
590 /// <summary>Удаляет связь с указанными началом (Source) и концом (Target).</summary>
591 /// <param name="links">Хранилище связей.</param>
592 /// <param name="source">Индекс связи, которая является началом удаляемой связи.</param>
593 /// <param name="target">Индекс связи, которая является концом удаляемой связи.</param>
594 [MethodImpl(MethodImplOptions.AggressiveInlining)]
595 public static TLink DeleteIfExists<TLink>(this ILinks<TLink> links, TLink source, TLink
596   ↳ target)
597 {
598     var link = links.SearchOrDefault(source, target);
599     if (!EqualityComparer<TLink>.Default.Equals(link, default))
600     {
601         links.Delete(link);
602     }
603 }

```

```

592         return link;
593     }
594     return default;
595 }
596
597 /// <summary>Удаляет несколько связей.</summary>
598 /// <param name="links">Хранилище связей.</param>
599 /// <param name="deletedLinks">Список адресов связей к удалению.</param>
600 [MethodImpl(MethodImplOptions.AggressiveInlining)]
601 public static void DeleteMany<TLink>(this ILinks<TLink> links, IList<TLink> deletedLinks)
602 {
603     for (int i = 0; i < deletedLinks.Count; i++)
604     {
605         links.Delete(deletedLinks[i]);
606     }
607 }
608
609 /// <remarks>Before execution of this method ensure that deleted link is detached (all
610 ↪ values - source and target are reset to null) or it might enter into infinite
611 ↪ recursion.</remarks>
612 public static void DeleteAllUsages<TLink>(this ILinks<TLink> links, TLink linkIndex)
613 {
614     var anyConstant = links.Constants.Any;
615     var usagesAsSourceQuery = new Link<TLink>(anyConstant, linkIndex, anyConstant);
616     links.DeleteByQuery(usagesAsSourceQuery);
617     var usagesAsTargetQuery = new Link<TLink>(anyConstant, linkIndex, anyConstant);
618     links.DeleteByQuery(usagesAsTargetQuery);
619 }
620
621 public static void DeleteByQuery<TLink>(this ILinks<TLink> links, Link<TLink> query)
622 {
623     var count = (Integer<TLink>)links.Count(query);
624     if (count > 0)
625     {
626         var queryResult = new TLink[count];
627         var queryResultFiller = new ArrayFiller<TLink, TLink>(queryResult,
628             ↪ links.Constants.Continue);
629         links.Each(queryResultFiller.AddFirstAndReturnConstant, query);
630         for (var i = (long)count - 1; i >= 0; i--)
631         {
632             links.Delete(queryResult[i]);
633         }
634     }
635 }
636
637 // TODO: Move to Platform.Data
638 public static bool AreValuesReset<TLink>(this ILinks<TLink> links, TLink linkIndex)
639 {
640     var nullConstant = links.Constants.Null;
641     var equalityComparer = EqualityComparer<TLink>.Default;
642     var link = links.GetLink(linkIndex);
643     for (int i = 1; i < link.Count; i++)
644     {
645         if (!equalityComparer.Equals(link[i], nullConstant))
646         {
647             return false;
648         }
649     }
650     return true;
651 }
652
653 // TODO: Create a universal version of this method in Platform.Data (with using of for
654 ↪ loop)
655 public static void ResetValues<TLink>(this ILinks<TLink> links, TLink linkIndex)
656 {
657     var nullConstant = links.Constants.Null;
658     var updateRequest = new Link<TLink>(linkIndex, nullConstant, nullConstant);
659     links.Update(updateRequest);
660 }
661
662 // TODO: Create a universal version of this method in Platform.Data (with using of for
663 ↪ loop)
664 public static void EnforceResetValues<TLink>(this ILinks<TLink> links, TLink linkIndex)
665 {
666     if (!links.AreValuesReset(linkIndex))
667     {
668         links.ResetValues(linkIndex);
669     }
670 }

```



```

665 }
666
667 /// <summary>
668 /// Merging two usages graphs, all children of old link moved to be children of new link
669   ↳ or deleted.
670 /// </summary>
671 public static TLink MergeUsages<TLink>(this ILinks<TLink> links, TLink oldLinkIndex,
672   ↳ TLink newLinkIndex)
673 {
674     var equalityComparer = EqualityComparer<TLink>.Default;
675     if (!equalityComparer.Equals(oldLinkIndex, newLinkIndex))
676     {
677         var constants = links.Constants;
678         var usagesAsSourceQuery = new Link<TLink>(constants.Any, oldLinkIndex,
679   ↳ constants.Any);
680         long usagesAsSourceCount = (Integer<TLink>)links.Count(usagesAsSourceQuery);
681         var usagesAsTargetQuery = new Link<TLink>(constants.Any, constants.Any,
682   ↳ oldLinkIndex);
683         long usagesAsTargetCount = (Integer<TLink>)links.Count(usagesAsTargetQuery);
684         var isStandalonePoint = Point<TLink>.IsFullPoint(links.GetLink(oldLinkIndex)) &&
685   ↳ usagesAsSourceCount == 1 && usagesAsTargetCount == 1;
686         if (!isStandalonePoint)
687         {
688             var totalUsages = usagesAsSourceCount + usagesAsTargetCount;
689             if (totalUsages > 0)
690             {
691                 var usages = ArrayPool.Allocate<TLink>(totalUsages);
692                 var usagesFiller = new ArrayFiller<TLink, TLink>(usages,
693   ↳ links.Constants.Continue);
694                 var i = 0L;
695                 if (usagesAsSourceCount > 0)
696                 {
697                     links.Each(usagesFiller.AddFirstAndReturnConstant,
698   ↳ usagesAsSourceQuery);
699                     for (; i < usagesAsSourceCount; i++)
700                     {
701                         var usage = usages[i];
702                         if (!equalityComparer.Equals(usage, oldLinkIndex))
703                         {
704                             links.Update(usage, newLinkIndex, links.GetTarget(usage));
705                         }
706                     }
707                 }
708                 if (usagesAsTargetCount > 0)
709                 {
710                     links.Each(usagesFiller.AddFirstAndReturnConstant,
711   ↳ usagesAsTargetQuery);
712                     for (; i < usages.Length; i++)
713                     {
714                         var usage = usages[i];
715                         if (!equalityComparer.Equals(usage, oldLinkIndex))
716                         {
717                             links.Update(usage, links.GetSource(usage), newLinkIndex);
718                         }
719                     }
720                 }
721                 ArrayPool.Free(usages);
722             }
723         }
724     }
725     return newLinkIndex;
726 }
727
728 /// <summary>
729 /// Replace one link with another (replaced link is deleted, children are updated or
730   ↳ deleted).
731 /// </summary>
732 [MethodImpl(MethodImplOptions.AggressiveInlining)]
733 public static TLink MergeAndDelete<TLink>(this ILinks<TLink> links, TLink oldLinkIndex,
734   ↳ TLink newLinkIndex)
735 {
736     var equalityComparer = EqualityComparer<TLink>.Default;
737     if (!equalityComparer.Equals(oldLinkIndex, newLinkIndex))
738     {
739         links.MergeUsages(oldLinkIndex, newLinkIndex);
740         links.Delete(oldLinkIndex);
741     }
742     return newLinkIndex;
743 }

```

```

733     }
734
735     public static ILinks<TLink>
736     ↪ DecorateWithAutomaticUniquenessAndUsagesResolution<TLink>(this ILinks<TLink> links)
737     {
738         links = new LinksCascadeUsagesResolver<TLink>(links);
739         links = new NonNullContentsLinkDeletionResolver<TLink>(links);
740         links = new LinksCascadeUniquenessAndUsagesResolver<TLink>(links);
741         return links;
742     }
743 }

```

./Platform.Data.Doublets/Incrementers/FrequencyIncrementer.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.Incrementers
7  {
8      public class FrequencyIncrementer<TLink> : LinksOperatorBase<TLink>, IIncrementer<TLink>
9      {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11         ↪ EqualityComparer<TLink>.Default;
12
13         private readonly TLink _frequencyMarker;
14         private readonly TLink _unaryOne;
15         private readonly IIncrementer<TLink> _unaryNumberIncrementer;
16
17         public FrequencyIncrementer(ILinks<TLink> links, TLink frequencyMarker, TLink unaryOne,
18         ↪ IIncrementer<TLink> unaryNumberIncrementer)
19         : base(links)
20         {
21             _frequencyMarker = frequencyMarker;
22             _unaryOne = unaryOne;
23             _unaryNumberIncrementer = unaryNumberIncrementer;
24         }
25
26         public TLink Increment(TLink frequency)
27         {
28             if (_equalityComparer.Equals(frequency, default))
29             {
30                 return Links.GetOrCreate(_unaryOne, _frequencyMarker);
31             }
32             var source = Links.GetSource(frequency);
33             var incrementedSource = _unaryNumberIncrementer.Increment(source);
34             return Links.GetOrCreate(incrementedSource, _frequencyMarker);
35         }
36     }
37 }

```

./Platform.Data.Doublets/Incrementers/UnaryNumberIncrementer.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.Incrementers
7  {
8      public class UnaryNumberIncrementer<TLink> : LinksOperatorBase<TLink>, IIncrementer<TLink>
9      {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11         ↪ EqualityComparer<TLink>.Default;
12
13         private readonly TLink _unaryOne;
14
15         public UnaryNumberIncrementer(ILinks<TLink> links, TLink unaryOne) : base(links) =>
16         ↪ _unaryOne = unaryOne;
17
18         public TLink Increment(TLink unaryNumber)
19         {
20             if (_equalityComparer.Equals(unaryNumber, _unaryOne))
21             {
22                 return Links.GetOrCreate(_unaryOne, _unaryOne);
23             }
24             var source = Links.GetSource(unaryNumber);
25             var target = Links.GetTarget(unaryNumber);
26             if (_equalityComparer.Equals(source, target))
27             {

```

```

26         return Links.GetOrCreate(unaryNumber, _unaryOne);
27     }
28     else
29     {
30         return Links.GetOrCreate(source, Increment(target));
31     }
32 }
33 }
34 }

```

./Platform.Data.Doublets/ISynchronizedLinks.cs

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  namespace Platform.Data.Doublets
4  {
5      public interface ISynchronizedLinks<TLink> : ISynchronizedLinks<TLink, ILinks<TLink>,
6          ↪ LinksConstants<TLink>>, ILinks<TLink>
7      {
8      }
9  }

```

./Platform.Data.Doublets/Link.cs

```

1  using Platform.Collections.Lists;
2  using Platform.Exceptions;
3  using Platform.Ranges;
4  using Platform.Singletons;
5  using System;
6  using System.Collections;
7  using System.Collections.Generic;
8  using System.Runtime.CompilerServices;
9
10 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
11
12 namespace Platform.Data.Doublets
13 {
14     /// <summary>
15     /// Структура описывающая уникальную связь.
16     /// </summary>
17     public struct Link<TLink> : IEquatable<Link<TLink>>, IReadOnlyList<TLink>, IList<TLink>
18     {
19         public static readonly Link<TLink> Null = new Link<TLink>();
20
21         private static readonly LinksConstants<TLink> _constants =
22             ↪ Default<LinksConstants<TLink>>.Instance;
23         private static readonly EqualityComparer<TLink> _equalityComparer =
24             ↪ EqualityComparer<TLink>.Default;
25
26         private const int Length = 3;
27
28         public readonly TLink Index;
29         public readonly TLink Source;
30         public readonly TLink Target;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         public Link(params TLink[] values) => SetValues(values, out Index, out Source, out
34             ↪ Target);
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         public Link(IList<TLink> values) => SetValues(values, out Index, out Source, out Target);
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         public Link(object other)
41         {
42             if (other is Link<TLink> otherLink)
43             {
44                 SetValues(ref otherLink, out Index, out Source, out Target);
45             }
46             else if (other is IList<TLink> otherList)
47             {
48                 SetValues(otherList, out Index, out Source, out Target);
49             }
50             else
51             {
52                 throw new NotSupportedException();
53             }
54         }
55
56         [MethodImpl(MethodImplOptions.AggressiveInlining)]
57         public Link(ref Link<TLink> other) => SetValues(ref other, out Index, out Source, out
58             ↪ Target);
59     }
60 }

```

```

55 [MethodImpl(MethodImplOptions.AggressiveInlining)]
56 public Link(TLink index, TLink source, TLink target)
57 {
58     Index = index;
59     Source = source;
60     Target = target;
61 }
62
63 [MethodImpl(MethodImplOptions.AggressiveInlining)]
64 private static void SetValues(ref Link<TLink> other, out TLink index, out TLink source,
65     ↪ out TLink target)
66 {
67     index = other.Index;
68     source = other.Source;
69     target = other.Target;
70 }
71
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 private static void SetValues(IList<TLink> values, out TLink index, out TLink source,
74     ↪ out TLink target)
75 {
76     switch (values.Count)
77     {
78         case 3:
79             index = values[0];
80             source = values[1];
81             target = values[2];
82             break;
83         case 2:
84             index = values[0];
85             source = values[1];
86             target = default;
87             break;
88         case 1:
89             index = values[0];
90             source = default;
91             target = default;
92             break;
93         default:
94             index = default;
95             source = default;
96             target = default;
97             break;
98     }
99 }
100 [MethodImpl(MethodImplOptions.AggressiveInlining)]
101 public override int GetHashCode() => (Index, Source, Target).GetHashCode();
102
103 [MethodImpl(MethodImplOptions.AggressiveInlining)]
104 public bool IsNull() => _equalityComparer.Equals(Index, _constants.Null)
105     && _equalityComparer.Equals(Source, _constants.Null)
106     && _equalityComparer.Equals(Target, _constants.Null);
107
108 [MethodImpl(MethodImplOptions.AggressiveInlining)]
109 public override bool Equals(object other) => other is Link<TLink> &&
110     ↪ Equals((Link<TLink>)other);
111
112 [MethodImpl(MethodImplOptions.AggressiveInlining)]
113 public bool Equals(Link<TLink> other) => _equalityComparer.Equals(Index, other.Index)
114     && _equalityComparer.Equals(Source, other.Source)
115     && _equalityComparer.Equals(Target, other.Target);
116
117 [MethodImpl(MethodImplOptions.AggressiveInlining)]
118 public static string ToString(TLink index, TLink source, TLink target) => $"{index}:
119     ↪ {source}->{target}";
120
121 [MethodImpl(MethodImplOptions.AggressiveInlining)]
122 public static string ToString(TLink source, TLink target) => $"{source}->{target}";
123
124 [MethodImpl(MethodImplOptions.AggressiveInlining)]
125 public static implicit operator TLink[] (Link<TLink> link) => link.ToArray();
126
127 [MethodImpl(MethodImplOptions.AggressiveInlining)]
128 public static implicit operator Link<TLink>(TLink[] linkArray) => new
    ↪ Link<TLink>(linkArray);

```

```

129 public override string ToString() => _equalityComparer.Equals(Index, _constants.Null) ?
    ↳ ToString(Source, Target) : ToString(Index, Source, Target);
130
131 #region IList
132
133 public int Count => Length;
134
135 public bool IsReadOnly => true;
136
137 public TLink this[int index]
138 {
139     [MethodImpl(MethodImplOptions.AggressiveInlining)]
140     get
141     {
142         Ensure.OnDebug.ArgumentInRange(index, new Range<int>(0, Length - 1),
143             ↳ nameof(index));
144         if (index == _constants.IndexPart)
145         {
146             return Index;
147         }
148         if (index == _constants.SourcePart)
149         {
150             return Source;
151         }
152         if (index == _constants.TargetPart)
153         {
154             return Target;
155         }
156         throw new NotSupportedException(); // Impossible path due to
157             ↳ Ensure.ArgumentInRange
158     }
159     [MethodImpl(MethodImplOptions.AggressiveInlining)]
160     set => throw new NotSupportedException();
161 }
162
163 [MethodImpl(MethodImplOptions.AggressiveInlining)]
164 IEnumerator IEnumerable.GetEnumerator() => GetEnumerator();
165
166 [MethodImpl(MethodImplOptions.AggressiveInlining)]
167 public IEnumerator<TLink> GetEnumerator()
168 {
169     yield return Index;
170     yield return Source;
171     yield return Target;
172 }
173
174 [MethodImpl(MethodImplOptions.AggressiveInlining)]
175 public void Add(TLink item) => throw new NotSupportedException();
176
177 [MethodImpl(MethodImplOptions.AggressiveInlining)]
178 public void Clear() => throw new NotSupportedException();
179
180 [MethodImpl(MethodImplOptions.AggressiveInlining)]
181 public bool Contains(TLink item) => IndexOf(item) >= 0;
182
183 [MethodImpl(MethodImplOptions.AggressiveInlining)]
184 public void CopyTo(TLink[] array, int arrayIndex)
185 {
186     Ensure.OnDebug.ArgumentNotNull(array, nameof(array));
187     Ensure.OnDebug.ArgumentInRange(arrayIndex, new Range<int>(0, array.Length - 1),
188         ↳ nameof(arrayIndex));
189     if (arrayIndex + Length > array.Length)
190     {
191         throw new InvalidOperationException();
192     }
193     array[arrayIndex++] = Index;
194     array[arrayIndex++] = Source;
195     array[arrayIndex] = Target;
196 }
197
198 [MethodImpl(MethodImplOptions.AggressiveInlining)]
199 public bool Remove(TLink item) => Throw.A.NotSupportedExceptionAndReturn<bool>();
200
201 [MethodImpl(MethodImplOptions.AggressiveInlining)]
202 public int IndexOf(TLink item)
203 {
204     if (_equalityComparer.Equals(Index, item))
205     {
206         return _constants.IndexPart;
207     }
208     if (_equalityComparer.Equals(Source, item))
209     {
210         return _constants.SourcePart;
211     }
212     if (_equalityComparer.Equals(Target, item))
213     {
214         return _constants.TargetPart;
215     }
216     return -1;
217 }

```

```

204     }
205     if (_equalityComparer.Equals(Source, item))
206     {
207         return _constants.SourcePart;
208     }
209     if (_equalityComparer.Equals(Target, item))
210     {
211         return _constants.TargetPart;
212     }
213     return -1;
214 }
215
216 [MethodImpl(MethodImplOptions.AggressiveInlining)]
217 public void Insert(int index, TLink item) => throw new NotSupportedException();
218
219 [MethodImpl(MethodImplOptions.AggressiveInlining)]
220 public void RemoveAt(int index) => throw new NotSupportedException();
221
222 #endregion
223 }
224 }

```

#### ./Platform.Data.Doublets/LinkExtensions.cs

```

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

```

#### ./Platform.Data.Doublets/LinksOperatorBase.cs

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  namespace Platform.Data.Doublets
4  {
5      public abstract class LinksOperatorBase<TLink>
6      {
7          public ILinks<TLink> Links { get; }
8          protected LinksOperatorBase(ILinks<TLink> links) => Links = links;
9      }
10 }

```

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

```

1  using Platform.Interfaces;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Numbers.Raw
6  {
7      public class AddressToRawNumberConverter<TLink> : IConverter<TLink>
8      {
9          public TLink Convert(TLink source) => new Hybrid<TLink>(source, isExternal: true);
10     }
11 }

```

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

```

1  using Platform.Interfaces;
2  using Platform.Numbers;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Numbers.Raw
7  {
8      public class RawNumberToAddressConverter<TLink> : IConverter<TLink>
9      {
10         public TLink Convert(TLink source) => (Integer<TLink>)new
11             ↪ Hybrid<TLink>(source).AbsoluteValue;
12     }
13 }

```

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

```
1 using System.Collections.Generic;
2 using Platform.Interfaces;
3 using Platform.Reflection;
4 using Platform.Numbers;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Numbers.Unary
9 {
10     public class AddressToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
11         ↪ IConverter<TLink>
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
14             ↪ EqualityComparer<TLink>.Default;
15
16         private readonly IConverter<int, TLink> _powerOf2ToUnaryNumberConverter;
17
18         public AddressToUnaryNumberConverter(ILinks<TLink> links, IConverter<int, TLink>
19             ↪ powerOf2ToUnaryNumberConverter) : base(links) => _powerOf2ToUnaryNumberConverter =
20             ↪ powerOf2ToUnaryNumberConverter;
21
22         public TLink Convert(TLink number)
23         {
24             var nullConstant = Links.Constants.Null;
25             var one = Integer<TLink>.One;
26             var target = nullConstant;
27             for (int i = 0; !_equalityComparer.Equals(number, default) && i <
28                 ↪ NumericType<TLink>.BitsLength; i++)
29             {
30                 if (_equalityComparer.Equals(Bit.And(number, one), one))
31                 {
32                     target = _equalityComparer.Equals(target, nullConstant)
33                         ? _powerOf2ToUnaryNumberConverter.Convert(i)
34                         : Links.GetOrCreate(_powerOf2ToUnaryNumberConverter.Convert(i), target);
35                 }
36                 number = Bit.ShiftRight(number, 1);
37             }
38             return target;
39         }
40     }
41 }
```

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

```
1 using System;
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.Numbers.Unary
8 {
9     public class LinkToItsFrequencyNumberConveter<TLink> : LinksOperatorBase<TLink>,
10         ↪ IConverter<Doublet<TLink>, TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
13             ↪ EqualityComparer<TLink>.Default;
14
15         private readonly IPropertyOperator<TLink, TLink> _frequencyPropertyOperator;
16         private readonly IConverter<TLink> _unaryNumberToAddressConverter;
17
18         public LinkToItsFrequencyNumberConveter(
19             ILinks<TLink> links,
20             IPropertyOperator<TLink, TLink> frequencyPropertyOperator,
21             IConverter<TLink> unaryNumberToAddressConverter)
22             : base(links)
23         {
24             _frequencyPropertyOperator = frequencyPropertyOperator;
25             _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
26         }
27
28         public TLink Convert(Doublet<TLink> doublet)
29         {
30             var link = Links.SearchOrDefault(doublet.Source, doublet.Target);
31             if (_equalityComparer.Equals(link, default))
32             {
33                 throw new ArgumentException($"Link ({doublet}) not found.", nameof(doublet));
34             }
35             var frequency = _frequencyPropertyOperator.Get(link);
36             if (_equalityComparer.Equals(frequency, default))
37             {
38                 throw new ArgumentException($"Frequency of {link} not found.", nameof(link));
39             }
40             return _unaryNumberToAddressConverter.Convert(frequency);
41         }
42     }
43 }
```

```

35     {
36         return default;
37     }
38     var frequencyNumber = Links.GetSource(frequency);
39     return _unaryNumberToAddressConverter.Convert(frequencyNumber);
40 }
41 }
42 }

```

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

```

1  using System.Collections.Generic;
2  using Platform.Exceptions;
3  using Platform.Interfaces;
4  using Platform.Ranges;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Numbers.Unary
9  {
10     public class PowerOf2ToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
11         ↪ IConverter<int, TLink>
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
14             ↪ EqualityComparer<TLink>.Default;
15
16         private readonly TLink[] _unaryNumberPowersOf2;
17
18         public PowerOf2ToUnaryNumberConverter(ILinks<TLink> links, TLink one) : base(links)
19         {
20             _unaryNumberPowersOf2 = new TLink[64];
21             _unaryNumberPowersOf2[0] = one;
22         }
23
24         public TLink Convert(int power)
25         {
26             Ensure.Always.ArgumentInRange(power, new Range<int>(0, _unaryNumberPowersOf2.Length
27                 ↪ - 1), nameof(power));
28             if (!_equalityComparer.Equals(_unaryNumberPowersOf2[power], default))
29             {
30                 return _unaryNumberPowersOf2[power];
31             }
32             var previousPowerOf2 = Convert(power - 1);
33             var powerOf2 = Links.GetOrCreate(previousPowerOf2, previousPowerOf2);
34             _unaryNumberPowersOf2[power] = powerOf2;
35             return powerOf2;
36         }
37     }
38 }

```

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

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Interfaces;
4  using Platform.Numbers;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Numbers.Unary
9  {
10     public class UnaryNumberToAddressAddOperationConverter<TLink> : LinksOperatorBase<TLink>,
11         ↪ IConverter<TLink>
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
14             ↪ EqualityComparer<TLink>.Default;
15
16         private Dictionary<TLink, TLink> _unaryToUInt64;
17         private readonly TLink _unaryOne;
18
19         public UnaryNumberToAddressAddOperationConverter(ILinks<TLink> links, TLink unaryOne)
20             : base(links)
21         {
22             _unaryOne = unaryOne;
23             InitUnaryToUInt64();
24         }
25
26         private void InitUnaryToUInt64()
27         {
28             var one = Integer<TLink>.One;
29             _unaryToUInt64 = new Dictionary<TLink, TLink>
30             {

```



```

29         { _unaryOne, one }
30     };
31     var unary = _unaryOne;
32     var number = one;
33     for (var i = 1; i < 64; i++)
34     {
35         unary = Links.GetOrCreate(unary, unary);
36         number = Double(number);
37         _unaryToUInt64.Add(unary, number);
38     }
39 }
40
41 public TLink Convert(TLink unaryNumber)
42 {
43     if (_equalityComparer.Equals(unaryNumber, default))
44     {
45         return default;
46     }
47     if (_equalityComparer.Equals(unaryNumber, _unaryOne))
48     {
49         return Integer<TLink>.One;
50     }
51     var source = Links.GetSource(unaryNumber);
52     var target = Links.GetTarget(unaryNumber);
53     if (_equalityComparer.Equals(source, target))
54     {
55         return _unaryToUInt64[unaryNumber];
56     }
57     else
58     {
59         var result = _unaryToUInt64[source];
60         TLink lastValue;
61         while (!_unaryToUInt64.TryGetValue(target, out lastValue))
62         {
63             source = Links.GetSource(target);
64             result = Arithmetic<TLink>.Add(result, _unaryToUInt64[source]);
65             target = Links.GetTarget(target);
66         }
67         result = Arithmetic<TLink>.Add(result, lastValue);
68         return result;
69     }
70 }
71
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 private static TLink Double(TLink number) => (Integer<TLink>)((Integer<TLink>)number *
74     ↪ 2UL);
75 }

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3 using Platform.Interfaces;
4 using Platform.Reflection;
5 using Platform.Numbers;
6
7 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9 namespace Platform.Data.Doublets.Numbers.Unary
10 {
11     public class UnaryNumberToAddressOrOperationConverter<TLink> : LinksOperatorBase<TLink>,
12         ↪ IConverter<TLink>
13     {
14         private static readonly EqualityComparer<TLink> _equalityComparer =
15             ↪ EqualityComparer<TLink>.Default;
16
17         private readonly IDictionary<TLink, int> _unaryNumberPowerOf2Indicies;
18
19         public UnaryNumberToAddressOrOperationConverter(ILinks<TLink> links, IConverter<int,
20             ↪ TLink> powerOf2ToUnaryNumberConverter)
21             : base(links)
22         {
23             _unaryNumberPowerOf2Indicies = new Dictionary<TLink, int>();
24             for (int i = 0; i < NumericType<TLink>.BitsLength; i++)
25             {
26                 _unaryNumberPowerOf2Indicies.Add(powerOf2ToUnaryNumberConverter.Convert(i), i);
27             }
28         }
29     }
30 }

```

```

27     public TLink Convert(TLink sourceNumber)
28     {
29         var nullConstant = Links.Constants.Null;
30         var source = sourceNumber;
31         var target = nullConstant;
32         if (!_equalityComparer.Equals(source, nullConstant))
33         {
34             while (true)
35             {
36                 if (_unaryNumberPowerOf2Indicies.TryGetValue(source, out int powerOf2Index))
37                 {
38                     SetBit(ref target, powerOf2Index);
39                     break;
40                 }
41                 else
42                 {
43                     powerOf2Index = _unaryNumberPowerOf2Indicies[Links.GetSource(source)];
44                     SetBit(ref target, powerOf2Index);
45                     source = Links.GetTarget(source);
46                 }
47             }
48         }
49         return target;
50     }
51
52     [MethodImpl(MethodImplOptions.AggressiveInlining)]
53     private static void SetBit(ref TLink target, int powerOf2Index) => target =
54         ↪ Bit.Or(target, Bit.ShiftLeft(Integer<TLink>.One, powerOf2Index));
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>,
10         ↪ IPropertiesOperator<TLink, TLink, TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
13             ↪ EqualityComparer<TLink>.Default;
14
15         public PropertiesOperator(ILinks<TLink> links) : base(links) { }
16
17         public TLink GetValue(TLink @object, TLink property)
18         {
19             var objectProperty = Links.SearchOrDefault(@object, property);
20             if (_equalityComparer.Equals(objectProperty, default))
21             {
22                 return default;
23             }
24             var valueLink = Links.All(Links.Constants.Any, objectProperty).SingleOrDefault();
25             if (valueLink == null)
26             {
27                 return default;
28             }
29             return Links.GetTarget(valueLink[Links.Constants.IndexPart]);
30         }
31
32         public void SetValue(TLink @object, TLink property, TLink value)
33         {
34             var objectProperty = Links.GetOrCreate(@object, property);
35             Links.DeleteMany(Links.AllIndices(Links.Constants.Any, objectProperty));
36             Links.GetOrCreate(objectProperty, value);
37         }
38     }
39 }

```

./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,
9         ↪ TLink>
10    {
11        private static readonly EqualityComparer<TLink> _equalityComparer =
12            ↪ EqualityComparer<TLink>.Default;
13
14        private readonly TLink _propertyMarker;
15        private readonly TLink _propertyValueMarker;
16
17        public PropertyOperator(ILinks<TLink> links, TLink propertyMarker, TLink
18            ↪ propertyValueMarker) : base(links)
19        {
20            _propertyMarker = propertyMarker;
21            _propertyValueMarker = propertyValueMarker;
22        }
23
24        public TLink Get(TLink link)
25        {
26            var property = Links.SearchOrDefault(link, _propertyMarker);
27            var container = GetContainer(property);
28            var value = GetValue(container);
29            return value;
30        }
31
32        private TLink GetContainer(TLink property)
33        {
34            var valueContainer = default(TLink);
35            if (_equalityComparer.Equals(property, default))
36            {
37                return valueContainer;
38            }
39            var constants = Links.Constants;
40            var countinueConstant = constants.Continue;
41            var breakConstant = constants.Break;
42            var anyConstant = constants.Any;
43            var query = new Link<TLink>(anyConstant, property, anyConstant);
44            Links.Each(candidate =>
45            {
46                var candidateTarget = Links.GetTarget(candidate);
47                var valueTarget = Links.GetTarget(candidateTarget);
48                if (_equalityComparer.Equals(valueTarget, _propertyValueMarker))
49                {
50                    valueContainer = Links.GetIndex(candidate);
51                    return breakConstant;
52                }
53                return countinueConstant;
54            }, query);
55            return valueContainer;
56        }
57
58        private TLink GetValue(TLink container) => _equalityComparer.Equals(container, default)
59            ↪ ? default : Links.GetTarget(container);
60
61        public void Set(TLink link, TLink value)
62        {
63            var property = Links.GetOrCreate(link, _propertyMarker);
64            var container = GetContainer(property);
65            if (_equalityComparer.Equals(container, default))
66            {
67                Links.GetOrCreate(property, value);
68            }
69            else
70            {
71                Links.Update(container, property, value);
72            }
73        }
74    }
75 }

```

./Platform.Data.Doublets/ResizableDirectMemory/Generic/LinksAvlBalancedTreeMethodsBase.cs

```

1 using System;
2 using System.Text;
3 using System.Collections.Generic;
4 using System.Runtime.CompilerServices;
5 using Platform.Numbers;
6 using Platform.Collections.Methods.Trees;
7 using static System.Runtime.CompilerServices.Unsafe;
8
9 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

```

```

10
11 namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
12 {
13     public unsafe abstract class LinksAvlBalancedTreeMethodsBase<TLink> :
14         ↳ SizedAndThreadedAVLBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
15     {
16         protected readonly TLink Break;
17         protected readonly TLink Continue;
18         protected readonly byte* Links;
19         protected readonly byte* Header;
20
21         public LinksAvlBalancedTreeMethodsBase(LinksConstants<TLink> constants, byte* links,
22             ↳ byte* header)
23         {
24             Links = links;
25             Header = header;
26             Break = constants.Break;
27             Continue = constants.Continue;
28
29             [MethodImpl(MethodImplOptions.AggressiveInlining)]
30             protected abstract TLink GetTreeRoot();
31
32             [MethodImpl(MethodImplOptions.AggressiveInlining)]
33             protected abstract TLink GetBasePartValue(TLink link);
34
35             [MethodImpl(MethodImplOptions.AggressiveInlining)]
36             protected abstract bool FirstIsToTheRightOfSecond(TLink source, TLink target, TLink
37                 ↳ rootSource, TLink rootTarget);
38
39             [MethodImpl(MethodImplOptions.AggressiveInlining)]
40             protected abstract bool FirstIsToTheLeftOfSecond(TLink source, TLink target, TLink
41                 ↳ rootSource, TLink rootTarget);
42
43             [MethodImpl(MethodImplOptions.AggressiveInlining)]
44             protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
45                 ↳ AsRef<LinksHeader<TLink>>(Header);
46
47             [MethodImpl(MethodImplOptions.AggressiveInlining)]
48             protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
49                 ↳ AsRef<RawLink<TLink>>(Links + RawLink<TLink>.SizeInBytes * (Integer<TLink>)link);
50
51             [MethodImpl(MethodImplOptions.AggressiveInlining)]
52             protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
53             {
54                 ref var link = ref GetLinkReference(linkIndex);
55                 return new Link<TLink>(linkIndex, link.Source, link.Target);
56             }
57
58             [MethodImpl(MethodImplOptions.AggressiveInlining)]
59             protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
60             {
61                 ref var firstLink = ref GetLinkReference(first);
62                 ref var secondLink = ref GetLinkReference(second);
63                 return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
64                     ↳ secondLink.Source, secondLink.Target);
65             }
66
67             [MethodImpl(MethodImplOptions.AggressiveInlining)]
68             protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
69             {
70                 ref var firstLink = ref GetLinkReference(first);
71                 ref var secondLink = ref GetLinkReference(second);
72                 return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
73                     ↳ secondLink.Source, secondLink.Target);
74             }
75
76             [MethodImpl(MethodImplOptions.AggressiveInlining)]
77             protected virtual TLink GetSizeValue(TLink value) => Bit<TLink>.PartialRead(value, 5,
78                 ↳ -5);
79
80             [MethodImpl(MethodImplOptions.AggressiveInlining)]
81             protected virtual void SetSizeValue(ref TLink storedValue, TLink size) => storedValue =
82                 ↳ Bit<TLink>.PartialWrite(storedValue, size, 5, -5);
83
84             [MethodImpl(MethodImplOptions.AggressiveInlining)]
85             protected virtual bool GetLeftIsChildValue(TLink value)
86             {
87                 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,
92             ↪ 1);
93         storedValue = modified;
94     }
95 }
96
97 [MethodImpl(MethodImplOptions.AggressiveInlining)]
98 protected virtual bool GetRightIsChildValue(TLink value)
99 {
100     unchecked
101     {
102         //return (Integer<TLink>)Bit<TLink>.PartialRead(previousValue, 3, 1);
103         return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 3, 1), default);
104     }
105 }
106
107 [MethodImpl(MethodImplOptions.AggressiveInlining)]
108 protected virtual void SetRightIsChildValue(ref TLink storedValue, bool value)
109 {
110     unchecked
111     {
112         var previousValue = storedValue;
113         var modified = Bit<TLink>.PartialWrite(previousValue, (Integer<TLink>)value, 3,
114             ↪ 1);
115         storedValue = modified;
116     }
117 }
118
119 [MethodImpl(MethodImplOptions.AggressiveInlining)]
120 protected bool IsChild(TLink parent, TLink possibleChild)
121 {
122     var parentSize = GetSize(parent);
123     var childSize = GetSizeOrZero(possibleChild);
124     return GreaterThanZero(childSize) && LessOrEqualThan(childSize, parentSize);
125 }
126
127 [MethodImpl(MethodImplOptions.AggressiveInlining)]
128 protected virtual sbyte GetBalanceValue(TLink storedValue)
129 {
130     unchecked
131     {
132         var value = (int)(Integer<TLink>)Bit<TLink>.PartialRead(storedValue, 0, 3);
133         value |= 0xF8 * ((value & 4) >> 2); // if negative, then continue ones to the
134             ↪ end of sbyte
135         return (sbyte)value;
136     }
137 }
138
139 [MethodImpl(MethodImplOptions.AggressiveInlining)]
140 protected virtual void SetBalanceValue(ref TLink storedValue, sbyte value)
141 {
142     unchecked
143     {
144         var packagedValue = (TLink)(Integer<TLink>)((byte)value >> 5 & 4 | value & 3);
145         var modified = Bit<TLink>.PartialWrite(storedValue, packagedValue, 0, 3);
146         storedValue = modified;
147     }
148 }
149
150 public TLink this[TLink index]
151 {
152     get
153     {
154         var root = GetTreeRoot();
155         if (GreaterOrEqualThan(index, GetSize(root)))
156         {
157             return Zero;
158         }
159     }
160 }

```

```

155     }
156     while (!EqualToZero(root))
157     {
158         var left = GetLeftOrDefault(root);
159         var leftSize = GetSizeOrZero(left);
160         if (LessThan(index, leftSize))
161         {
162             root = left;
163             continue;
164         }
165         if (IsEquals(index, leftSize))
166         {
167             return root;
168         }
169         root = GetRightOrDefault(root);
170         index = Subtract(index, Increment(leftSize));
171     }
172     return Zero; // TODO: Impossible situation exception (only if tree structure
173                 ↪ broken)
174 }
175
176 /// <summary>
177 /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
178 ↪ (концом).
179 /// </summary>
180 /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
181 /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
182 /// <returns>Индекс искомой связи.</returns>
183 public TLink Search(TLink source, TLink target)
184 {
185     var root = GetTreeRoot();
186     while (!EqualToZero(root))
187     {
188         ref var rootLink = ref GetLinkReference(root);
189         var rootSource = rootLink.Source;
190         var rootTarget = rootLink.Target;
191         if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
192             ↪ node.Key < root.Key
193         {
194             root = GetLeftOrDefault(root);
195         }
196         else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget)) //
197             ↪ node.Key > root.Key
198         {
199             root = GetRightOrDefault(root);
200         }
201         else // node.Key == root.Key
202         {
203             return root;
204         }
205     }
206     return Zero;
207 }
208
209 // TODO: Return indices range instead of references count
210 public TLink CountUsages(TLink link)
211 {
212     var root = GetTreeRoot();
213     var total = GetSize(root);
214     var totalRightIgnore = Zero;
215     while (!EqualToZero(root))
216     {
217         var @base = GetBasePartValue(root);
218         if (LessOrEqualThan(@base, link))
219         {
220             root = GetRightOrDefault(root);
221         }
222         else
223         {
224             totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
225             root = GetLeftOrDefault(root);
226         }
227     }
228     root = GetTreeRoot();
229     var totalLeftIgnore = Zero;
230     while (!EqualToZero(root))
231     {

```

```

229     var @base = GetBasePartValue(root);
230     if (GreaterOrEqualThan(@base, link))
231     {
232         root = GetLeftOrDefault(root);
233     }
234     else
235     {
236         totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
237
238         root = GetRightOrDefault(root);
239     }
240 }
241 return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
242 }
243
244 public TLink EachUsage(TLink link, Func<IList<TLink>, TLink> handler)
245 {
246     var root = GetTreeRoot();
247     if (EqualToZero(root))
248     {
249         return Continue;
250     }
251     TLink first = Zero, current = root;
252     while (!EqualToZero(current))
253     {
254         var @base = GetBasePartValue(current);
255         if (GreaterOrEqualThan(@base, link))
256         {
257             if (IsEquals(@base, link))
258             {
259                 first = current;
260             }
261             current = GetLeftOrDefault(current);
262         }
263         else
264         {
265             current = GetRightOrDefault(current);
266         }
267     }
268     if (!EqualToZero(first))
269     {
270         current = first;
271         while (true)
272         {
273             if (IsEquals(handler(GetLinkValues(current)), Break))
274             {
275                 return Break;
276             }
277             current = GetNext(current);
278             if (EqualToZero(current) || !IsEquals(GetBasePartValue(current), link))
279             {
280                 break;
281             }
282         }
283     }
284     return Continue;
285 }
286
287 protected override void PrintNodeValue(TLink node, StringBuilder sb)
288 {
289     ref var link = ref GetLinkReference(node);
290     sb.Append(' ');
291     sb.Append(link.Source);
292     sb.Append('-');
293     sb.Append('>');
294     sb.Append(link.Target);
295 }
296 }
297 }

```

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

```

1 using System;
2 using System.Text;
3 using System.Collections.Generic;
4 using System.Runtime.CompilerServices;
5 using Platform.Numbers;
6 using Platform.Collections.Methods.Trees;
7 using static System.Runtime.CompilerServices.Unsafe;
8

```

```

9  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
10
11 namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
12 {
13     public unsafe abstract class LinksSizeBalancedTreeMethodsBase<TLink> :
14         ↳ SizeBalancedTreeMethods2<TLink>, ILinksTreeMethods<TLink>
15     {
16         protected readonly TLink Break;
17         protected readonly TLink Continue;
18         protected readonly byte* Links;
19         protected readonly byte* Header;
20
21         public LinksSizeBalancedTreeMethodsBase(LinksConstants<TLink> constants, byte* links,
22             ↳ byte* header)
23         {
24             Links = links;
25             Header = header;
26             Break = constants.Break;
27             Continue = constants.Continue;
28
29             [MethodImpl(MethodImplOptions.AggressiveInlining)]
30             protected abstract TLink GetTreeRoot();
31
32             [MethodImpl(MethodImplOptions.AggressiveInlining)]
33             protected abstract TLink GetBasePartValue(TLink link);
34
35             [MethodImpl(MethodImplOptions.AggressiveInlining)]
36             protected abstract bool FirstIsToTheRightOfSecond(TLink source, TLink target, TLink
37                 ↳ rootSource, TLink rootTarget);
38
39             [MethodImpl(MethodImplOptions.AggressiveInlining)]
40             protected abstract bool FirstIsToTheLeftOfSecond(TLink source, TLink target, TLink
41                 ↳ rootSource, TLink rootTarget);
42
43             [MethodImpl(MethodImplOptions.AggressiveInlining)]
44             protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
45                 ↳ AsRef<LinksHeader<TLink>>(Header);
46
47             [MethodImpl(MethodImplOptions.AggressiveInlining)]
48             protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
49                 ↳ AsRef<RawLink<TLink>>(Links + RawLink<TLink>.SizeInBytes * (Integer<TLink>)link);
50
51             [MethodImpl(MethodImplOptions.AggressiveInlining)]
52             protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
53             {
54                 ref var link = ref GetLinkReference(linkIndex);
55                 return new Link<TLink>(linkIndex, link.Source, link.Target);
56             }
57
58             [MethodImpl(MethodImplOptions.AggressiveInlining)]
59             protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
60             {
61                 ref var firstLink = ref GetLinkReference(first);
62                 ref var secondLink = ref GetLinkReference(second);
63                 return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
64                     ↳ secondLink.Source, secondLink.Target);
65             }
66
67             [MethodImpl(MethodImplOptions.AggressiveInlining)]
68             protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
69             {
70                 ref var firstLink = ref GetLinkReference(first);
71                 ref var secondLink = ref GetLinkReference(second);
72                 return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
73                     ↳ secondLink.Source, secondLink.Target);
74             }
75
76             public TLink this[TLink index]
77             {
78                 get
79                 {
80                     var root = GetTreeRoot();
81                     if (GreaterOrEqualThan(index, GetSize(root)))
82                     {
83                         return Zero;
84                     }
85                     while (!EqualToZero(root))
86                     {

```



```

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     {
136         var @base = GetBasePartValue(root);
137         if (LessOrEqualThan(@base, link))
138         {
139             root = GetRightOrDefault(root);
140         }
141         else
142         {
143             totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
144             root = GetLeftOrDefault(root);
145         }
146     }
147     root = GetTreeRoot();
148     var totalLeftIgnore = Zero;
149     while (!EqualToZero(root))
150     {
151         var @base = GetBasePartValue(root);
152         if (GreaterOrEqualThan(@base, link))
153         {

```

```

154         root = GetLeftOrDefault(root);
155     }
156     else
157     {
158         totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
159
160         root = GetRightOrDefault(root);
161     }
162 }
163 return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
164 }
165
166 [MethodImpl(MethodImplOptions.AggressiveInlining)]
167 public TLink EachUsage(TLink @base, Func<IList<TLink>, TLink> handler) =>
168     ↳ EachUsageCore(@base, GetTreeRoot(), handler);
169
170 // TODO: 1. Move target, handler to separate object. 2. Use stack or walker 3. Use
171 ↳ low-level MSIL stack.
172 private TLink EachUsageCore(TLink @base, TLink link, Func<IList<TLink>, TLink> handler)
173 {
174     var @continue = Continue;
175     if (EqualToZero(link))
176     {
177         return @continue;
178     }
179     var linkBasePart = GetBasePartValue(link);
180     var @break = Break;
181     if (GreaterThan(linkBasePart, @base))
182     {
183         if (IsEquals(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
184         {
185             return @break;
186         }
187     }
188     else if (LessThan(linkBasePart, @base))
189     {
190         if (IsEquals(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
191         {
192             return @break;
193         }
194     }
195     else //if (linkBasePart == @base)
196     {
197         if (IsEquals(handler(GetLinkValues(link)), @break))
198         {
199             return @break;
200         }
201         if (IsEquals(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
202         {
203             return @break;
204         }
205         if (IsEquals(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
206         {
207             return @break;
208         }
209     }
210     return @continue;
211 }
212
213 protected override void PrintNodeValue(TLink node, StringBuilder sb)
214 {
215     ref var link = ref GetLinkReference(node);
216     sb.Append(' ');
217     sb.Append(link.Source);
218     sb.Append(' - ');
219     sb.Append(' > ');
220     sb.Append(link.Target);
221 }
222 }

```

./Platform.Data.Doublets/ResizableDirectMemory/Generic/LinksSourcesAvlBalancedTreeMethods.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.Generic
6 {
7     public unsafe class LinksSourcesAvlBalancedTreeMethods<TLink> :
8         ↳ LinksAvlBalancedTreeMethodsBase<TLink>

```

```

8 {
9     public LinksSourcesAvlBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
10         ↳ byte* header) : base(constants, links, header) { }
11
12     [MethodImpl(MethodImplOptions.AggressiveInlining)]
13     protected unsafe override ref TLink GetLeftReference(TLink node) => ref
14         ↳ GetLinkReference(node).LeftAsSource;
15
16     [MethodImpl(MethodImplOptions.AggressiveInlining)]
17     protected unsafe override ref TLink GetRightReference(TLink node) => ref
18         ↳ GetLinkReference(node).RightAsSource;
19
20     [MethodImpl(MethodImplOptions.AggressiveInlining)]
21     protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsSource;
22
23     [MethodImpl(MethodImplOptions.AggressiveInlining)]
24     protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsSource;
25
26     [MethodImpl(MethodImplOptions.AggressiveInlining)]
27     protected override void SetLeft(TLink node, TLink left) =>
28         ↳ GetLinkReference(node).LeftAsSource = left;
29
30     [MethodImpl(MethodImplOptions.AggressiveInlining)]
31     protected override void SetRight(TLink node, TLink right) =>
32         ↳ GetLinkReference(node).RightAsSource = right;
33
34     [MethodImpl(MethodImplOptions.AggressiveInlining)]
35     protected override TLink GetSize(TLink node) =>
36         ↳ GetSizeValue(GetLinkReference(node).SizeAsSource);
37
38     [MethodImpl(MethodImplOptions.AggressiveInlining)]
39     protected override void SetSize(TLink node, TLink size) => SetSizeValue(ref
40         ↳ GetLinkReference(node).SizeAsSource, size);
41
42     [MethodImpl(MethodImplOptions.AggressiveInlining)]
43     protected override bool GetLeftIsChild(TLink node) =>
44         ↳ GetLeftIsChildValue(GetLinkReference(node).SizeAsSource);
45
46     [MethodImpl(MethodImplOptions.AggressiveInlining)]
47     protected override void SetLeftIsChild(TLink node, bool value) =>
48         ↳ SetLeftIsChildValue(ref GetLinkReference(node).SizeAsSource, value);
49
50     [MethodImpl(MethodImplOptions.AggressiveInlining)]
51     protected override bool GetRightIsChild(TLink node) =>
52         ↳ GetRightIsChildValue(GetLinkReference(node).SizeAsSource);
53
54     [MethodImpl(MethodImplOptions.AggressiveInlining)]
55     protected override void SetRightIsChild(TLink node, bool value) =>
56         ↳ SetRightIsChildValue(ref GetLinkReference(node).SizeAsSource, value);
57
58     [MethodImpl(MethodImplOptions.AggressiveInlining)]
59     protected override sbyte GetBalance(TLink node) =>
60         ↳ GetBalanceValue(GetLinkReference(node).SizeAsSource);
61
62     [MethodImpl(MethodImplOptions.AggressiveInlining)]
63     protected override void SetBalance(TLink node, sbyte value) => SetBalanceValue(ref
64         ↳ GetLinkReference(node).SizeAsSource, value);
65
66     [MethodImpl(MethodImplOptions.AggressiveInlining)]
67     protected override TLink GetTreeRoot() => GetHeaderReference().FirstAsSource;
68
69     [MethodImpl(MethodImplOptions.AggressiveInlining)]
70     protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Source;
71
72     [MethodImpl(MethodImplOptions.AggressiveInlining)]
73     protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
74         ↳ TLink secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) ||
75         ↳ IsEquals(firstSource, secondSource) && LessThan(firstTarget, secondTarget);
76
77     [MethodImpl(MethodImplOptions.AggressiveInlining)]
78     protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
79         ↳ TLink secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) ||
80         ↳ IsEquals(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget);
81
82     [MethodImpl(MethodImplOptions.AggressiveInlining)]
83     protected override void ClearNode(TLink node)
84     {
85         ref var link = ref GetLinkReference(node);

```

```

69         link.LeftAsSource = Zero;
70         link.RightAsSource = Zero;
71         link.SizeAsSource = Zero;
72     }
73 }
74 }

```

./Platform.Data.Doublets/ResizableDirectMemory/Generic/LinksSourcesSizeBalancedTreeMethods.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.Generic
6  {
7      public unsafe class LinksSourcesSizeBalancedTreeMethods<TLink> :
8          ↳ LinksSizeBalancedTreeMethodsBase<TLink>
9      {
10         public LinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
11             ↳ byte* header) : base(constants, links, header) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         protected unsafe override ref TLink GetLeftReference(TLink node) => ref
15             ↳ GetLinkReference(node).LeftAsSource;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         protected unsafe override ref TLink GetRightReference(TLink node) => ref
19             ↳ GetLinkReference(node).RightAsSource;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsSource;
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsSource;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected override void SetLeft(TLink node, TLink left) =>
29             ↳ GetLinkReference(node).LeftAsSource = left;
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected override void SetRight(TLink node, TLink right) =>
33             ↳ GetLinkReference(node).RightAsSource = right;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override TLink GetSize(TLink node) => GetLinkReference(node).SizeAsSource;
37
38         [MethodImpl(MethodImplOptions.AggressiveInlining)]
39         protected override void SetSize(TLink node, TLink size) =>
40             ↳ GetLinkReference(node).SizeAsSource = size;
41
42         [MethodImpl(MethodImplOptions.AggressiveInlining)]
43         protected override TLink GetTreeRoot() => GetHeaderReference().FirstAsSource;
44
45         [MethodImpl(MethodImplOptions.AggressiveInlining)]
46         protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Source;
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
50             ↳ TLink secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) ||
51             ↳ IsEquals(firstSource, secondSource) && LessThan(firstTarget, secondTarget);
52
53         [MethodImpl(MethodImplOptions.AggressiveInlining)]
54         protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
55             ↳ TLink secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) ||
56             ↳ IsEquals(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget);
57
58         [MethodImpl(MethodImplOptions.AggressiveInlining)]
59         protected override void ClearNode(TLink node)
60         {
61             ref var link = ref GetLinkReference(node);
62             link.LeftAsSource = Zero;
63             link.RightAsSource = Zero;
64             link.SizeAsSource = Zero;
65         }
66     }
67 }

```

./Platform.Data.Doublets/ResizableDirectMemory/Generic/LinksTargetsAvlBalancedTreeMethods.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.Generic
6  {
7      public unsafe class LinksTargetsAvlBalancedTreeMethods<TLink> :
8          ↳ LinksAvlBalancedTreeMethodsBase<TLink>
9      {
10         public LinksTargetsAvlBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
11             ↳ byte* header) : base(constants, links, header) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         protected unsafe override ref TLink GetLeftReference(TLink node) => ref
15             ↳ GetLinkReference(node).LeftAsTarget;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         protected unsafe override ref TLink GetRightReference(TLink node) => ref
19             ↳ GetLinkReference(node).RightAsTarget;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsTarget;
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsTarget;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected override void SetLeft(TLink node, TLink left) =>
29             ↳ GetLinkReference(node).LeftAsTarget = left;
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected override void SetRight(TLink node, TLink right) =>
33             ↳ GetLinkReference(node).RightAsTarget = right;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override TLink GetSize(TLink node) =>
37             ↳ GetSizeValue(GetLinkReference(node).SizeAsTarget);
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override void SetSize(TLink node, TLink size) => SetSizeValue(ref
41             ↳ GetLinkReference(node).SizeAsTarget, size);
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         protected override bool GetLeftIsChild(TLink node) =>
45             ↳ GetLeftIsChildValue(GetLinkReference(node).SizeAsTarget);
46
47         [MethodImpl(MethodImplOptions.AggressiveInlining)]
48         protected override void SetLeftIsChild(TLink node, bool value) =>
49             ↳ SetLeftIsChildValue(ref GetLinkReference(node).SizeAsTarget, value);
50
51         [MethodImpl(MethodImplOptions.AggressiveInlining)]
52         protected override bool GetRightIsChild(TLink node) =>
53             ↳ GetRightIsChildValue(GetLinkReference(node).SizeAsTarget);
54
55         [MethodImpl(MethodImplOptions.AggressiveInlining)]
56         protected override void SetRightIsChild(TLink node, bool value) =>
57             ↳ SetRightIsChildValue(ref GetLinkReference(node).SizeAsTarget, value);
58
59         [MethodImpl(MethodImplOptions.AggressiveInlining)]
60         protected override sbyte GetBalance(TLink node) =>
61             ↳ GetBalanceValue(GetLinkReference(node).SizeAsTarget);
62
63         [MethodImpl(MethodImplOptions.AggressiveInlining)]
64         protected override void SetBalance(TLink node, sbyte value) => SetBalanceValue(ref
65             ↳ GetLinkReference(node).SizeAsTarget, value);
66
67         [MethodImpl(MethodImplOptions.AggressiveInlining)]
68         protected override TLink GetTreeRoot() => GetHeaderReference().FirstAsTarget;
69
70         [MethodImpl(MethodImplOptions.AggressiveInlining)]
71         protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Target;
72
73         [MethodImpl(MethodImplOptions.AggressiveInlining)]
74         protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
75             ↳ TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
76             ↳ IsEquals(firstTarget, secondTarget) && LessThan(firstSource, secondSource);
77
78         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

63     protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
64         ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
65         ↪ IsEquals(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource);
66
67     [MethodImpl(MethodImplOptions.AggressiveInlining)]
68     protected override void ClearNode(TLink node)
69     {
70         ref var link = ref GetLinkReference(node);
71         link.LeftAsTarget = Zero;
72         link.RightAsTarget = Zero;
73         link.SizeAsTarget = Zero;
74     }
75 }

```

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

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
6  {
7      public unsafe class LinksTargetsSizeBalancedTreeMethods<TLink> :
8          ↪ LinksSizeBalancedTreeMethodsBase<TLink>
9      {
10         public LinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
11             ↪ byte* header) : base(constants, links, header) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         protected unsafe override ref TLink GetLeftReference(TLink node) => ref
15             ↪ GetLinkReference(node).LeftAsTarget;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         protected unsafe override ref TLink GetRightReference(TLink node) => ref
19             ↪ GetLinkReference(node).RightAsTarget;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsTarget;
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsTarget;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected override void SetLeft(TLink node, TLink left) =>
29             ↪ GetLinkReference(node).LeftAsTarget = left;
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected override void SetRight(TLink node, TLink right) =>
33             ↪ GetLinkReference(node).RightAsTarget = right;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override TLink GetSize(TLink node) => GetLinkReference(node).SizeAsTarget;
37
38         [MethodImpl(MethodImplOptions.AggressiveInlining)]
39         protected override void SetSize(TLink node, TLink size) =>
40             ↪ GetLinkReference(node).SizeAsTarget = size;
41
42         [MethodImpl(MethodImplOptions.AggressiveInlining)]
43         protected override TLink GetTreeRoot() => GetHeaderReference().FirstAsTarget;
44
45         [MethodImpl(MethodImplOptions.AggressiveInlining)]
46         protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Target;
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
50             ↪ TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
51             ↪ IsEquals(firstTarget, secondTarget) && LessThan(firstSource, secondSource);
52
53         [MethodImpl(MethodImplOptions.AggressiveInlining)]
54         protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
55             ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
56             ↪ IsEquals(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource);
57
58         [MethodImpl(MethodImplOptions.AggressiveInlining)]
59         protected override void ClearNode(TLink node)
60         {
61             ref var link = ref GetLinkReference(node);
62             link.LeftAsTarget = Zero;
63             link.RightAsTarget = Zero;
64         }
65     }
66 }

```

```

53         link.SizeAsTarget = Zero;
54     }
55 }
56 }

```

./Platform.Data.Doublets/ResizableDirectMemory/Generic/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.Generic
14 {
15     public abstract class ResizableDirectMemoryLinksBase<TLink> : DisposableBase, ILinks<TLink>
16     {
17         protected static readonly EqualityComparer<TLink> EqualityComparer =
18             ↳ EqualityComparer<TLink>.Default;
19         protected static readonly Comparer<TLink> Comparer = Comparer<TLink>.Default;
20
21         /// <summary>Возвращает размер одной связи в байтах.</summary>
22         /// <remarks>
23         ///     Используется только во вне класса, не рекомендуется использовать внутри.
24         ///     Так как во вне не обязательно будет доступен unsafe C#.
25         /// </remarks>
26         public static readonly long LinkSizeInBytes = RawLink<TLink>.SizeInBytes;
27
28         public static readonly long LinkHeaderSizeInBytes = LinksHeader<TLink>.SizeInBytes;
29
30         public static readonly long DefaultLinksSizeStep = LinkSizeInBytes * 1024 * 1024;
31
32         protected readonly IResizableDirectMemory _memory;
33         protected readonly long _memoryReservationStep;
34
35         protected ILinksTreeMethods<TLink> TargetsTreeMethods;
36         protected ILinksTreeMethods<TLink> SourcesTreeMethods;
37         // TODO: Возможно чтобы гарантированно проверять на то, является ли связь удалённой,
38         // ↳ нужно использовать не список а дерево, так как так можно быстрее проверить на
39         // ↳ наличие связи внутри
40         protected ILinksListMethods<TLink> UnusedLinksListMethods;
41
42         /// <summary>
43         ///     Возвращает общее число связей находящихся в хранилище.
44         /// </summary>
45         protected virtual TLink Total
46         {
47             get
48             {
49                 ref var header = ref GetHeaderReference();
50                 return Subtract(header.AllocatedLinks, header.FreeLinks);
51             }
52         }
53
54         public virtual LinksConstants<TLink> Constants { get; }
55
56         [MethodImpl(MethodImplOptions.AggressiveInlining)]
57         public ResizableDirectMemoryLinksBase(IResizableDirectMemory memory, long
58             ↳ memoryReservationStep, LinksConstants<TLink> constants)
59         {
60             _memory = memory;
61             _memoryReservationStep = memoryReservationStep;
62             Constants = constants;
63         }
64
65         [MethodImpl(MethodImplOptions.AggressiveInlining)]
66         public ResizableDirectMemoryLinksBase(IResizableDirectMemory memory, long
67             ↳ memoryReservationStep) : this(memory, memoryReservationStep,
68             ↳ Default<LinksConstants<TLink>>.Instance) { }
69
70         protected virtual void Init(IResizableDirectMemory memory, long memoryReservationStep)
71         {
72             if (memory.ReservedCapacity < memoryReservationStep)
73             {
74                 memory.ReservedCapacity = memoryReservationStep;
75             }
76         }
77     }
78 }

```

```

70     SetPointers(_memory);
71     ref var header = ref GetHeaderReference();
72     // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
73     _memory.UsedCapacity = ConvertToUInt64(header.AllocatedLinks) * LinkSizeInBytes +
        ↪ LinkHeaderSizeInBytes;
74     // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
75     header.ReservedLinks = ConvertToAddress((_memory.ReservedCapacity -
        ↪ LinkHeaderSizeInBytes) / LinkSizeInBytes);
76 }
77
78 [MethodImpl(MethodImplOptions.AggressiveInlining)]
79 public virtual TLink Count(IList<TLink> restrictions)
80 {
81     // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
82     if (restrictions.Count == 0)
83     {
84         return Total;
85     }
86     var constants = Constants;
87     var any = constants.Any;
88     var index = restrictions[constants.IndexPart];
89     if (restrictions.Count == 1)
90     {
91         if (AreEqual(index, any))
92         {
93             return Total;
94         }
95         return Exists(index) ? GetOne() : GetZero();
96     }
97     if (restrictions.Count == 2)
98     {
99         var value = restrictions[1];
100         if (AreEqual(index, any))
101         {
102             if (AreEqual(value, any))
103             {
104                 return Total; // Any - как отсутствие ограничения
105             }
106             return Add(SourcesTreeMethods.CountUsages(value),
                ↪ TargetsTreeMethods.CountUsages(value));
107         }
108         else
109         {
110             if (!Exists(index))
111             {
112                 return GetZero();
113             }
114             if (AreEqual(value, any))
115             {
116                 return GetOne();
117             }
118             ref var storedLinkValue = ref GetLinkReference(index);
119             if (AreEqual(storedLinkValue.Source, value) ||
                ↪ AreEqual(storedLinkValue.Target, value))
120             {
121                 return GetOne();
122             }
123             return GetZero();
124         }
125     }
126     if (restrictions.Count == 3)
127     {
128         var source = restrictions[constants.SourcePart];
129         var target = restrictions[constants.TargetPart];
130         if (AreEqual(index, any))
131         {
132             if (AreEqual(source, any) && AreEqual(target, any))
133             {
134                 return Total;
135             }
136             else if (AreEqual(source, any))
137             {
138                 return TargetsTreeMethods.CountUsages(target);
139             }
140             else if (AreEqual(target, any))
141             {
142                 return SourcesTreeMethods.CountUsages(source);
143             }
144         }
145     }
146 }

```



```

144     else //if(source != Any && target != Any)
145     {
146         // Эквивалент Exists(source, target) => Count(Any, source, target) > 0
147         var link = SourcesTreeMethods.Search(source, target);
148         return AreEqual(link, constants.Null) ? GetZero() : GetOne();
149     }
150 }
151 else
152 {
153     if (!Exists(index))
154     {
155         return GetZero();
156     }
157     if (AreEqual(source, any) && AreEqual(target, any))
158     {
159         return GetOne();
160     }
161     ref var storedLinkValue = ref GetLinkReference(index);
162     if (!AreEqual(source, any) && !AreEqual(target, any))
163     {
164         if (AreEqual(storedLinkValue.Source, source) &&
165             ↪ AreEqual(storedLinkValue.Target, target))
166         {
167             return GetOne();
168         }
169         return GetZero();
170     }
171     var value = default(TLink);
172     if (AreEqual(source, any))
173     {
174         value = target;
175     }
176     if (AreEqual(target, any))
177     {
178         value = source;
179     }
180     if (AreEqual(storedLinkValue.Source, value) ||
181         ↪ AreEqual(storedLinkValue.Target, value))
182     {
183         return GetOne();
184     }
185     return GetZero();
186 }
187 }
188
189 [MethodImpl(MethodImplOptions.AggressiveInlining)]
190 public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
191 {
192     var constants = Constants;
193     var @break = constants.Break;
194     if (restrictions.Count == 0)
195     {
196         for (var link = GetOne(); LessOrEqualThan(link,
197             ↪ GetHeaderReference().AllocatedLinks); link = Increment(link))
198         {
199             if (Exists(link) && AreEqual(handler(GetLinkStruct(link)), @break))
200             {
201                 return @break;
202             }
203         }
204         return @break;
205     }
206     var @continue = constants.Continue;
207     var any = constants.Any;
208     var index = restrictions[constants.IndexPart];
209     if (restrictions.Count == 1)
210     {
211         if (AreEqual(index, any))
212         {
213             return Each(handler, GetEmptyList());
214         }
215         if (!Exists(index))
216         {
217             return @continue;
218         }
219     }

```

```

218     return handler(GetLinkStruct(index));
219 }
220 if (restrictions.Count == 2)
221 {
222     var value = restrictions[1];
223     if (AreEqual(index, any))
224     {
225         if (AreEqual(value, any))
226         {
227             return Each(handler, GetEmptyList());
228         }
229         if (AreEqual(Each(handler, new Link<TLink>(index, value, any)), @break))
230         {
231             return @break;
232         }
233         return Each(handler, new Link<TLink>(index, any, value));
234     }
235     else
236     {
237         if (!Exists(index))
238         {
239             return @continue;
240         }
241         if (AreEqual(value, any))
242         {
243             return handler(GetLinkStruct(index));
244         }
245         ref var storedLinkValue = ref GetLinkReference(index);
246         if (AreEqual(storedLinkValue.Source, value) ||
247             AreEqual(storedLinkValue.Target, value))
248         {
249             return handler(GetLinkStruct(index));
250         }
251         return @continue;
252     }
253 }
254 if (restrictions.Count == 3)
255 {
256     var source = restrictions[constants.SourcePart];
257     var target = restrictions[constants.TargetPart];
258     if (AreEqual(index, any))
259     {
260         if (AreEqual(source, any) && AreEqual(target, any))
261         {
262             return Each(handler, GetEmptyList());
263         }
264         else if (AreEqual(source, any))
265         {
266             return TargetsTreeMethods.EachUsage(target, handler);
267         }
268         else if (AreEqual(target, any))
269         {
270             return SourcesTreeMethods.EachUsage(source, handler);
271         }
272         else //if(source != Any && target != Any)
273         {
274             var link = SourcesTreeMethods.Search(source, target);
275             return AreEqual(link, constants.Null) ? @continue :
276                 ↪ handler(GetLinkStruct(link));
277         }
278     }
279     else
280     {
281         if (!Exists(index))
282         {
283             return @continue;
284         }
285         if (AreEqual(source, any) && AreEqual(target, any))
286         {
287             return handler(GetLinkStruct(index));
288         }
289         ref var storedLinkValue = ref GetLinkReference(index);
290         if (!AreEqual(source, any) && !AreEqual(target, any))
291         {
292             if (AreEqual(storedLinkValue.Source, source) &&
293                 AreEqual(storedLinkValue.Target, target))
294             {
295                 return handler(GetLinkStruct(index));
296             }
297         }
298     }
299 }

```

```

295         }
296         return @continue;
297     }
298     var value = default(TLink);
299     if (AreEqual(source, any))
300     {
301         value = target;
302     }
303     if (AreEqual(target, any))
304     {
305         value = source;
306     }
307     if (AreEqual(storedLinkValue.Source, value) ||
308         AreEqual(storedLinkValue.Target, value))
309     {
310         return handler(GetLinkStruct(index));
311     }
312     return @continue;
313 }
314 }
315 throw new NotSupportedException("Другие размеры и способы ограничений не
    ↳ поддерживаются.");
316 }
317
318 /// <remarks>
319 /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
    ↳ в другом месте (но не в менеджере памяти, а в логике Links)
320 /// </remarks>
321 [MethodImpl(MethodImplOptions.AggressiveInlining)]
322 public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
323 {
324     var constants = Constants;
325     var @null = constants.Null;
326     var linkIndex = restrictions[constants.IndexPart];
327     ref var link = ref GetLinkReference(linkIndex);
328     ref var header = ref GetHeaderReference();
329     ref var firstAsSource = ref header.FirstAsSource;
330     ref var firstAsTarget = ref header.FirstAsTarget;
331     // Будет корректно работать только в том случае, если пространство выделенной связи
    ↳ предварительно заполнено нулями
332     if (!AreEqual(link.Source, @null))
333     {
334         SourcesTreeMethods.Detach(ref firstAsSource, linkIndex);
335     }
336     if (!AreEqual(link.Target, @null))
337     {
338         TargetsTreeMethods.Detach(ref firstAsTarget, linkIndex);
339     }
340     link.Source = substitution[constants.SourcePart];
341     link.Target = substitution[constants.TargetPart];
342     if (!AreEqual(link.Source, @null))
343     {
344         SourcesTreeMethods.Attach(ref firstAsSource, linkIndex);
345     }
346     if (!AreEqual(link.Target, @null))
347     {
348         TargetsTreeMethods.Attach(ref firstAsTarget, linkIndex);
349     }
350     return linkIndex;
351 }
352
353 /// <remarks>
354 /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
    ↳ пространство
355 /// </remarks>
356 public virtual TLink Create(IList<TLink> restrictions)
357 {
358     ref var header = ref GetHeaderReference();
359     var freeLink = header.FirstFreeLink;
360     if (!AreEqual(freeLink, Constants.Null))
361     {
362         UnusedLinksListMethods.Detach(freeLink);
363     }
364     else
365     {
366         var maximumPossibleInnerReference =
            ↳ Constants.PossibleInnerReferencesRange.Maximum;
367         if (GreaterThan(header.AllocatedLinks, maximumPossibleInnerReference))
368         {

```

```

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

```

```

444 [MethodImpl(MethodImplOptions.AggressiveInlining)]
445 protected virtual bool IsUnusedLink(TLink linkIndex)
446 {
447     if (!AreEqual(GetHeaderReference().FirstFreeLink, linkIndex)) // May be this check
448         ↪ is not needed
449     {
450         ref var link = ref GetLinkReference(linkIndex);
451         return AreEqual(link.SizeAsSource, default) && !AreEqual(link.Source, default);
452     }
453     else
454     {
455         return true;
456     }
457 }
458
459 [MethodImpl(MethodImplOptions.AggressiveInlining)]
460 protected virtual TLink GetOne() => Integer<TLink>.One;
461
462 [MethodImpl(MethodImplOptions.AggressiveInlining)]
463 protected virtual TLink GetZero() => Integer<TLink>.Zero;
464
465 [MethodImpl(MethodImplOptions.AggressiveInlining)]
466 protected virtual bool AreEqual(TLink first, TLink second) =>
467     ↪ EqualityComparer.Equals(first, second);
468
469 [MethodImpl(MethodImplOptions.AggressiveInlining)]
470 protected virtual bool LessThan(TLink first, TLink second) => Comparer.Compare(first,
471     ↪ second) < 0;
472
473 [MethodImpl(MethodImplOptions.AggressiveInlining)]
474 protected virtual bool LessOrEqualThan(TLink first, TLink second) =>
475     ↪ Comparer.Compare(first, second) <= 0;
476
477 [MethodImpl(MethodImplOptions.AggressiveInlining)]
478 protected virtual bool GreaterThan(TLink first, TLink second) => Comparer.Compare(first,
479     ↪ second) > 0;
480
481 [MethodImpl(MethodImplOptions.AggressiveInlining)]
482 protected virtual bool GreaterOrEqualThan(TLink first, TLink second) =>
483     ↪ Comparer.Compare(first, second) >= 0;
484
485 [MethodImpl(MethodImplOptions.AggressiveInlining)]
486 protected virtual long ConvertToInt64(TLink value) => (Integer<TLink>)value;
487
488 [MethodImpl(MethodImplOptions.AggressiveInlining)]
489 protected virtual TLink ConvertToAddress(long value) => (Integer<TLink>)value;
490
491 [MethodImpl(MethodImplOptions.AggressiveInlining)]
492 protected virtual TLink Add(TLink first, TLink second) => Arithmetic<TLink>.Add(first,
493     ↪ second);
494
495 [MethodImpl(MethodImplOptions.AggressiveInlining)]
496 protected virtual TLink Subtract(TLink first, TLink second) =>
497     ↪ Arithmetic<TLink>.Subtract(first, second);
498
499 [MethodImpl(MethodImplOptions.AggressiveInlining)]
500 protected virtual TLink Increment(TLink link) => Arithmetic<TLink>.Increment(link);
501
502 [MethodImpl(MethodImplOptions.AggressiveInlining)]
503 protected virtual TLink Decrement(TLink link) => Arithmetic<TLink>.Decrement(link);
504
505 [MethodImpl(MethodImplOptions.AggressiveInlining)]
506 protected virtual IList<TLink> GetEmptyList() => ArrayPool<TLink>.Empty;
507
508 #region Disposable
509
510 protected override bool AllowMultipleDisposeCalls => true;
511
512 protected override void Dispose(bool manual, bool wasDisposed)
513 {
514     if (!wasDisposed)
515     {
516         ResetPointers();
517         _memory.DisposeIfPossible();
518     }
519 }
520
521 #endregion

```

```
515     }
516 }
```

```
./Platform.Data.Doublets/ResizableDirectMemory/Generic/ResizableDirectMemoryLinks.cs
1  using System.Runtime.CompilerServices;
2  using Platform.Numbers;
3  using Platform.Memory;
4  using static System.Runtime.CompilerServices.Unsafe;
5  using System;
6  using Platform.Singletons;
7
8  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
11 {
12     public unsafe partial class ResizableDirectMemoryLinks<TLink> :
13         ↳ ResizableDirectMemoryLinksBase<TLink>
14     {
15         private readonly Func<ILinksTreeMethods<TLink>> _createSourceTreeMethods;
16         private readonly Func<ILinksTreeMethods<TLink>> _createTargetTreeMethods;
17         private byte* _header;
18         private byte* _links;
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         public ResizableDirectMemoryLinks(string address) : this(address, DefaultLinksSizeStep)
22             ↳ { }
23
24         /// <summary>
25         /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
26         ↳ минимальным шагом расширения базы данных.
27         /// </summary>
28         /// <param name="address">Полный путь к файлу базы данных.</param>
29         /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
30         ↳ байтах.</param>
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         public ResizableDirectMemoryLinks(string address, long memoryReservationStep) : this(new
33             ↳ FileMappedResizableDirectMemory(address, memoryReservationStep),
34             ↳ memoryReservationStep) { }
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         public ResizableDirectMemoryLinks(IResizableDirectMemory memory) : this(memory,
38             ↳ DefaultLinksSizeStep) { }
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         public ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
42             ↳ memoryReservationStep) : this(memory, memoryReservationStep,
43             ↳ Default<LinksConstants<TLink>>.Instance, true) { }
44
45         [MethodImpl(MethodImplOptions.AggressiveInlining)]
46         public ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
47             ↳ memoryReservationStep, LinksConstants<TLink> constants, bool useAvlBasedIndex) :
48             ↳ base(memory, memoryReservationStep, constants)
49         {
50             if (useAvlBasedIndex)
51             {
52                 _createSourceTreeMethods = () => new
53                     ↳ LinksSourcesAvlBalancedTreeMethods<TLink>(Constants, _links, _header);
54                 _createTargetTreeMethods = () => new
55                     ↳ LinksTargetsAvlBalancedTreeMethods<TLink>(Constants, _links, _header);
56             }
57             else
58             {
59                 _createSourceTreeMethods = () => new
60                     ↳ LinksSourcesSizeBalancedTreeMethods<TLink>(Constants, _links, _header);
61                 _createTargetTreeMethods = () => new
62                     ↳ LinksTargetsSizeBalancedTreeMethods<TLink>(Constants, _links, _header);
63             }
64             Init(memory, memoryReservationStep);
65         }
66
67         [MethodImpl(MethodImplOptions.AggressiveInlining)]
68         protected override void SetPointers(IResizableDirectMemory memory)
69         {
70             _links = (byte*)memory.Pointer;
71             _header = _links;
72             SourcesTreeMethods = _createSourceTreeMethods();
73             TargetsTreeMethods = _createTargetTreeMethods();
74             UnusedLinksListMethods = new UnusedLinksListMethods<TLink>(_links, _header);
75         }
76     }
77 }
```

```

60     }
61
62     [MethodImpl(MethodImplOptions.AggressiveInlining)]
63     protected override void ResetPointers()
64     {
65         base.ResetPointers();
66         _links = null;
67         _header = null;
68     }
69
70     [MethodImpl(MethodImplOptions.AggressiveInlining)]
71     protected override ref LinksHeader<TLink> GetHeaderReference() => ref
72     ↪ AsRef<LinksHeader<TLink>>(_header);
73
74     [MethodImpl(MethodImplOptions.AggressiveInlining)]
75     protected override ref RawLink<TLink> GetLinkReference(TLink linkIndex) => ref
76     ↪ AsRef<RawLink<TLink>>(_links + LinkSizeInBytes * (Integer<TLink>)linkIndex);
77 }

```

./Platform.Data.Doublets/ResizableDirectMemory/Generic/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.Generic
9  {
10     public unsafe class UnusedLinksListMethods<TLink> : CircularDoublyLinkedListMethods<TLink>,
11     ↪ ILinksListMethods<TLink>
12     {
13         private readonly byte* _links;
14         private readonly byte* _header;
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         public UnusedLinksListMethods(byte* links, byte* header)
18         {
19             _links = links;
20             _header = header;
21         }
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
25         ↪ AsRef<LinksHeader<TLink>>(_header);
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
29         ↪ AsRef<RawLink<TLink>>(_links + RawLink<TLink>.SizeInBytes * (Integer<TLink>)link);
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected override TLink GetFirst() => GetHeaderReference().FirstFreeLink;
33
34         [MethodImpl(MethodImplOptions.AggressiveInlining)]
35         protected override TLink GetLast() => GetHeaderReference().LastFreeLink;
36
37         [MethodImpl(MethodImplOptions.AggressiveInlining)]
38         protected override TLink GetPrevious(TLink element) => GetLinkReference(element).Source;
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         protected override TLink GetNext(TLink element) => GetLinkReference(element).Target;
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         protected override TLink GetSize() => GetHeaderReference().FreeLinks;
45
46         [MethodImpl(MethodImplOptions.AggressiveInlining)]
47         protected override void SetFirst(TLink element) => GetHeaderReference().FirstFreeLink =
48         ↪ element;
49
50         [MethodImpl(MethodImplOptions.AggressiveInlining)]
51         protected override void SetLast(TLink element) => GetHeaderReference().LastFreeLink =
52         ↪ element;
53
54         [MethodImpl(MethodImplOptions.AggressiveInlining)]
55         protected override void SetPrevious(TLink element, TLink previous) =>
56         ↪ GetLinkReference(element).Source = previous;
57
58         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

53         protected override void SetNext(TLink element, TLink next) =>
54             ↪ GetLinkReference(element).Target = next;
55
56         [MethodImpl(MethodImplOptions.AggressiveInlining)]
57         protected override void SetSize(TLink size) => GetHeaderReference().FreeLinks = size;
58     }

```

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

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  namespace Platform.Data.Doublets.ResizableDirectMemory
4  {
5      public interface ILinksListMethods<TLink>
6      {
7          void Detach(TLink freeLink);
8          void AttachAsFirst(TLink link);
9      }
10 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.ResizableDirectMemory
7  {
8      public interface ILinksTreeMethods<TLink>
9      {
10         TLink CountUsages(TLink link);
11         TLink Search(TLink source, TLink target);
12         TLink EachUsage(TLink source, Func<IList<TLink>, TLink> handler);
13         void Detach(ref TLink firstAsSource, TLink linkIndex);
14         void Attach(ref TLink firstAsSource, TLink linkIndex);
15     }
16 }

```

./Platform.Data.Doublets/ResizableDirectMemory/LinksHeader.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 LinksHeader<TLink>
8      {
9          public static readonly long SizeInBytes = Structure<LinksHeader<TLink>>.Size;
10
11         public TLink AllocatedLinks;
12         public TLink ReservedLinks;
13         public TLink FreeLinks;
14         public TLink FirstFreeLink;
15         public TLink FirstAsSource;
16         public TLink FirstAsTarget;
17         public TLink LastFreeLink;
18         public TLink Reserved8;
19     }
20 }

```

./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/Specific/UInt64LinksAvlBalancedTreeMethodsBase.cs

```
1 using System.Runtime.CompilerServices;
2 using Platform.Data.Doublets.ResizableDirectMemory.Generic;
3 using static System.Runtime.CompilerServices.Unsafe;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Data.Doublets.ResizableDirectMemory.Specific
8 {
9     public unsafe abstract class UInt64LinksAvlBalancedTreeMethodsBase :
10         ↳ LinksAvlBalancedTreeMethodsBase<ulong>
11     {
12         protected new readonly RawLink<ulong>* Links;
13         protected new readonly LinksHeader<ulong>* Header;
14
15         public UInt64LinksAvlBalancedTreeMethodsBase(LinksConstants<ulong> constants,
16             ↳ RawLink<ulong>* links, LinksHeader<ulong>* header)
17             : base(constants, (byte*)links, (byte*)header)
18         {
19             Links = links;
20             Header = header;
21         }
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected override ulong GetZero() => OUL;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         protected override bool EqualToZero(ulong value) => value == OUL;
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         protected override bool IsEquals(ulong first, ulong second) => first == second;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override bool GreaterThanZero(ulong value) => value > OUL;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override bool GreaterThan(ulong first, ulong second) => first > second;
37
38         [MethodImpl(MethodImplOptions.AggressiveInlining)]
39         protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
40
41         [MethodImpl(MethodImplOptions.AggressiveInlining)]
42         protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
43             ↳ always true for ulong
44
45         [MethodImpl(MethodImplOptions.AggressiveInlining)]
46         protected override bool LessOrEqualThanZero(ulong value) => value == OUL; // value is
47             ↳ always >= 0 for ulong
48
49         [MethodImpl(MethodImplOptions.AggressiveInlining)]
50         protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
51
52         [MethodImpl(MethodImplOptions.AggressiveInlining)]
53         protected override bool LessThanZero(ulong value) => false; // value < 0 is always false
54             ↳ for ulong
55
56         [MethodImpl(MethodImplOptions.AggressiveInlining)]
57         protected override bool LessThan(ulong first, ulong second) => first < second;
58
59         [MethodImpl(MethodImplOptions.AggressiveInlining)]
60         protected override ulong Increment(ulong value) => ++value;
61
62         [MethodImpl(MethodImplOptions.AggressiveInlining)]
63         protected override ulong Decrement(ulong value) => --value;
64
65         [MethodImpl(MethodImplOptions.AggressiveInlining)]
66         protected override ulong Add(ulong first, ulong second) => first + second;
67
68         [MethodImpl(MethodImplOptions.AggressiveInlining)]
69         protected override ulong Subtract(ulong first, ulong second) => first - second;
70
71         [MethodImpl(MethodImplOptions.AggressiveInlining)]
72         protected override bool FirstIsToTheLeftOfSecond(ulong first, ulong second)
73         {
74             ref var firstLink = ref Links[first];
75             ref var secondLink = ref Links[second];
76             return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
77                 ↳ secondLink.Source, secondLink.Target);
78         }
79     }
80 }
```

```

74 [MethodImpl(MethodImplOptions.AggressiveInlining)]
75 protected override bool FirstIsToTheRightOfSecond(ulong first, ulong second)
76 {
77     ref var firstLink = ref Links[first];
78     ref var secondLink = ref Links[second];
79     return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
    ↪ secondLink.Source, secondLink.Target);
80 }
81
82 [MethodImpl(MethodImplOptions.AggressiveInlining)]
83 protected override ulong GetSizeValue(ulong value) => unchecked((value & 4294967264UL)
    ↪ >> 5);
84
85 [MethodImpl(MethodImplOptions.AggressiveInlining)]
86 protected override void SetSizeValue(ref ulong storedValue, ulong size) => storedValue =
    ↪ unchecked(storedValue & 31UL | (size & 134217727UL) << 5);
87
88 [MethodImpl(MethodImplOptions.AggressiveInlining)]
89 protected override bool GetLeftIsChildValue(ulong value) => unchecked((value & 16UL) >>
    ↪ 4 == 1UL);
90
91 [MethodImpl(MethodImplOptions.AggressiveInlining)]
92 protected override void SetLeftIsChildValue(ref ulong storedValue, bool value) =>
    ↪ storedValue = unchecked(storedValue & 4294967279UL | (As<bool, byte>(ref value) &
    ↪ 1UL) << 4);
93
94 [MethodImpl(MethodImplOptions.AggressiveInlining)]
95 protected override bool GetRightIsChildValue(ulong value) => unchecked((value & 8UL) >>
    ↪ 3 == 1UL);
96
97 [MethodImpl(MethodImplOptions.AggressiveInlining)]
98 protected override void SetRightIsChildValue(ref ulong storedValue, bool value) =>
    ↪ storedValue = unchecked(storedValue & 4294967287UL | (As<bool, byte>(ref value) &
    ↪ 1UL) << 3);
99
100 [MethodImpl(MethodImplOptions.AggressiveInlining)]
101 protected override sbyte GetBalanceValue(ulong value) => unchecked((sbyte)(value & 7UL |
    ↪ 0xF8UL * ((value & 4UL) >> 2))); // if negative, then continue ones to the end of
    ↪ sbyte
102
103 [MethodImpl(MethodImplOptions.AggressiveInlining)]
104 protected override void SetBalanceValue(ref ulong storedValue, sbyte value) =>
    ↪ storedValue = unchecked(storedValue & 4294967288UL | (ulong)((byte)value >> 5 & 4 |
    ↪ value & 3) & 7UL);
105
106 [MethodImpl(MethodImplOptions.AggressiveInlining)]
107 protected override ref LinksHeader<ulong> GetHeaderReference() => ref *Header;
108
109 [MethodImpl(MethodImplOptions.AggressiveInlining)]
110 protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref Links[link];
111 }
112 }

```

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

```

1 using System.Runtime.CompilerServices;
2 using Platform.Data.Doublets.ResizableDirectMemory.Generic;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.ResizableDirectMemory.Specific
7 {
8     public unsafe abstract class UInt64LinksSizeBalancedTreeMethodsBase :
    ↪ LinksSizeBalancedTreeMethodsBase<ulong>
9     {
10         protected new readonly RawLink<ulong>* Links;
11         protected new readonly LinksHeader<ulong>* Header;
12
13         public UInt64LinksSizeBalancedTreeMethodsBase(LinksConstants<ulong> constants,
    ↪ RawLink<ulong>* links, LinksHeader<ulong>* header)
14             : base(constants, (byte*)links, (byte*)header)
15         {
16             Links = links;
17             Header = header;
18         }
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         protected override ulong GetZero() => 0UL;
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

24     protected override bool EqualToZero(ulong value) => value == 0UL;
25
26     [MethodImpl(MethodImplOptions.AggressiveInlining)]
27     protected override bool IsEquals(ulong first, ulong second) => first == second;
28
29     [MethodImpl(MethodImplOptions.AggressiveInlining)]
30     protected override bool GreaterThanZero(ulong value) => value > 0UL;
31
32     [MethodImpl(MethodImplOptions.AggressiveInlining)]
33     protected override bool GreaterThan(ulong first, ulong second) => first > second;
34
35     [MethodImpl(MethodImplOptions.AggressiveInlining)]
36     protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
37
38     [MethodImpl(MethodImplOptions.AggressiveInlining)]
39     protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
    ↪ always true for ulong
40
41     [MethodImpl(MethodImplOptions.AggressiveInlining)]
42     protected override bool LessOrEqualThanZero(ulong value) => value == 0UL; // value is
    ↪ always >= 0 for ulong
43
44     [MethodImpl(MethodImplOptions.AggressiveInlining)]
45     protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
46
47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     protected override bool LessThanZero(ulong value) => false; // value < 0 is always false
    ↪ for ulong
49
50     [MethodImpl(MethodImplOptions.AggressiveInlining)]
51     protected override bool LessThan(ulong first, ulong second) => first < second;
52
53     [MethodImpl(MethodImplOptions.AggressiveInlining)]
54     protected override ulong Increment(ulong value) => ++value;
55
56     [MethodImpl(MethodImplOptions.AggressiveInlining)]
57     protected override ulong Decrement(ulong value) => --value;
58
59     [MethodImpl(MethodImplOptions.AggressiveInlining)]
60     protected override ulong Add(ulong first, ulong second) => first + second;
61
62     [MethodImpl(MethodImplOptions.AggressiveInlining)]
63     protected override ulong Subtract(ulong first, ulong second) => first - second;
64
65     [MethodImpl(MethodImplOptions.AggressiveInlining)]
66     protected override bool FirstIsToLeftOfSecond(ulong first, ulong second)
67     {
68         ref var firstLink = ref Links[first];
69         ref var secondLink = ref Links[second];
70         return FirstIsToLeftOfSecond(firstLink.Source, firstLink.Target,
    ↪ secondLink.Source, secondLink.Target);
71     }
72
73     [MethodImpl(MethodImplOptions.AggressiveInlining)]
74     protected override bool FirstIsToTheRightOfSecond(ulong first, ulong second)
75     {
76         ref var firstLink = ref Links[first];
77         ref var secondLink = ref Links[second];
78         return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
    ↪ secondLink.Source, secondLink.Target);
79     }
80
81     [MethodImpl(MethodImplOptions.AggressiveInlining)]
82     protected override ref LinksHeader<ulong> GetHeaderReference() => ref *Header;
83
84     [MethodImpl(MethodImplOptions.AggressiveInlining)]
85     protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref Links[link];
86 }
87 }

```

./Platform.Data.Doublets/ResizableDirectMemory/Specific/UInt64LinksSourcesAvlBalancedTreeMethods.cs

```

1 using System.Runtime.CompilerServices;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.ResizableDirectMemory.Specific
6 {
7     public unsafe class UInt64LinksSourcesAvlBalancedTreeMethods :
    ↪ UInt64LinksAvlBalancedTreeMethodsBase

```

```

8 {
9     public UInt64LinksSourcesAvlBalancedTreeMethods(LinksConstants<ulong> constants,
10         ↳ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
11         ↳ { }
12
13     [MethodImpl(MethodImplOptions.AggressiveInlining)]
14     protected override ref ulong GetLeftReference(ulong node) => ref
15         ↳ Links[node].LeftAsSource;
16
17     [MethodImpl(MethodImplOptions.AggressiveInlining)]
18     protected override ref ulong GetRightReference(ulong node) => ref
19         ↳ Links[node].RightAsSource;
20
21     [MethodImpl(MethodImplOptions.AggressiveInlining)]
22     protected override ulong GetLeft(ulong node) => Links[node].LeftAsSource;
23
24     [MethodImpl(MethodImplOptions.AggressiveInlining)]
25     protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsSource =
26         ↳ left;
27
28     [MethodImpl(MethodImplOptions.AggressiveInlining)]
29     protected override void SetRight(ulong node, ulong right) => Links[node].RightAsSource =
30         ↳ right;
31
32     [MethodImpl(MethodImplOptions.AggressiveInlining)]
33     protected override ulong GetSize(ulong node) => GetSizeValue(Links[node].SizeAsSource);
34
35     [MethodImpl(MethodImplOptions.AggressiveInlining)]
36     protected override void SetSize(ulong node, ulong size) => SetSizeValue(ref
37         ↳ Links[node].SizeAsSource, size);
38
39     [MethodImpl(MethodImplOptions.AggressiveInlining)]
40     protected override bool GetLeftIsChild(ulong node) =>
41         ↳ GetLeftIsChildValue(Links[node].SizeAsSource);
42
43     //[MethodImpl(MethodImplOptions.AggressiveInlining)]
44     //protected override bool GetLeftIsChild(ulong node) => IsChild(node, GetLeft(node));
45
46     [MethodImpl(MethodImplOptions.AggressiveInlining)]
47     protected override void SetLeftIsChild(ulong node, bool value) =>
48         ↳ SetLeftIsChildValue(ref Links[node].SizeAsSource, value);
49
50     [MethodImpl(MethodImplOptions.AggressiveInlining)]
51     protected override bool GetRightIsChild(ulong node) =>
52         ↳ GetRightIsChildValue(Links[node].SizeAsSource);
53
54     //[MethodImpl(MethodImplOptions.AggressiveInlining)]
55     //protected override bool GetRightIsChild(ulong node) => IsChild(node, GetRight(node));
56
57     [MethodImpl(MethodImplOptions.AggressiveInlining)]
58     protected override void SetRightIsChild(ulong node, bool value) =>
59         ↳ SetRightIsChildValue(ref Links[node].SizeAsSource, value);
60
61     [MethodImpl(MethodImplOptions.AggressiveInlining)]
62     protected override sbyte GetBalance(ulong node) =>
63         ↳ GetBalanceValue(Links[node].SizeAsSource);
64
65     [MethodImpl(MethodImplOptions.AggressiveInlining)]
66     protected override void SetBalance(ulong node, sbyte value) => SetBalanceValue(ref
67         ↳ Links[node].SizeAsSource, value);
68
69     [MethodImpl(MethodImplOptions.AggressiveInlining)]
70     protected override ulong GetTreeRoot() => Header->FirstAsSource;
71
72     [MethodImpl(MethodImplOptions.AggressiveInlining)]
73     protected override ulong GetBasePartValue(ulong link) => Links[link].Source;
74
75     [MethodImpl(MethodImplOptions.AggressiveInlining)]
76     protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
77         ↳ ulong secondSource, ulong secondTarget)
78         ↳ => firstSource < secondSource || firstSource == secondSource && firstTarget <
79         ↳ secondTarget;
80
81     [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

70     protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
71     ↪     ulong secondSource, ulong secondTarget)
72     => firstSource > secondSource || firstSource == secondSource && firstTarget >
73     ↪     secondTarget;
74
75     [MethodImpl(MethodImplOptions.AggressiveInlining)]
76     protected override void ClearNode(ulong node)
77     {
78         ref var link = ref Links[node];
79         link.LeftAsSource = OUL;
80         link.RightAsSource = OUL;
81         link.SizeAsSource = OUL;
82     }
83 }

```

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

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.ResizableDirectMemory.Specific
6  {
7      public unsafe class UInt64LinksSourcesSizeBalancedTreeMethods :
8      ↪     UInt64LinksSizeBalancedTreeMethodsBase
9      {
10         public UInt64LinksSourcesSizeBalancedTreeMethods(LinksConstants<ulong> constants,
11         ↪     RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
12         ↪     { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected override ref ulong GetLeftReference(ulong node) => ref
16         ↪     Links[node].LeftAsSource;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override ref ulong GetRightReference(ulong node) => ref
20         ↪     Links[node].RightAsSource;
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected override ulong GetLeft(ulong node) => Links[node].LeftAsSource;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected override ulong GetRight(ulong node) => Links[node].RightAsSource;
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsSource =
30         ↪     left;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override void SetRight(ulong node, ulong right) => Links[node].RightAsSource =
34         ↪     right;
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected override ulong GetSize(ulong node) => Links[node].SizeAsSource;
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override void SetSize(ulong node, ulong size) => Links[node].SizeAsSource =
41         ↪     size;
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         protected override ulong GetTreeRoot() => Header->FirstAsSource;
45
46         [MethodImpl(MethodImplOptions.AggressiveInlining)]
47         protected override ulong GetBasePartValue(ulong link) => Links[link].Source;
48
49         [MethodImpl(MethodImplOptions.AggressiveInlining)]
50         protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
51         ↪     ulong secondSource, ulong secondTarget)
52         => firstSource < secondSource || firstSource == secondSource && firstTarget <
53         ↪     secondTarget;
54
55         [MethodImpl(MethodImplOptions.AggressiveInlining)]
56         protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
57         ↪     ulong secondSource, ulong secondTarget)
58         => firstSource > secondSource || firstSource == secondSource && firstTarget >
59         ↪     secondTarget;
60
61         [MethodImpl(MethodImplOptions.AggressiveInlining)]
62         protected override void ClearNode(ulong node)

```

```

51     {
52         ref var link = ref Links[node];
53         link.LeftAsSource = OUL;
54         link.RightAsSource = OUL;
55         link.SizeAsSource = OUL;
56     }
57 }
58 }

```

./Platform.Data.Doublets/ResizableDirectMemory/Specific/UInt64LinksTargetsAvlBalancedTreeMethods.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.Specific
6  {
7      public unsafe class UInt64LinksTargetsAvlBalancedTreeMethods :
8          ↳ UInt64LinksAvlBalancedTreeMethodsBase
9      {
10
11         public UInt64LinksTargetsAvlBalancedTreeMethods(LinksConstants<ulong> constants,
12             ↳ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
13             ↳ { }
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         protected override ref ulong GetLeftReference(ulong node) => ref
17             ↳ Links[node].LeftAsTarget;
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         protected override ref ulong GetRightReference(ulong node) => ref
21             ↳ Links[node].RightAsTarget;
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected override ulong GetLeft(ulong node) => Links[node].LeftAsTarget;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         protected override ulong GetRight(ulong node) => Links[node].RightAsTarget;
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsTarget =
31             ↳ left;
32
33         [MethodImpl(MethodImplOptions.AggressiveInlining)]
34         protected override void SetRight(ulong node, ulong right) => Links[node].RightAsTarget =
35             ↳ right;
36
37         [MethodImpl(MethodImplOptions.AggressiveInlining)]
38         protected override ulong GetSize(ulong node) => GetSizeValue(Links[node].SizeAsTarget);
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         protected override void SetSize(ulong node, ulong size) => SetSizeValue(ref
42             ↳ Links[node].SizeAsTarget, size);
43
44         [MethodImpl(MethodImplOptions.AggressiveInlining)]
45         protected override bool GetLeftIsChild(ulong node) =>
46             ↳ GetLeftIsChildValue(Links[node].SizeAsTarget);
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         protected override void SetLeftIsChild(ulong node, bool value) =>
50             ↳ SetLeftIsChildValue(ref Links[node].SizeAsTarget, value);
51
52         [MethodImpl(MethodImplOptions.AggressiveInlining)]
53         protected override bool GetRightIsChild(ulong node) =>
54             ↳ GetRightIsChildValue(Links[node].SizeAsTarget);
55
56         [MethodImpl(MethodImplOptions.AggressiveInlining)]
57         protected override void SetRightIsChild(ulong node, bool value) =>
58             ↳ SetRightIsChildValue(ref Links[node].SizeAsTarget, value);
59
60         [MethodImpl(MethodImplOptions.AggressiveInlining)]
61         protected override sbyte GetBalance(ulong node) =>
62             ↳ GetBalanceValue(Links[node].SizeAsTarget);
63
64         [MethodImpl(MethodImplOptions.AggressiveInlining)]
65         protected override void SetBalance(ulong node, sbyte value) => SetBalanceValue(ref
66             ↳ Links[node].SizeAsTarget, value);
67
68         [MethodImpl(MethodImplOptions.AggressiveInlining)]
69         protected override ulong GetTreeRoot() => Header->FirstAsTarget;
70
71     }
72 }

```

```

56 [MethodImpl(MethodImplOptions.AggressiveInlining)]
57 protected override ulong GetBasePartValue(ulong link) => Links[link].Target;
58
59 [MethodImpl(MethodImplOptions.AggressiveInlining)]
60 protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
61     ↳ ulong secondSource, ulong secondTarget)
62     => firstTarget < secondTarget || firstTarget == secondTarget && firstSource <
63     ↳ secondSource;
64
65 [MethodImpl(MethodImplOptions.AggressiveInlining)]
66 protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
67     ↳ ulong secondSource, ulong secondTarget)
68     => firstTarget > secondTarget || firstTarget == secondTarget && firstSource >
69     ↳ secondSource;
70
71 [MethodImpl(MethodImplOptions.AggressiveInlining)]
72 protected override void ClearNode(ulong node)
73 {
74     ref var link = ref Links[node];
75     link.LeftAsTarget = OUL;
76     link.RightAsTarget = OUL;
77     link.SizeAsTarget = OUL;
78 }
79 }

```

./Platform.Data.Doublets/ResizableDirectMemory/Specific/UInt64LinksTargetsSizeBalancedTreeMethods.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.Specific
6 {
7     public unsafe class UInt64LinksTargetsSizeBalancedTreeMethods :
8     ↳ UInt64LinksSizeBalancedTreeMethodsBase
9     {
10         public UInt64LinksTargetsSizeBalancedTreeMethods(LinksConstants<ulong> constants,
11     ↳ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
12     ↳ { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected override ref ulong GetLeftReference(ulong node) => ref
16     ↳ Links[node].LeftAsTarget;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override ref ulong GetRightReference(ulong node) => ref
20     ↳ Links[node].RightAsTarget;
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected override ulong GetLeft(ulong node) => Links[node].LeftAsTarget;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected override ulong GetRight(ulong node) => Links[node].RightAsTarget;
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsTarget =
30     ↳ left;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override void SetRight(ulong node, ulong right) => Links[node].RightAsTarget =
34     ↳ right;
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected override ulong GetSize(ulong node) => Links[node].SizeAsTarget;
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override void SetSize(ulong node, ulong size) => Links[node].SizeAsTarget =
41     ↳ size;
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         protected override ulong GetTreeRoot() => Header->FirstAsTarget;
45
46         [MethodImpl(MethodImplOptions.AggressiveInlining)]
47         protected override ulong GetBasePartValue(ulong link) => Links[link].Target;
48
49         [MethodImpl(MethodImplOptions.AggressiveInlining)]
50         protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
51     ↳ ulong secondSource, ulong secondTarget)

```

```

43         => firstTarget < secondTarget || firstTarget == secondTarget && firstSource <
           ↳ secondSource;
44
45     [MethodImpl(MethodImplOptions.AggressiveInlining)]
46     protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
           ↳ ulong secondSource, ulong secondTarget)
47         => firstTarget > secondTarget || firstTarget == secondTarget && firstSource >
           ↳ secondSource;
48
49     [MethodImpl(MethodImplOptions.AggressiveInlining)]
50     protected override void ClearNode(ulong node)
51     {
52         ref var link = ref Links[node];
53         link.LeftAsTarget = OUL;
54         link.RightAsTarget = OUL;
55         link.SizeAsTarget = OUL;
56     }
57 }
58 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Memory;
5  using Platform.Data.Doublets.ResizableDirectMemory.Generic;
6  using Platform.Singletons;
7
8  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets.ResizableDirectMemory.Specific
11 {
12     public unsafe class UInt64ResizableDirectMemoryLinks : ResizableDirectMemoryLinksBase<ulong>
13     {
14         private readonly Func<ILinksTreeMethods<ulong>> _createSourceTreeMethods;
15         private readonly Func<ILinksTreeMethods<ulong>> _createTargetTreeMethods;
16         private LinksHeader<ulong>* _header;
17         private RawLink<ulong>* _links;
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         public UInt64ResizableDirectMemoryLinks(string address) : this(address,
           ↳ DefaultLinksSizeStep) { }
21
22         /// <summary>
23         /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
           ↳ минимальным шагом расширения базы данных.
24         /// </summary>
25         /// <param name="address">Полный путь к файлу базы данных.</param>
26         /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
           ↳ байтах.</param>
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         public UInt64ResizableDirectMemoryLinks(string address, long memoryReservationStep) :
           ↳ this(new FileMappedResizableDirectMemory(address, memoryReservationStep),
           ↳ memoryReservationStep) { }
29
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]
31         public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory) : this(memory,
           ↳ DefaultLinksSizeStep) { }
32
33         [MethodImpl(MethodImplOptions.AggressiveInlining)]
34         public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
           ↳ memoryReservationStep) : this(memory, memoryReservationStep,
           ↳ Default<LinksConstants<ulong>>.Instance, true) { }
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
           ↳ memoryReservationStep, LinksConstants<ulong> constants, bool useAvlBasedIndex) :
           ↳ base(memory, memoryReservationStep, constants)
38         {
39             if (useAvlBasedIndex)
40             {
41                 _createSourceTreeMethods = () => new
           ↳ UInt64LinksSourcesAvlBalancedTreeMethods(Constants, _links, _header);
42                 _createTargetTreeMethods = () => new
           ↳ UInt64LinksTargetsAvlBalancedTreeMethods(Constants, _links, _header);
43             }
44             else
45             {

```



```

46         _createSourceTreeMethods = () => new
47         ↪ UInt64LinksSourcesSizeBalancedTreeMethods(Constants, _links, _header);
48     _createTargetTreeMethods = () => new
49     ↪ UInt64LinksTargetsSizeBalancedTreeMethods(Constants, _links, _header);
50 }
51 Init(memory, memoryReservationStep);
52 }
53 [MethodImpl(MethodImplOptions.AggressiveInlining)]
54 protected override void SetPointers(IResizableDirectMemory memory)
55 {
56     _header = (LinksHeader<ulong>*)memory.Pointer;
57     _links = (RawLink<ulong>*)memory.Pointer;
58     SourcesTreeMethods = _createSourceTreeMethods();
59     TargetsTreeMethods = _createTargetTreeMethods();
60     UnusedLinksListMethods = new UInt64UnusedLinksListMethods(_links, _header);
61 }
62 [MethodImpl(MethodImplOptions.AggressiveInlining)]
63 protected override void ResetPointers()
64 {
65     base.ResetPointers();
66     _links = null;
67     _header = null;
68 }
69 [MethodImpl(MethodImplOptions.AggressiveInlining)]
70 protected override ref LinksHeader<ulong> GetHeaderReference() => ref *_header;
71 [MethodImpl(MethodImplOptions.AggressiveInlining)]
72 protected override ref RawLink<ulong> GetLinkReference(ulong linkIndex) => ref
73 ↪ _links[linkIndex];
74 [MethodImpl(MethodImplOptions.AggressiveInlining)]
75 protected override bool AreEqual(ulong first, ulong second) => first == second;
76 [MethodImpl(MethodImplOptions.AggressiveInlining)]
77 protected override bool LessThan(ulong first, ulong second) => first < second;
78 [MethodImpl(MethodImplOptions.AggressiveInlining)]
79 protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
80 [MethodImpl(MethodImplOptions.AggressiveInlining)]
81 protected override bool GreaterThan(ulong first, ulong second) => first > second;
82 [MethodImpl(MethodImplOptions.AggressiveInlining)]
83 protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
84 [MethodImpl(MethodImplOptions.AggressiveInlining)]
85 protected override bool GetZero() => 0UL;
86 [MethodImpl(MethodImplOptions.AggressiveInlining)]
87 protected override bool GetOne() => 1UL;
88 [MethodImpl(MethodImplOptions.AggressiveInlining)]
89 protected override long ConvertToUInt64(ulong value) => (long)value;
90 [MethodImpl(MethodImplOptions.AggressiveInlining)]
91 protected override ulong ConvertToAddress(long value) => (ulong)value;
92 [MethodImpl(MethodImplOptions.AggressiveInlining)]
93 protected override ulong Add(ulong first, ulong second) => first + second;
94 [MethodImpl(MethodImplOptions.AggressiveInlining)]
95 protected override ulong Subtract(ulong first, ulong second) => first - second;
96 [MethodImpl(MethodImplOptions.AggressiveInlining)]
97 protected override ulong Increment(ulong link) => ++link;
98 [MethodImpl(MethodImplOptions.AggressiveInlining)]
99 protected override ulong Decrement(ulong link) => --link;
100 [MethodImpl(MethodImplOptions.AggressiveInlining)]
101 protected override IList<ulong> GetEmptyList() => new ulong[0];
102 }
103 }

```

./Platform.Data.Doublets/ResizableDirectMemory/Specific/UInt64UnusedLinksListMethods.cs

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

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

```
1 using System;
2 using System.Collections.Generic;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences
7 {
8     public static class ArrayExtensions
9     {
10         public static IList<TLink> ConvertToRestrictionsValues<TLink>(this TLink[] array)
11         {
12             var restrictions = new TLink[array.Length + 1];
13             Array.Copy(array, 0, restrictions, 1, array.Length);
14             return restrictions;
15         }
16     }
17 }
```

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

```
1 using System.Collections.Generic;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.Sequences.Converters
6 {
7     public class BalancedVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
8     {
9         public BalancedVariantConverter(ILinks<TLink> links) : base(links) { }
10
11         public override TLink Convert(IList<TLink> sequence)
12         {
13             var length = sequence.Count;
14             if (length < 1)
15             {
16                 return default;
17             }
18             if (length == 1)
19             {
20                 return sequence[0];
21             }
22             // Make copy of next layer
23             if (length > 2)
24             {
25                 // TODO: Try to use stackalloc (which at the moment is not working with
26                 // ↪ generics) but will be possible with Sigil
27                 var halvedSequence = new TLink[(length / 2) + (length % 2)];
28                 HalveSequence(halvedSequence, sequence, length);
29                 sequence = halvedSequence;
30                 length = halvedSequence.Length;
31             }
32         }
33     }
34 }
```

```

31 // Keep creating layer after layer
32 while (length > 2)
33 {
34     HalveSequence(sequence, sequence, length);
35     length = (length / 2) + (length % 2);
36 }
37 return Links.GetOrCreate(sequence[0], sequence[1]);
38 }
39
40 private void HalveSequence(IList<TLink> destination, IList<TLink> source, int length)
41 {
42     var loopedLength = length - (length % 2);
43     for (var i = 0; i < loopedLength; i += 2)
44     {
45         destination[i / 2] = Links.GetOrCreate(source[i], source[i + 1]);
46     }
47     if (length > loopedLength)
48     {
49         destination[length / 2] = source[length - 1];
50     }
51 }
52 }
53 }

```

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

```

1 using System;
2 using System.Collections.Generic;
3 using System.Runtime.CompilerServices;
4 using Platform.Interfaces;
5 using Platform.Collections;
6 using Platform.Singletons;
7 using Platform.Numbers;
8 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
9
10 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
11
12 namespace Platform.Data.Doublets.Sequences.Converters
13 {
14     /// <remarks>
15     /// TODO: Возможно будет лучше если алгоритм будет выполняться полностью изолированно от
16     /// ↪ Links на этапе сжатия.
17     /// А именно будет создаваться временный список пар необходимых для выполнения сжатия, в
18     /// ↪ таком случае тип значения элемента массива может быть любым, как char так и ulong.
19     /// Как только список/словарь пар был выявлен можно разом выполнить создание всех этих
20     /// ↪ пар, а так же разом выполнить замену.
21     /// </remarks>
22     public class CompressingConverter<TLink> : LinksListToSequenceConverterBase<TLink>
23     {
24         private static readonly LinksConstants<TLink> _constants =
25             ↪ Default<LinksConstants<TLink>>.Instance;
26         private static readonly EqualityComparer<TLink> _equalityComparer =
27             ↪ EqualityComparer<TLink>.Default;
28         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
29
30         private readonly IConverter<IList<TLink>, TLink> _baseConverter;
31         private readonly LinkFrequenciesCache<TLink> _doubletFrequenciesCache;
32         private readonly TLink _minFrequencyToCompress;
33         private readonly bool _doInitialFrequenciesIncrement;
34         private Doublet<TLink> _maxDoublet;
35         private LinkFrequency<TLink> _maxDoubletData;
36
37         private struct HalfDoublet
38         {
39             public TLink Element;
40             public LinkFrequency<TLink> DoubletData;
41
42             public HalfDoublet(TLink element, LinkFrequency<TLink> doubletData)
43             {
44                 Element = element;
45                 DoubletData = doubletData;
46             }
47
48             public override string ToString() => $"{Element}: ({DoubletData})";
49         }
50
51         public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
52             ↪ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache)
53             : this(links, baseConverter, doubletFrequenciesCache, Integer<TLink>.One, true)
54         {
55         }
56     }
57 }

```

```

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 stackalloc 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         {
100             data = _doubletFrequenciesCache.IncrementFrequency(ref doublet);
101         }
102         else
103         {
104             data = _doubletFrequenciesCache.GetFrequency(ref doublet);
105             if (data == null)
106             {
107                 throw new NotSupportedException("If you ask not to increment
                    ↳ frequencies, it is expected that all frequencies for the sequence
                    ↳ are prepared.");
108             }
109         }
110         copy[i - 1].Element = sequence[i - 1];
111         copy[i - 1].DoubletData = data;
112         UpdateMaxDoublet(ref doublet, data);
113     }
114     copy[sequence.Count - 1].Element = sequence[sequence.Count - 1];
115     copy[sequence.Count - 1].DoubletData = new LinkFrequency<TLink>();
116     if (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
117     {
118         var newLength = ReplaceDoublets(copy);
119         sequence = new TLink[newLength];

```

```

120         for (int i = 0; i < newLength; i++)
121         {
122             sequence[i] = copy[i].Element;
123         }
124     }
125     return sequence;
126 }
127
128 /// <remarks>
129 /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte\_pair\_encoding
130 /// </remarks>
131 private int ReplaceDoublets(HalfDoublet[] copy)
132 {
133     var oldLength = copy.Length;
134     var newLength = copy.Length;
135     while (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
136     {
137         var maxDoubletSource = _maxDoublet.Source;
138         var maxDoubletTarget = _maxDoublet.Target;
139         if (_equalityComparer.Equals(_maxDoubletData.Link, _constants.Null))
140         {
141             _maxDoubletData.Link = Links.GetOrCreate(maxDoubletSource, maxDoubletTarget);
142         }
143         var maxDoubletReplacementLink = _maxDoubletData.Link;
144         oldLength--;
145         var oldLengthMinusTwo = oldLength - 1;
146         // Substitute all usages
147         int w = 0, r = 0; // (r == read, w == write)
148         for (; r < oldLength; r++)
149         {
150             if (_equalityComparer.Equals(copy[r].Element, maxDoubletSource) &&
151                 ↪ _equalityComparer.Equals(copy[r + 1].Element, maxDoubletTarget))
152             {
153                 if (r > 0)
154                 {
155                     var previous = copy[w - 1].Element;
156                     copy[w - 1].DoubletData.DecrementFrequency();
157                     copy[w - 1].DoubletData =
158                         ↪ _doubletFrequenciesCache.IncrementFrequency(previous,
159                             ↪ maxDoubletReplacementLink);
160                 }
161                 if (r < oldLengthMinusTwo)
162                 {
163                     var next = copy[r + 2].Element;
164                     copy[r + 1].DoubletData.DecrementFrequency();
165                     copy[w].DoubletData = _doubletFrequenciesCache.IncrementFrequency(maxDoubletReplacementLink,
166                         ↪ next);
167                 }
168                 copy[w++].Element = maxDoubletReplacementLink;
169                 r++;
170                 newLength--;
171             }
172             else
173             {
174                 copy[w++] = copy[r];
175             }
176         }
177         if (w < newLength)
178         {
179             copy[w] = copy[r];
180         }
181         oldLength = newLength;
182         ResetMaxDoublet();
183         UpdateMaxDoublet(copy, newLength);
184     }
185     return newLength;
186 }
187
188 [MethodImpl(MethodImplOptions.AggressiveInlining)]
189 private void ResetMaxDoublet()
190 {
191     _maxDoublet = new Doublet<TLink>();
192     _maxDoubletData = new LinkFrequency<TLink>();
193 }
194
195 [MethodImpl(MethodImplOptions.AggressiveInlining)]
196 private void UpdateMaxDoublet(HalfDoublet[] copy, int length)
197 {

```

```

194     Doublet<TLink> doublet = default;
195     for (var i = 1; i < length; i++)
196     {
197         doublet.Source = copy[i - 1].Element;
198         doublet.Target = copy[i].Element;
199         UpdateMaxDoublet(ref doublet, copy[i - 1].DoubletData);
200     }
201 }
202
203 [MethodImpl(MethodImplOptions.AggressiveInlining)]
204 private void UpdateMaxDoublet(ref Doublet<TLink> doublet, LinkFrequency<TLink> data)
205 {
206     var frequency = data.Frequency;
207     var maxFrequency = _maxDoubletData.Frequency;
208     //if (frequency > _minFrequencyToCompress && (maxFrequency < frequency ||
209     ↪ (maxFrequency == frequency && doublet.Source + doublet.Target < /* gives better
210     ↪ compression string data (and gives collisions quickly) */ _maxDoublet.Source +
211     ↪ _maxDoublet.Target)))
212     if (_comparer.Compare(frequency, _minFrequencyToCompress) > 0 &&
213     ↪ (_comparer.Compare(maxFrequency, frequency) < 0 ||
214     ↪ (_equalityComparer.Equals(maxFrequency, frequency) &&
215     ↪ _comparer.Compare(Arithmetic.Add(doublet.Source, doublet.Target),
216     ↪ Arithmetic.Add(_maxDoublet.Source, _maxDoublet.Target)) > 0))) /* gives
217     ↪ better stability and better compression on sequent data and even on random
218     ↪ numbers data (but gives collisions anyway) */
219     {
220         _maxDoublet = doublet;
221         _maxDoubletData = data;
222     }
223 }
224 }
225 }
226 }
227 }

```

#### ./Platform.Data.Doublets/Sequences/Converters/LinksListToSequenceConverterBase.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.Sequences.Converters
7 {
8     public abstract class LinksListToSequenceConverterBase<TLink> : IConverter<IList<TLink>,
9     ↪ TLink>
10     {
11         protected readonly ILinks<TLink> Links;
12         public LinksListToSequenceConverterBase(ILinks<TLink> links) => Links = links;
13         public abstract TLink Convert(IList<TLink> source);
14     }
15 }

```

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

```

1 using System.Collections.Generic;
2 using System.Linq;
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.Sequences.Converters
8 {
9     public class OptimalVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
10     {
11         private static readonly EqualityComparer<TLink> _equalityComparer =
12         ↪ EqualityComparer<TLink>.Default;
13         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
14         private readonly IConverter<IList<TLink>> _sequenceToItsLocalElementLevelsConverter;
15
16         public OptimalVariantConverter(ILinks<TLink> links, IConverter<IList<TLink>>
17         ↪ sequenceToItsLocalElementLevelsConverter) : base(links)
18         => _sequenceToItsLocalElementLevelsConverter =
19         ↪ sequenceToItsLocalElementLevelsConverter;
20
21         public override TLink Convert(IList<TLink> sequence)
22         {
23             var length = sequence.Count;
24             if (length == 1)
25             {
26                 return sequence[0];
27             }
28         }
29     }
30 }

```

```

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,
51                             ↪ currentLevel) :
52                         i < 2 ?
53                         GetNextLowerThanCurrentOrCurrent(currentLevel, levels[i + 1]) :
54                         GetGreatestNeighbourLowerThanCurrentOrCurrent(previousLevel,
55                             ↪ currentLevel, levels[i + 1]);
56                     levels[w] = newLevel;
57                     previousLevel = currentLevel;
58                     w++;
59                     levelRepeat = 0;
60                     skipOnce = true;
61                 }
62                 else if (i == length - 1)
63                 {
64                     sequence[w] = sequence[i];
65                     levels[w] = levels[i];
66                     w++;
67                 }
68             }
69             else
70             {
71                 currentLevel = levels[i];
72                 levelRepeat = 1;
73                 if (skipOnce)
74                 {
75                     skipOnce = false;
76                 }
77                 else
78                 {
79                     sequence[w] = sequence[i - 1];
80                     levels[w] = levels[i - 1];
81                     previousLevel = levels[w];
82                     w++;
83                 }
84                 if (i == length - 1)
85                 {
86                     sequence[w] = sequence[i];
87                     levels[w] = levels[i];
88                     w++;
89                 }
90             }
91         }
92         length = w;
93     }
94     return links.GetOrCreate(sequence[0], sequence[1]);
95 }
96
97 private static TLink GetGreatestNeighbourLowerThanCurrentOrCurrent(TLink previous, TLink
98     ↪ current, TLink next)
99 {
100     return _comparer.Compare(previous, next) > 0
101         ? _comparer.Compare(previous, current) < 0 ? previous : current
102         : _comparer.Compare(next, current) < 0 ? next : current;
103 }

```

```

102     private static TLink GetNextLowerThanCurrentOrCurrent(TLink current, TLink next) =>
103         ↪ _comparer.Compare(next, current) < 0 ? next : current;
104
105     private static TLink GetPreviousLowerThanCurrentOrCurrent(TLink previous, TLink current)
106         ↪ => _comparer.Compare(previous, current) < 0 ? previous : current;
    }
}

```

./Platform.Data.Doublets/Sequences/Converters/SequenceToItsLocalElementLevelsConverter.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.Sequences.Converters
7  {
8      public class SequenceToItsLocalElementLevelsConverter<TLink> : LinksOperatorBase<TLink>,
9          ↪ IConverter<IList<TLink>>
10     {
11         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
12
13         private readonly IConverter<Doublet<TLink>, TLink> _linkToItsFrequencyToNumberConveter;
14
15         public SequenceToItsLocalElementLevelsConverter(ILinks<TLink> links,
16             ↪ IConverter<Doublet<TLink>, TLink> linkToItsFrequencyToNumberConveter) : base(links)
17             ↪ => _linkToItsFrequencyToNumberConveter = linkToItsFrequencyToNumberConveter;
18
19         public IList<TLink> Convert(IList<TLink> sequence)
20         {
21             var levels = new TLink[sequence.Count];
22             levels[0] = GetFrequencyNumber(sequence[0], sequence[1]);
23             for (var i = 1; i < sequence.Count - 1; i++)
24             {
25                 var previous = GetFrequencyNumber(sequence[i - 1], sequence[i]);
26                 var next = GetFrequencyNumber(sequence[i], sequence[i + 1]);
27                 levels[i] = _comparer.Compare(previous, next) > 0 ? previous : next;
28             }
29             levels[levels.Length - 1] = GetFrequencyNumber(sequence[sequence.Count - 2],
30                 ↪ sequence[sequence.Count - 1]);
31             return levels;
32         }
33
34         public TLink GetFrequencyNumber(TLink source, TLink target) =>
35             ↪ _linkToItsFrequencyToNumberConveter.Convert(new Doublet<TLink>(source, target));
36     }
37 }

```

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

```

1  using Platform.Interfaces;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Sequences.CreteriaMatchers
6  {
7      public class DefaultSequenceElementCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
8          ↪ ICriterionMatcher<TLink>
9      {
10         public DefaultSequenceElementCriterionMatcher(ILinks<TLink> links) : base(links) { }
11         public bool IsMatched(TLink argument) => Links.IsPartialPoint(argument);
12     }
13 }

```

./Platform.Data.Doublets/Sequences/CreteriaMatchers/MarkedSequenceCriterionMatcher.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.Sequences.CreteriaMatchers
7  {
8      public class MarkedSequenceCriterionMatcher<TLink> : ICriterionMatcher<TLink>
9      {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11             ↪ EqualityComparer<TLink>.Default;
12
13         private readonly ILinks<TLink> _links;
14         private readonly TLink _sequenceMarkerLink;
15
16         public MarkedSequenceCriterionMatcher(ILinks<TLink> links, TLink sequenceMarkerLink)

```



```

16     {
17         _links = links;
18         _sequenceMarkerLink = sequenceMarkerLink;
19     }
20
21     public bool IsMatched(TLink sequenceCandidate)
22     => _equalityComparer.Equals(_links.GetSource(sequenceCandidate), _sequenceMarkerLink)
23     || !_equalityComparer.Equals(_links.SearchOrDefault(_sequenceMarkerLink,
24         ↪ sequenceCandidate), _links.Constants.Null);
25 }

```

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

```

1  using System.Collections.Generic;
2  using Platform.Collections.Stacks;
3  using Platform.Data.Doublets.Sequences.HeightProviders;
4  using Platform.Data.Sequences;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Sequences
9  {
10     public class DefaultSequenceAppender<TLink> : LinksOperatorBase<TLink>,
11         ↪ ISequenceAppender<TLink>
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
14             ↪ EqualityComparer<TLink>.Default;
15
16         private readonly IStack<TLink> _stack;
17         private readonly ISequenceHeightProvider<TLink> _heightProvider;
18
19         public DefaultSequenceAppender(ILinks<TLink> links, IStack<TLink> stack,
20             ↪ ISequenceHeightProvider<TLink> heightProvider)
21             : base(links)
22         {
23             _stack = stack;
24             _heightProvider = heightProvider;
25         }
26
27         public TLink Append(TLink sequence, TLink appendant)
28         {
29             var cursor = sequence;
30             while (!_equalityComparer.Equals(_heightProvider.Get(cursor), default))
31             {
32                 var source = Links.GetSource(cursor);
33                 var target = Links.GetTarget(cursor);
34                 if (_equalityComparer.Equals(_heightProvider.Get(source),
35                     ↪ _heightProvider.Get(target)))
36                 {
37                     break;
38                 }
39                 else
40                 {
41                     _stack.Push(source);
42                     cursor = target;
43                 }
44             }
45             var left = cursor;
46             var right = appendant;
47             while (!_equalityComparer.Equals(cursor = _stack.Pop(), Links.Constants.Null))
48             {
49                 right = Links.GetOrCreate(left, right);
50                 left = cursor;
51             }
52             return Links.GetOrCreate(left, right);
53         }
54     }
55 }

```

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

```

1  using System.Collections.Generic;
2  using System.Linq;
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.Sequences
8  {
9     public class DuplicateSegmentsCounter<TLink> : ICounter<int>
10     {

```

```

11     private readonly IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
12         ↪ _duplicateFragmentsProvider;
13     public DuplicateSegmentsCounter(IProvider<IList<KeyValuePair<IList<TLink>,
14         ↪ IList<TLink>>>> duplicateFragmentsProvider) => _duplicateFragmentsProvider =
15         ↪ duplicateFragmentsProvider;
16     public int Count() => _duplicateFragmentsProvider.Get().Sum(x => x.Value.Count);
17 }
18 }

```

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

```

1  using System;
2  using System.Linq;
3  using System.Collections.Generic;
4  using Platform.Interfaces;
5  using Platform.Collections;
6  using Platform.Collections.Lists;
7  using Platform.Collections.Segments;
8  using Platform.Collections.Segments.Walkers;
9  using Platform.Singletons;
10 using Platform.Numbers;
11 using Platform.Data.Doublets.Unicode;
12
13 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
14
15 namespace Platform.Data.Doublets.Sequences
16 {
17     public class DuplicateSegmentsProvider<TLink> :
18         ↪ DictionaryBasedDuplicateSegmentsWalkerBase<TLink>,
19         ↪ IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
20     {
21         private readonly ILinks<TLink> _links;
22         private readonly ILinks<TLink> _sequences;
23         private HashSet<KeyValuePair<IList<TLink>, IList<TLink>>> _groups;
24         private BitString _visited;
25
26         private class ItemEquilityComparer : IEqualityComparer<KeyValuePair<IList<TLink>,
27             ↪ IList<TLink>>>
28         {
29             private readonly IListEqualityComparer<TLink> _listComparer;
30             public ItemEquilityComparer() => _listComparer =
31                 ↪ Default<IListEqualityComparer<TLink>>.Instance;
32             public bool Equals(KeyValuePair<IList<TLink>, IList<TLink>> left,
33                 ↪ KeyValuePair<IList<TLink>, IList<TLink>> right) =>
34                 ↪ _listComparer.Equals(left.Key, right.Key) && _listComparer.Equals(left.Value,
35                 ↪ right.Value);
36             public int GetHashCode(KeyValuePair<IList<TLink>, IList<TLink>> pair) =>
37                 ↪ (_listComparer.GetHashCode(pair.Key),
38                 ↪ _listComparer.GetHashCode(pair.Value)).GetHashCode();
39         }
40
41         private class ItemComparer : IComparer<KeyValuePair<IList<TLink>, IList<TLink>>>
42         {
43             private readonly IListComparer<TLink> _listComparer;
44
45             public ItemComparer() => _listComparer = Default<IListComparer<TLink>>.Instance;
46
47             public int Compare(KeyValuePair<IList<TLink>, IList<TLink>> left,
48                 ↪ KeyValuePair<IList<TLink>, IList<TLink>> right)
49             {
50                 var intermediateResult = _listComparer.Compare(left.Key, right.Key);
51                 if (intermediateResult == 0)
52                 {
53                     intermediateResult = _listComparer.Compare(left.Value, right.Value);
54                 }
55                 return intermediateResult;
56             }
57         }
58
59         public DuplicateSegmentsProvider(ILinks<TLink> links, ILinks<TLink> sequences)
60             : base(minimumStringSegmentLength: 2)
61         {
62             _links = links;
63             _sequences = sequences;
64         }
65
66         public IList<KeyValuePair<IList<TLink>, IList<TLink>>> Get()
67         {
68             _groups = new HashSet<KeyValuePair<IList<TLink>,
69                 ↪ IList<TLink>>>(Default<ItemEquilityComparer>.Instance);
70             var count = _links.Count();

```

```

60     _visited = new BitString((long)(Integer<TLink>)count + 1);
61     _links.Each(link =>
62     {
63         var linkIndex = _links.GetIndex(link);
64         var linkBitIndex = (long)(Integer<TLink>)linkIndex;
65         if (!_visited.Get(linkBitIndex))
66         {
67             var sequenceElements = new List<TLink>();
68             var filler = new ListFiller<TLink, TLink>(sequenceElements,
69                 ↪ _sequences.Constants.Break);
70             _sequences.Each(filler.AddAllValuesAndReturnConstant, new
71                 ↪ LinkAddress<TLink>(linkIndex));
72             if (sequenceElements.Count > 2)
73             {
74                 WalkAll(sequenceElements);
75             }
76             return _links.Constants.Continue;
77         });
78         var resultList = _groups.ToList();
79         var comparer = Default<ItemComparer>.Instance;
80         resultList.Sort(comparer);
81         #if DEBUG
82         foreach (var item in resultList)
83         {
84             PrintDuplicates(item);
85         }
86         #endif
87         return resultList;
88     }
89     protected override Segment<TLink> CreateSegment(IList<TLink> elements, int offset, int
90         ↪ length) => new Segment<TLink>(elements, offset, length);
91     protected override void OnDuplicateFound(Segment<TLink> segment)
92     {
93         var duplicates = CollectDuplicatesForSegment(segment);
94         if (duplicates.Count > 1)
95         {
96             _groups.Add(new KeyValuePair<IList<TLink>, IList<TLink>>(segment.ToArray(),
97                 ↪ duplicates));
98         }
99     }
100     private List<TLink> CollectDuplicatesForSegment(Segment<TLink> segment)
101     {
102         var duplicates = new List<TLink>();
103         var readAsElement = new HashSet<TLink>();
104         var restrictions = segment.ConvertToRestrictionsValues();
105         restrictions[0] = _sequences.Constants.Any;
106         _sequences.Each(sequence =>
107         {
108             var sequenceIndex = sequence[_sequences.Constants.IndexPart];
109             duplicates.Add(sequenceIndex);
110             readAsElement.Add(sequenceIndex);
111             return _sequences.Constants.Continue;
112         }, restrictions);
113         if (duplicates.Any(x => _visited.Get((Integer<TLink>)x)))
114         {
115             return new List<TLink>();
116         }
117         foreach (var duplicate in duplicates)
118         {
119             var duplicateBitIndex = (long)(Integer<TLink>)duplicate;
120             _visited.Set(duplicateBitIndex);
121         }
122         if (_sequences is Sequences sequencesExperiments)
123         {
124             var partiallyMatched = sequencesExperiments.GetAllPartiallyMatchingSequences4((H
125                 ↪ ashSet<ulong>)(object)readAsElement,
126                 ↪ (IList<ulong>)segment);
127             foreach (var partiallyMatchedSequence in partiallyMatched)
128             {
129                 TLink sequenceIndex = (Integer<TLink>)partiallyMatchedSequence;
130                 duplicates.Add(sequenceIndex);
131             }
132         }
133         duplicates.Sort();

```

```

132         return duplicates;
133     }
134
135     private void PrintDuplicates(KeyValuePair<IList<TLink>, IList<TLink>> duplicatesItem)
136     {
137         if (!(_links is ILinks<ulong> ulongLinks))
138         {
139             return;
140         }
141         var duplicatesKey = duplicatesItem.Key;
142         var keyString = UnicodeMap.FromLinksToString((IList<ulong>)duplicatesKey);
143         Console.WriteLine($"{keyString} ({string.Join(", ", duplicatesKey)})");
144         var duplicatesList = duplicatesItem.Value;
145         for (int i = 0; i < duplicatesList.Count; i++)
146         {
147             ulong sequenceIndex = (Integer<TLink>)duplicatesList[i];
148             var formattedSequenceStructure = ulongLinks.FormatStructure(sequenceIndex, x =>
149                 ↳ Point<ulong>.IsPartialPoint(x), (sb, link) => _ =
150                 ↳ UnicodeMap.IsCharLink(link.Index) ?
151                 ↳ sb.Append(UnicodeMap.FromLinkToChar(link.Index)) : sb.Append(link.Index));
152             Console.WriteLine(formattedSequenceStructure);
153             var sequenceString = UnicodeMap.FromSequenceLinkToString(sequenceIndex,
154                 ↳ ulongLinks);
155             Console.WriteLine(sequenceString);
156         }
157         Console.WriteLine();
158     }
159 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Interfaces;
5  using Platform.Numbers;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
10 {
11     /// <remarks>
12     /// Can be used to operate with many CompressingConverters (to keep global frequencies data
13     ↳ between them).
14     /// TODO: Extract interface to implement frequencies storage inside Links storage
15     /// </remarks>
16     public class LinkFrequenciesCache<TLink> : LinksOperatorBase<TLink>
17     {
18         private static readonly EqualityComparer<TLink> _equalityComparer =
19             ↳ EqualityComparer<TLink>.Default;
20         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
21
22         private readonly Dictionary<Doublet<TLink>, LinkFrequency<TLink>> _doubletsCache;
23         private readonly ICounter<TLink, TLink> _frequencyCounter;
24
25         public LinkFrequenciesCache(ILinks<TLink> links, ICounter<TLink, TLink> frequencyCounter)
26             : base(links)
27         {
28             _doubletsCache = new Dictionary<Doublet<TLink>, LinkFrequency<TLink>>(4096,
29                 ↳ DoubletComparer<TLink>.Default);
30             _frequencyCounter = frequencyCounter;
31         }
32
33         [MethodImpl(MethodImplOptions.AggressiveInlining)]
34         public LinkFrequency<TLink> GetFrequency(TLink source, TLink target)
35         {
36             var doublet = new Doublet<TLink>(source, target);
37             return GetFrequency(ref doublet);
38         }
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         public LinkFrequency<TLink> GetFrequency(ref Doublet<TLink> doublet)
42         {
43             _doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data);
44             return data;
45         }
46
47         public void IncrementFrequencies(IList<TLink> sequence)
48         {

```

```

46     for (var i = 1; i < sequence.Count; i++)
47     {
48         IncrementFrequency(sequence[i - 1], sequence[i]);
49     }
50 }
51
52 [MethodImpl(MethodImplOptions.AggressiveInlining)]
53 public LinkFrequency<TLink> IncrementFrequency(TLink source, TLink target)
54 {
55     var doublet = new Doublet<TLink>(source, target);
56     return IncrementFrequency(ref doublet);
57 }
58
59 public void PrintFrequencies(IList<TLink> sequence)
60 {
61     for (var i = 1; i < sequence.Count; i++)
62     {
63         PrintFrequency(sequence[i - 1], sequence[i]);
64     }
65 }
66
67 public void PrintFrequency(TLink source, TLink target)
68 {
69     var number = GetFrequency(source, target).Frequency;
70     Console.WriteLine("{0},{1} - {2}", source, target, number);
71 }
72
73 [MethodImpl(MethodImplOptions.AggressiveInlining)]
74 public LinkFrequency<TLink> IncrementFrequency(ref Doublet<TLink> doublet)
75 {
76     if (_doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data))
77     {
78         data.IncrementFrequency();
79     }
80     else
81     {
82         var link = Links.SearchOrDefault(doublet.Source, doublet.Target);
83         data = new LinkFrequency<TLink>(Integer<TLink>.One, link);
84         if (!_equalityComparer.Equals(link, default))
85         {
86             data.Frequency = Arithmetic.Add(data.Frequency,
87                 ↪ _frequencyCounter.Count(link));
88             _doubletsCache.Add(doublet, data);
89         }
90         return data;
91     }
92 }
93
94 public void ValidateFrequencies()
95 {
96     foreach (var entry in _doubletsCache)
97     {
98         var value = entry.Value;
99         var linkIndex = value.Link;
100         if (!_equalityComparer.Equals(linkIndex, default))
101         {
102             var frequency = value.Frequency;
103             var count = _frequencyCounter.Count(linkIndex);
104             // TODO: Why `frequency` always greater than `count` by 1?
105             if (((_comparer.Compare(frequency, count) > 0) &&
106                 ↪ (_comparer.Compare(Arithmetic.Subtract(frequency, count),
107                 ↪ Integer<TLink>.One) > 0))
108                 || ((_comparer.Compare(count, frequency) > 0) &&
109                 ↪ (_comparer.Compare(Arithmetic.Subtract(count, frequency),
110                 ↪ Integer<TLink>.One) > 0)))
111             {
112                 throw new InvalidOperationException("Frequencies validation failed.");
113             }
114         }
115         //else
116         //{
117             if (value.Frequency > 0)
118             {
119                 var frequency = value.Frequency;
120                 linkIndex = _createLink(entry.Key.Source, entry.Key.Target);
121                 var count = _countLinkFrequency(linkIndex);
122             }
123         }
124     }

```

```

118         //         if ((frequency > count && frequency - count > 1) || (count > frequency
119             ↳ && count - frequency > 1))
120         //             throw new Exception("Frequencies validation failed.");
121         //     }
122         //}
123     }
124 }
125 }

```

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

```

1 using System.Runtime.CompilerServices;
2 using Platform.Numbers;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
7 {
8     public class LinkFrequency<TLink>
9     {
10         public TLink Frequency { get; set; }
11         public TLink Link { get; set; }
12
13         public LinkFrequency(TLink frequency, TLink link)
14         {
15             Frequency = frequency;
16             Link = link;
17         }
18
19         public LinkFrequency() { }
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public void IncrementFrequency() => Frequency = Arithmetic<TLink>.Increment(Frequency);
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         public void DecrementFrequency() => Frequency = Arithmetic<TLink>.Decrement(Frequency);
26
27         public override string ToString() => $"F: {Frequency}, L: {Link}";
28     }
29 }

```

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

```

1 using Platform.Interfaces;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
6 {
7     public class FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<TLink> :
8         ↳ IConverter<Doublet<TLink>, TLink>
9     {
10         private readonly LinkFrequenciesCache<TLink> _cache;
11         public
12         ↳ FrequenciesCacheBasedLinkToItsFrequencyNumberConverter(LinkFrequenciesCache<TLink>
13         ↳ cache) => _cache = cache;
14         public TLink Convert(Doublet<TLink> source) => _cache.GetFrequency(ref source).Frequency;
15     }
16 }

```

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

```

1 using Platform.Interfaces;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
6 {
7     public class MarkedSequenceSymbolFrequencyOneOffCounter<TLink> :
8         ↳ SequenceSymbolFrequencyOneOffCounter<TLink>
9     {
10         private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
11
12         public MarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
13         ↳ ICriterionMatcher<TLink> markedSequenceMatcher, TLink sequenceLink, TLink symbol)
14         : base(links, sequenceLink, symbol)
15         => _markedSequenceMatcher = markedSequenceMatcher;
16
17         public override TLink Count()
18         {
19             if (!_markedSequenceMatcher.IsMatched(_sequenceLink))

```

```

18         {
19             return default;
20         }
21         return base.Count();
22     }
23 }
24 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3 using Platform.Numbers;
4 using Platform.Data.Sequences;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
9 {
10     public class SequenceSymbolFrequencyOneOffCounter<TLink> : ICounter<TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
13             ↪ EqualityComparer<TLink>.Default;
14         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
15
16         protected readonly ILinks<TLink> _links;
17         protected readonly TLink _sequenceLink;
18         protected readonly TLink _symbol;
19         protected TLink _total;
20
21         public SequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink sequenceLink,
22             ↪ TLink symbol)
23         {
24             _links = links;
25             _sequenceLink = sequenceLink;
26             _symbol = symbol;
27             _total = default;
28         }
29
30         public virtual TLink Count()
31         {
32             if (_comparer.Compare(_total, default) > 0)
33             {
34                 return _total;
35             }
36             StopableSequenceWalker.WalkRight(_sequenceLink, _links.GetSource, _links.GetTarget,
37                 ↪ IsElement, VisitElement);
38             return _total;
39         }
40
41         private bool IsElement(TLink x) => _equalityComparer.Equals(x, _symbol) ||
42             ↪ _links.IsPartialPoint(x); // TODO: Use SequenceElementCriteriaMatcher instead of
43             ↪ IsPartialPoint
44
45         private bool VisitElement(TLink element)
46         {
47             if (_equalityComparer.Equals(element, _symbol))
48             {
49                 _total = Arithmetic.Increment(_total);
50             }
51             return true;
52         }
53     }
54 }

```

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

```

1 using Platform.Interfaces;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
6 {
7     public class TotalMarkedSequenceSymbolFrequencyCounter<TLink> : ICounter<TLink, TLink>
8     {
9         private readonly ILinks<TLink> _links;
10         private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
11
12         public TotalMarkedSequenceSymbolFrequencyCounter(ILinks<TLink> links,
13             ↪ ICriterionMatcher<TLink> markedSequenceMatcher)
14         {
15             _links = links;
16         }
17     }
18 }

```

```

15         _markedSequenceMatcher = markedSequenceMatcher;
16     }
17
18     public TLink Count(TLink argument) => new
        ↳ TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
        ↳ _markedSequenceMatcher, argument).Count();
19 }
20 }

```

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

```

1 using Platform.Interfaces;
2 using Platform.Numbers;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
7 {
8     public class TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink> :
        ↳ TotalSequenceSymbolFrequencyOneOffCounter<TLink>
9     {
10         private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
11
12         public TotalMarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
            ↳ ICriterionMatcher<TLink> markedSequenceMatcher, TLink symbol)
13             : base(links, symbol)
14             => _markedSequenceMatcher = markedSequenceMatcher;
15
16         protected override void CountSequenceSymbolFrequency(TLink link)
17         {
18             var symbolFrequencyCounter = new
                ↳ MarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
                ↳ _markedSequenceMatcher, link, _symbol);
19             _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
20         }
21     }
22 }

```

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

```

1 using Platform.Interfaces;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
6 {
7     public class TotalSequenceSymbolFrequencyCounter<TLink> : ICounter<TLink, TLink>
8     {
9         private readonly ILinks<TLink> _links;
10         public TotalSequenceSymbolFrequencyCounter(ILinks<TLink> links) => _links = links;
11         public TLink Count(TLink symbol) => new
            ↳ TotalSequenceSymbolFrequencyOneOffCounter<TLink>(_links, symbol).Count();
12     }
13 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3 using Platform.Numbers;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
8 {
9     public class TotalSequenceSymbolFrequencyOneOffCounter<TLink> : ICounter<TLink>
10     {
11         private static readonly EqualityComparer<TLink> _equalityComparer =
            ↳ EqualityComparer<TLink>.Default;
12         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
13
14         protected readonly ILinks<TLink> _links;
15         protected readonly TLink _symbol;
16         protected readonly HashSet<TLink> _visits;
17         protected TLink _total;
18
19         public TotalSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink symbol)
20         {
21             _links = links;
22             _symbol = symbol;
23             _visits = new HashSet<TLink>();
24             _total = default;
25         }
26     }
27 }

```



```

26
27 public TLink Count()
28 {
29     if (_comparer.Compare(_total, default) > 0 || _visits.Count > 0)
30     {
31         return _total;
32     }
33     CountCore(_symbol);
34     return _total;
35 }
36
37 private void CountCore(TLink link)
38 {
39     var any = _links.Constants.Any;
40     if (_equalityComparer.Equals(_links.Count(any, link), default))
41     {
42         CountSequenceSymbolFrequency(link);
43     }
44     else
45     {
46         _links.Each(EachElementHandler, any, link);
47     }
48 }
49
50 protected virtual void CountSequenceSymbolFrequency(TLink link)
51 {
52     var symbolFrequencyCounter = new SequenceSymbolFrequencyOneOffCounter<TLink>(_links,
53     ↪ link, _symbol);
54     _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
55 }
56
57 private TLink EachElementHandler(IList<TLink> doublet)
58 {
59     var constants = _links.Constants;
60     var doubletIndex = doublet[constants.IndexPart];
61     if (_visits.Add(doubletIndex))
62     {
63         CountCore(doubletIndex);
64     }
65     return constants.Continue;
66 }
67 }

```

./Platform.Data.Doublets/Sequences/HeightProviders/CachedSequenceHeightProvider.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.Sequences.HeightProviders
7 {
8     public class CachedSequenceHeightProvider<TLink> : LinksOperatorBase<TLink>,
9     ↪ ISequenceHeightProvider<TLink>
10     {
11         private static readonly EqualityComparer<TLink> _equalityComparer =
12         ↪ EqualityComparer<TLink>.Default;
13
14         private readonly TLink _heightPropertyMarker;
15         private readonly ISequenceHeightProvider<TLink> _baseHeightProvider;
16         private readonly IConverter<TLink> _addressToUnaryNumberConverter;
17         private readonly IConverter<TLink> _unaryNumberToAddressConverter;
18         private readonly IPropertiesOperator<TLink, TLink, TLink> _propertyOperator;
19
20         public CachedSequenceHeightProvider(
21             ILinks<TLink> links,
22             ISequenceHeightProvider<TLink> baseHeightProvider,
23             IConverter<TLink> addressToUnaryNumberConverter,
24             IConverter<TLink> unaryNumberToAddressConverter,
25             TLink heightPropertyMarker,
26             IPropertiesOperator<TLink, TLink, TLink> propertyOperator)
27             : base(links)
28         {
29             _heightPropertyMarker = heightPropertyMarker;
30             _baseHeightProvider = baseHeightProvider;
31             _addressToUnaryNumberConverter = addressToUnaryNumberConverter;
32             _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
33             _propertyOperator = propertyOperator;
34         }
35
36         public TLink Get(TLink sequence)

```

```

35     {
36         TLink height;
37         var heightValue = _propertyOperator.GetValue(sequence, _heightPropertyMarker);
38         if (_equalityComparer.Equals(heightValue, default))
39         {
40             height = _baseHeightProvider.Get(sequence);
41             heightValue = _addressToUnaryNumberConverter.Convert(height);
42             _propertyOperator.SetValue(sequence, _heightPropertyMarker, heightValue);
43         }
44         else
45         {
46             height = _unaryNumberToAddressConverter.Convert(heightValue);
47         }
48         return height;
49     }
50 }
51 }

```

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

```

1  using Platform.Interfaces;
2  using Platform.Numbers;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Sequences.HeightProviders
7  {
8      public class DefaultSequenceRightHeightProvider<TLink> : LinksOperatorBase<TLink>,
9          ↳ ISequenceHeightProvider<TLink>
10     {
11         private readonly ICriterionMatcher<TLink> _elementMatcher;
12
13         public DefaultSequenceRightHeightProvider(ILinks<TLink> links, ICriterionMatcher<TLink>
14             ↳ elementMatcher) : base(links) => _elementMatcher = elementMatcher;
15
16         public TLink Get(TLink sequence)
17         {
18             var height = default(TLink);
19             var pairOrElement = sequence;
20             while (!_elementMatcher.IsMatched(pairOrElement))
21             {
22                 pairOrElement = Links.GetTarget(pairOrElement);
23                 height = Arithmetic.Increment(height);
24             }
25             return height;
26         }
27     }
28 }

```

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

```

1  using Platform.Interfaces;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Sequences.HeightProviders
6  {
7      public interface ISequenceHeightProvider<TLink> : IProvider<TLink, TLink>
8      {
9      }
10 }

```

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

```

1  using Platform.Collections;
2  using System.Collections.Generic;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Sequences
7  {
8      public static class IListExtensions
9      {
10         public static TLink[] ExtractValues<TLink>(this IList<TLink> restrictions)
11         {
12             if(restrictions.IsNullOrEmpty() || restrictions.Count == 1)
13             {
14                 return new TLink[0];
15             }
16             var values = new TLink[restrictions.Count - 1];
17             for (int i = 1, j = 0; i < restrictions.Count; i++, j++)
18             {

```

```

19         values[j] = restrictions[i];
20     }
21     return values;
22 }
23
24 public static IList<TLink> ConvertToRestrictionsValues<TLink>(this IList<TLink> list)
25 {
26     var restrictions = new TLink[list.Count + 1];
27     for (int i = 0, j = 1; i < list.Count; i++, j++)
28     {
29         restrictions[j] = list[i];
30     }
31     return restrictions;
32 }
33 }
34 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences.Indexes
7 {
8     public class CachedFrequencyIncrementingSequenceIndex<TLink> : ISequenceIndex<TLink>
9     {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11             ↳ EqualityComparer<TLink>.Default;
12
13         private readonly LinkFrequenciesCache<TLink> _cache;
14
15         public CachedFrequencyIncrementingSequenceIndex(LinkFrequenciesCache<TLink> cache) =>
16             ↳ _cache = cache;
17
18         public bool Add(IList<TLink> sequence)
19         {
20             var indexed = true;
21             var i = sequence.Count;
22             while (--i >= 1 && (indexed = IsIndexedWithIncrement(sequence[i - 1], sequence[i])))
23                 ↳ { }
24             for (; i >= 1; i--)
25             {
26                 _cache.IncrementFrequency(sequence[i - 1], sequence[i]);
27             }
28             return indexed;
29         }
30
31         private bool IsIndexedWithIncrement(TLink source, TLink target)
32         {
33             var frequency = _cache.GetFrequency(source, target);
34             if (frequency == null)
35             {
36                 return false;
37             }
38             var indexed = !_equalityComparer.Equals(frequency.Frequency, default);
39             if (indexed)
40             {
41                 _cache.IncrementFrequency(source, target);
42             }
43             return indexed;
44         }
45
46         public bool MightContain(IList<TLink> sequence)
47         {
48             var indexed = true;
49             var i = sequence.Count;
50             while (--i >= 1 && (indexed = IsIndexed(sequence[i - 1], sequence[i]))) { }
51             return indexed;
52         }
53
54         private bool IsIndexed(TLink source, TLink target)
55         {
56             var frequency = _cache.GetFrequency(source, target);
57             if (frequency == null)
58             {
59                 return false;
60             }
61             return !_equalityComparer.Equals(frequency.Frequency, default);
62         }
63     }
64 }

```

```

60     }
61 }

./Platform.Data.Doublets/Sequences/Indexes/FrequencyIncrementingSequenceIndex.cs
1  using Platform.Interfaces;
2  using System.Collections.Generic;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Sequences.Indexes
7  {
8      public class FrequencyIncrementingSequenceIndex<TLink> : SequenceIndex<TLink>,
9          ↳ ISequenceIndex<TLink>
10     {
11         private static readonly EqualityComparer<TLink> _equalityComparer =
12             ↳ EqualityComparer<TLink>.Default;
13
14         private readonly IPropertyOperator<TLink, TLink> _frequencyPropertyOperator;
15         private readonly IIncrementer<TLink> _frequencyIncrementer;
16
17         public FrequencyIncrementingSequenceIndex(ILinks<TLink> links, IPropertyOperator<TLink,
18             ↳ TLink> frequencyPropertyOperator, IIncrementer<TLink> frequencyIncrementer)
19             : base(links)
20         {
21             _frequencyPropertyOperator = frequencyPropertyOperator;
22             _frequencyIncrementer = frequencyIncrementer;
23         }
24
25         public override bool Add(IList<TLink> sequence)
26         {
27             var indexed = true;
28             var i = sequence.Count;
29             while (--i >= 1 && (indexed = IsIndexedWithIncrement(sequence[i - 1], sequence[i])))
30                 ↳ { }
31             for (; i >= 1; i--)
32             {
33                 Increment(Links.GetOrCreate(sequence[i - 1], sequence[i]));
34             }
35             return indexed;
36         }
37
38         private bool IsIndexedWithIncrement(TLink source, TLink target)
39         {
40             var link = Links.SearchOrCreate(source, target);
41             var indexed = !_equalityComparer.Equals(link, default);
42             if (indexed)
43             {
44                 Increment(link);
45             }
46             return indexed;
47         }
48
49         private void Increment(TLink link)
50         {
51             var previousFrequency = _frequencyPropertyOperator.Get(link);
52             var frequency = _frequencyIncrementer.Increment(previousFrequency);
53             _frequencyPropertyOperator.Set(link, frequency);
54         }
55     }
56 }

```

```

./Platform.Data.Doublets/Sequences/Indexes/ISequenceIndex.cs
1  using System.Collections.Generic;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Sequences.Indexes
6  {
7      public interface ISequenceIndex<TLink>
8      {
9          /// <summary>
10         /// Индексирует последовательность глобально, и возвращает значение,
11         /// определяющие была ли запрошенная последовательность проиндексирована ранее.
12         /// </summary>
13         /// <param name="sequence">Последовательность для индексации.</param>
14         bool Add(IList<TLink> sequence);
15
16         bool MightContain(IList<TLink> sequence);
17     }
18 }

```

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

```
1 using System.Collections.Generic;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.Sequences.Indexes
6 {
7     public class SequenceIndex<TLink> : LinksOperatorBase<TLink>, ISequenceIndex<TLink>
8     {
9         private static readonly EqualityComparer<TLink> _equalityComparer =
10             ↳ EqualityComparer<TLink>.Default;
11
12         public SequenceIndex(ILinks<TLink> links) : base(links) { }
13
14         public virtual bool Add(IList<TLink> sequence)
15         {
16             var indexed = true;
17             var i = sequence.Count;
18             while (--i >= 1 && (indexed =
19                 ↳ !_equalityComparer.Equals(Links.SearchOrDefault(sequence[i - 1], sequence[i]),
20                 ↳ default))) { }
21             for (; i >= 1; i--)
22             {
23                 Links.GetOrCreate(sequence[i - 1], sequence[i]);
24             }
25             return indexed;
26         }
27
28         public virtual bool MightContain(IList<TLink> sequence)
29         {
30             var indexed = true;
31             var i = sequence.Count;
32             while (--i >= 1 && (indexed =
33                 ↳ !_equalityComparer.Equals(Links.SearchOrDefault(sequence[i - 1], sequence[i]),
34                 ↳ default))) { }
35             return indexed;
36         }
37     }
38 }
```

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

```
1 using System.Collections.Generic;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.Sequences.Indexes
6 {
7     public class SynchronizedSequenceIndex<TLink> : ISequenceIndex<TLink>
8     {
9         private static readonly EqualityComparer<TLink> _equalityComparer =
10             ↳ EqualityComparer<TLink>.Default;
11
12         private readonly ISynchronizedLinks<TLink> _links;
13
14         public SynchronizedSequenceIndex(ISynchronizedLinks<TLink> links) => _links = links;
15
16         public bool Add(IList<TLink> sequence)
17         {
18             var indexed = true;
19             var i = sequence.Count;
20             var links = _links.Unsync;
21             _links.SyncRoot.ExecuteReadOperation(() =>
22             {
23                 while (--i >= 1 && (indexed =
24                     ↳ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
25                     ↳ sequence[i]), default))) { }
26             });
27             if (!indexed)
28             {
29                 _links.SyncRoot.ExecuteWriteOperation(() =>
30                 {
31                     for (; i >= 1; i--)
32                     {
33                         links.GetOrCreate(sequence[i - 1], sequence[i]);
34                     }
35                 });
36             }
37             return indexed;
38         }
39     }
40 }
```

```

37     public bool MightContain(ICollection<TLink> sequence)
38     {
39         var links = _links.Unsync;
40         return _links.SyncRoot.ExecuteReadOperation(() =>
41         {
42             var indexed = true;
43             var i = sequence.Count;
44             while (--i >= 1 && (indexed =
45                 ↳ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
46                 ↳ sequence[i]), default))) { }
47             return indexed;
48         });
49     }

```

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

```

1  using System.Collections.Generic;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Sequences.Indexes
6  {
7      public class Unindex<TLink> : ISequenceIndex<TLink>
8      {
9          public virtual bool Add(ICollection<TLink> sequence) => false;
10
11          public virtual bool MightContain(ICollection<TLink> sequence) => true;
12      }
13  }

```

./Platform.Data.Doublets/Sequences/ListFiller.cs

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Sequences
7  {
8      public class ListFiller<TElement, TReturnConstant>
9      {
10         protected readonly List<TElement> _list;
11         protected readonly TReturnConstant _returnConstant;
12
13         public ListFiller(List<TElement> list, TReturnConstant returnConstant)
14         {
15             _list = list;
16             _returnConstant = returnConstant;
17         }
18
19         public ListFiller(List<TElement> list) : this(list, default) { }
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public void Add(TElement element) => _list.Add(element);
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         public bool AddAndReturnTrue(TElement element)
26         {
27             _list.Add(element);
28             return true;
29         }
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         public bool AddFirstAndReturnTrue(ICollection<TElement> collection)
33         {
34             _list.Add(collection[0]);
35             return true;
36         }
37
38         [MethodImpl(MethodImplOptions.AggressiveInlining)]
39         public TReturnConstant AddAndReturnConstant(TElement element)
40         {
41             _list.Add(element);
42             return _returnConstant;
43         }
44
45         [MethodImpl(MethodImplOptions.AggressiveInlining)]
46         public TReturnConstant AddFirstAndReturnConstant(ICollection<TElement> collection)
47         {
48             _list.Add(collection[0]);

```

```

49         return _returnConstant;
50     }
51
52     [MethodImpl(MethodImplOptions.AggressiveInlining)]
53     public TReturnConstant AddAllValuesAndReturnConstant(IList<TElement> collection)
54     {
55         for (int i = 1; i < collection.Count; i++)
56         {
57             _list.Add(collection[i]);
58         }
59         return _returnConstant;
60     }
61 }
62 }

```

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

```

1  using Platform.Collections;
2  using Platform.Collections.Lists;
3  using Platform.Collections.Stacks;
4  using Platform.Data.Doublets.Sequences.Walkers;
5  using Platform.Singletons;
6  using Platform.Threading.Synchronization;
7  using System;
8  using System.Collections.Generic;
9  using System.Linq;
10 using System.Runtime.CompilerServices;
11 using LinkIndex = System.UInt64;
12
13 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
14
15 namespace Platform.Data.Doublets.Sequences
16 {
17     /// <summary>
18     /// Представляет коллекцию последовательностей связей.
19     /// </summary>
20     /// <remarks>
21     /// Обязательно реализовать атомарность каждого публичного метода.
22     ///
23     /// TODO:
24     ///
25     /// !!! Повышение вероятности повторного использования групп (подпоследовательностей),
26     /// через естественную группировку по unicode типам, все whitespace вместе, все символы
27     /// ↪ вместе, все числа вместе и т.п.
28     /// + использовать ровно сбалансированный вариант, чтобы уменьшать вложенность (глубину
29     /// ↪ графа)
30     ///
31     /// х*у - найти все связи между, в последовательностях любой формы, если не стоит
32     /// ↪ ограничитель на то, что является последовательностью, а что нет,
33     /// то находятся любые структуры связей, которые содержат эти элементы именно в таком
34     /// ↪ порядке.
35     ///
36     /// Рост последовательности слева и справа.
37     /// Поиск со звёздочкой.
38     /// URL, PURL - реестр используемых во вне ссылок на ресурсы,
39     /// так же проблема может быть решена при реализации дистанционных триггеров.
40     /// Нужны ли уникальные указатели вообще?
41     /// Что если обращение к информации будет происходить через содержимое всегда?
42     ///
43     /// Писать тесты.
44     ///
45     /// Можно убрать зависимость от конкретной реализации Links,
46     /// на зависимость от абстрактного элемента, который может быть представлен несколькими
47     /// ↪ способами.
48     ///
49     /// Можно ли как-то сделать один общий интерфейс
50     ///
51     /// Блокчейн и/или гит для распределённой записи транзакций.
52     /// </remarks>
53     public partial class Sequences : ILinks<LinkIndex> // IList<string>, IList<LinkIndex[]>
54     ↪ (после завершения реализации Sequences)
55     {
56         /// <summary>Возвращает значение LinkIndex, обозначающее любое количество
57         /// ↪ связей.</summary>
58         public const LinkIndex ZeroOrMany = LinkIndex.MaxValue;
59
60         public SequencesOptions<LinkIndex> Options { get; }
61     }
62 }

```

```

57 public SynchronizedLinks<LinkIndex> Links { get; }
58 private readonly ISynchronization _sync;
59
60 public LinksConstants<LinkIndex> Constants { get; }
61
62 public Sequences(SynchronizedLinks<LinkIndex> links, SequencesOptions<LinkIndex> options)
63 {
64     Links = links;
65     _sync = links.SyncRoot;
66     Options = options;
67     Options.ValidateOptions();
68     Options.InitOptions(Links);
69     Constants = links.Constants;
70 }
71
72 public Sequences(SynchronizedLinks<LinkIndex> links)
73 : this(links, new SequencesOptions<LinkIndex>())
74 {
75 }
76
77 public bool IsSequence(LinkIndex sequence)
78 {
79     return _sync.ExecuteReadOperation(() =>
80     {
81         if (Options.UseSequenceMarker)
82         {
83             return Options.MarkedSequenceMatcher.IsMatched(sequence);
84         }
85         return !Links.Unsync.IsPartialPoint(sequence);
86     });
87 }
88
89 [MethodImpl(MethodImplOptions.AggressiveInlining)]
90 private LinkIndex GetSequenceByElements(LinkIndex sequence)
91 {
92     if (Options.UseSequenceMarker)
93     {
94         return Links.SearchOrDefault(Options.SequenceMarkerLink, sequence);
95     }
96     return sequence;
97 }
98
99 private LinkIndex GetSequenceElements(LinkIndex sequence)
100 {
101     if (Options.UseSequenceMarker)
102     {
103         var linkContents = new Link<ulong>(Links.GetLink(sequence));
104         if (linkContents.Source == Options.SequenceMarkerLink)
105         {
106             return linkContents.Target;
107         }
108         if (linkContents.Target == Options.SequenceMarkerLink)
109         {
110             return linkContents.Source;
111         }
112     }
113     return sequence;
114 }
115
116 #region Count
117
118 public LinkIndex Count(IList<LinkIndex> restrictions)
119 {
120     if (restrictions.IsNullOrEmpty())
121     {
122         return Links.Count(Constants.Any, Options.SequenceMarkerLink, Constants.Any);
123     }
124     if (restrictions.Count == 1) // Первая связь это адрес
125     {
126         var sequenceIndex = restrictions[0];
127         if (sequenceIndex == Constants.Null)
128         {
129             return 0;
130         }
131         if (sequenceIndex == Constants.Any)
132         {
133             return Count(null);
134         }
135         if (Options.UseSequenceMarker)

```



```

136         {
137             return Links.Count(Constants.Any, Options.SequenceMarkerLink, sequenceIndex);
138         }
139         return Links.Exists(sequenceIndex) ? 1UL : 0;
140     }
141     throw new NotImplementedException();
142 }
143
144 private LinkIndex CountUsages(params LinkIndex[] restrictions)
145 {
146     if (restrictions.Length == 0)
147     {
148         return 0;
149     }
150     if (restrictions.Length == 1) // Первая связь это адрес
151     {
152         if (restrictions[0] == Constants.Null)
153         {
154             return 0;
155         }
156         var any = Constants.Any;
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(any, sequenceLink) + Links.Count(any, elementsLink) -
164                     ↪ 1;
165             }
166             return Links.Count(any, elementsLink);
167         }
168         return Links.Count(any, restrictions[0]);
169     }
170     throw new NotImplementedException();
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             return 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             if (Options.UseSequenceMarker)
257             {
258                 var sequenceLinkValues = Links.Unsync.GetLink(link);
259                 if (sequenceLinkValues[Constants.SourcePart] ==
    ↪ Options.SequenceMarkerLink)
260                 {
261                     link = sequenceLinkValues[Constants.TargetPart];
262                 }
263             }
264             var sequence =
    ↪ Options.Walker.Walk(link).ToArray().ConvertToRestrictionsValues();
265             sequence[0] = link;
266             return handler(sequence);
267         }
268         else if (restrictions.Count == 2)
269         {
270             throw new NotImplementedException();
271         }
272         else if (restrictions.Count == 3)
273         {
274             return Links.Unsync.Each(handler, restrictions);
275         }
276         else
277         {
278             var sequence = restrictions.ExtractValues();
279             if (Options.UseIndex && !Options.Index.MightContain(sequence))
280             {
281                 return Constants.Break;
282             }
283             return EachCore(handler, sequence);
284         }
285     });

```

```

286 }
287
288 private LinkIndex EachCore(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
    ↪ values)
289 {
290     var matcher = new Matcher(this, values, new HashSet<LinkIndex>(), handler);
291     // TODO: Find out why matcher.HandleFullMatched executed twice for the same sequence
    ↪ Id.
292     Func<IList<LinkIndex>, LinkIndex> innerHandler = Options.UseSequenceMarker ?
    ↪ (Func<IList<LinkIndex>, LinkIndex>)matcher.HandleFullMatchedSequence :
    ↪ matcher.HandleFullMatched;
293     //if (sequence.Length >= 2)
294     if (StepRight(innerHandler, values[0], values[1]) != Constants.Continue)
295     {
296         return Constants.Break;
297     }
298     var last = values.Count - 2;
299     for (var i = 1; i < last; i++)
300     {
301         if (PartialStepRight(innerHandler, values[i], values[i + 1]) !=
    ↪ Constants.Continue)
302         {
303             return Constants.Break;
304         }
305     }
306     if (values.Count >= 3)
307     {
308         if (StepLeft(innerHandler, values[values.Count - 2], values[values.Count - 1])
    ↪ != Constants.Continue)
309         {
310             return Constants.Break;
311         }
312     }
313     return Constants.Continue;
314 }
315
316 private LinkIndex PartialStepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
    ↪ left, LinkIndex right)
317 {
318     return Links.Unsync.Each(doublet =>
319     {
320         var doubletIndex = doublet[Constants.IndexPart];
321         if (StepRight(handler, doubletIndex, right) != Constants.Continue)
322         {
323             return Constants.Break;
324         }
325         if (left != doubletIndex)
326         {
327             return PartialStepRight(handler, doubletIndex, right);
328         }
329         return Constants.Continue;
330     }, new Link<LinkIndex>(Constants.Any, Constants.Any, left));
331 }
332
333 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));
334
335 private LinkIndex TryStepRightUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
    ↪ right, LinkIndex stepFrom)
336 {
337     var upStep = stepFrom;
338     var firstSource = Links.Unsync.GetTarget(upStep);
339     while (firstSource != right && firstSource != upStep)
340     {
341         upStep = firstSource;
342         firstSource = Links.Unsync.GetSource(upStep);
343     }
344     if (firstSource == right)
345     {
346         return handler(new LinkAddress<LinkIndex>(stepFrom));
347     }
348     return Constants.Continue;
349 }
350

```

```

351 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));
352
353 private LinkIndex TryStepLeftUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
    ↳ left, LinkIndex stepFrom)
354 {
355     var upStep = stepFrom;
356     var firstTarget = Links.Unsync.GetSource(upStep);
357     while (firstTarget != left && firstTarget != upStep)
358     {
359         upStep = firstTarget;
360         firstTarget = Links.Unsync.GetTarget(upStep);
361     }
362     if (firstTarget == left)
363     {
364         return handler(new LinkAddress<LinkIndex>(stepFrom));
365     }
366     return Constants.Continue;
367 }
368
369 #endregion
370
371 #region Update
372
373 public LinkIndex Update(IList<LinkIndex> restrictions, IList<LinkIndex> substitution)
374 {
375     var sequence = restrictions.ExtractValues();
376     var newSequence = substitution.ExtractValues();
377
378     if (sequence.IsNullOrEmpty() && newSequence.IsNullOrEmpty())
379     {
380         return Constants.Null;
381     }
382     if (sequence.IsNullOrEmpty())
383     {
384         return Create(substitution);
385     }
386     if (newSequence.IsNullOrEmpty())
387     {
388         Delete(restrictions);
389         return Constants.Null;
390     }
391     return _sync.ExecuteWriteOperation((Func<ulong>)(() =>
392     {
393         ILinksExtensions.EnsureLinkIsAnyOrExists<ulong>(Links, (IList<ulong>)sequence);
394         Links.EnsureLinkExists(newSequence);
395         return UpdateCore(sequence, newSequence);
396     })));
397 }
398
399 private LinkIndex UpdateCore(IList<LinkIndex> sequence, IList<LinkIndex> newSequence)
400 {
401     LinkIndex bestVariant;
402     if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew &&
403         ↳ !sequence.EqualTo(newSequence))
404     {
405         bestVariant = CompactCore(newSequence);
406     }
407     else
408     {
409         bestVariant = CreateCore(newSequence);
410     }
411     // TODO: Check all options only ones before loop execution
412     // Возможно нужно две версии Each, возвращающий фактические последовательности и с
413     ↳ маркером,
414     // или возможно даже возвращать и тот и тот вариант. С другой стороны все варианты
415     ↳ можно получить имея только фактические последовательности.
416     foreach (var variant in Each(sequence))
417     {
418         if (variant != bestVariant)
419         {
420             UpdateOneCore(variant, bestVariant);
421         }
422     }
423     return bestVariant;
424 }

```

```

423 private void UpdateOneCore(LinkIndex sequence, LinkIndex newSequence)
424 {
425     if (Options.UseGarbageCollection)
426     {
427         var sequenceElements = GetSequenceElements(sequence);
428         var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
429         var sequenceLink = GetSequenceByElements(sequenceElements);
430         var newSequenceElements = GetSequenceElements(newSequence);
431         var newSequenceLink = GetSequenceByElements(newSequenceElements);
432         if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
433         {
434             if (sequenceLink != Constants.Null)
435             {
436                 Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
437             }
438             Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
439         }
440         ClearGarbage(sequenceElementsContents.Source);
441         ClearGarbage(sequenceElementsContents.Target);
442     }
443     else
444     {
445         if (Options.UseSequenceMarker)
446         {
447             var sequenceElements = GetSequenceElements(sequence);
448             var sequenceLink = GetSequenceByElements(sequenceElements);
449             var newSequenceElements = GetSequenceElements(newSequence);
450             var newSequenceLink = GetSequenceByElements(newSequenceElements);
451             if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
452             {
453                 if (sequenceLink != Constants.Null)
454                 {
455                     Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
456                 }
457                 Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
458             }
459         }
460         else
461         {
462             if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
463             {
464                 Links.Unsync.MergeAndDelete(sequence, newSequence);
465             }
466         }
467     }
468 }
469 #endregion
470 #region Delete
471 public void Delete(IList<LinkIndex> restrictions)
472 {
473     _sync.ExecuteWriteOperation(() =>
474     {
475         var sequence = restrictions.ExtractValues();
476         // TODO: Check all options only ones before loop execution
477         foreach (var linkToDelete in Each(sequence))
478         {
479             DeleteOneCore(linkToDelete);
480         }
481     });
482 }
483 #endregion
484 private void DeleteOneCore(LinkIndex link)
485 {
486     if (Options.UseGarbageCollection)
487     {
488         var sequenceElements = GetSequenceElements(link);
489         var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
490         var sequenceLink = GetSequenceByElements(sequenceElements);
491         if (Options.UseCascadeDelete || CountUsages(link) == 0)
492         {
493             if (sequenceLink != Constants.Null)
494             {
495                 Links.Unsync.Delete(sequenceLink);
496             }
497             Links.Unsync.Delete(link);
498         }
499     }
500 }

```

```

501     }
502     ClearGarbage(sequenceElementsContents.Source);
503     ClearGarbage(sequenceElementsContents.Target);
504 }
505 else
506 {
507     if (Options.UseSequenceMarker)
508     {
509         var sequenceElements = GetSequenceElements(link);
510         var sequenceLink = GetSequenceByElements(sequenceElements);
511         if (Options.UseCascadeDelete || CountUsages(link) == 0)
512         {
513             if (sequenceLink != Constants.Null)
514             {
515                 Links.Unsync.Delete(sequenceLink);
516             }
517             Links.Unsync.Delete(link);
518         }
519     }
520     else
521     {
522         if (Options.UseCascadeDelete || CountUsages(link) == 0)
523         {
524             Links.Unsync.Delete(link);
525         }
526     }
527 }
528 }
529
530 #endregion
531
532 #region Compactification
533
534 public void CompactAll()
535 {
536     _sync.ExecuteWriteOperation(() =>
537     {
538         var sequences = Each((LinkAddress<LinkIndex>) Constants.Any);
539         for (int i = 0; i < sequences.Count; i++)
540         {
541             var sequence = this.ToList(sequences[i]);
542             Compact(sequence.ConvertToRestrictionsValues());
543         }
544     });
545 }
546
547 /// <remarks>
548 /// bestVariant можно выбирать по максимальному числу использований,
549 /// но балансированный позволяет гарантировать уникальность (если есть возможность,
550 /// гарантировать его использование в других местах).
551 ///
552 /// Получается этот метод должен игнорировать Options.EnforceSingleSequenceVersionOnWrite
553 /// </remarks>
554 public LinkIndex Compact(ICollection<LinkIndex> sequence)
555 {
556     return _sync.ExecuteWriteOperation(() =>
557     {
558         if (sequence.IsNullOrEmpty())
559         {
560             return Constants.Null;
561         }
562         Links.EnsureInnerReferenceExists(sequence, nameof(sequence));
563         return CompactCore(sequence);
564     });
565 }
566
567 [MethodImpl(MethodImplOptions.AggressiveInlining)]
568 private LinkIndex CompactCore(ICollection<LinkIndex> sequence) => UpdateCore(sequence,
569     ↪ sequence);
570
571 #endregion
572
573 #region Garbage Collection
574
575 /// <remarks>
576 /// TODO: Добавить дополнительный обработчик / событие CanBeDeleted которое можно
577     ↪ определить извне или в унаследованном классе
578 /// </remarks>
579 [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

578 private bool IsGarbage(LinkIndex link) => link != Options.SequenceMarkerLink &&
    ↳ !Links.Unsync.IsPartialPoint(link) && Links.Count(Constants.Any, link) == 0;
579
580 private void ClearGarbage(LinkIndex link)
581 {
582     if (IsGarbage(link))
583     {
584         var contents = new Link<ulong>(Links.GetLink(link));
585         Links.Unsync.Delete(link);
586         ClearGarbage(contents.Source);
587         ClearGarbage(contents.Target);
588     }
589 }
590
591 #endregion
592
593 #region Walkers
594
595 public bool EachPart(Func<LinkIndex, bool> handler, LinkIndex sequence)
596 {
597     return _sync.ExecuteReadOperation(() =>
598     {
599         var links = Links.Unsync;
600         foreach (var part in Options.Walker.Walk(sequence))
601         {
602             if (!handler(part))
603             {
604                 return false;
605             }
606         }
607         return true;
608     });
609 }
610
611 public class Matcher : RightSequenceWalker<LinkIndex>
612 {
613     private readonly Sequences _sequences;
614     private readonly IList<LinkIndex> _patternSequence;
615     private readonly HashSet<LinkIndex> _linksInSequence;
616     private readonly HashSet<LinkIndex> _results;
617     private readonly Func<IList<LinkIndex>, LinkIndex> _stopableHandler;
618     private readonly HashSet<LinkIndex> _readAsElements;
619     private int _filterPosition;
620
621     public Matcher(Sequences sequences, IList<LinkIndex> patternSequence,
        ↳ HashSet<LinkIndex> results, Func<IList<LinkIndex>, LinkIndex> stopableHandler,
        ↳ HashSet<LinkIndex> readAsElements = null)
        : base(sequences.Links.Unsync, new DefaultStack<LinkIndex>())
622     {
623         _sequences = sequences;
624         _patternSequence = patternSequence;
625         _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
626             ↳ Links.Constants.Any && x != ZeroOrMany));
627         _results = results;
628         _stopableHandler = stopableHandler;
629         _readAsElements = readAsElements;
630     }
631
632     protected override bool IsElement(LinkIndex link) => base.IsElement(link) ||
        ↳ (_readAsElements != null && _readAsElements.Contains(link)) ||
        ↳ _linksInSequence.Contains(link);
633
634     public bool FullMatch(LinkIndex sequenceToMatch)
635     {
636         _filterPosition = 0;
637         foreach (var part in Walk(sequenceToMatch))
638         {
639             if (!FullMatchCore(part))
640             {
641                 break;
642             }
643         }
644         return _filterPosition == _patternSequence.Count;
645     }
646
647     private bool FullMatchCore(LinkIndex element)
648     {
649         if (_filterPosition == _patternSequence.Count)
650         {
651             _filterPosition = -2; // Длиннее чем нужно

```

```

652         return false;
653     }
654     if (_patternSequence[_filterPosition] != Links.Constants.Any
655         && element != _patternSequence[_filterPosition])
656     {
657         _filterPosition = -1;
658         return false; // Начинается/Продолжается иначе
659     }
660     _filterPosition++;
661     return true;
662 }
663
664 public void AddFullMatchedToResults(IList<LinkIndex> restrictions)
665 {
666     var sequenceToMatch = restrictions[Links.Constants.IndexPart];
667     if (FullMatch(sequenceToMatch))
668     {
669         _results.Add(sequenceToMatch);
670     }
671 }
672
673 public LinkIndex HandleFullMatched(IList<LinkIndex> restrictions)
674 {
675     var sequenceToMatch = restrictions[Links.Constants.IndexPart];
676     if (FullMatch(sequenceToMatch) && _results.Add(sequenceToMatch))
677     {
678         return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
679     }
680     return Links.Constants.Continue;
681 }
682
683 public LinkIndex HandleFullMatchedSequence(IList<LinkIndex> restrictions)
684 {
685     var sequenceToMatch = restrictions[Links.Constants.IndexPart];
686     var sequence = _sequences.GetSequenceByElements(sequenceToMatch);
687     if (sequence != Links.Constants.Null && FullMatch(sequenceToMatch) &&
688         ↪ _results.Add(sequenceToMatch))
689     {
690         return _stopableHandler(new LinkAddress<LinkIndex>(sequence));
691     }
692     return Links.Constants.Continue;
693 }
694
695 /// <remarks>
696 /// TODO: Add support for LinksConstants.Any
697 /// </remarks>
698 public bool PartialMatch(LinkIndex sequenceToMatch)
699 {
700     _filterPosition = -1;
701     foreach (var part in Walk(sequenceToMatch))
702     {
703         if (!PartialMatchCore(part))
704         {
705             break;
706         }
707     }
708     return _filterPosition == _patternSequence.Count - 1;
709 }
710
711 private bool PartialMatchCore(LinkIndex element)
712 {
713     if (_filterPosition == (_patternSequence.Count - 1))
714     {
715         return false; // Нашлось
716     }
717     if (_filterPosition >= 0)
718     {
719         if (element == _patternSequence[_filterPosition + 1])
720         {
721             _filterPosition++;
722         }
723         else
724         {
725             _filterPosition = -1;
726         }
727     }
728     if (_filterPosition < 0)
729     {
730         if (element == _patternSequence[0])

```



```

730         {
731             _filterPosition = 0;
732         }
733     }
734     return true; // Ищем дальше
735 }
736
737 public void AddPartialMatchedToResults(LinkIndex sequenceToMatch)
738 {
739     if (PartialMatch(sequenceToMatch))
740     {
741         _results.Add(sequenceToMatch);
742     }
743 }
744
745 public LinkIndex HandlePartialMatched(ICollection<LinkIndex> restrictions)
746 {
747     var sequenceToMatch = restrictions[Links.Constants.IndexPart];
748     if (PartialMatch(sequenceToMatch))
749     {
750         return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
751     }
752     return Links.Constants.Continue;
753 }
754
755 public void AddAllPartialMatchedToResults(IEnumerable<LinkIndex> sequencesToMatch)
756 {
757     foreach (var sequenceToMatch in sequencesToMatch)
758     {
759         if (PartialMatch(sequenceToMatch))
760         {
761             _results.Add(sequenceToMatch);
762         }
763     }
764 }
765
766 public void AddAllPartialMatchedToResultsAndReadAsElements(IEnumerable<LinkIndex>
↵ sequencesToMatch)
767 {
768     foreach (var sequenceToMatch in sequencesToMatch)
769     {
770         if (PartialMatch(sequenceToMatch))
771         {
772             _readAsElements.Add(sequenceToMatch);
773             _results.Add(sequenceToMatch);
774         }
775     }
776 }
777 }
778
779 #endregion
780 }
781 }

```

./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         {
32             return new ulong[0];
33         }
34         Links.EnsureLinkExists(sequence);
35         if (sequence.Length == 1)
36         {
37             return sequence;
38         }
39         return CreateAllVariants2Core(sequence, 0, sequence.Length - 1);
40     });
41 }
42
43 private ulong[] CreateAllVariants2Core(ulong[] sequence, long startAt, long stopAt)
44 {
45     #if DEBUG
46         if ((stopAt - startAt) < 0)
47         {
48             throw new ArgumentOutOfRangeException(nameof(startAt), "startAt должен быть
49                 ↳ меньше или равен stopAt");
50         }
51     #endif
52     if ((stopAt - startAt) == 0)
53     {
54         return new[] { sequence[startAt] };
55     }
56     if ((stopAt - startAt) == 1)
57     {
58         return new[] { Links.Unsync.CreateAndUpdate(sequence[startAt], sequence[stopAt])
59             ↳ };
60     }
61     var variants = new ulong[(ulong)Platform.Numbers.Math.Catalan(stopAt - startAt)];
62     var last = 0;
63     for (var splitter = startAt; splitter < stopAt; splitter++)
64     {
65         var left = CreateAllVariants2Core(sequence, startAt, splitter);
66         var right = CreateAllVariants2Core(sequence, splitter + 1, stopAt);
67         for (var i = 0; i < left.Length; i++)
68         {
69             for (var j = 0; j < right.Length; j++)
70             {
71                 var variant = Links.Unsync.CreateAndUpdate(left[i], right[j]);
72                 if (variant == Constants.Null)
73                 {
74                     throw new NotImplementedException("Creation cancellation is not
75                         ↳ implemented.");
76                 }
77                 variants[last++] = variant;
78             }
79         }
80     }
81     return variants;
82 }
83
84 public List<ulong> CreateAllVariants1(params ulong[] sequence)
85 {
86     return _sync.ExecuteWriteOperation(() =>
87     {
88         if (sequence.IsNullOrEmpty())
89         {
90             return new List<ulong>();
91         }
92         Links.Unsync.EnsureLinkExists(sequence);
93         if (sequence.Length == 1)
94         {
95             return new List<ulong> { sequence[0] };
96         }
97         var results = new
98             ↳ List<ulong>((int)Platform.Numbers.Math.Catalan(sequence.Length));
99         return CreateAllVariants1Core(sequence, results);
100     });
101 }
102
103 private List<ulong> CreateAllVariants1Core(ulong[] sequence, List<ulong> results)

```

```

100 {
101     if (sequence.Length == 2)
102     {
103         var link = Links.Unsync.CreateAndUpdate(sequence[0], sequence[1]);
104         if (link == Constants.Null)
105         {
106             throw new NotImplementedException("Creation cancellation is not
107                 ↳ implemented.");
108         }
109         results.Add(link);
110         return results;
111     }
112     var innerSequenceLength = sequence.Length - 1;
113     var innerSequence = new ulong[innerSequenceLength];
114     for (var li = 0; li < innerSequenceLength; li++)
115     {
116         var link = Links.Unsync.CreateAndUpdate(sequence[li], sequence[li + 1]);
117         if (link == Constants.Null)
118         {
119             throw new NotImplementedException("Creation cancellation is not
120                 ↳ implemented.");
121         }
122         for (var isi = 0; isi < li; isi++)
123         {
124             innerSequence[isi] = sequence[isi];
125         }
126         innerSequence[li] = link;
127         for (var isi = li + 1; isi < innerSequenceLength; isi++)
128         {
129             innerSequence[isi] = sequence[isi + 1];
130         }
131         CreateAllVariants1Core(innerSequence, results);
132     }
133     return results;
134 }
135
136 #endregion
137
138 public HashSet<ulong> Each1(params ulong[] sequence)
139 {
140     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
141     Each1(link =>
142     {
143         if (!visitedLinks.Contains(link))
144         {
145             visitedLinks.Add(link); // изучить почему случаются повторы
146         }
147         return true;
148     }, sequence);
149     return visitedLinks;
150 }
151
152 private void Each1(Func<ulong, bool> handler, params ulong[] sequence)
153 {
154     if (sequence.Length == 2)
155     {
156         Links.Unsync.Each(sequence[0], sequence[1], handler);
157     }
158     else
159     {
160         var innerSequenceLength = sequence.Length - 1;
161         for (var li = 0; li < innerSequenceLength; li++)
162         {
163             var left = sequence[li];
164             var right = sequence[li + 1];
165             if (left == 0 && right == 0)
166             {
167                 continue;
168             }
169             var linkIndex = li;
170             ulong[] innerSequence = null;
171             Links.Unsync.Each(doublet =>
172             {
173                 if (innerSequence == null)
174                 {
175                     innerSequence = new ulong[innerSequenceLength];
176                     for (var isi = 0; isi < linkIndex; isi++)
177                     {

```

```

176         innerSequence[isi] = sequence[isi];
177     }
178     for (var isi = linkIndex + 1; isi < innerSequenceLength; isi++)
179     {
180         innerSequence[isi] = sequence[isi + 1];
181     }
182 }
183 innerSequence[linkIndex] = doublet[Constants.IndexPart];
184 Each1(handler, innerSequence);
185 return Constants.Continue;
186 }, Constants.Any, left, right);
187 }
188 }
189 }
190
191 public HashSet<ulong> EachPart(params ulong[] sequence)
192 {
193     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
194     EachPartCore(link =>
195     {
196         var linkIndex = link[Constants.IndexPart];
197         if (!visitedLinks.Contains(linkIndex))
198         {
199             visitedLinks.Add(linkIndex); // изучить почему случаются повторы
200         }
201         return Constants.Continue;
202     }, sequence);
203     return visitedLinks;
204 }
205
206 public void EachPart(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[] sequence)
207 {
208     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
209     EachPartCore(link =>
210     {
211         var linkIndex = link[Constants.IndexPart];
212         if (!visitedLinks.Contains(linkIndex))
213         {
214             visitedLinks.Add(linkIndex); // изучить почему случаются повторы
215             return handler(new LinkAddress<LinkIndex>(linkIndex));
216         }
217         return Constants.Continue;
218     }, sequence);
219 }
220
221 private void EachPartCore(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[]
222 ↪ sequence)
223 {
224     if (sequence.IsNullOrEmpty())
225     {
226         return;
227     }
228     Links.EnsureLinkIsAnyOrExists(sequence);
229     if (sequence.Length == 1)
230     {
231         var link = sequence[0];
232         if (link > 0)
233         {
234             handler(new LinkAddress<LinkIndex>(link));
235         }
236         else
237         {
238             Links.Each(Constants.Any, Constants.Any, handler);
239         }
240     }
241     else if (sequence.Length == 2)
242     {
243         //_links.Each(sequence[0], sequence[1], handler);
244         //  o_|      x_o ...
245         // x_|      |__|
246         Links.Each(sequence[1], Constants.Any, doublet =>
247         {
248             var match = Links.SearchOrDefault(sequence[0], doublet);
249             if (match != Constants.Null)
250             {
251                 handler(new LinkAddress<LinkIndex>(match));
252             }
253             return true;
254         });
255     }
256 }

```

```

253     });
254     // |_x      ... x_o
255     // |_o      |___|
256     Links.Unsync.Each(Constants.Any, sequence[0], doublet =>
257     {
258         var match = Links.SearchOrDefault(doublet, sequence[1]);
259         if (match != 0)
260         {
261             handler(new LinkAddress<LinkIndex>(match));
262         }
263         return true;
264     });
265     //      .-x o-.
266     //      |___|
267     PartialStepRight(x => handler(x), sequence[0], sequence[1]);
268 }
269 else
270 {
271     throw new NotImplementedException();
272 }
273 }
274
275 private void PartialStepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
276 {
277     Links.Unsync.Each(Constants.Any, left, doublet =>
278     {
279         StepRight(handler, doublet, right);
280         if (left != doublet)
281         {
282             PartialStepRight(handler, doublet, right);
283         }
284         return true;
285     });
286 }
287
288 private void StepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
289 {
290     Links.Unsync.Each(left, Constants.Any, rightStep =>
291     {
292         TryStepRightUp(handler, right, rightStep);
293         return true;
294     });
295 }
296
297 private void TryStepRightUp(Action<IList<LinkIndex>> handler, ulong right, ulong
298 ↪ stepFrom)
299 {
300     var upStep = stepFrom;
301     var firstSource = Links.Unsync.GetTarget(upStep);
302     while (firstSource != right && firstSource != upStep)
303     {
304         upStep = firstSource;
305         firstSource = Links.Unsync.GetSource(upStep);
306     }
307     if (firstSource == right)
308     {
309         handler(new LinkAddress<LinkIndex>(stepFrom));
310     }
311 }
312
313 // TODO: Test
314 private void PartialStepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
315 {
316     Links.Unsync.Each(right, Constants.Any, doublet =>
317     {
318         StepLeft(handler, left, doublet);
319         if (right != doublet)
320         {
321             PartialStepLeft(handler, left, doublet);
322         }
323         return true;
324     });
325 }
326
327 private void StepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
328 {
329     Links.Unsync.Each(Constants.Any, right, leftStep =>
330     {
331         TryStepLeftUp(handler, left, leftStep);
332     });
333 }

```

```

331         return true;
332     });
333 }
334
335 private void TryStepLeftUp(Action<IList<LinkIndex>> handler, ulong left, ulong stepFrom)
336 {
337     var upStep = stepFrom;
338     var firstTarget = Links.Unsync.GetSource(upStep);
339     while (firstTarget != left && firstTarget != upStep)
340     {
341         upStep = firstTarget;
342         firstTarget = Links.Unsync.GetTarget(upStep);
343     }
344     if (firstTarget == left)
345     {
346         handler(new LinkAddress<LinkIndex>(stepFrom));
347     }
348 }
349
350 private bool StartsWith(ulong sequence, ulong link)
351 {
352     var upStep = sequence;
353     var firstSource = Links.Unsync.GetSource(upStep);
354     while (firstSource != link && firstSource != upStep)
355     {
356         upStep = firstSource;
357         firstSource = Links.Unsync.GetSource(upStep);
358     }
359     return firstSource == link;
360 }
361
362 private bool EndsWith(ulong sequence, ulong link)
363 {
364     var upStep = sequence;
365     var lastTarget = Links.Unsync.GetTarget(upStep);
366     while (lastTarget != link && lastTarget != upStep)
367     {
368         upStep = lastTarget;
369         lastTarget = Links.Unsync.GetTarget(upStep);
370     }
371     return lastTarget == link;
372 }
373
374 public List<ulong> GetAllMatchingSequences0(params ulong[] sequence)
375 {
376     return _sync.ExecuteReadOperation(() =>
377     {
378         var results = new List<ulong>();
379         if (sequence.Length > 0)
380         {
381             Links.EnsureLinkExists(sequence);
382             var firstElement = sequence[0];
383             if (sequence.Length == 1)
384             {
385                 results.Add(firstElement);
386                 return results;
387             }
388             if (sequence.Length == 2)
389             {
390                 var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
391                 if (doublet != Constants.Null)
392                 {
393                     results.Add(doublet);
394                 }
395                 return results;
396             }
397             var linksInSequence = new HashSet<ulong>(sequence);
398             void handler(IList<LinkIndex> result)
399             {
400                 var resultIndex = result[Links.Constants.IndexPart];
401                 var filterPosition = 0;
402                 StopableSequenceWalker.WalkRight(resultIndex, Links.Unsync.GetSource,
403                     ↪ Links.Unsync.GetTarget,
404                     ↪ x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
405                     ↪ x =>
406                     {
407                         if (filterPosition == sequence.Length)
408                         {
409                             filterPosition = -2; // Длиннее чем нужно
410                         }
411                     }
412                 );
413             }
414         }
415     });
416 }

```

```

408         return false;
409     }
410     if (x != sequence[filterPosition])
411     {
412         filterPosition = -1;
413         return false; // Начинается иначе
414     }
415     filterPosition++;
416
417     return true;
418     });
419     if (filterPosition == sequence.Length)
420     {
421         results.Add(resultIndex);
422     }
423 }
424 if (sequence.Length >= 2)
425 {
426     StepRight(handler, sequence[0], sequence[1]);
427 }
428 var last = sequence.Length - 2;
429 for (var i = 1; i < last; i++)
430 {
431     PartialStepRight(handler, sequence[i], sequence[i + 1]);
432 }
433 if (sequence.Length >= 3)
434 {
435     StepLeft(handler, sequence[sequence.Length - 2],
436         ↪ sequence[sequence.Length - 1]);
437 }
438 return results;
439 });
440 }
441
442 public HashSet<ulong> GetAllMatchingSequences1(params ulong[] sequence)
443 {
444     return _sync.ExecuteReadOperation(() =>
445     {
446         var results = new HashSet<ulong>();
447         if (sequence.Length > 0)
448         {
449             Links.EnsureLinkExists(sequence);
450             var firstElement = sequence[0];
451             if (sequence.Length == 1)
452             {
453                 results.Add(firstElement);
454                 return results;
455             }
456             if (sequence.Length == 2)
457             {
458                 var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
459                 if (doublet != Constants.Null)
460                 {
461                     results.Add(doublet);
462                 }
463                 return results;
464             }
465             var matcher = new Matcher(this, sequence, results, null);
466             if (sequence.Length >= 2)
467             {
468                 StepRight(matcher.AddFullMatchedToResults, sequence[0], sequence[1]);
469             }
470             var last = sequence.Length - 2;
471             for (var i = 1; i < last; i++)
472             {
473                 PartialStepRight(matcher.AddFullMatchedToResults, sequence[i],
474                     ↪ sequence[i + 1]);
475             }
476             if (sequence.Length >= 3)
477             {
478                 StepLeft(matcher.AddFullMatchedToResults, sequence[sequence.Length - 2],
479                     ↪ sequence[sequence.Length - 1]);
480             }
481             return results;
482         }
483     });
484 }

```

```

483 public const int MaxSequenceFormatSize = 200;
484
485 public string FormatSequence(LinkIndex sequenceLink, params LinkIndex[] knownElements)
486     => FormatSequence(sequenceLink, (sb, x) => sb.Append(x), true, knownElements);
487
488 public string FormatSequence(LinkIndex sequenceLink, Action<StringBuilder, LinkIndex>
489     elementToString, bool insertComma, params LinkIndex[] knownElements) =>
490     Links.SyncRoot.ExecuteReadOperation(() => FormatSequence(Links.Unsync, sequenceLink,
491         elementToString, insertComma, knownElements));
492
493 private string FormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
494     Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
495     LinkIndex[] knownElements)
496 {
497     var linksInSequence = new HashSet<ulong>(knownElements);
498     //var entered = new HashSet<ulong>();
499     var sb = new StringBuilder();
500     sb.Append('{');
501     if (links.Exists(sequenceLink))
502     {
503         StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
504             x => linksInSequence.Contains(x) || links.IsPartialPoint(x), element => //
505             entered.AddAndReturnVoid, x => { }, entered.DoNotContains
506             {
507                 if (insertComma && sb.Length > 1)
508                 {
509                     sb.Append(',');
510                 }
511                 //if (entered.Contains(element))
512                 //{
513                 //    sb.Append('{');
514                 //    elementToString(sb, element);
515                 //    sb.Append('}');
516                 //}
517                 //else
518                 elementToString(sb, element);
519                 if (sb.Length < MaxSequenceFormatSize)
520                 {
521                     return true;
522                 }
523                 sb.Append(insertComma ? ", ..." : "...");
524                 return false;
525             });
526     }
527     sb.Append('}');
528     return sb.ToString();
529 }
530
531 public string SafeFormatSequence(LinkIndex sequenceLink, params LinkIndex[]
532     knownElements) => SafeFormatSequence(sequenceLink, (sb, x) => sb.Append(x), true,
533     knownElements);
534
535 public string SafeFormatSequence(LinkIndex sequenceLink, Action<StringBuilder,
536     LinkIndex> elementToString, bool insertComma, params LinkIndex[] knownElements) =>
537     Links.SyncRoot.ExecuteReadOperation(() => SafeFormatSequence(Links.Unsync,
538         sequenceLink, elementToString, insertComma, knownElements));
539
540 private string SafeFormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
541     Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
542     LinkIndex[] knownElements)
543 {
544     var linksInSequence = new HashSet<ulong>(knownElements);
545     var entered = new HashSet<ulong>();
546     var sb = new StringBuilder();
547     sb.Append('{');
548     if (links.Exists(sequenceLink))
549     {
550         StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
551             x => linksInSequence.Contains(x) || links.IsFullPoint(x),
552             entered.AddAndReturnVoid, x => { }, entered.DoNotContains, element =>
553             {
554                 if (insertComma && sb.Length > 1)
555                 {
556                     sb.Append(',');
557                 }
558                 if (entered.Contains(element))

```



```

545         {
546             sb.Append('{');
547             elementToString(sb, element);
548             sb.Append('}');
549         }
550         else
551         {
552             elementToString(sb, element);
553         }
554         if (sb.Length < MaxSequenceFormatSize)
555         {
556             return true;
557         }
558         sb.Append(insertComma ? ", ..." : "...");
559         return false;
560     });
561 }
562 sb.Append('}');
563 return sb.ToString();
564 }
565
566 public List<ulong> GetAllPartiallyMatchingSequences0(params ulong[] sequence)
567 {
568     return _sync.ExecuteReadOperation(() =>
569     {
570         if (sequence.Length > 0)
571         {
572             Links.EnsureLinkExists(sequence);
573             var results = new HashSet<ulong>();
574             for (var i = 0; i < sequence.Length; i++)
575             {
576                 AllUsagesCore(sequence[i], results);
577             }
578             var filteredResults = new List<ulong>();
579             var linksInSequence = new HashSet<ulong>(sequence);
580             foreach (var result in results)
581             {
582                 var filterPosition = -1;
583                 StopableSequenceWalker.WalkRight(result, Links.Unsync.GetSource,
584                     ↪ Links.Unsync.GetTarget,
585                     x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
586                     ↪ x =>
587                     {
588                         if (filterPosition == (sequence.Length - 1))
589                         {
590                             return false;
591                         }
592                         if (filterPosition >= 0)
593                         {
594                             if (x == sequence[filterPosition + 1])
595                             {
596                                 filterPosition++;
597                             }
598                             else
599                             {
600                                 return false;
601                             }
602                         }
603                         if (filterPosition < 0)
604                         {
605                             if (x == sequence[0])
606                             {
607                                 filterPosition = 0;
608                             }
609                         }
610                         return true;
611                     });
612                 if (filterPosition == (sequence.Length - 1))
613                 {
614                     filteredResults.Add(result);
615                 }
616             }
617             return filteredResults;
618         }
619         return new List<ulong>();
620     });
621 }
622
623 public HashSet<ulong> GetAllPartiallyMatchingSequences1(params ulong[] sequence)

```

```

622 {
623     return _sync.ExecuteReadOperation(() =>
624     {
625         if (sequence.Length > 0)
626         {
627             Links.EnsureLinkExists(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,
643     → params ulong[] sequence)
644 {
645     return _sync.ExecuteReadOperation(() =>
646     {
647         if (sequence.Length > 0)
648         {
649             Links.EnsureLinkExists(sequence);
650
651             var results = new HashSet<ulong>();
652             var filteredResults = new HashSet<ulong>();
653             var matcher = new Matcher(this, sequence, filteredResults, handler);
654             for (var i = 0; i < sequence.Length; i++)
655             {
656                 if (!AllUsagesCore1(sequence[i], results, matcher.HandlePartialMatched))
657                 {
658                     return false;
659                 }
660             }
661             return true;
662         }
663         return true;
664     });
665 }
666
667 //public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
668 //{
669 //    return Sync.ExecuteReadOperation(() =>
670 //    {
671 //        if (sequence.Length > 0)
672 //        {
673 //            _links.EnsureEachLinkIsAnyOrExists(sequence);
674 //
675 //            var firstResults = new HashSet<ulong>();
676 //            var lastResults = new HashSet<ulong>();
677 //
678 //            var first = sequence.First(x => x != LinksConstants.Any);
679 //            var last = sequence.Last(x => x != LinksConstants.Any);
680 //
681 //            AllUsagesCore(first, firstResults);
682 //            AllUsagesCore(last, lastResults);
683 //
684 //            firstResults.IntersectWith(lastResults);
685 //
686 //            //for (var i = 0; i < sequence.Length; i++)
687 //            //    AllUsagesCore(sequence[i], results);
688 //
689 //            var filteredResults = new HashSet<ulong>();
690 //            var matcher = new Matcher(this, sequence, filteredResults, null);
691 //            matcher.AddAllPartialMatchedToResults(firstResults);
692 //            return filteredResults;
693 //        }
694 //
695 //        return new HashSet<ulong>();
696 //    });
697 //}
698
699 public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
700 {

```

```

700     return _sync.ExecuteReadOperation((Func<HashSet<ulong>>)(() =>
701     {
702         if (sequence.Length > 0)
703         {
704             ILinksExtensions.EnsureLinkIsAnyOrExists<ulong>(Links,
705                 ↳ (IList<ulong>)sequence);
706             var firstResults = new HashSet<ulong>();
707             var lastResults = new HashSet<ulong>();
708             var first = sequence.First(x => x != Constants.Any);
709             var last = sequence.Last(x => x != Constants.Any);
710             AllUsagesCore(first, firstResults);
711             AllUsagesCore(last, lastResults);
712             firstResults.IntersectWith(lastResults);
713             //for (var i = 0; i < sequence.Length; i++)
714             //    AllUsagesCore(sequence[i], results);
715             var filteredResults = new HashSet<ulong>();
716             var matcher = new Matcher(this, sequence, filteredResults, null);
717             matcher.AddAllPartialMatchedToResults(firstResults);
718             return filteredResults;
719         }
720         return new HashSet<ulong>();
721     }));
722 }
723 public HashSet<ulong> GetAllPartiallyMatchingSequences4(HashSet<ulong> readAsElements,
724     ↳ IList<ulong> sequence)
725 {
726     return _sync.ExecuteReadOperation(() =>
727     {
728         if (sequence.Count > 0)
729         {
730             Links.EnsureLinkExists(sequence);
731             var results = new HashSet<LinkIndex>();
732             //var nextResults = new HashSet<ulong>();
733             //for (var i = 0; i < sequence.Length; i++)
734             //{
735             //    AllUsagesCore(sequence[i], nextResults);
736             //    if (results.IsNullOrEmpty())
737             //    {
738             //        results = nextResults;
739             //        nextResults = new HashSet<ulong>();
740             //    }
741             //    else
742             //    {
743             //        results.IntersectWith(nextResults);
744             //        nextResults.Clear();
745             //    }
746             //}
747             var collector1 = new AllUsagesCollector1(Links.Unsync, results);
748             collector1.Collect(Links.Unsync.GetLink(sequence[0]));
749             var next = new HashSet<ulong>();
750             for (var i = 1; i < sequence.Count; i++)
751             {
752                 var collector = new AllUsagesCollector1(Links.Unsync, next);
753                 collector.Collect(Links.Unsync.GetLink(sequence[i]));
754                 results.IntersectWith(next);
755                 next.Clear();
756             }
757             var filteredResults = new HashSet<ulong>();
758             var matcher = new Matcher(this, sequence, filteredResults, null,
759                 ↳ readAsElements);
760             matcher.AddAllPartialMatchedToResultsAndReadAsElements(results.OrderBy(x =>
761                 ↳ x)); // OrderBy is a Hack
762             return filteredResults;
763         }
764         return new HashSet<ulong>();
765     }));
766 }
767 // Does not work
768 //public HashSet<ulong> GetAllPartiallyMatchingSequences5(HashSet<ulong> readAsElements,
769 //    ↳ params ulong[] sequence)
770 //{
771 //    var visited = new HashSet<ulong>();
772 //    var results = new HashSet<ulong>();
773 //    var matcher = new Matcher(this, sequence, visited, x => { results.Add(x); return
774 //        ↳ true; }, readAsElements);

```

```

772 //     var last = sequence.Length - 1;
773 //     for (var i = 0; i < last; i++)
774 //     {
775 //         PartialStepRight(matcher.PartialMatch, sequence[i], sequence[i + 1]);
776 //     }
777 //     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.EnsureLinkExists(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))
804             //        results.Add(x);
805             //    return true;
806             //};
807             //if (sequence.Length >= 2)
808             //    StepRight(handler, sequence[0], sequence[1]);
809             //var last = sequence.Length - 2;
810             //for (var i = 1; i < last; i++)
811             //    PartialStepRight(handler, sequence[i], sequence[i + 1]);
812             //if (sequence.Length >= 3)
813             //    StepLeft(handler, sequence[sequence.Length - 2],
814             //        sequence[sequence.Length - 1]);
815             //if (sequence.Length == 1)
816             //if (sequence.Length == 2)
817             //if (sequence.Length == 2)
818             //if (sequence.Length == 2)
819             //if (sequence.Length == 2)
820             //if (sequence.Length == 2)
821             //if (sequence.Length == 2)
822             //if (sequence.Length == 2)
823             //if (sequence.Length == 2)
824             //if (sequence.Length == 2)
825             //if (sequence.Length == 2)
826             //if (sequence.Length == 2)
827             //if (sequence.Length == 2)
828             //if (sequence.Length == 2)
829             //if (sequence.Length == 2)
830             //if (sequence.Length == 2)
831             //if (sequence.Length == 2)
832             //if (sequence.Length == 2)
833             //if (sequence.Length == 2)
834             //if (sequence.Length == 2)
835             //if (sequence.Length == 2)
836             //if (sequence.Length == 2)
837             //if (sequence.Length == 2)
838             //if (sequence.Length == 2)
839             //if (sequence.Length == 2)
840             //if (sequence.Length == 2)
841             //if (sequence.Length == 2)
842             //if (sequence.Length == 2)
843             //if (sequence.Length == 2)
844             //if (sequence.Length == 2)

```

```

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>() {
862     //    sequence[0] }; // or all sequences, containing this element?
863     //return GetAllPartiallyMatchingSequencesCore(sequence, firstLinkUsages,
864     //    1).ToList();
865     var results = new HashSet<ulong>();
866     foreach (var match in GetAllPartiallyMatchingSequencesCore(sequence,
867     //    firstLinkUsages, 1))
868     {
869         AllUsagesCore(match, results);
870     }
871     return results.ToList();
872 }
873
874 /// <remarks>
875 /// TODO: Может потребоваться 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
888 //    той связи с которой начинался поиск (STTTSSSTT),
889 // причём достаточно одного бита для хранения перехода влево или вправо
890 private void AllUsagesCore(ulong link, HashSet<ulong> usages)
891 {
892     bool handler(ulong doublet)
893     {
894         if (usages.Add(doublet))
895         {
896             AllUsagesCore(doublet, usages);
897         }
898         return true;
899     }
900     Links.Unsync.Each(link, Constants.Any, handler);
901     Links.Unsync.Each(Constants.Any, link, handler);
902 }
903
904 public HashSet<ulong> AllBottomUsages(ulong link)
905 {
906     return _sync.ExecuteReadOperation(() =>
907     {
908         var visits = new HashSet<ulong>();
909         var usages = new HashSet<ulong>();
910         AllBottomUsagesCore(link, visits, usages);
911         return usages;
912     });
913 }
914
915 private void AllBottomUsagesCore(ulong link, HashSet<ulong> visits, HashSet<ulong>
916 //    usages)
917 {
918     bool handler(ulong doublet)
919     {

```

```

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

```

```

993     public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
994         ↪ CalculateCore);
995
996     private bool CalculateCore(ulong link)
997     {
998         if (_totals[link] == 0)
999         {
1000             var total = 1UL;
1001             _totals[link] = total;
1002             var visitedChildren = new HashSet<ulong>();
1003             bool linkCalculator(ulong child)
1004             {
1005                 if (link != child && visitedChildren.Add(child))
1006                 {
1007                     total += _totals[child] == 0 ? 1 : _totals[child];
1008                 }
1009                 return true;
1010             }
1011             _links.Unsync.Each(link, _links.Constants.Any, linkCalculator);
1012             _links.Unsync.Each(_links.Constants.Any, link, linkCalculator);
1013             _totals[link] = total;
1014         }
1015         return true;
1016     }
1017
1018     private class AllUsagesCalculator2
1019     {
1020         private readonly SynchronizedLinks<ulong> _links;
1021         private readonly ulong[] _totals;
1022
1023         public AllUsagesCalculator2(SynchronizedLinks<ulong> links, ulong[] totals)
1024         {
1025             _links = links;
1026             _totals = totals;
1027         }
1028
1029         public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
1030             ↪ CalculateCore);
1031
1032         private bool IsElement(ulong link)
1033         {
1034             // _linksInSequence.Contains(link) ||
1035             return _links.Unsync.GetTarget(link) == link || _links.Unsync.GetSource(link) ==
1036                 ↪ link;
1037         }
1038
1039         private bool CalculateCore(ulong link)
1040         {
1041             // TODO: Проработать защиту от заикливания
1042             // Основано на SequenceWalker.WalkLeft
1043             Func<ulong, ulong> getSource = _links.Unsync.GetSource;
1044             Func<ulong, ulong> getTarget = _links.Unsync.GetTarget;
1045             Func<ulong, bool> isElement = IsElement;
1046             void visitLeaf(ulong parent)
1047             {
1048                 if (link != parent)
1049                 {
1050                     _totals[parent]++;
1051                 }
1052             }
1053             void visitNode(ulong parent)
1054             {
1055                 if (link != parent)
1056                 {
1057                     _totals[parent]++;
1058                 }
1059             }
1060             var stack = new Stack();
1061             var element = link;
1062             if (isElement(element))
1063             {
1064                 visitLeaf(element);
1065             }
1066             else
1067             {
1068                 while (true)
1069                 {
1070                     if (isElement(element))

```

```

1069         {
1070             if (stack.Count == 0)
1071             {
1072                 break;
1073             }
1074             element = stack.Pop();
1075             var source = getSource(element);
1076             var target = getTarget(element);
1077             // 06паборка элемента
1078             if (isElement(target))
1079             {
1080                 visitLeaf(target);
1081             }
1082             if (isElement(source))
1083             {
1084                 visitLeaf(source);
1085             }
1086             element = source;
1087         }
1088         else
1089         {
1090             stack.Push(element);
1091             visitNode(element);
1092             element = getTarget(element);
1093         }
1094     }
1095 }
1096 _totals[link]++;
1097 return true;
1098 }
1099 }
1100
1101 private class AllUsagesCollector
1102 {
1103     private readonly ILinks<ulong> _links;
1104     private readonly HashSet<ulong> _usages;
1105
1106     public AllUsagesCollector(ILinks<ulong> links, HashSet<ulong> usages)
1107     {
1108         _links = links;
1109         _usages = usages;
1110     }
1111
1112     public bool Collect(ulong link)
1113     {
1114         if (_usages.Add(link))
1115         {
1116             _links.Each(link, _links.Constants.Any, Collect);
1117             _links.Each(_links.Constants.Any, link, Collect);
1118         }
1119         return true;
1120     }
1121 }
1122
1123 private class AllUsagesCollector1
1124 {
1125     private readonly ILinks<ulong> _links;
1126     private readonly HashSet<ulong> _usages;
1127     private readonly ulong _continue;
1128
1129     public AllUsagesCollector1(ILinks<ulong> links, HashSet<ulong> usages)
1130     {
1131         _links = links;
1132         _usages = usages;
1133         _continue = _links.Constants.Continue;
1134     }
1135
1136     public ulong Collect(ICollection<ulong> link)
1137     {
1138         var linkIndex = _links.GetIndex(link);
1139         if (_usages.Add(linkIndex))
1140         {
1141             _links.Each(Collect, _links.Constants.Any, linkIndex);
1142         }
1143         return _continue;
1144     }
1145 }
1146
1147 private class AllUsagesCollector2
1148 {

```



```

1149     private readonly ILinks<ulong> _links;
1150     private readonly BitString _usages;
1151
1152     public AllUsagesCollector2(ILinks<ulong> links, BitString usages)
1153     {
1154         _links = links;
1155         _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 private HashSet<ulong> GetAllPartiallyMatchingSequencesCore(ulong[] sequence,
1226     ↳ HashSet<ulong> previousMatchings, long startAt)
1227 {
1228     if (startAt >= sequence.Length) // ?
1229     {
1230         return previousMatchings;
1231     }
1232     var secondLinkUsages = new HashSet<ulong>();
1233     AllUsagesCore(sequence[startAt], secondLinkUsages);
1234     secondLinkUsages.Add(sequence[startAt]);
1235     var matchings = new HashSet<ulong>();
1236     var filler = new SetFiller<LinkIndex, LinkIndex>(matchings, Constants.Continue);
1237     //for (var i = 0; i < previousMatchings.Count; i++)
1238     foreach (var secondLinkUsage in secondLinkUsages)
1239     {
1240         foreach (var previousMatching in previousMatchings)
1241         {
1242             //AllCloseConnections(matchings.AddAndReturnVoid, previousMatching,
1243             ↳ secondLinkUsage);
1244             StepRight(filler.AddFirstAndReturnConstant, previousMatching,
1245             ↳ secondLinkUsage);
1246             TryStepRightUp(filler.AddFirstAndReturnConstant, secondLinkUsage,
1247             ↳ previousMatching);
1248             //PartialStepRight(matchings.AddAndReturnVoid, secondLinkUsage,
1249             ↳ sequence[startAt]); // почему-то эта ошибочная запись приводит к
1250             ↳ желаемым результатам.
1251             PartialStepRight(filler.AddFirstAndReturnConstant, previousMatching,
1252             ↳ secondLinkUsage);
1253         }
1254     }
1255     if (matchings.Count == 0)
1256     {
1257         return matchings;
1258     }
1259     return GetAllPartiallyMatchingSequencesCore(sequence, matchings, startAt + 1); // ??
1260 }
1261
1262 private static void EnsureEachLinkIsAnyOrZeroOrManyOrExists(SynchronizedLinks<ulong>
1263     ↳ links, params ulong[] sequence)
1264 {
1265     if (sequence == null)
1266     {
1267         return;
1268     }
1269     for (var i = 0; i < sequence.Length; i++)
1270     {
1271         if (sequence[i] != links.Constants.Any && sequence[i] != ZeroOrMany &&
1272             ↳ !links.Exists(sequence[i]))
1273         {
1274             throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
1275             ↳ $"patternSequence[{i}]");
1276         }
1277     }
1278 }
1279
1280 // Pattern Matching -> Key To Triggers
1281 public HashSet<ulong> MatchPattern(params ulong[] patternSequence)
1282 {
1283     return _sync.ExecuteReadOperation(() =>
1284     {
1285         patternSequence = Simplify(patternSequence);
1286         if (patternSequence.Length > 0)
1287         {
1288             EnsureEachLinkIsAnyOrZeroOrManyOrExists(Links, patternSequence);
1289             var uniqueSequenceElements = new HashSet<ulong>();
1290             for (var i = 0; i < patternSequence.Length; i++)
1291             {
1292                 if (patternSequence[i] != Constants.Any && patternSequence[i] !=
1293                     ↳ ZeroOrMany)
1294                 {
1295                     uniqueSequenceElements.Add(patternSequence[i]);
1296                 }
1297             }
1298             var results = new HashSet<ulong>();
1299             foreach (var uniqueSequenceElement in uniqueSequenceElements)
1300             {

```

```

1291         AllUsagesCore(uniqueSequenceElement, results);
1292     }
1293     var filteredResults = new HashSet<ulong>();
1294     var matcher = new PatternMatcher(this, patternSequence, filteredResults);
1295     matcher.AddAllPatternMatchedToResults(results);
1296     return filteredResults;
1297 }
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
1305 //        несколько раз в последовательности)
1306 public HashSet<ulong> GetAllConnections(params ulong[] linksToConnect)
1307 {
1308     return _sync.ExecuteReadOperation(() =>
1309     {
1310         var results = new HashSet<ulong>();
1311         if (linksToConnect.Length > 0)
1312         {
1313             Links.EnsureLinkExists(linksToConnect);
1314             AllUsagesCore(linksToConnect[0], results);
1315             for (var i = 1; i < linksToConnect.Length; i++)
1316             {
1317                 var next = new HashSet<ulong>();
1318                 AllUsagesCore(linksToConnect[i], next);
1319                 results.IntersectWith(next);
1320             }
1321             return results;
1322         }
1323     });
1324 }
1325
1326 public HashSet<ulong> GetAllConnections1(params ulong[] linksToConnect)
1327 {
1328     return _sync.ExecuteReadOperation(() =>
1329     {
1330         var results = new HashSet<ulong>();
1331         if (linksToConnect.Length > 0)
1332         {
1333             Links.EnsureLinkExists(linksToConnect);
1334             var collector1 = new AllUsagesCollector(Links.Unsync, results);
1335             collector1.Collect(linksToConnect[0]);
1336             var next = new HashSet<ulong>();
1337             for (var i = 1; i < linksToConnect.Length; i++)
1338             {
1339                 var collector = new AllUsagesCollector(Links.Unsync, next);
1340                 collector.Collect(linksToConnect[i]);
1341                 results.IntersectWith(next);
1342                 next.Clear();
1343             }
1344             return results;
1345         }
1346     });
1347 }
1348
1349 public HashSet<ulong> GetAllConnections2(params ulong[] linksToConnect)
1350 {
1351     return _sync.ExecuteReadOperation(() =>
1352     {
1353         var results = new HashSet<ulong>();
1354         if (linksToConnect.Length > 0)
1355         {
1356             Links.EnsureLinkExists(linksToConnect);
1357             var collector1 = new AllUsagesCollector(Links, results);
1358             collector1.Collect(linksToConnect[0]);
1359             //AllUsagesCore(linksToConnect[0], results);
1360             for (var i = 1; i < linksToConnect.Length; i++)
1361             {
1362                 var next = new HashSet<ulong>();
1363                 var collector = new AllUsagesIntersectingCollector(Links, results, next);
1364                 collector.Collect(linksToConnect[i]);
1365                 //AllUsagesCore(linksToConnect[i], next);
1366                 //results.IntersectWith(next);
1367                 results = next;
1368             }
1369         }
1370     });
1371 }

```

```

1368     }
1369     return results;
1370 });
1371 }
1372
1373 public List<ulong> GetAllConnections3(params ulong[] linksToConnect)
1374 {
1375     return _sync.ExecuteReadOperation(() =>
1376     {
1377         var results = new BitString((long)Links.Unsync.Count() + 1); // new
1378         ↪ BitArray((int)_links.Total + 1);
1379         if (linksToConnect.Length > 0)
1380         {
1381             Links.EnsureLinkExists(linksToConnect);
1382             var collector1 = new AllUsagesCollector2(Links.Unsync, results);
1383             collector1.Collect(linksToConnect[0]);
1384             for (var i = 1; i < linksToConnect.Length; i++)
1385             {
1386                 var next = new BitString((long)Links.Unsync.Count() + 1); //new
1387                 ↪ BitArray((int)_links.Total + 1);
1388                 var collector = new AllUsagesCollector2(Links.Unsync, next);
1389                 collector.Collect(linksToConnect[i]);
1390                 results = results.And(next);
1391             }
1392             return results.GetSetUInt64Indices();
1393         }
1394     });
1395 }
1396
1397 private static ulong[] Simplify(ulong[] sequence)
1398 {
1399     // Считаем новый размер последовательности
1400     long newLength = 0;
1401     var zeroOrManyStepped = false;
1402     for (var i = 0; i < sequence.Length; i++)
1403     {
1404         if (sequence[i] == ZeroOrMany)
1405         {
1406             if (zeroOrManyStepped)
1407             {
1408                 continue;
1409             }
1410             zeroOrManyStepped = true;
1411         }
1412         else
1413         {
1414             //if (zeroOrManyStepped) Is it efficient?
1415             zeroOrManyStepped = false;
1416             newLength++;
1417         }
1418     }
1419     // Строим новую последовательность
1420     zeroOrManyStepped = false;
1421     var newSequence = new ulong[newLength];
1422     long j = 0;
1423     for (var i = 0; i < sequence.Length; i++)
1424     {
1425         //var current = zeroOrManyStepped;
1426         //zeroOrManyStepped = patternSequence[i] == zeroOrMany;
1427         //if (current && zeroOrManyStepped)
1428         //    continue;
1429         //var newZeroOrManyStepped = patternSequence[i] == zeroOrMany;
1430         //if (zeroOrManyStepped && newZeroOrManyStepped)
1431         //    continue;
1432         //zeroOrManyStepped = newZeroOrManyStepped;
1433         if (sequence[i] == ZeroOrMany)
1434         {
1435             if (zeroOrManyStepped)
1436             {
1437                 continue;
1438             }
1439             zeroOrManyStepped = true;
1440         }
1441         else
1442         {
1443             //if (zeroOrManyStepped) Is it efficient?
1444             zeroOrManyStepped = false;
1445             newSequence[j++] = sequence[i];
1446         }
1447     }
1448 }

```

```

1445     }
1446     return newSequence;
1447 }
1448
1449 public static void TestSimplify()
1450 {
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)
1525             {
1526                 CollectMatchingSequences(leftLink, leftBound, middleLinks,
1527                                         ↪ elements[i], rightBound - 1, ref results);
1528             }
1529         }
1530     }
1531     else
1532     {
1533         for (var i = elements.Length - 1; i >= 0; i--)
1534         {
1535             var element = elements[i];
1536             if (element != 0)
1537             {
1538                 results.Add(element);
1539             }
1540         }
1541     }
1542 }
1543
1544 public ulong[] GetRightElements(ulong startLink, ulong rightLink)
1545 {
1546     var result = new ulong[5];
1547     TryStepRight(startLink, rightLink, result, 0);
1548     Links.Each(Constants.Any, startLink, couple =>
1549     {
1550         if (couple != startLink)
1551         {
1552             if (TryStepRight(couple, rightLink, result, 2))
1553             {
1554                 return false;
1555             }
1556         }
1557         return true;
1558     });
1559     if (Links.GetTarget(Links.GetTarget(startLink)) == rightLink)
1560     {
1561         result[4] = startLink;
1562     }
1563     return result;
1564 }
1565
1566 public bool TryStepRight(ulong startLink, ulong rightLink, ulong[] result, int offset)
1567 {
1568     var added = 0;
1569     Links.Each(startLink, Constants.Any, couple =>
1570     {
1571         if (couple != startLink)
1572         {
1573             var coupleTarget = Links.GetTarget(couple);
1574             if (coupleTarget == rightLink)
1575             {
1576                 result[offset] = couple;
1577                 if (++added == 2)
1578                 {
1579                     return false;
1580                 }
1581             }
1582             else if (Links.GetSource(coupleTarget) == rightLink) // coupleTarget.Linker
1583                 ↪ == Net.And &&
1584             {
1585                 result[offset + 1] = couple;
1586                 if (++added == 2)
1587                 {
1588                     return false;
1589                 }
1590             }
1591         }
1592         return true;
1593     });
1594     return added > 0;
1595 }

```

```

1595 public ulong[] GetLeftElements(ulong startLink, ulong leftLink)
1596 {
1597     var result = new ulong[5];
1598     TryStepLeft(startLink, leftLink, result, 0);
1599     Links.Each(startLink, Constants.Any, couple =>
1600     {
1601         if (couple != startLink)
1602         {
1603             if (TryStepLeft(couple, leftLink, result, 2))
1604             {
1605                 return false;
1606             }
1607         }
1608         return true;
1609     });
1610     if (Links.GetSource(Links.GetSource(leftLink)) == startLink)
1611     {
1612         result[4] = leftLink;
1613     }
1614     return result;
1615 }
1616
1617 public bool TryStepLeft(ulong startLink, ulong leftLink, ulong[] result, int offset)
1618 {
1619     var added = 0;
1620     Links.Each(Constants.Any, startLink, couple =>
1621     {
1622         if (couple != startLink)
1623         {
1624             var coupleSource = Links.GetSource(couple);
1625             if (coupleSource == leftLink)
1626             {
1627                 result[offset] = couple;
1628                 if (++added == 2)
1629                 {
1630                     return false;
1631                 }
1632             }
1633             else if (Links.GetTarget(coupleSource) == leftLink) // coupleSource.Linker
1634             ↪ == Net.And &&
1635             {
1636                 result[offset + 1] = couple;
1637                 if (++added == 2)
1638                 {
1639                     return false;
1640                 }
1641             }
1642         }
1643         return true;
1644     });
1645     return added > 0;
1646 }
1647
1648 #endregion
1649
1650 #region Walkers
1651
1652 public class PatternMatcher : RightSequenceWalker<ulong>
1653 {
1654     private readonly Sequences _sequences;
1655     private readonly ulong[] _patternSequence;
1656     private readonly HashSet<LinkIndex> _linksInSequence;
1657     private readonly HashSet<LinkIndex> _results;
1658
1659     #region Pattern Match
1660
1661     enum PatternBlockType
1662     {
1663         Undefined,
1664         Gap,
1665         Elements
1666     }
1667
1668     struct PatternBlock
1669     {
1670         public PatternBlockType Type;
1671         public long Start;
1672         public long Stop;
1673     }

```

```

1674 private readonly List<PatternBlock> _pattern;
1675 private int _patternPosition;
1676 private long _sequencePosition;
1677
1678 #endregion
1679
1680
1681 public PatternMatcher(Sequences sequences, LinkIndex[] patternSequence,
1682     ↳ HashSet<LinkIndex> results)
1683     : base(sequences.Links.Unsync, new DefaultStack<ulong>())
1684 {
1685     _sequences = sequences;
1686     _patternSequence = patternSequence;
1687     _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
1688     ↳ _sequences.Constants.Any && x != ZeroOrMany));
1689     _results = results;
1690     _pattern = CreateDetailedPattern();
1691 }
1692
1693 protected override bool IsElement(ulong link) => _linksInSequence.Contains(link) ||
1694     ↳ base.IsElement(link);
1695
1696 public bool PatternMatch(LinkIndex sequenceToMatch)
1697 {
1698     _patternPosition = 0;
1699     _sequencePosition = 0;
1700     foreach (var part in Walk(sequenceToMatch))
1701     {
1702         if (!PatternMatchCore(part))
1703         {
1704             break;
1705         }
1706     }
1707     return _patternPosition == _pattern.Count || (_patternPosition == _pattern.Count
1708     ↳ - 1 && _pattern[_patternPosition].Start == 0);
1709 }
1710
1711 private List<PatternBlock> CreateDetailedPattern()
1712 {
1713     var pattern = new List<PatternBlock>();
1714     var patternBlock = new PatternBlock();
1715     for (var i = 0; i < _patternSequence.Length; i++)
1716     {
1717         if (patternBlock.Type == PatternBlockType.Undefined)
1718         {
1719             if (_patternSequence[i] == _sequences.Constants.Any)
1720             {
1721                 patternBlock.Type = PatternBlockType.Gap;
1722                 patternBlock.Start = 1;
1723                 patternBlock.Stop = 1;
1724             }
1725             else if (_patternSequence[i] == ZeroOrMany)
1726             {
1727                 patternBlock.Type = PatternBlockType.Gap;
1728                 patternBlock.Start = 0;
1729                 patternBlock.Stop = long.MaxValue;
1730             }
1731             else
1732             {
1733                 patternBlock.Type = PatternBlockType.Elements;
1734                 patternBlock.Start = i;
1735                 patternBlock.Stop = i;
1736             }
1737         }
1738         else if (patternBlock.Type == PatternBlockType.Elements)
1739         {
1740             if (_patternSequence[i] == _sequences.Constants.Any)
1741             {
1742                 pattern.Add(patternBlock);
1743                 patternBlock = new PatternBlock
1744                 {
1745                     Type = PatternBlockType.Gap,
1746                     Start = 1,
1747                     Stop = 1
1748                 };
1749             }
1750             else if (_patternSequence[i] == ZeroOrMany)
1751             {
1752                 pattern.Add(patternBlock);
1753                 patternBlock = new PatternBlock

```



```

1750         {
1751             Type = PatternBlockType.Gap,
1752             Start = 0,
1753             Stop = long.MaxValue
1754         };
1755     }
1756     else
1757     {
1758         patternBlock.Stop = i;
1759     }
1760 }
1761 else // patternBlock.Type == PatternBlockType.Gap
1762 {
1763     if (_patternSequence[i] == _sequences.Constants.Any)
1764     {
1765         patternBlock.Start++;
1766         if (patternBlock.Stop < patternBlock.Start)
1767         {
1768             patternBlock.Stop = patternBlock.Start;
1769         }
1770     }
1771     else if (_patternSequence[i] == ZeroOrMany)
1772     {
1773         patternBlock.Stop = long.MaxValue;
1774     }
1775     else
1776     {
1777         pattern.Add(patternBlock);
1778         patternBlock = new PatternBlock
1779         {
1780             Type = PatternBlockType.Elements,
1781             Start = i,
1782             Stop = i
1783         };
1784     }
1785 }
1786 }
1787 if (patternBlock.Type != PatternBlockType.Undefined)
1788 {
1789     pattern.Add(patternBlock);
1790 }
1791 return pattern;
1792 }
1793
1794 // match: search for regexp anywhere in text
1795 //int match(char* regexp, char* text)
1796 //{
1797 //    do
1798 //    {
1799 //        } while (*text++ != '\0');
1800 //    return 0;
1801 //}
1802
1803 // matchhere: search for regexp at beginning of text
1804 //int matchhere(char* regexp, char* text)
1805 //{
1806 //    if (regexp[0] == '\0')
1807 //        return 1;
1808 //    if (regexp[1] == '*')
1809 //        return matchstar(regexp[0], regexp + 2, text);
1810 //    if (regexp[0] == '$' && regexp[1] == '\0')
1811 //        return *text == '\0';
1812 //    if (*text != '\0' && (regexp[0] == '.' || regexp[0] == *text))
1813 //        return matchhere(regexp + 1, text + 1);
1814 //    return 0;
1815 //}
1816
1817 // matchstar: search for c*regexp at beginning of text
1818 //int matchstar(int c, char* regexp, char* text)
1819 //{
1820 //    do
1821 //    {
1822 //        /* a * matches zero or more instances */
1823 //        if (matchhere(regexp, text))
1824 //            return 1;
1825 //    } while (*text != '\0' && (*text++ == c || c == '.'));
1826 //    return 0;
1827 //}

```

```

1828 //private void GetNextPatternElement(out LinkIndex element, out long mininumGap, out
1829 ↪ long maximumGap)
1830 //{
1831 //    mininumGap = 0;
1832 //    maximumGap = 0;
1833 //    element = 0;
1834 //    for (; _patternPosition < _patternSequence.Length; _patternPosition++)
1835 //    {
1836 //        if (_patternSequence[_patternPosition] == Doublets.Links.Null)
1837 //            mininumGap++;
1838 //        else if (_patternSequence[_patternPosition] == ZeroOrMany)
1839 //            maximumGap = long.MaxValue;
1840 //        else
1841 //            break;
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 -
1858         ↪ _lastMatchedBlockPosition);
1859         if (_sequencePosition < currentPatternBlock.Start)
1860         {
1861             _sequencePosition++;
1862             return true; // Двигаемся дальше
1863         }
1864         // Это последний блок
1865         if (_pattern.Count == _patternPosition + 1)
1866         {
1867             _patternPosition++;
1868             _sequencePosition = 0;
1869             return false; // Полное соответствие
1870         }
1871         else
1872         {
1873             if (_sequencePosition > currentPatternBlock.Stop)
1874             {
1875                 return false; // Соответствие невозможно
1876             }
1877             var nextPatternBlock = _pattern[_patternPosition + 1];
1878             if (_patternSequence[nextPatternBlock.Start] == element)
1879             {
1880                 if (nextPatternBlock.Start < nextPatternBlock.Stop)
1881                 {
1882                     _patternPosition++;
1883                     _sequencePosition = 1;
1884                 }
1885                 else
1886                 {
1887                     _patternPosition += 2;
1888                     _sequencePosition = 0;
1889                 }
1890             }
1891         }
1892     }
1893     else // currentPatternBlock.Type == PatternBlockType.Elements
1894     {
1895         var patternElementPosition = currentPatternBlock.Start + _sequencePosition;
1896         if (_patternSequence[patternElementPosition] != element)
1897         {
1898             return false; // Соответствие невозможно
1899         }
1900         if (patternElementPosition == currentPatternBlock.Stop)
1901         {
1902             _patternPosition++;
1903             _sequencePosition = 0;
1904         }
1905         else

```

```

1905         {
1906             _sequencePosition++;
1907         }
1908     }
1909     return true;
1910     //if (_patternSequence[_patternPosition] != element)
1911     //    return false;
1912     //else
1913     //{
1914     //    _sequencePosition++;
1915     //    _patternPosition++;
1916     //    return true;
1917     //}
1918     ///////
1919     //if (_filterPosition == _patternSequence.Length)
1920     //{
1921     //    _filterPosition = -2; // Длиннее чем нужно
1922     //    return false;
1923     //}
1924     //if (element != _patternSequence[_filterPosition])
1925     //{
1926     //    _filterPosition = -1;
1927     //    return false; // Начинается иначе
1928     //}
1929     //_filterPosition++;
1930     //if (_filterPosition == (_patternSequence.Length - 1))
1931     //    return false;
1932     //if (_filterPosition >= 0)
1933     //{
1934     //    if (element == _patternSequence[_filterPosition + 1])
1935     //        _filterPosition++;
1936     //    else
1937     //        return false;
1938     //}
1939     //if (_filterPosition < 0)
1940     //{
1941     //    if (element == _patternSequence[0])
1942     //        _filterPosition = 0;
1943     //}
1944 }
1945
1946 public void AddAllPatternMatchedToResults(IEnumerable<ulong> sequencesToMatch)
1947 {
1948     foreach (var sequenceToMatch in sequencesToMatch)
1949     {
1950         if (PatternMatch(sequenceToMatch))
1951         {
1952             _results.Add(sequenceToMatch);
1953         }
1954     }
1955 }
1956
1957 #endregion
1958
1959 }
1960

```

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

```

1  using System;
2  using System.Collections.Generic;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Sequences
7  {
8      public static class SequencesExtensions
9      {
10         public static TLink Create<TLink>(this ILinks<TLink> sequences, IList<TLink[]>
            ↳ groupedSequence)
11         {
12             var finalSequence = new TLink[groupedSequence.Count];
13             for (var i = 0; i < finalSequence.Length; i++)
14             {
15                 var part = groupedSequence[i];
16                 finalSequence[i] = part.Length == 1 ? part[0] :
                    ↳ sequences.Create(part.ConvertToRestrictionsValues());
17             }
18             return sequences.Create(finalSequence.ConvertToRestrictionsValues());

```

```

19     }
20
21     public static IList<TLink> ToList<TLink>(this ILinks<TLink> sequences, TLink sequence)
22     {
23         var list = new List<TLink>();
24         var filler = new ListFiller<TLink, TLink>(list, sequences.Constants.Break);
25         sequences.Each(filler.AddAllValuesAndReturnConstant, new
26             ↪ LinkAddress<TLink>(sequence));
27         return list;
28     }
29 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Interfaces;
4  using Platform.Collections.Stacks;
5  using Platform.Data.Doublets.Sequences.Frequencies.Cache;
6  using Platform.Data.Doublets.Sequences.Frequencies.Counters;
7  using Platform.Data.Doublets.Sequences.Converters;
8  using Platform.Data.Doublets.Sequences.CriteriaMatchers;
9  using Platform.Data.Doublets.Sequences.Walkers;
10 using Platform.Data.Doublets.Sequences.Indexes;
11
12 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
13
14 namespace Platform.Data.Doublets.Sequences
15 {
16     public class SequencesOptions<TLink> // TODO: To use type parameter <TLink> the
17     ↪ ILinks<TLink> must contain GetConstants function.
18     {
19         private static readonly EqualityComparer<TLink> _equalityComparer =
20         ↪ EqualityComparer<TLink>.Default;
21
22         public TLink SequenceMarkerLink { get; set; }
23         public bool UseCascadeUpdate { get; set; }
24         public bool UseCascadeDelete { get; set; }
25         public bool UseIndex { get; set; } // TODO: Update Index on sequence update/delete.
26         public bool UseSequenceMarker { get; set; }
27         public bool UseCompression { get; set; }
28         public bool UseGarbageCollection { get; set; }
29         public bool EnforceSingleSequenceVersionOnWriteBasedOnExisting { get; set; }
30         public bool EnforceSingleSequenceVersionOnWriteBasedOnNew { get; set; }
31
32         public MarkedSequenceCriterionMatcher<TLink> MarkedSequenceMatcher { get; set; }
33         public IConverter<IList<TLink>, TLink> LinksToSequenceConverter { get; set; }
34         public ISequenceIndex<TLink> Index { get; set; }
35         public ISequenceWalker<TLink> Walker { get; set; }
36         public bool ReadFullSequence { get; set; }
37
38         // TODO: Реализовать компактификацию при чтении
39         //public bool EnforceSingleSequenceVersionOnRead { get; set; }
40         //public bool UseRequestMarker { get; set; }
41         //public bool StoreRequestResults { get; set; }
42
43         public void InitOptions(ISynchronizedLinks<TLink> links)
44         {
45             if (UseSequenceMarker)
46             {
47                 if (_equalityComparer.Equals(SequenceMarkerLink, links.Constants.Null))
48                 {
49                     SequenceMarkerLink = links.CreatePoint();
50                 }
51                 else
52                 {
53                     if (!links.Exists(SequenceMarkerLink))
54                     {
55                         var link = links.CreatePoint();
56                         if (!_equalityComparer.Equals(link, SequenceMarkerLink))
57                         {
58                             throw new InvalidOperationException("Cannot recreate sequence marker
59                             ↪ link.");
60                         }
61                     }
62                 }
63             }
64             if (MarkedSequenceMatcher == null)
65             {
66                 MarkedSequenceMatcher = new MarkedSequenceCriterionMatcher<TLink>(links,
67                     ↪ SequenceMarkerLink);
68             }
69         }
70     }
71 }

```

```

63     }
64 }
65 var balancedVariantConverter = new BalancedVariantConverter<TLink>(links);
66 if (UseCompression)
67 {
68     if (LinksToSequenceConverter == null)
69     {
70         ICounter<TLink, TLink> totalSequenceSymbolFrequencyCounter;
71         if (UseSequenceMarker)
72         {
73             totalSequenceSymbolFrequencyCounter = new
74                 ↪ TotalMarkedSequenceSymbolFrequencyCounter<TLink>(links,
75                 ↪ MarkedSequenceMatcher);
76         }
77         else
78         {
79             totalSequenceSymbolFrequencyCounter = new
80                 ↪ TotalSequenceSymbolFrequencyCounter<TLink>(links);
81         }
82         var doubletFrequenciesCache = new LinkFrequenciesCache<TLink>(links,
83             ↪ totalSequenceSymbolFrequencyCounter);
84         var compressingConverter = new CompressingConverter<TLink>(links,
85             ↪ balancedVariantConverter, doubletFrequenciesCache);
86         LinksToSequenceConverter = compressingConverter;
87     }
88 }
89 else
90 {
91     if (LinksToSequenceConverter == null)
92     {
93         LinksToSequenceConverter = balancedVariantConverter;
94     }
95 }
96 if (UseIndex && Index == null)
97 {
98     Index = new SequenceIndex<TLink>(links);
99 }
100 if (Walker == null)
101 {
102     Walker = new RightSequenceWalker<TLink>(links, new DefaultStack<TLink>());
103 }
104 }
105
106 public void ValidateOptions()
107 {
108     if (UseGarbageCollection && !UseSequenceMarker)
109     {
110         throw new NotSupportedException("To use garbage collection UseSequenceMarker
111             ↪ option must be on.");
112     }
113 }
114 }
115 }

```

./Platform.Data.Doublets/Sequences/SetFiller.cs

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Sequences
7  {
8      public class SetFiller<TElement, TReturnConstant>
9      {
10         protected readonly ISet<TElement> _set;
11         protected readonly TReturnConstant _returnConstant;
12
13         public SetFiller(ISet<TElement> set, TReturnConstant returnConstant)
14         {
15             _set = set;
16             _returnConstant = returnConstant;
17         }
18
19         public SetFiller(ISet<TElement> set) : this(set, default) { }
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public void Add(TElement element) => _set.Add(element);
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

25     public bool AddAndReturnTrue(TElement element)
26     {
27         _set.Add(element);
28         return true;
29     }
30
31     [MethodImpl(MethodImplOptions.AggressiveInlining)]
32     public bool AddFirstAndReturnTrue(ICollection<TElement> collection)
33     {
34         _set.Add(collection[0]);
35         return true;
36     }
37
38     [MethodImpl(MethodImplOptions.AggressiveInlining)]
39     public TReturnConstant AddAndReturnConstant(TElement element)
40     {
41         _set.Add(element);
42         return _returnConstant;
43     }
44
45     [MethodImpl(MethodImplOptions.AggressiveInlining)]
46     public TReturnConstant AddFirstAndReturnConstant(ICollection<TElement> collection)
47     {
48         _set.Add(collection[0]);
49         return _returnConstant;
50     }
51 }
52 }

```

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

```

1  using System.Collections.Generic;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Sequences.Walkers
6  {
7      public interface ISequenceWalker<TLink>
8      {
9          IEnumerable<TLink> Walk(TLink sequence);
10     }
11 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Collections.Stacks;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Sequences.Walkers
9  {
10     public class LeftSequenceWalker<TLink> : SequenceWalkerBase<TLink>
11     {
12         public LeftSequenceWalker(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
13             ↪ isElement) : base(links, stack, isElement) { }
14
15         public LeftSequenceWalker(ILinks<TLink> links, IStack<TLink> stack) : base(links, stack,
16             ↪ links.IsPartialPoint) { }
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override TLink GetNextElementAfterPop(TLink element) =>
20             ↪ Links.GetSource(element);
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected override TLink GetNextElementAfterPush(TLink element) =>
24             ↪ Links.GetTarget(element);
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         protected override IEnumerable<TLink> WalkContents(TLink element)
28         {
29             var parts = Links.GetLink(element);
30             var start = Links.Constants.IndexPart + 1;
31             for (var i = parts.Count - 1; i >= start; i--)
32             {
33                 var part = parts[i];
34                 if (IsElement(part))
35                 {
36                     yield return part;
37                 }
38             }
39         }
40     }
41 }

```

```

33     }
34 }
35 }
36 }
37 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  //#define USEARRAYPOOL
8  #if USEARRAYPOOL
9  using Platform.Collections;
10 #endif
11
12 namespace Platform.Data.Doublets.Sequences.Walkers
13 {
14     public class LeveledSequenceWalker<TLink> : LinksOperatorBase<TLink>, ISequenceWalker<TLink>
15     {
16         private static readonly EqualityComparer<TLink> _equalityComparer =
17             ↳ EqualityComparer<TLink>.Default;
18
19         private readonly Func<TLink, bool> _isElement;
20
21         public LeveledSequenceWalker(ILinks<TLink> links, Func<TLink, bool> isElement) :
22             ↳ base(links) => _isElement = isElement;
23
24         public LeveledSequenceWalker(ILinks<TLink> links) : base(links) => _isElement =
25             ↳ Links.IsPartialPoint;
26
27         public IEnumerable<TLink> Walk(TLink sequence) => ToArray(sequence);
28
29         public TLink[] ToArray(TLink sequence)
30         {
31             var length = 1;
32             var array = new TLink[length];
33             array[0] = sequence;
34             if (_isElement(sequence))
35             {
36                 return array;
37             }
38             bool hasElements;
39             do
40             {
41                 length *= 2;
42 #if USEARRAYPOOL
43                 var nextArray = ArrayPool.Allocate<ulong>(length);
44 #else
45                 var nextArray = new TLink[length];
46 #endif
47                 hasElements = false;
48                 for (var i = 0; i < array.Length; i++)
49                 {
50                     var candidate = array[i];
51                     if (_equalityComparer.Equals(array[i], default))
52                     {
53                         continue;
54                     }
55                     var doubletOffset = i * 2;
56                     if (_isElement(candidate))
57                     {
58                         nextArray[doubletOffset] = candidate;
59                     }
60                     else
61                     {
62                         var link = Links.GetLink(candidate);
63                         var linkSource = Links.GetSource(link);
64                         var linkTarget = Links.GetTarget(link);
65                         nextArray[doubletOffset] = linkSource;
66                         nextArray[doubletOffset + 1] = linkTarget;
67                         if (!hasElements)
68                         {
69                             hasElements = !(_isElement(linkSource) && _isElement(linkTarget));
70                         }
71                     }
72                 }
73             } while (length < array.Length);
74             return nextArray;
75         }
76     }
77 #if USEARRAYPOOL
78 }
79 #endif

```

```

71         if (array.Length > 1)
72         {
73             ArrayPool.Free(array);
74         }
75 #endif
76         array = nextArray;
77     }
78     while (hasElements);
79     var filledElementsCount = CountFilledElements(array);
80     if (filledElementsCount == array.Length)
81     {
82         return array;
83     }
84     else
85     {
86         return CopyFilledElements(array, filledElementsCount);
87     }
88 }
89
90 [MethodImpl(MethodImplOptions.AggressiveInlining)]
91 private static TLink[] CopyFilledElements(TLink[] array, int filledElementsCount)
92 {
93     var finalArray = new TLink[filledElementsCount];
94     for (int i = 0, j = 0; i < array.Length; i++)
95     {
96         if (!_equalityComparer.Equals(array[i], default))
97         {
98             finalArray[j] = array[i];
99             j++;
100         }
101     }
102 #if USEARRAYPOOL
103     ArrayPool.Free(array);
104 #endif
105     return finalArray;
106 }
107
108 [MethodImpl(MethodImplOptions.AggressiveInlining)]
109 private static int CountFilledElements(TLink[] array)
110 {
111     var count = 0;
112     for (var i = 0; i < array.Length; i++)
113     {
114         if (!_equalityComparer.Equals(array[i], default))
115         {
116             count++;
117         }
118     }
119     return count;
120 }
121 }
122 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Collections.Stacks;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Sequences.Walkers
9  {
10     public class RightSequenceWalker<TLink> : SequenceWalkerBase<TLink>
11     {
12         public RightSequenceWalker(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
13             ↪ isElement) : base(links, stack, isElement) { }
14
15         public RightSequenceWalker(ILinks<TLink> links, IStack<TLink> stack) : base(links,
16             ↪ stack, links.IsPartialPoint) { }
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override TLink GetNextElementAfterPop(TLink element) =>
20             ↪ Links.GetTarget(element);
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected override TLink GetNextElementAfterPush(TLink element) =>
24             ↪ Links.GetSource(element);
25     }
26 }

```



```

22     [MethodImpl(MethodImplOptions.AggressiveInlining)]
23     protected override IEnumerable<TLink> WalkContents(TLink element)
24     {
25         var parts = Links.GetLink(element);
26         for (var i = Links.Constants.IndexPart + 1; i < parts.Count; i++)
27         {
28             var part = parts[i];
29             if (IsElement(part))
30             {
31                 yield return part;
32             }
33         }
34     }
35 }
36 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Collections.Stacks;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Sequences.Walkers
9  {
10     public abstract class SequenceWalkerBase<TLink> : LinksOperatorBase<TLink>,
11         ↳ ISequenceWalker<TLink>
12     {
13         private readonly IStack<TLink> _stack;
14         private readonly Func<TLink, bool> _isElement;
15
16         protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
17             ↳ isElement) : base(links)
18         {
19             _stack = stack;
20             _isElement = isElement;
21         }
22
23         protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack) : this(links,
24             ↳ stack, links.IsPartialPoint)
25         {
26         }
27
28         public IEnumerable<TLink> Walk(TLink sequence)
29         {
30             _stack.Clear();
31             var element = sequence;
32             if (IsElement(element))
33             {
34                 yield return element;
35             }
36             else
37             {
38                 while (true)
39                 {
40                     if (IsElement(element))
41                     {
42                         if (_stack.IsEmpty)
43                         {
44                             break;
45                         }
46                         element = _stack.Pop();
47                         foreach (var output in WalkContents(element))
48                         {
49                             yield return output;
50                         }
51                         element = GetNextElementAfterPop(element);
52                     }
53                     else
54                     {
55                         _stack.Push(element);
56                         element = GetNextElementAfterPush(element);
57                     }
58                 }
59             }
60         }
61     }
62 }

```

[MethodImpl(MethodImplOptions.AggressiveInlining)]

```

60     protected virtual bool IsElement(TLink elementLink) => _isElement(elementLink);
61
62     [MethodImpl(MethodImplOptions.AggressiveInlining)]
63     protected abstract TLink GetNextElementAfterPop(TLink element);
64
65     [MethodImpl(MethodImplOptions.AggressiveInlining)]
66     protected abstract TLink GetNextElementAfterPush(TLink element);
67
68     [MethodImpl(MethodImplOptions.AggressiveInlining)]
69     protected abstract IEnumerable<TLink> WalkContents(TLink element);
70 }
71 }

```

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

```

1  using System.Collections.Generic;
2  using Platform.Collections.Stacks;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Stacks
7  {
8      public class Stack<TLink> : IStack<TLink>
9      {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11             ↳ EqualityComparer<TLink>.Default;
12
13         private readonly ILinks<TLink> _links;
14         private readonly TLink _stack;
15
16         public bool IsEmpty => _equalityComparer.Equals(Peek(), _stack);
17
18         public Stack(ILinks<TLink> links, TLink stack)
19         {
20             _links = links;
21             _stack = stack;
22         }
23
24         private TLink GetStackMarker() => _links.GetSource(_stack);
25
26         private TLink GetTop() => _links.GetTarget(_stack);
27
28         public TLink Peek() => _links.GetTarget(GetTop());
29
30         public TLink Pop()
31         {
32             var element = Peek();
33             if (!_equalityComparer.Equals(element, _stack))
34             {
35                 var top = GetTop();
36                 var previousTop = _links.GetSource(top);
37                 _links.Update(_stack, GetStackMarker(), previousTop);
38                 _links.Delete(top);
39             }
40             return element;
41         }
42
43         public void Push(TLink element) => _links.Update(_stack, GetStackMarker(),
44             ↳ _links.GetOrCreate(GetTop(), element));
45     }
46 }

```

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

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  namespace Platform.Data.Doublets.Stacks
4  {
5      public static class StackExtensions
6      {
7         public static TLink CreateStack<TLink>(this ILinks<TLink> links, TLink stackMarker)
8         {
9             var stackPoint = links.CreatePoint();
10            var stack = links.Update(stackPoint, stackMarker, stackPoint);
11            return stack;
12        }
13    }
14 }

```

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

```
1 using System;
2 using System.Collections.Generic;
3 using Platform.Data.Doublets;
4 using Platform.Threading.Synchronization;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets
9 {
10     /// <remarks>
11     /// TODO: Autogeneration of synchronized wrapper (decorator).
12     /// TODO: Try to unfold code of each method using IL generation for performance improvements.
13     /// TODO: Or even to unfold multiple layers of implementations.
14     /// </remarks>
15     public class SynchronizedLinks<TLinkAddress> : ISynchronizedLinks<TLinkAddress>
16     {
17         public LinksConstants<TLinkAddress> Constants { get; }
18         public ISynchronization SyncRoot { get; }
19         public ILinks<TLinkAddress> Sync { get; }
20         public ILinks<TLinkAddress> Unsync { get; }
21
22         public SynchronizedLinks(ILinks<TLinkAddress> links) : this(new
            ↳ ReaderWriterLockSynchronization(), links) { }
23
24         public SynchronizedLinks(ISynchronization synchronization, ILinks<TLinkAddress> links)
25         {
26             SyncRoot = synchronization;
27             Sync = this;
28             Unsync = links;
29             Constants = links.Constants;
30         }
31
32         public TLinkAddress Count(IList<TLinkAddress> restriction) =>
            ↳ SyncRoot.ExecuteReadOperation(restriction, Unsync.Count);
33         public TLinkAddress Each(Func<IList<TLinkAddress>, TLinkAddress> handler,
            ↳ IList<TLinkAddress> restrictions) => SyncRoot.ExecuteReadOperation(handler,
            ↳ restrictions, (handler1, restrictions1) => Unsync.Each(handler1, restrictions1));
34         public TLinkAddress Create(IList<TLinkAddress> restrictions) =>
            ↳ SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Create);
35         public TLinkAddress Update(IList<TLinkAddress> restrictions, IList<TLinkAddress>
            ↳ substitution) => SyncRoot.ExecuteWriteOperation(restrictions, substitution,
            ↳ Unsync.Update);
36         public void Delete(IList<TLinkAddress> restrictions) =>
            ↳ SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Delete);
37
38         //public T Trigger(IList<T> restriction, Func<IList<T>, IList<T>, T> matchedHandler,
39         //↳ IList<T> substitution, Func<IList<T>, IList<T>, T> substitutedHandler)
40         //{
41         //    if (restriction != null && substitution != null &&
42         //        ↳ !substitution.EqualTo(restriction))
43         //        return SyncRoot.ExecuteWriteOperation(restriction, matchedHandler,
44         //        ↳ substitution, substitutedHandler, Unsync.Trigger);
45         //    return SyncRoot.ExecuteReadOperation(restriction, matchedHandler, substitution,
46         //        ↳ substitutedHandler, Unsync.Trigger);
47         //}
48     }
49 }
```

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

```
1 using System;
2 using System.Text;
3 using System.Collections.Generic;
4 using Platform.Singletons;
5 using Platform.Data.Exceptions;
6 using Platform.Data.Doublets.Unicode;
7
8 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets
11 {
12     public static class UInt64LinksExtensions
13     {
14         public static readonly LinksConstants<ulong> Constants =
            ↳ Default<LinksConstants<ulong>>.Instance;
15
16         public static void UseUnicode(this ILinks<ulong> links) => UnicodeMap.InitNew(links);
17     }
18 }
```

```

18
19
20 public static bool AnyLinkIsAny(this ILinks<ulong> links, params ulong[] sequence)
21 {
22     if (sequence == null)
23     {
24         return false;
25     }
26     var constants = links.Constants;
27     for (var i = 0; i < sequence.Length; i++)
28     {
29         if (sequence[i] == constants.Any)
30         {
31             return true;
32         }
33     }
34     return false;
35 }
36
37 public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
    ↪ Func<Link<ulong>, bool> isElement, bool renderIndex = false, bool renderDebug =
    ↪ false)
38 {
39     var sb = new StringBuilder();
40     var visited = new HashSet<ulong>();
41     links.AppendStructure(sb, visited, linkIndex, isElement, (innerSb, link) =>
    ↪ innerSb.Append(link.Index), renderIndex, renderDebug);
42     return sb.ToString();
43 }
44
45 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)
46 {
47     var sb = new StringBuilder();
48     var visited = new HashSet<ulong>();
49     links.AppendStructure(sb, visited, linkIndex, isElement, appendElement, renderIndex,
    ↪ renderDebug);
50     return sb.ToString();
51 }
52
53 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)
54 {
55     if (sb == null)
56     {
57         throw new ArgumentNullException(nameof(sb));
58     }
59     if (linkIndex == Constants.Null || linkIndex == Constants.Any || linkIndex ==
    ↪ Constants.Itself)
60     {
61         return;
62     }
63     if (links.Exists(linkIndex))
64     {
65         if (visited.Add(linkIndex))
66         {
67             sb.Append('(');
68             var link = new Link<ulong>(links.GetLink(linkIndex));
69             if (renderIndex)
70             {
71                 sb.Append(link.Index);
72                 sb.Append(':');
73             }
74             if (link.Source == link.Index)
75             {
76                 sb.Append(link.Index);
77             }
78             else
79             {
80                 var source = new Link<ulong>(links.GetLink(link.Source));
81                 if (isElement(source))
82                 {
83                     appendElement(sb, source);
84                 }
85                 else

```

```

86         {
87             links.AppendStructure(sb, visited, source.Index, isElement,
88                 ↪ appendElement, renderIndex);
89         }
90         sb.Append(' ');
91         if (link.Target == link.Index)
92         {
93             sb.Append(link.Index);
94         }
95         else
96         {
97             var target = new Link<ulong>(links.GetLink(link.Target));
98             if (isElement(target))
99             {
100                 appendElement(sb, target);
101             }
102             else
103             {
104                 links.AppendStructure(sb, visited, target.Index, isElement,
105                     ↪ appendElement, renderIndex);
106             }
107             sb.Append(' ');
108         }
109         else
110         {
111             if (renderDebug)
112             {
113                 sb.Append('*');
114             }
115             sb.Append(linkIndex);
116         }
117     }
118     else
119     {
120         if (renderDebug)
121         {
122             sb.Append('~');
123         }
124         sb.Append(linkIndex);
125     }
126 }
127 }
128 }

```

./Platform.Data.Doublets/UInt64LinksTransactionsLayer.cs

```

1  using System;
2  using System.Linq;
3  using System.Collections.Generic;
4  using System.IO;
5  using System.Runtime.CompilerServices;
6  using System.Threading;
7  using System.Threading.Tasks;
8  using Platform.Disposables;
9  using Platform.Timestamps;
10 using Platform.Unsafe;
11 using Platform.IO;
12 using Platform.Data.Doublets.Decorators;
13 using Platform.Exceptions;
14
15 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
16
17 namespace Platform.Data.Doublets
18 {
19     public class UInt64LinksTransactionsLayer : LinksDisposableDecoratorBase<ulong> //-V3073
20     {
21         /// <remarks>
22         /// Альтернативные варианты хранения трансформации (элемента транзакции):
23         ///
24         /// private enum TransitionType
25         /// {
26         ///     Creation,
27         ///     UpdateOf,
28         ///     UpdateTo,
29         ///     Deletion
30         /// }
31         ///
32         /// private struct Transition

```

```

33     /// {
34     ///     public ulong TransactionId;
35     ///     public UniqueTimestamp Timestamp;
36     ///     public TransactionItemType Type;
37     ///     public Link Source;
38     ///     public Link Linker;
39     ///     public Link Target;
40     /// }
41     ///
42     /// Или
43     ///
44     /// public struct TransitionHeader
45     /// {
46     ///     public ulong TransactionIdCombined;
47     ///     public ulong TimestampCombined;
48     ///
49     ///     public ulong TransactionId
50     ///     {
51     ///         get
52     ///         {
53     ///             return (ulong) mask & TransactionIdCombined;
54     ///         }
55     ///     }
56     ///
57     ///     public UniqueTimestamp Timestamp
58     ///     {
59     ///         get
60     ///         {
61     ///             return (UniqueTimestamp)mask & TransactionIdCombined;
62     ///         }
63     ///     }
64     ///
65     ///     public TransactionItemType Type
66     ///     {
67     ///         get
68     ///         {
69     ///             // Использовать по одному биту из TransactionId и Timestamp,
70     ///             // для значения в 2 бита, которое представляет тип операции
71     ///             throw new NotImplementedException();
72     ///         }
73     ///     }
74     /// }
75     ///
76     /// private struct Transition
77     /// {
78     ///     public TransitionHeader Header;
79     ///     public Link Source;
80     ///     public Link Linker;
81     ///     public Link Target;
82     /// }
83     ///
84     /// </remarks>
85     public struct Transition
86     {
87         public static readonly long Size = Structure<Transition>.Size;
88
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
95         ↪ transactionId, Link<ulong> before, Link<ulong> after)
96         {
97             TransactionId = transactionId;
98             Before = before;
99             After = after;
100             Timestamp = uniqueTimestampFactory.Create();
101         }
102
103         public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
104         ↪ transactionId, Link<ulong> before)
105         : this(uniqueTimestampFactory, transactionId, before, default)
106         {
107         }
108
109         public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong transactionId)
110         : 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;
159         IsReverted = false;
160         _transitions = new Queue<Transition>();
161         SetCurrentTransaction(layer, this);
162     }
163
164     public void Commit()
165     {
166         EnsureTransactionAllowsWriteOperations(this);
167         while (_transitions.Count > 0)
168         {
169             var transition = _transitions.Dequeue();
170             _layer._transitions.Enqueue(transition);
171         }
172         _layer._lastCommittedTransactionId = _layer._currentTransactionId;
173         IsCommitted = true;
174     }
175
176     private void Revert()
177     {
178         EnsureTransactionAllowsWriteOperations(this);
179         var transitionsToRevert = new Transition[_transitions.Count];

```

```

180         _transitions.CopyTo(transitionsToRevert, 0);
181     for (var i = transitionsToRevert.Length - 1; i >= 0; i--)
182     {
183         _layer.RevertTransition(transitionsToRevert[i]);
184     }
185     IsReverted = true;
186 }
187
188 public static void SetCurrentTransaction(UInt64LinksTransactionsLayer layer,
189     ↪ Transaction transaction)
190 {
191     layer._currentTransactionId = layer._lastCommittedTransactionId + 1;
192     layer._currentTransactionTransitions = transaction._transitions;
193     layer._currentTransaction = transaction;
194 }
195
196 public static void EnsureTransactionAllowsWriteOperations(Transaction transaction)
197 {
198     if (transaction.IsReverted)
199     {
200         throw new InvalidOperationException("Transation is reverted.");
201     }
202     if (transaction.IsCommitted)
203     {
204         throw new InvalidOperationException("Transation is committed.");
205     }
206 }
207
208 protected override void Dispose(bool manual, bool wasDisposed)
209 {
210     if (!wasDisposed && _layer != null && !_layer.IsDisposed)
211     {
212         if (!IsCommitted && !IsReverted)
213         {
214             Revert();
215         }
216         _layer.ResetCurrentTransation();
217     }
218 }
219
220 public static readonly TimeSpan DefaultPushDelay = TimeSpan.FromSeconds(0.1);
221
222 private readonly string _logAddress;
223 private readonly FileStream _log;
224 private readonly Queue<Transition> _transitions;
225 private readonly UniqueTimestampFactory _uniqueTimestampFactory;
226 private Task _transitionsPusher;
227 private Transition _lastCommittedTransition;
228 private ulong _currentTransactionId;
229 private Queue<Transition> _currentTransactionTransitions;
230 private Transaction _currentTransaction;
231 private ulong _lastCommittedTransactionId;
232
233 public UInt64LinksTransactionsLayer(ILinks<ulong> links, string logAddress)
234     : base(links)
235 {
236     if (string.IsNullOrEmpty(logAddress))
237     {
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 lastCommittedTransition = FileHelpers.ReadFirstOrDefault<Transition>(logAddress);
245     var lastWrittenTransition = FileHelpers.ReadLastOrDefault<Transition>(logAddress);
246     if (!lastCommittedTransition.Equals(lastWrittenTransition))
247     {
248         Dispose();
249         throw new NotSupportedException("Database is damaged, autorecovery is not
250             ↪ supported yet.");
251     }
252     if (lastCommittedTransition.Equals(default(Transition)))
253     {
254         FileHelpers.WriteFirst(logAddress, lastCommittedTransition);
255     }
256     _lastCommittedTransition = lastCommittedTransition;
257     // TODO: Think about a better way to calculate or store this value

```



```

257     var allTransitions = FileHelpers.ReadAll<Transition>(logAddress);
258     _lastCommittedTransactionId = 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,
274         ↪ default, createdLink));
275     return createdLinkIndex;
276 }
277
278 public override ulong Update(IList<ulong> restrictions, IList<ulong> substitution)
279 {
280     var linkIndex = restrictions[Constants.IndexPart];
281     var beforeLink = new Link<ulong>(Links.GetLink(linkIndex));
282     linkIndex = Links.Update(restrictions, substitution);
283     var afterLink = new Link<ulong>(Links.GetLink(linkIndex));
284     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
285         ↪ beforeLink, afterLink));
286     return linkIndex;
287 }
288
289 public override void Delete(IList<ulong> restrictions)
290 {
291     var link = restrictions[Constants.IndexPart];
292     var deletedLink = new Link<ulong>(Links.GetLink(link));
293     Links.Delete(link);
294     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
295         ↪ deletedLink, default));
296 }
297
298 [MethodImpl(MethodImplOptions.AggressiveInlining)]
299 private Queue<Transition> GetCurrentTransitions() => _currentTransactionTransitions ??
300     ↪ _transitions;
301
302 private void CommitTransition(Transition transition)
303 {
304     if (_currentTransaction != null)
305     {
306         Transaction.EnsureTransactionAllowsWriteOperations(_currentTransaction);
307     }
308     var transitions = GetCurrentTransitions();
309     transitions.Enqueue(transition);
310 }
311
312 private void RevertTransition(Transition transition)
313 {
314     if (transition.After.IsNull()) // Revert Deletion with Creation
315     {
316         Links.Create();
317     }
318     else if (transition.Before.IsNull()) // Revert Creation with Deletion
319     {
320         Links.Delete(transition.After.Index);
321     }
322     else // Revert Update
323     {
324         Links.Update(new[] { transition.After.Index, transition.Before.Source,
325             ↪ transition.Before.Target });
326     }
327 }
328
329 private void ResetCurrentTransation()
330 {
331     _currentTransactionId = 0;
332     _currentTransactionTransitions = null;
333     _currentTransaction = null;
334 }

```

```

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         _lastCommittedTransition = 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, _lastCommittedTransition);
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);
389 }
390
391 #endregion
392 }
393

```

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

```

1 using Platform.Interfaces;
2 using Platform.Numbers;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Unicode
7 {
8     public class CharToUnicodeSymbolConverter<TLink> : LinksOperatorBase<TLink>,
9         ⇨ IConverter<char, TLink>
10     {
11         private readonly IConverter<TLink> _addressToNumberConverter;
12         private readonly TLink _unicodeSymbolMarker;
13

```

```

13     public CharToUnicodeSymbolConverter(ILinks<TLink> links, IConverter<TLink>
14         ↪ addressToNumberConverter, TLink unicodeSymbolMarker) : base(links)
15     {
16         _addressToNumberConverter = addressToNumberConverter;
17         _unicodeSymbolMarker = unicodeSymbolMarker;
18     }
19     public TLink Convert(char source)
20     {
21         var unaryNumber = _addressToNumberConverter.Convert((Integer<TLink>)source);
22         return Links.GetOrCreate(unaryNumber, _unicodeSymbolMarker);
23     }
24 }
25 }

```

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

```

1  using Platform.Data.Doublets.Sequences.Indexes;
2  using Platform.Interfaces;
3  using System.Collections.Generic;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Unicode
8  {
9      public class StringToUnicodeSequenceConverter<TLink> : LinksOperatorBase<TLink>,
10         ↪ IConverter<string, TLink>
11      {
12          private readonly IConverter<char, TLink> _charToUnicodeSymbolConverter;
13          private readonly ISequenceIndex<TLink> _index;
14          private readonly IConverter<IList<TLink>, TLink> _listToSequenceLinkConverter;
15          private readonly TLink _unicodeSequenceMarker;
16
17          public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<char, TLink>
18             ↪ charToUnicodeSymbolConverter, ISequenceIndex<TLink> index, IConverter<IList<TLink>,
19             ↪ TLink> listToSequenceLinkConverter, TLink unicodeSequenceMarker) : base(links)
20          {
21              _charToUnicodeSymbolConverter = charToUnicodeSymbolConverter;
22              _index = index;
23              _listToSequenceLinkConverter = listToSequenceLinkConverter;
24              _unicodeSequenceMarker = unicodeSequenceMarker;
25          }
26
27          public TLink Convert(string source)
28          {
29              var elements = new TLink[source.Length];
30              for (int i = 0; i < source.Length; i++)
31              {
32                  elements[i] = _charToUnicodeSymbolConverter.Convert(source[i]);
33              }
34              _index.Add(elements);
35              var sequence = _listToSequenceLinkConverter.Convert(elements);
36              return Links.GetOrCreate(sequence, _unicodeSequenceMarker);
37          }
38      }
39  }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Globalization;
4  using System.Runtime.CompilerServices;
5  using System.Text;
6  using Platform.Data.Sequences;
7
8  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets.Unicode
11 {
12     public class UnicodeMap
13     {
14         public static readonly ulong FirstCharLink = 1;
15         public static readonly ulong LastCharLink = FirstCharLink + char.MaxValue;
16         public static readonly ulong MapSize = 1 + char.MaxValue;
17
18         private readonly ILinks<ulong> _links;
19         private bool _initialized;
20
21         public UnicodeMap(ILinks<ulong> links) => _links = links;
22
23         public static UnicodeMap InitNew(ILinks<ulong> links)

```

```

24 {
25     var map = new UnicodeMap(links);
26     map.Init();
27     return map;
28 }
29
30 public void Init()
31 {
32     if (_initialized)
33     {
34         return;
35     }
36     _initialized = true;
37     var firstLink = _links.CreatePoint();
38     if (firstLink != FirstCharLink)
39     {
40         _links.Delete(firstLink);
41     }
42     else
43     {
44         for (var i = FirstCharLink + 1; i <= LastCharLink; i++)
45         {
46             // From NIL to It (NIL -> Character) transformation meaning, (or infinite
47             // ↪ amount of NIL characters before actual Character)
48             var createdLink = _links.CreatePoint();
49             _links.Update(createdLink, firstLink, createdLink);
50             if (createdLink != i)
51             {
52                 throw new InvalidOperationException("Unable to initialize UTF 16
53                 ↪ table.");
54             }
55         }
56     }
57 }
58
59 // 0 - null link
60 // 1 - nil character (0 character)
61 // ...
62 // 65536 (0(1) + 65535 = 65536 possible values)
63
64 [MethodImpl(MethodImplOptions.AggressiveInlining)]
65 public static ulong FromCharToLink(char character) => (ulong)character + 1;
66
67 [MethodImpl(MethodImplOptions.AggressiveInlining)]
68 public static char FromLinkToChar(ulong link) => (char)(link - 1);
69
70 [MethodImpl(MethodImplOptions.AggressiveInlining)]
71 public static bool IsCharLink(ulong link) => link <= MapSize;
72
73 public static string FromLinksToString(IList<ulong> linksList)
74 {
75     var sb = new StringBuilder();
76     for (int i = 0; i < linksList.Count; i++)
77     {
78         sb.Append(FromLinkToChar(linksList[i]));
79     }
80     return sb.ToString();
81 }
82
83 public static string FromSequenceLinkToString(ulong link, ILinks<ulong> links)
84 {
85     var sb = new StringBuilder();
86     if (links.Exists(link))
87     {
88         StopableSequenceWalker.WalkRight(link, links.GetSource, links.GetTarget,
89             x => x <= MapSize || links.GetSource(x) == x || links.GetTarget(x) == x,
90             ↪ element =>
91             {
92                 sb.Append(FromLinkToChar(element));
93                 return true;
94             }
95         );
96     }
97     return sb.ToString();
98 }
99
100 public static ulong[] FromCharsToLinkArray(char[] chars) => FromCharsToLinkArray(chars,
101     ↪ chars.Length);

```

```

98 public static ulong[] FromCharsToLinkArray(char[] chars, int count)
99 {
100     // char array to ulong array
101     var linksSequence = new ulong[count];
102     for (var i = 0; i < count; i++)
103     {
104         linksSequence[i] = FromCharToLink(chars[i]);
105     }
106     return linksSequence;
107 }
108
109 public static ulong[] FromStringToLinkArray(string sequence)
110 {
111     // char array to ulong array
112     var linksSequence = new ulong[sequence.Length];
113     for (var i = 0; i < sequence.Length; i++)
114     {
115         linksSequence[i] = FromCharToLink(sequence[i]);
116     }
117     return linksSequence;
118 }
119
120 public static List<ulong[]> FromStringToLinkArrayGroups(string sequence)
121 {
122     var result = new List<ulong[]>();
123     var offset = 0;
124     while (offset < sequence.Length)
125     {
126         var currentCategory = CharUnicodeInfo.GetUnicodeCategory(sequence[offset]);
127         var relativeLength = 1;
128         var absoluteLength = offset + relativeLength;
129         while (absoluteLength < sequence.Length &&
130             currentCategory ==
131                 CharUnicodeInfo.GetUnicodeCategory(sequence[absoluteLength]))
132         {
133             relativeLength++;
134             absoluteLength++;
135         }
136         // char array to ulong array
137         var innerSequence = new ulong[relativeLength];
138         var maxLength = offset + relativeLength;
139         for (var i = offset; i < maxLength; i++)
140         {
141             innerSequence[i - offset] = FromCharToLink(sequence[i]);
142         }
143         result.Add(innerSequence);
144         offset += relativeLength;
145     }
146     return result;
147 }
148
149 public static List<ulong[]> FromLinkArrayToLinkArrayGroups(ulong[] array)
150 {
151     var result = new List<ulong[]>();
152     var offset = 0;
153     while (offset < array.Length)
154     {
155         var relativeLength = 1;
156         if (array[offset] <= LastCharLink)
157         {
158             var currentCategory =
159                 CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(array[offset]));
160             var absoluteLength = offset + relativeLength;
161             while (absoluteLength < array.Length &&
162                 array[absoluteLength] <= LastCharLink &&
163                 currentCategory == CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(
164                     array[absoluteLength])))
165             {
166                 relativeLength++;
167                 absoluteLength++;
168             }
169         }
170         else
171         {
172             var absoluteLength = offset + relativeLength;
173             while (absoluteLength < array.Length && array[absoluteLength] > LastCharLink)
174             {
175                 relativeLength++;
176                 absoluteLength++;
177             }
178         }
179     }
180     return result;
181 }

```

```

174     }
175 }
176 // copy array
177 var innerSequence = new ulong[relativeLength];
178 var maxLength = offset + relativeLength;
179 for (var i = offset; i < maxLength; i++)
180 {
181     innerSequence[i - offset] = array[i];
182 }
183 result.Add(innerSequence);
184 offset += relativeLength;
185 }
186 return result;
187 }
188 }
189 }

```

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

```

1 using Platform.Interfaces;
2 using System.Collections.Generic;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Unicode
7 {
8     public class UnicodeSequenceCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
9         ↳ ICriterionMatcher<TLink>
10     {
11         private static readonly EqualityComparer<TLink> _equalityComparer =
12             ↳ EqualityComparer<TLink>.Default;
13         private readonly TLink _unicodeSequenceMarker;
14         public UnicodeSequenceCriterionMatcher(ILinks<TLink> links, TLink unicodeSequenceMarker)
15             ↳ : base(links) => _unicodeSequenceMarker = unicodeSequenceMarker;
16         public bool IsMatched(TLink link) => _equalityComparer.Equals(Links.GetTarget(link),
17             ↳ _unicodeSequenceMarker);
18     }
19 }

```

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

```

1 using System;
2 using System.Linq;
3 using Platform.Data.Doublets.Sequences.Walkers;
4 using Platform.Interfaces;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Unicode
9 {
10     public class UnicodeSequenceToStringConverter<TLink> : LinksOperatorBase<TLink>,
11         ↳ IConverter<TLink, string>
12     {
13         private readonly ICriterionMatcher<TLink> _unicodeSequenceCriterionMatcher;
14         private readonly ISequenceWalker<TLink> _sequenceWalker;
15         private readonly IConverter<TLink, char> _unicodeSymbolToCharConverter;
16
17         public UnicodeSequenceToStringConverter(ILinks<TLink> links, ICriterionMatcher<TLink>
18             ↳ unicodeSequenceCriterionMatcher, ISequenceWalker<TLink> sequenceWalker,
19             ↳ IConverter<TLink, char> unicodeSymbolToCharConverter) : base(links)
20         {
21             _unicodeSequenceCriterionMatcher = unicodeSequenceCriterionMatcher;
22             _sequenceWalker = sequenceWalker;
23             _unicodeSymbolToCharConverter = unicodeSymbolToCharConverter;
24         }
25
26         public string Convert(TLink source)
27         {
28             if(!_unicodeSequenceCriterionMatcher.IsMatched(source))
29             {
30                 throw new ArgumentOutOfRangeException(nameof(source), source, "Specified link is
31                     ↳ not a unicode sequence.");
32             }
33             var sequence = Links.GetSource(source);
34             var charArray = _sequenceWalker.Walk(sequence).Select(_unicodeSymbolToCharConverter.
35                 ↳ Convert).ToArray();
36             return new string(charArray);
37         }
38     }
39 }

```

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

```
1 using Platform.Interfaces;
2 using System.Collections.Generic;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Unicode
7 {
8     public class UnicodeSymbolCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
9         ↳ ICriterionMatcher<TLink>
10    {
11        private static readonly EqualityComparer<TLink> _equalityComparer =
12            ↳ EqualityComparer<TLink>.Default;
13        private readonly TLink _unicodeSymbolMarker;
14        public UnicodeSymbolCriterionMatcher(ILinks<TLink> links, TLink unicodeSymbolMarker) :
15            ↳ base(links) => _unicodeSymbolMarker = unicodeSymbolMarker;
16        public bool IsMatched(TLink link) => _equalityComparer.Equals(Links.GetTarget(link),
17            ↳ _unicodeSymbolMarker);
18    }
19 }
```

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

```
1 using System;
2 using Platform.Interfaces;
3 using Platform.Numbers;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Data.Doublets.Unicode
8 {
9     public class UnicodeSymbolToCharConverter<TLink> : LinksOperatorBase<TLink>,
10         ↳ IConverter<TLink, char>
11    {
12        private readonly IConverter<TLink> _numberToAddressConverter;
13        private readonly ICriterionMatcher<TLink> _unicodeSymbolCriterionMatcher;
14
15        public UnicodeSymbolToCharConverter(ILinks<TLink> links, IConverter<TLink>
16            ↳ numberToAddressConverter, ICriterionMatcher<TLink> unicodeSymbolCriterionMatcher) :
17            ↳ base(links)
18        {
19            _numberToAddressConverter = numberToAddressConverter;
20            _unicodeSymbolCriterionMatcher = unicodeSymbolCriterionMatcher;
21        }
22
23        public char Convert(TLink source)
24        {
25            if (!_unicodeSymbolCriterionMatcher.IsMatched(source))
26            {
27                throw new ArgumentOutOfRangeException(nameof(source), source, "Specified link is
28                    ↳ not a unicode symbol.");
29            }
30            return (char)(ushort)(Integer<TLink>)_numberToAddressConverter.Convert(Links.GetSource
31                ↳ (source));
32        }
33    }
34 }
```

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

```
1 using System;
2 using System.Collections.Generic;
3 using Xunit;
4 using Platform.Diagnostics;
5
6 namespace Platform.Data.Doublets.Tests
7 {
8     public static class ComparisonTests
9     {
10         private class UInt64Comparer : IComparer<ulong>
11         {
12             public int Compare(ulong x, ulong y) => x.CompareTo(y);
13         }
14
15         private static int Compare(ulong x, ulong y) => x.CompareTo(y);
16
17         [Fact]
18         public static void GreaterOrEqualPerformanceTest()
19         {
20             const int N = 1000000;
21
22             ulong x = 10;
```

```

23     ulong y = 500;
24
25     bool result = false;
26
27     var ts1 = Performance.Measure(() =>
28     {
29         for (int i = 0; i < N; i++)
30         {
31             result = Compare(x, y) >= 0;
32         }
33     });
34
35     var comparer1 = Comparer<ulong>.Default;
36
37     var ts2 = Performance.Measure(() =>
38     {
39         for (int i = 0; i < N; i++)
40         {
41             result = comparer1.Compare(x, y) >= 0;
42         }
43     });
44
45     Func<ulong, ulong, int> compareReference = comparer1.Compare;
46
47     var ts3 = Performance.Measure(() =>
48     {
49         for (int i = 0; i < N; i++)
50         {
51             result = compareReference(x, y) >= 0;
52         }
53     });
54
55     var comparer2 = new UInt64Comparer();
56
57     var ts4 = Performance.Measure(() =>
58     {
59         for (int i = 0; i < N; i++)
60         {
61             result = comparer2.Compare(x, y) >= 0;
62         }
63     });
64
65     Console.WriteLine($"{ts1} {ts2} {ts3} {ts4} {result}");
66 }
67
68 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Xunit;
4  using Platform.Diagnostics;
5
6  namespace Platform.Data.Doublets.Tests
7  {
8      public static class EqualityTests
9      {
10         protected class UInt64EqualityComparer : IEqualityComparer<ulong>
11         {
12             public bool Equals(ulong x, ulong y) => x == y;
13
14             public int GetHashCode(ulong obj) => obj.GetHashCode();
15         }
16
17         private static bool Equals1<T>(T x, T y) => Equals(x, y);
18
19         private static bool Equals2<T>(T x, T y) => x.Equals(y);
20
21         private static bool Equals3(ulong x, ulong y) => x == y;
22
23         [Fact]
24         public static void EqualsPerfomanceTest()
25         {
26             const int N = 1000000;
27
28             ulong x = 10;
29             ulong y = 500;
30
31             bool result = false;
32

```



```

33     var ts1 = Performance.Measure(() =>
34     {
35         for (int i = 0; i < N; i++)
36         {
37             result = Equals1(x, y);
38         }
39     });
40
41     var ts2 = Performance.Measure(() =>
42     {
43         for (int i = 0; i < N; i++)
44         {
45             result = Equals2(x, y);
46         }
47     });
48
49     var ts3 = Performance.Measure(() =>
50     {
51         for (int i = 0; i < N; i++)
52         {
53             result = Equals3(x, y);
54         }
55     });
56
57     var equalityComparer1 = EqualityComparer<ulong>.Default;
58
59     var ts4 = Performance.Measure(() =>
60     {
61         for (int i = 0; i < N; i++)
62         {
63             result = equalityComparer1.Equals(x, y);
64         }
65     });
66
67     var equalityComparer2 = new UInt64EqualityComparer();
68
69     var ts5 = Performance.Measure(() =>
70     {
71         for (int i = 0; i < N; i++)
72         {
73             result = equalityComparer2.Equals(x, y);
74         }
75     });
76
77     Func<ulong, ulong, bool> equalityComparer3 = equalityComparer2.Equals;
78
79     var ts6 = Performance.Measure(() =>
80     {
81         for (int i = 0; i < N; i++)
82         {
83             result = equalityComparer3(x, y);
84         }
85     });
86
87     var comparer = Comparer<ulong>.Default;
88
89     var ts7 = Performance.Measure(() =>
90     {
91         for (int i = 0; i < N; i++)
92         {
93             result = comparer.Compare(x, y) == 0;
94         }
95     });
96
97     Assert.True(ts2 < ts1);
98     Assert.True(ts3 < ts2);
99     Assert.True(ts5 < ts4);
100    Assert.True(ts5 < ts6);
101
102    Console.WriteLine($"{ts1} {ts2} {ts3} {ts4} {ts5} {ts6} {ts7} {result}");
103 }
104 }
105 }

```

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

```

1 using System;
2 using Xunit;
3 using Platform.Reflection;
4 using Platform.Memory;

```

```

5 using Platform.Scopes;
6 using Platform.Data.Doublets.ResizableDirectMemory.Generic;
7
8 namespace Platform.Data.Doublets.Tests
9 {
10     public unsafe static class GenericLinksTests
11     {
12         [Fact]
13         public static void CRUDTest()
14         {
15             Using<byte>(links => links.TestCRUDOperations());
16             Using<ushort>(links => links.TestCRUDOperations());
17             Using<uint>(links => links.TestCRUDOperations());
18             Using<ulong>(links => links.TestCRUDOperations());
19         }
20
21         [Fact]
22         public static void RawNumbersCRUDTest()
23         {
24             Using<byte>(links => links.TestRawNumbersCRUDOperations());
25             Using<ushort>(links => links.TestRawNumbersCRUDOperations());
26             Using<uint>(links => links.TestRawNumbersCRUDOperations());
27             Using<ulong>(links => links.TestRawNumbersCRUDOperations());
28         }
29
30         [Fact]
31         public static void MultipleRandomCreationsAndDeletionsTest()
32         {
33             Using<byte>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Test
34                 ↪ MultipleRandomCreationsAndDeletions(16)); // Cannot use more because current
35                 ↪ implementation of tree cuts out 5 bits from the address space.
36             Using<ushort>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Te
37                 ↪ stMultipleRandomCreationsAndDeletions(100));
38             Using<uint>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Test
39                 ↪ MultipleRandomCreationsAndDeletions(100));
40             Using<ulong>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Tes
41                 ↪ tMultipleRandomCreationsAndDeletions(100));
42         }
43
44         private static void Using<TLink>(Action<ILinks<TLink>> action)
45         {
46             using (var scope = new Scope<Types<HeapResizableDirectMemory,
47                 ↪ ResizableDirectMemoryLinks<TLink>>>())
48             {
49                 action(scope.Use<ILinks<TLink>>());
50             }
51         }
52     }
53 }

```

./Platform.Data.Doublets.Tests/LinksConstantsTests.cs

```

1 using Xunit;
2
3 namespace Platform.Data.Doublets.Tests
4 {
5     public static class LinksConstantsTests
6     {
7         [Fact]
8         public static void ExternalReferencesTest()
9         {
10             LinksConstants<ulong> constants = new LinksConstants<ulong>((1, long.MaxValue),
11                 ↪ (long.MaxValue + 1UL, ulong.MaxValue));
12
13             //var minimum = new Hybrid<ulong>(0, isExternal: true);
14             var minimum = new Hybrid<ulong>(1, isExternal: true);
15             var maximum = new Hybrid<ulong>(long.MaxValue, isExternal: true);
16
17             Assert.True(constants.IsExternalReference(minimum));
18             Assert.True(constants.IsExternalReference(maximum));
19         }
20     }
21 }

```

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

```

1 using System;
2 using System.Linq;
3 using System.Collections.Generic;
4 using Xunit;

```

```

5 using Platform.Data.Doublets.Sequences;
6 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
7 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
8 using Platform.Data.Doublets.Sequences.Converters;
9 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 using Platform.Memory;
16 using Platform.Data.Doublets.ResizableDirectMemory;
17 using Platform.Data.Doublets.Decorators;
18 using Platform.Data.Doublets.ResizableDirectMemory.Specific;
19 using Platform.Data.Doublets.Numbers.Raw;
20 using Platform.Collections.Stacks;
21
22 namespace Platform.Data.Doublets.Tests
23 {
24     public static class OptimalVariantSequenceTests
25     {
26         private static readonly string _sequenceExample = "зеленела зелёная зелень";
27         private static readonly string _loremIpsumExample = @"Lorem ipsum dolor sit amet,
                ↳ consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore
                ↳ magna aliqua.
Facilisi nullam vehicula ipsum a arcu cursus vitae congue mauris.
Et malesuada fames ac turpis egestas sed.
Eget velit aliquet sagittis id consectetur purus.
Dignissim cras tincidunt lobortis feugiat vivamus.
Vitae aliquet nec ullamcorper sit.
Lectus quam id leo in vitae.
Tortor dignissim convallis aenean et tortor at risus viverra adipiscing.
Sed risus ultricies tristique nulla aliquet enim tortor at auctor.
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Suspendisse potenti nullam ac tortor vitae purus faucibus ornare.
Nulla facilisi etiam dignissim diam quis enim lobortis scelerisque.
Imperdiet proin fermentum leo vel orci.
In ante metus dictum at tempor commodo.
Nisi lacus sed viverra tellus in.
Quam vulputate dignissim suspendisse in.
Elit scelerisque mauris pellentesque pulvinar pellentesque habitant morbi tristique senectus.
Gravida cum sociis natoque penatibus et magnis dis parturient.
Risus quis varius quam quisque id diam.
Congue nisi vitae suscipit tellus mauris a diam maecenas.
Eget nunc scelerisque viverra mauris in aliquam sem fringilla.
Pharetra vel turpis nunc eget lorem dolor sed viverra.
Mattis pellentesque id nibh tortor id aliquet.
Purus non enim praesent elementum facilisis leo vel.
Etiam sit amet nisl purus in mollis nunc sed.
Tortor at auctor urna nunc id cursus metus aliquam.
Volutpat odio facilisis mauris sit amet.
Turpis egestas pretium aenean pharetra magna ac placerat.
Fermentum dui faucibus in ornare quam viverra orci sagittis eu.
Porttitor leo a diam sollicitudin tempor id eu.
Volutpat sed cras ornare arcu dui.
Ut aliquam purus sit amet luctus venenatis lectus magna.
Aliquet risus feugiat in ante metus dictum at.
Mattis nunc sed blandit libero.
Elit pellentesque habitant morbi tristique senectus et netus.
Nibh sit amet commodo nulla facilisi nullam vehicula ipsum a.
Enim sit amet venenatis urna cursus eget nunc scelerisque viverra.
Amet venenatis urna cursus eget nunc scelerisque viverra mauris in.
Diam donec adipiscing tristique risus nec feugiat.
Pulvinar mattis nunc sed blandit libero volutpat.
Cras fermentum odio eu feugiat pretium nibh ipsum.
In nulla posuere sollicitudin aliquam ultrices sagittis orci a.
Mauris pellentesque pulvinar pellentesque habitant morbi tristique senectus et.
A iaculis at erat pellentesque.
Morbi blandit cursus risus at ultrices mi tempus imperdiet nulla.
Eget lorem dolor sed viverra ipsum nunc.
Leo a diam sollicitudin tempor id eu.
Interdum consectetur libero id faucibus nisl tincidunt eget nullam non.";
                ];
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71
72
73
74
75
76
77
78         [Fact]
79         public static void LinksBasedFrequencyStoredOptimalVariantSequenceTest()
80         {
81             using (var scope = new TempLinksTestScope(useSequences: false))
82             {
83                 var links = scope.Links;
84                 var constants = links.Constants;
85
86                 links.UseUnicode();

```

```

87
88     var sequence = UnicodeMap.FromStringToLinkArray(_sequenceExample);
89
90     var meaningRoot = links.CreatePoint();
91     var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
92     var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
93     var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
94         ↳ constants.Itself);
95
96     var unaryNumberToAddressConverter = new
97         ↳ UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
98     var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
99     var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
100         ↳ frequencyMarker, unaryOne, unaryNumberIncrementer);
101     var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
102         ↳ frequencyPropertyMarker, frequencyMarker);
103     var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
104         ↳ frequencyPropertyOperator, frequencyIncrementer);
105     var linkToItsFrequencyNumberConverter = new
106         ↳ LinkToItsFrequencyNumberConverter<ulong>(links, frequencyPropertyOperator,
107         ↳ unaryNumberToAddressConverter);
108     var sequenceToItsLocalElementLevelsConverter = new
109         ↳ SequenceToItsLocalElementLevelsConverter<ulong>(links,
110         ↳ linkToItsFrequencyNumberConverter);
111     var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
112         ↳ sequenceToItsLocalElementLevelsConverter);
113
114     var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
115         ↳ Walker = new LeveledSequenceWalker<ulong>(links) });
116
117     ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
118         ↳ index, optimalVariantConverter);
119 }
120
121 [Fact]
122 public static void DictionaryBasedFrequencyStoredOptimalVariantSequenceTest()
123 {
124     using (var scope = new TempLinksTestScope(useSequences: false))
125     {
126         var links = scope.Links;
127
128         links.UseUnicode();
129
130         var sequence = UnicodeMap.FromStringToLinkArray(_sequenceExample);
131
132         var totalSequenceSymbolFrequencyCounter = new
133             ↳ TotalSequenceSymbolFrequencyCounter<ulong>(links);
134
135         var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
136             ↳ totalSequenceSymbolFrequencyCounter);
137
138         var index = new
139             ↳ CachedFrequencyIncrementingSequenceIndex<ulong>(linkFrequenciesCache);
140         var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<ulong>(linkFrequenciesCache);
141
142         var sequenceToItsLocalElementLevelsConverter = new
143             ↳ SequenceToItsLocalElementLevelsConverter<ulong>(links,
144             ↳ linkToItsFrequencyNumberConverter);
145         var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
146             ↳ sequenceToItsLocalElementLevelsConverter);
147
148         var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
149             ↳ Walker = new LeveledSequenceWalker<ulong>(links) });
150
151         ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
152             ↳ index, optimalVariantConverter);
153     }
154 }
155
156 private static void ExecuteTest(Sequences.Sequences sequences, ulong[] sequence,
157     ↳ SequenceToItsLocalElementLevelsConverter<ulong>
158     ↳ sequenceToItsLocalElementLevelsConverter, ISequenceIndex<ulong> index,
159     ↳ OptimalVariantConverter<ulong> optimalVariantConverter)
160 {
161     index.Add(sequence);
162 }

```

```

141     var optimalVariant = optimalVariantConverter.Convert(sequence);
142
143     var readSequence1 = sequences.ToList(optimalVariant);
144
145     Assert.True(sequence.SequenceEqual(readSequence1));
146 }
147
148 [Fact]
149 public static void SavedSequencesOptimizationTest()
150 {
151     LinksConstants<ulong> constants = new LinksConstants<ulong>((1, long.MaxValue),
152         ↳ (long.MaxValue + 1UL, ulong.MaxValue));
153
154     using (var memory = new HeapResizableDirectMemory())
155     using (var disposableLinks = new UInt64ResizableDirectMemoryLinks(memory,
156         ↳ UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep, constants,
157         ↳ useAvlBasedIndex: false))
158     {
159         var links = new UInt64Links(disposableLinks);
160
161         var root = links.CreatePoint();
162
163         //var numberToAddressConverter = new RawNumberToAddressConverter<ulong>();
164         var addressToNumberConverter = new AddressToRawNumberConverter<ulong>();
165
166         var unicodeSymbolMarker = links.GetOrCreate(root,
167             ↳ addressToNumberConverter.Convert(1));
168         var unicodeSequenceMarker = links.GetOrCreate(root,
169             ↳ addressToNumberConverter.Convert(2));
170
171         var totalSequenceSymbolFrequencyCounter = new
172             ↳ TotalSequenceSymbolFrequencyCounter<ulong>(links);
173         var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
174             ↳ totalSequenceSymbolFrequencyCounter);
175         var index = new
176             ↳ CachedFrequencyIncrementingSequenceIndex<ulong>(linkFrequenciesCache);
177         var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFreque
178             ↳ ncyNumberConverter<ulong>(linkFrequenciesCache);
179         var sequenceToItsLocalElementLevelsConverter = new
180             ↳ SequenceToItsLocalElementLevelsConverter<ulong>(links,
181             ↳ linkToItsFrequencyNumberConverter);
182         var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
183             ↳ sequenceToItsLocalElementLevelsConverter);
184
185         var walker = new RightSequenceWalker<ulong>(links, new DefaultStack<ulong>(),
186             ↳ (link) => constants.IsExternalReference(link) || links.IsPartialPoint(link));
187
188         var unicodeSequencesOptions = new SequencesOptions<ulong>()
189         {
190             UseSequenceMarker = true,
191             SequenceMarkerLink = unicodeSequenceMarker,
192             UseIndex = true,
193             Index = index,
194             LinksToSequenceConverter = optimalVariantConverter,
195             Walker = walker,
196             UseGarbageCollection = true
197         };
198
199         var unicodeSequences = new Sequences.Sequences(new
200             ↳ SynchronizedLinks<ulong>(links), unicodeSequencesOptions);
201
202         // Create some sequences
203         var strings = _loremIpsumExample.Split(new[] { '\n', '\r' },
204             ↳ StringSplitOptions.RemoveEmptyEntries);
205         var arrays = strings.Select(x => x.Select(y =>
206             ↳ addressToNumberConverter.Convert(y)).ToArray()).ToArray();
207         for (int i = 0; i < arrays.Length; i++)
208         {
209             unicodeSequences.Create(arrays[i].ConvertToRestrictionsValues());
210         }
211
212         var linksCountAfterCreation = links.Count();
213
214         // get list of sequences links
215         // for each sequence link
216         // create new sequence version
217         // if new sequence is not the same as sequence link
218         // delete sequence link

```

```

203         // collect garbadage
204         //unicodeSequences.CompactAll();
205
206         //var linksCountAfterCompactification = links.Count();
207
208         //Assert.True(linksCountAfterCompactification < linksCountAfterCreation);
209     }
210 }
211 }
212 }

```

# ./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

```

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

```
1 using System.IO;
2 using Xunit;
3 using Platform.Singletons;
4 using Platform.Memory;
5 using Platform.Data.Doublets.ResizableDirectMemory.Specific;
6
7 namespace Platform.Data.Doublets.Tests
8 {
9     public static class ResizableDirectMemoryLinksTests
10     {
11         private static readonly LinksConstants<ulong> _constants =
12             ↳ Default<LinksConstants<ulong>>.Instance;
13
14         [Fact]
15         public static void BasicFileMappedMemoryTest()
16         {
17             var tempFilename = Path.GetTempFileName();
18             using (var memoryAdapter = new UInt64ResizableDirectMemoryLinks(tempFilename))
19             {
20                 memoryAdapter.TestBasicMemoryOperations();
21             }
22             File.Delete(tempFilename);
23
24             [Fact]
25             public static void BasicHeapMemoryTest()
26             {
27                 using (var memory = new
28                     ↳ HeapResizableDirectMemory(UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep))
29                 using (var memoryAdapter = new UInt64ResizableDirectMemoryLinks(memory,
30                     ↳ UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep))
31                 {
32                     memoryAdapter.TestBasicMemoryOperations();
33                 }
34
35                 private static void TestBasicMemoryOperations(this ILinks<ulong> memoryAdapter)
36                 {
37                     var link = memoryAdapter.Create();
38                     memoryAdapter.Delete(link);
39
40                     [Fact]
41                     public static void NonexistentReferencesHeapMemoryTest()
42                     {
43                         using (var memory = new
44                             ↳ HeapResizableDirectMemory(UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep))
45                         using (var memoryAdapter = new UInt64ResizableDirectMemoryLinks(memory,
46                             ↳ UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep))
47                         {
48                             memoryAdapter.TestNonexistentReferences();
49
50                             private static void TestNonexistentReferences(this ILinks<ulong> memoryAdapter)
51                             {
52                                 var link = memoryAdapter.Create();
53                                 memoryAdapter.Update(link, ulong.MaxValue, ulong.MaxValue);
54                                 var resultLink = _constants.Null;
55                                 memoryAdapter.Each(foundLink =>
56                                 {
57                                     resultLink = foundLink[_constants.IndexPart];
58                                     return _constants.Break;
59                                 }, _constants.Any, ulong.MaxValue, ulong.MaxValue);
60                                 Assert.True(resultLink == link);
61                                 Assert.True(memoryAdapter.Count(ulong.MaxValue) == 0);
62                                 memoryAdapter.Delete(link);
63                             }
64                         }
65                     }
66                 }
67             }
68         }
69     }
70 }
```

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

```
1 using Xunit;
2 using Platform.Scopes;
3 using Platform.Memory;
4 using Platform.Data.Doublets.Decorators;
5 using Platform.Reflection;
6 using Platform.Data.Doublets.ResizableDirectMemory.Generic;
```

```

7 using Platform.Data.Doublets.ResizableDirectMemory.Specific;
8
9 namespace Platform.Data.Doublets.Tests
10 {
11     public static class ScopeTests
12     {
13         [Fact]
14         public static void SingleDependencyTest()
15         {
16             using (var scope = new Scope())
17             {
18                 scope.IncludeAssemblyOf<IMemory>();
19                 var instance = scope.Use<IDirectMemory>();
20                 Assert.IsType<HeapResizableDirectMemory>(instance);
21             }
22         }
23
24         [Fact]
25         public static void CascadeDependencyTest()
26         {
27             using (var scope = new Scope())
28             {
29                 scope.Include<TemporaryFileMappedResizableDirectMemory>();
30                 scope.Include<UInt64ResizableDirectMemoryLinks>();
31                 var instance = scope.Use<ILinks<ulong>>();
32                 Assert.IsType<UInt64ResizableDirectMemoryLinks>(instance);
33             }
34         }
35
36         [Fact]
37         public static void FullAutoResolutionTest()
38         {
39             using (var scope = new Scope(autoInclude: true, autoExplore: true))
40             {
41                 var instance = scope.Use<UInt64Links>();
42                 Assert.IsType<UInt64Links>(instance);
43             }
44         }
45
46         [Fact]
47         public static void TypeParametersTest()
48         {
49             using (var scope = new Scope<Types<HeapResizableDirectMemory,
50 ↪ ResizableDirectMemoryLinks<ulong>>>())
51             {
52                 var links = scope.Use<ILinks<ulong>>();
53                 Assert.IsType<ResizableDirectMemoryLinks<ulong>>(links);
54             }
55         }
56     }

```

./Platform.Data.Doublets.Tests/SequencesTests.cs

```

1 using System;
2 using System.Collections.Generic;
3 using System.Diagnostics;
4 using System.Linq;
5 using Xunit;
6 using Platform.Collections;
7 using Platform.Random;
8 using Platform.IO;
9 using Platform.Singletons;
10 using Platform.Data.Doublets.Sequences;
11 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
12 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
13 using Platform.Data.Doublets.Sequences.Converters;
14 using Platform.Data.Doublets.Unicode;
15
16 namespace Platform.Data.Doublets.Tests
17 {
18     public static class SequencesTests
19     {
20         private static readonly LinksConstants<ulong> _constants =
21             ↪ Default<LinksConstants<ulong>>.Instance;
22
23         static SequencesTests()
24         {
25             // Trigger static constructor to not mess with performance measurements
26             _ = BitString.GetBitMaskFromIndex(1);
27         }

```



```

27 [Fact]
28 public static void CreateAllVariantsTest()
29 {
30     const long sequenceLength = 8;
31
32     using (var scope = new TempLinksTestScope(useSequences: true))
33     {
34         var links = scope.Links;
35         var sequences = scope.Sequences;
36
37         var sequence = new ulong[sequenceLength];
38         for (var i = 0; i < sequenceLength; i++)
39         {
40             sequence[i] = links.Create();
41         }
42
43         var sw1 = Stopwatch.StartNew();
44         var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
45
46         var sw2 = Stopwatch.StartNew();
47         var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();
48
49         Assert.True(results1.Count > results2.Length);
50         Assert.True(sw1.Elapsed > sw2.Elapsed);
51
52         for (var i = 0; i < sequenceLength; i++)
53         {
54             links.Delete(sequence[i]);
55         }
56
57         Assert.True(links.Count() == 0);
58     }
59 }
60
61 // [Fact]
62 // public void CUDTest()
63 // {
64 //     var tempFilename = Path.GetTempFileName();
65 //
66 //     const long sequenceLength = 8;
67 //
68 //     const ulong itself = LinksConstants.Itself;
69 //
70 //     using (var memoryAdapter = new ResizableDirectMemoryLinks(tempFilename,
71 //         ↪ DefaultLinksSizeStep))
72 //     using (var links = new Links(memoryAdapter))
73 //     {
74 //         var sequence = new ulong[sequenceLength];
75 //         for (var i = 0; i < sequenceLength; i++)
76 //             sequence[i] = links.Create(itself, itself);
77 //
78 //         SequencesOptions o = new SequencesOptions();
79 //
80 //         TODO: Из числа в bool значения o.UseSequenceMarker = ((value & 1) != 0)
81 //             o.
82 //
83 //         var sequences = new Sequences(links);
84 //
85 //         var sw1 = Stopwatch.StartNew();
86 //         var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
87 //
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());
133     ↪ sw3.Stop();
134
135     var intersection0 = createResults.Intersect(searchResults0).ToList();
136     Assert.True(intersection0.Count == searchResults0.Count);
137     Assert.True(intersection0.Count == createResults.Length);
138
139     var intersection1 = createResults.Intersect(searchResults1).ToList();
140     Assert.True(intersection1.Count == searchResults1.Count);
141     Assert.True(intersection1.Count == createResults.Length);
142
143     var intersection2 = createResults.Intersect(searchResults2).ToList();
144     Assert.True(intersection2.Count == searchResults2.Count);
145     Assert.True(intersection2.Count == createResults.Length);
146
147     var intersection3 = createResults.Intersect(searchResults3).ToList();
148     Assert.True(intersection3.Count == searchResults3.Count);
149     Assert.True(intersection3.Count == createResults.Length);
150
151     for (var i = 0; i < sequenceLength; i++)
152     {
153         links.Delete(sequence[i]);
154     }
155 }
156
157 [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
167         var sequence = new ulong[sequenceLength];
168         for (var i = 0; i < sequenceLength; i++)
169         {
170             sequence[i] = links.Create();
171         }
172
173         var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
174
175         var sw1 = Stopwatch.StartNew();
176         var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();
177
178         var sw2 = Stopwatch.StartNew();
179         var searchResults2 = sequences.GetAllMatchingSequences0(sequence); sw2.Stop();
180
181         var sw3 = Stopwatch.StartNew();
182         var searchResults3 = sequences.GetAllMatchingSequences1(sequence); sw3.Stop();
183
184         // На количестве в 200 элементов это будет занимать вечность

```

```

185     //var sw4 = Stopwatch.StartNew();
186     //var searchResults4 = sequences.Each(sequence); sw4.Stop();
187
188     Assert.True(searchResults2.Count == 1 && balancedVariant == searchResults2[0]);
189
190     Assert.True(searchResults3.Count == 1 && balancedVariant ==
191         ↳ searchResults3.First());
192
193     //Assert.True(sw1.Elapsed < sw2.Elapsed);
194
195     for (var i = 0; i < sequenceLength; i++)
196     {
197         links.Delete(sequence[i]);
198     }
199 }
200
201 [Fact]
202 public static void AllPartialVariantsSearchTest()
203 {
204     const long sequenceLength = 8;
205
206     using (var scope = new TempLinksTestScope(useSequences: true))
207     {
208         var links = scope.Links;
209         var sequences = scope.Sequences;
210
211         var sequence = new ulong[sequenceLength];
212         for (var i = 0; i < sequenceLength; i++)
213         {
214             sequence[i] = links.Create();
215         }
216
217         var createResults = sequences.CreateAllVariants2(sequence);
218
219         //var createResultsStrings = createResults.Select(x => x + ": " +
220             ↳ sequences.FormatSequence(x)).ToList();
221         //Global.Trash = createResultsStrings;
222
223         var partialSequence = new ulong[sequenceLength - 2];
224
225         Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
226
227         var sw1 = Stopwatch.StartNew();
228         var searchResults1 =
229             ↳ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
230
231         var sw2 = Stopwatch.StartNew();
232         var searchResults2 =
233             ↳ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
234
235         //var sw3 = Stopwatch.StartNew();
236         //var searchResults3 =
237             ↳ sequences.GetAllPartiallyMatchingSequences2(partialSequence); sw3.Stop();
238
239         var sw4 = Stopwatch.StartNew();
240         var searchResults4 =
241             ↳ sequences.GetAllPartiallyMatchingSequences3(partialSequence); sw4.Stop();
242
243         //Global.Trash = searchResults3;
244
245         //var searchResults1Strings = searchResults1.Select(x => x + ": " +
246             ↳ sequences.FormatSequence(x)).ToList();
247         //Global.Trash = searchResults1Strings;
248
249         var intersection1 = createResults.Intersect(searchResults1).ToList();
250         Assert.True(intersection1.Count == createResults.Length);
251
252         var intersection2 = createResults.Intersect(searchResults2).ToList();
253         Assert.True(intersection2.Count == createResults.Length);
254
255         var intersection4 = createResults.Intersect(searchResults4).ToList();
256         Assert.True(intersection4.Count == createResults.Length);
257
258         for (var i = 0; i < sequenceLength; i++)
259         {
260             links.Delete(sequence[i]);
261         }
262     }
263 }

```

```

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 =
285                 ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
286
287             var sw2 = Stopwatch.StartNew();
288             var searchResults2 =
289                 ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
290
291             Assert.True(searchResults1.Count == 1 && balancedVariant == searchResults1[0]);
292
293             Assert.True(searchResults2.Count == 1 && balancedVariant ==
294                 ↪ searchResults2.First());
295
296             for (var i = 0; i < sequenceLength; i++)
297             {
298                 links.Delete(sequence[i]);
299             }
300         }
301
302     [Fact(Skip = "Correct implementation is pending")]
303     public static void PatternMatchTest()
304     {
305         var zeroOrMany = Sequences.Sequences.ZeroOrMany;
306
307         using (var scope = new TempLinksTestScope(useSequences: true))
308         {
309             var links = scope.Links;
310             var sequences = scope.Sequences;
311
312             var e1 = links.Create();
313             var e2 = links.Create();
314
315             var sequence = new[]
316             {
317                 e1, e2, e1, e2 // mama / papa
318             };
319
320             var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
321
322             var balancedVariant = balancedVariantConverter.Convert(sequence);
323
324             // 1: [1]
325             // 2: [2]
326             // 3: [1,2]
327             // 4: [1,2,1,2]
328
329             var doublet = links.GetSource(balancedVariant);
330
331             var matchedSequences1 = sequences.MatchPattern(e2, e1, zeroOrMany);
332
333             Assert.True(matchedSequences1.Count == 0);
334
335             var matchedSequences2 = sequences.MatchPattern(zeroOrMany, e2, e1);

```

```

334     Assert.True(matchedSequences2.Count == 0);
335
336     var matchedSequences3 = sequences.MatchPattern(e1, zeroOrMany, e1);
337
338     Assert.True(matchedSequences3.Count == 0);
339
340     var matchedSequences4 = sequences.MatchPattern(e1, zeroOrMany, e2);
341
342     Assert.Contains(doublet, matchedSequences4);
343     Assert.Contains(balancedVariant, matchedSequences4);
344
345     for (var i = 0; i < sequence.Length; i++)
346     {
347         links.Delete(sequence[i]);
348     }
349 }
350
351 }
352
353 [Fact]
354 public static void IndexTest()
355 {
356     using (var scope = new TempLinksTestScope(new SequencesOptions<ulong> { UseIndex =
357         ↪ true }, useSequences: true))
358     {
359         var links = scope.Links;
360         var sequences = scope.Sequences;
361         var index = sequences.Options.Index;
362
363         var e1 = links.Create();
364         var e2 = links.Create();
365
366         var sequence = new[]
367         {
368             e1, e2, e1, e2 // mama / papa
369         };
370
371         Assert.False(index.MightContain(sequence));
372
373         index.Add(sequence);
374
375         Assert.True(index.MightContain(sequence));
376     }
377
378     /// <summary>Imported from https://raw.githubusercontent.com/Konard/LinksPlatform/%
379     ↪ DO%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
380     ↪ %D0%B8%D0%BD%D0%B0%D0%BB%D0%BE%D1%81%D1%8C.md</summary>
381     private static readonly string _exampleText =
382         @"([english
383         ↪ version](https://github.com/Konard/LinksPlatform/wiki/About-the-beginning))
384
385     Обозначение пустоты, какое оно? Темнота ли это? Там где отсутствие света, отсутствие фотонов
386     ↪ (носителей света)? Или это то, что полностью отражает свет? Пустой белый лист бумаги? Там
387     ↪ где есть место для нового начала? Разве пустота это не характеристика пространства?
388     ↪ Пространство это то, что можно чем-то наполнить?
389
390     [![чёрное пространство, белое
391     ↪ пространство](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/1.png
392     ↪ "чёрное пространство, белое пространство")] (https://raw.githubusercontent.com/Konard/Links
393     ↪ Platform/master/doc/Intro/1.png)
394
395     Что может быть минимальным рисунком, образом, графикой? Может быть это точка? Это ли простейшая
396     ↪ форма? Но есть ли у точки размер? Цвет? Масса? Координаты? Время существования?
397
398     [![чёрное пространство, чёрная
399     ↪ точка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/2.png
400     ↪ "чёрное пространство, чёрная
401     ↪ точка")] (https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/2.png)
402
403     А что если повторить? Сделать копию? Создать дубликат? Из одного сделать два? Может это быть
404     ↪ так? Инверсия? Отражение? Сумма?
405
406     [![белая точка, чёрная
407     ↪ точка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/3.png "белая
408     ↪ точка, чёрная
409     ↪ точка")] (https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/3.png)

```

394 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?

395

396 [![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)

397

398 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?

399

400 [![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)

401

402 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?

403

404 [![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)

405

406 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?

407

408 [![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)

409

410 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?

411

412 [![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)

413

414 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?

415

416 [![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)

417

418 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?

419

420 [![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)

421

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

423

```

424  [![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)
425
426  Последовательность? Массив? Список? Множество? Объект? Таблица? Элементы? Цвета? Символы? Буквы?
↳      Слово? Цифры? Число? Алфавит? Дерево? Сеть? Граф? Гиперграф?
427
428  [![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)
429
430  ...
431
432  [![анимация](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro-animat
↳      ion-500.gif
↳      "анимация")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro
↳      -animation-500.gif)";
433
434      private static readonly string _exampleLoremIpsumText =
435          @"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor
↳              incididunt ut labore et dolore magna aliqua.
436  Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo
↳      consequat.";
437
438      [Fact]
439      public static void CompressionTest()
440      {
441          using (var scope = new TempLinksTestScope(useSequences: true))
442          {
443              var links = scope.Links;
444              var sequences = scope.Sequences;
445
446              var e1 = links.Create();
447              var e2 = links.Create();
448
449              var sequence = new[]
450              {
451                  e1, e2, e1, e2 // mama / papa / template [(m/p), a] { [1] [2] [1] [2] }
452              };
453
454              var balancedVariantConverter = new BalancedVariantConverter<ulong>(links.Unsync);
455              var totalSequenceSymbolFrequencyCounter = new
↳                  TotalSequenceSymbolFrequencyCounter<ulong>(links.Unsync);
456              var doubletFrequenciesCache = new LinkFrequenciesCache<ulong>(links.Unsync,
↳                  totalSequenceSymbolFrequencyCounter);
457              var compressingConverter = new CompressingConverter<ulong>(links.Unsync,
↳                  balancedVariantConverter, doubletFrequenciesCache);
458
459              var compressedVariant = compressingConverter.Convert(sequence);
460
461              // 1: [1]          (1->1) point
462              // 2: [2]          (2->2) point
463              // 3: [1,2]        (1->2) doublet
464              // 4: [1,2,1,2]    (3->3) doublet
465
466              Assert.True(links.GetSource(links.GetSource(compressedVariant)) == sequence[0]);
467              Assert.True(links.GetTarget(links.GetSource(compressedVariant)) == sequence[1]);
468              Assert.True(links.GetSource(links.GetTarget(compressedVariant)) == sequence[2]);
469              Assert.True(links.GetTarget(links.GetTarget(compressedVariant)) == sequence[3]);
470
471              var source = _constants.SourcePart;
472              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)
483     ↪ == sequence[2]);
484     Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 3)
485     ↪ == sequence[3]);
486 }
487 }
488 [Fact]
489 public static void CompressionEfficiencyTest()
490 {
491     var strings = _exampleLoremIpsumText.Split(new[] { '\n', '\r' },
492     ↪ StringSplitOptions.RemoveEmptyEntries);
493     var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
494     var totalCharacters = arrays.Select(x => x.Length).Sum();
495
496     using (var scope1 = new TempLinksTestScope(useSequences: true))
497     using (var scope2 = new TempLinksTestScope(useSequences: true))
498     using (var scope3 = new TempLinksTestScope(useSequences: true))
499     {
500         scope1.Links.Unsync.UseUnicode();
501         scope2.Links.Unsync.UseUnicode();
502         scope3.Links.Unsync.UseUnicode();
503
504         var balancedVariantConverter1 = new
505         ↪ BalancedVariantConverter<ulong>(scope1.Links.Unsync);
506         var totalSequenceSymbolFrequencyCounter = new
507         ↪ TotalSequenceSymbolFrequencyCounter<ulong>(scope1.Links.Unsync);
508         var linkFrequenciesCache1 = new LinkFrequenciesCache<ulong>(scope1.Links.Unsync,
509         ↪ totalSequenceSymbolFrequencyCounter);
510         var compressor1 = new CompressingConverter<ulong>(scope1.Links.Unsync,
511         ↪ balancedVariantConverter1, linkFrequenciesCache1,
512         ↪ doInitialFrequenciesIncrement: false);
513
514         //var compressor2 = scope2.Sequences;
515         var compressor3 = scope3.Sequences;
516
517         var constants = Default<LinksConstants<ulong>>.Instance;
518
519         var sequences = compressor3;
520         //var meaningRoot = links.CreatePoint();
521         //var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
522         //var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
523         //var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
524         ↪ constants.Itself);
525
526         //var unaryNumberToAddressConverter = new
527         ↪ UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
528         //var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links,
529         ↪ unaryOne);
530         //var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
531         ↪ frequencyMarker, unaryOne, unaryNumberIncrementer);
532         //var frequencyPropertyOperator = new FrequencyPropertyOperator<ulong>(links,
533         ↪ frequencyPropertyMarker, frequencyMarker);
534         //var linkFrequencyIncrementer = new LinkFrequencyIncrementer<ulong>(links,
535         ↪ frequencyPropertyOperator, frequencyIncrementer);
536         //var linkToItsFrequencyNumberConverter = new
537         ↪ LinkToItsFrequencyNumberConverter<ulong>(links, frequencyPropertyOperator,
538         ↪ unaryNumberToAddressConverter);
539
540         var linkFrequenciesCache3 = new LinkFrequenciesCache<ulong>(scope3.Links.Unsync,
541         ↪ totalSequenceSymbolFrequencyCounter);
542
543         var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<ulong>(linkFrequenciesCache3);
544
545         var sequenceToItsLocalElementLevelsConverter = new
546         ↪ SequenceToItsLocalElementLevelsConverter<ulong>(scope3.Links.Unsync,
547         ↪ linkToItsFrequencyNumberConverter);
548         var optimalVariantConverter = new
549         ↪ OptimalVariantConverter<ulong>(scope3.Links.Unsync,
550         ↪ sequenceToItsLocalElementLevelsConverter);
551
552         var compressed1 = new ulong[arrays.Length];
553         var compressed2 = new ulong[arrays.Length];
554         var compressed3 = new ulong[arrays.Length];
555
556         var START = 0;
557         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
555     ↪ BalancedVariantConverter<ulong>(scope2.Links.Unsync);
556
557 var initialCount2 = scope2.Links.Unsync.Count();
558
559 var sw2 = Stopwatch.StartNew();
560
561 for (int i = START; i < END; i++)
562 {
563     compressed2[i] = balancedVariantConverter2.Convert(arrays[i]);
564 }
565
566 var elapsed2 = sw2.Elapsed;
567
568 for (int i = START; i < END; i++)
569 {
570     linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
571 }
572
573 var initialCount3 = scope3.Links.Unsync.Count();
574
575 var sw3 = Stopwatch.StartNew();
576
577 for (int i = START; i < END; i++)
578 {
579     //linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
580     compressed3[i] = optimalVariantConverter.Convert(arrays[i]);
581 }
582
583 var elapsed3 = sw3.Elapsed;
584
585 Console.WriteLine($"Compressor: {elapsed1}, Balanced variant: {elapsed2},
586     ↪ Optimal variant: {elapsed3}");
587
588 // Assert.True(elapsed1 > elapsed2);
589
590 // Checks
591 for (int i = START; i < END; i++)
592 {
593     var sequence1 = compressed1[i];
594     var sequence2 = compressed2[i];
595     var sequence3 = compressed3[i];
596
597     var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
598         ↪ scope1.Links.Unsync);
599
600     var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
601         ↪ scope2.Links.Unsync);
602
603     var decompress3 = UnicodeMap.FromSequenceLinkToString(sequence3,
604         ↪ scope3.Links.Unsync);
605
606     var structure1 = scope1.Links.Unsync.FormatStructure(sequence1, link =>
607         ↪ link.IsPartialPoint());
608     var structure2 = scope2.Links.Unsync.FormatStructure(sequence2, link =>
609         ↪ link.IsPartialPoint());
610     var structure3 = scope3.Links.Unsync.FormatStructure(sequence3, link =>
611         ↪ link.IsPartialPoint());
612
613     //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
614     ↪ arrays[i].Length > 3)
615     //    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 }))
        using (var scope2 = new TempLinksTestScope(useSequences: true))
669     {
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:
736 ↪ {elapsed2}");
737
738 Assert.True(elapsed1 > elapsed2);
739
740 // Checks
741 for (int i = START; i < END; i++)
742 {
743     var sequence1 = compressed1[i];
744     var sequence2 = compressed2[i];
745
746     if (sequence1 != _constants.Null && sequence2 != _constants.Null)
747     {
748         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
749             ↪ scope1.Links);

```

```

749         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
750             ↪ scope2.Links);
751
752         //var structure1 = scope1.Links.FormatStructure(sequence1, link =>
753             ↪ link.IsPartialPoint());
754         //var structure2 = scope2.Links.FormatStructure(sequence2, link =>
755             ↪ link.IsPartialPoint());
756
757         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
758             ↪ arrays[i].Length > 3)
759         //    Assert.False(structure1 == structure2);
760
761         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
762     }
763 }
764
765 Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
766 Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
767
768 Debug.WriteLine($"{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
769     ↪ totalCharacters} | {(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
770     ↪ totalCharacters}");
771
772 Assert.True(scope1.Links.Count() <= scope2.Links.Count());
773
774 //compressor1.ValidateFrequencies();
775 }
776 }
777
778 [Fact]
779 public static void RandomNumbersCompressionQualityTest()
780 {
781     const ulong N = 500;
782
783     //const ulong minNumbers = 10000;
784     //const ulong maxNumbers = 20000;
785
786     //var strings = new List<string>();
787
788     //for (ulong i = 0; i < N; i++)
789     //    strings.Add(RandomHelpers.DefaultFactory.NextUInt64(minNumbers,
790         ↪ maxNumbers).ToString());
791
792     var strings = new List<string>();
793
794     for (ulong i = 0; i < N; i++)
795     {
796         strings.Add(RandomHelpers.Default.NextUInt64().ToString());
797     }
798
799     strings = strings.Distinct().ToList();
800
801     var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
802     var totalCharacters = arrays.Select(x => x.Length).Sum();
803
804     using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
805         ↪ SequencesOptions<ulong> { UseCompression = true,
806         ↪ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
807     using (var scope2 = new TempLinksTestScope(useSequences: true))
808     {
809         scope1.Links.UseUnicode();
810         scope2.Links.UseUnicode();
811
812         var compressor1 = scope1.Sequences;
813         var compressor2 = scope2.Sequences;
814
815         var compressed1 = new ulong[arrays.Length];
816         var compressed2 = new ulong[arrays.Length];
817
818         var sw1 = Stopwatch.StartNew();
819
820         var START = 0;
821         var END = arrays.Length;
822
823         for (int i = START; i < END; i++)
824         {
825             compressed1[i] = compressor1.Create(arrays[i].ConvertToRestrictionsValues());
826         }
827     }
828 }

```

```

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($"Compressor: {elapsed1}, Balanced sequence creator:
833         ↳ {elapsed2}");
834
835     Assert.True(elapsed1 > elapsed2);
836
837     // Checks
838     for (int i = START; i < END; i++)
839     {
840         var sequence1 = compressed1[i];
841         var sequence2 = compressed2[i];
842
843         if (sequence1 != _constants.Null && sequence2 != _constants.Null)
844         {
845             var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
846                 ↳ scope1.Links);
847
848             var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
849                 ↳ scope2.Links);
850
851             Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
852         }
853     }
854
855     Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
856     Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
857
858     Debug.WriteLine($"{{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
859         ↳ totalCharacters}} | {{(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
860         ↳ totalCharacters}}");
861
862     // Can be worse than balanced variant
863     //Assert.True(scope1.Links.Count() <= scope2.Links.Count());
864
865     //compressor1.ValidateFrequencies();
866 }
867
868 [Fact]
869 public static void AllTreeBreakDownAtSequencesCreationBugTest()
870 {
871     // Made out of AllPossibleConnectionsTest test.
872
873     //const long sequenceLength = 5; //100% bug
874     const long sequenceLength = 4; //100% bug
875     //const long sequenceLength = 3; //100% _no_bug (ok)
876
877     using (var scope = new TempLinksTestScope(useSequences: true))
878     {
879         var links = scope.Links;
880         var sequences = scope.Sequences;
881
882         var sequence = new ulong[sequenceLength];
883         for (var i = 0; i < sequenceLength; i++)
884         {
885             sequence[i] = links.Create();
886         }
887
888         var createResults = sequences.CreateAllVariants2(sequence);
889
890         Global.Trash = createResults;
891
892         for (var i = 0; i < sequenceLength; i++)
893         {
894             links.Delete(sequence[i]);
895         }
896     }
897 }

```

```

893     }
894
895     [Fact]
896     public static void AllPossibleConnectionsTest()
897     {
898         const long sequenceLength = 5;
899
900         using (var scope = new TempLinksTestScope(useSequences: true))
901         {
902             var links = scope.Links;
903             var sequences = scope.Sequences;
904
905             var sequence = new ulong[sequenceLength];
906             for (var i = 0; i < sequenceLength; i++)
907             {
908                 sequence[i] = links.Create();
909             }
910
911             var createResults = sequences.CreateAllVariants2(sequence);
912             var reverseResults = sequences.CreateAllVariants2(sequence.Reverse().ToArray());
913
914             for (var i = 0; i < 1; i++)
915             {
916                 var sw1 = Stopwatch.StartNew();
917                 var searchResults1 = sequences.GetAllConnections(sequence); sw1.Stop();
918
919                 var sw2 = Stopwatch.StartNew();
920                 var searchResults2 = sequences.GetAllConnections1(sequence); sw2.Stop();
921
922                 var sw3 = Stopwatch.StartNew();
923                 var searchResults3 = sequences.GetAllConnections2(sequence); sw3.Stop();
924
925                 var sw4 = Stopwatch.StartNew();
926                 var searchResults4 = sequences.GetAllConnections3(sequence); sw4.Stop();
927
928                 Global.Trash = searchResults3;
929                 Global.Trash = searchResults4; //-V3008
930
931                 var intersection1 = createResults.Intersect(searchResults1).ToList();
932                 Assert.True(intersection1.Count == createResults.Length);
933
934                 var intersection2 = reverseResults.Intersect(searchResults1).ToList();
935                 Assert.True(intersection2.Count == reverseResults.Length);
936
937                 var intersection0 = searchResults1.Intersect(searchResults2).ToList();
938                 Assert.True(intersection0.Count == searchResults2.Count);
939
940                 var intersection3 = searchResults2.Intersect(searchResults3).ToList();
941                 Assert.True(intersection3.Count == searchResults3.Count);
942
943                 var intersection4 = searchResults3.Intersect(searchResults4).ToList();
944                 Assert.True(intersection4.Count == searchResults4.Count);
945             }
946
947             for (var i = 0; i < sequenceLength; i++)
948             {
949                 links.Delete(sequence[i]);
950             }
951         }
952     }
953
954     [Fact(Skip = "Correct implementation is pending")]
955     public static void CalculateAllUsagesTest()
956     {
957         const long sequenceLength = 3;
958
959         using (var scope = new TempLinksTestScope(useSequences: true))
960         {
961             var links = scope.Links;
962             var sequences = scope.Sequences;
963
964             var sequence = new ulong[sequenceLength];
965             for (var i = 0; i < sequenceLength; i++)
966             {
967                 sequence[i] = links.Create();
968             }
969
970             var createResults = sequences.CreateAllVariants2(sequence);
971

```

```

972         //var reverseResults =
973         ↪ sequences.CreateAllVariants2(sequence.Reverse().ToArray());
974     for (var i = 0; i < 1; i++)
975     {
976         var linksTotalUsages1 = new ulong[links.Count() + 1];
977
978         sequences.CalculateAllUsages(linksTotalUsages1);
979
980         var linksTotalUsages2 = new ulong[links.Count() + 1];
981
982         sequences.CalculateAllUsages2(linksTotalUsages2);
983
984         var intersection1 = linksTotalUsages1.Intersect(linksTotalUsages2).ToList();
985         Assert.True(intersection1.Count == linksTotalUsages2.Length);
986     }
987
988     for (var i = 0; i < sequenceLength; i++)
989     {
990         links.Delete(sequence[i]);
991     }
992 }
993 }
994 }
995 }

```

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

```

1  using System.IO;
2  using Platform.Disposables;
3  using Platform.Data.Doublets.Sequences;
4  using Platform.Data.Doublets.Decorators;
5  using Platform.Data.Doublets.ResizableDirectMemory.Specific;
6
7  namespace Platform.Data.Doublets.Tests
8  {
9      public class TempLinksTestScope : DisposableBase
10     {
11         public ILinks<ulong> MemoryAdapter { get; }
12         public SynchronizedLinks<ulong> Links { get; }
13         public Sequences.Sequences Sequences { get; }
14         public string TempFilename { get; }
15         public string TempTransactionLogFilename { get; }
16         private readonly bool _deleteFiles;
17
18         public TempLinksTestScope(bool deleteFiles = true, bool useSequences = false, bool
19             ↪ useLog = false) : this(new SequencesOptions<ulong>(), deleteFiles, useSequences,
20             ↪ useLog) { }
21
22         public TempLinksTestScope(SequencesOptions<ulong> sequencesOptions, bool deleteFiles =
23             ↪ true, bool useSequences = false, bool useLog = false)
24         {
25             _deleteFiles = deleteFiles;
26             TempFilename = Path.GetTempFileName();
27             TempTransactionLogFilename = Path.GetTempFileName();
28             var coreMemoryAdapter = new UInt64ResizableDirectMemoryLinks(TempFilename);
29             MemoryAdapter = useLog ? (ILinks<ulong>)new
30                 ↪ UInt64LinksTransactionsLayer(coreMemoryAdapter, TempTransactionLogFilename) :
31                 ↪ coreMemoryAdapter;
32             Links = new SynchronizedLinks<ulong>(new UInt64Links(MemoryAdapter));
33             if (useSequences)
34             {
35                 Sequences = new Sequences.Sequences(Links, sequencesOptions);
36             }
37         }
38
39         protected override void Dispose(bool manual, bool wasDisposed)
40         {
41             if (!wasDisposed)
42             {
43                 Links.Unsync.DisposeIfPossible();
44                 if (_deleteFiles)
45                 {
46                     DeleteFiles();
47                 }
48             }
49         }
50
51         public void DeleteFiles()
52         {
53
54         }
55     }
56 }

```

```

48         File.Delete(TempFilename);
49         File.Delete(TempTransactionLogFilename);
50     }
51 }
52 }

```

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

```

1  using System.Collections.Generic;
2  using Xunit;
3  using Platform.Ranges;
4  using Platform.Numbers;
5  using Platform.Random;
6  using Platform.Setters;
7
8  namespace Platform.Data.Doublets.Tests
9  {
10     public static class TestExtensions
11     {
12         public static void TestCRUDOperations<T>(this ILinks<T> links)
13         {
14             var constants = links.Constants;
15
16             var equalityComparer = EqualityComparer<T>.Default;
17
18             // Create Link
19             Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.Zero));
20
21             var setter = new Setter<T>(constants.Null);
22             links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);
23
24             Assert.True(equalityComparer.Equals(setter.Result, constants.Null));
25
26             var linkAddress = links.Create();
27
28             var link = new Link<T>(links.GetLink(linkAddress));
29
30             Assert.True(link.Count == 3);
31             Assert.True(equalityComparer.Equals(link.Index, linkAddress));
32             Assert.True(equalityComparer.Equals(link.Source, constants.Null));
33             Assert.True(equalityComparer.Equals(link.Target, constants.Null));
34
35             Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.One));
36
37             // Get first link
38             setter = new Setter<T>(constants.Null);
39             links.Each(constants.Any, constants.Any, setter.SetAndReturnFalse);
40
41             Assert.True(equalityComparer.Equals(setter.Result, linkAddress));
42
43             // Update link to reference itself
44             links.Update(linkAddress, linkAddress, linkAddress);
45
46             link = new Link<T>(links.GetLink(linkAddress));
47
48             Assert.True(equalityComparer.Equals(link.Source, linkAddress));
49             Assert.True(equalityComparer.Equals(link.Target, linkAddress));
50
51             // Update link to reference null (prepare for delete)
52             var updated = links.Update(linkAddress, constants.Null, constants.Null);
53
54             Assert.True(equalityComparer.Equals(updated, linkAddress));
55
56             link = new Link<T>(links.GetLink(linkAddress));
57
58             Assert.True(equalityComparer.Equals(link.Source, constants.Null));
59             Assert.True(equalityComparer.Equals(link.Target, constants.Null));
60
61             // Delete link
62             links.Delete(linkAddress);
63
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);
144     links.Each(constants.Any, constants.Any, setter3.SetAndReturnTrue);
145
146     Assert.True(equalityComparer.Equals(setter3.Result, linkAddress2));
147 }
148
149 public static void TestMultipleRandomCreationsAndDeletions<TLink>(this ILinks<TLink>
↪ links, int maximumOperationsPerCycle)
150 {
151     var comparer = Comparer<TLink>.Default;
152     for (var N = 1; N < maximumOperationsPerCycle; N++)
153     {

```

```

154     var random = new System.Random(N);
155     var created = 0;
156     var deleted = 0;
157     for (var i = 0; i < N; i++)
158     {
159         long linksCount = (Integer<TLink>)links.Count();
160         var createPoint = random.NextBoolean();
161         if (linksCount > 2 && createPoint)
162         {
163             var linksAddressRange = new Range<ulong>(1, (ulong)linksCount);
164             TLink source = (Integer<TLink>)random.NextUInt64(linksAddressRange);
165             TLink target = (Integer<TLink>)random.NextUInt64(linksAddressRange);
166             ↪ //-V3086
167             var resultLink = links.CreateAndUpdate(source, target);
168             if (comparer.Compare(resultLink, (Integer<TLink>)linksCount) > 0)
169             {
170                 created++;
171             }
172             else
173             {
174                 links.Create();
175                 created++;
176             }
177         }
178         Assert.True(created == (Integer<TLink>)links.Count());
179         for (var i = 0; i < N; i++)
180         {
181             TLink link = (Integer<TLink>)(i + 1);
182             if (links.Exists(link))
183             {
184                 links.Delete(link);
185                 deleted++;
186             }
187         }
188         Assert.True((Integer<TLink>)links.Count() == 0);
189     }
190 }
191 }
192 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Diagnostics;
4  using System.IO;
5  using System.Text;
6  using System.Threading;
7  using System.Threading.Tasks;
8  using Xunit;
9  using Platform.Disposables;
10 using Platform.IO;
11 using Platform.Ranges;
12 using Platform.Random;
13 using Platform.Timestamps;
14 using Platform.Reflection;
15 using Platform.Singletons;
16 using Platform.Scopes;
17 using Platform.Counters;
18 using Platform.Diagnostics;
19 using Platform.Memory;
20 using Platform.Data.Doublets.Decorators;
21 using Platform.Data.Doublets.ResizableDirectMemory.Specific;
22
23 namespace Platform.Data.Doublets.Tests
24 {
25     public static class UInt64LinksTests
26     {
27         private static readonly LinksConstants<ulong> _constants =
28             ↪ Default<LinksConstants<ulong>>.Instance;
29
30         private const long Iterations = 10 * 1024;
31
32         #region Concept
33
34         [Fact]
35         public static void MultipleCreateAndDeleteTest()
36         {
37             using (var scope = new Scope<Types<HeapResizableDirectMemory,
38                 ↪ UInt64ResizableDirectMemoryLinks>>())
39             {

```

```

38         new UInt64Links(scope.Use<ILinks<ulong>>()).TestMultipleRandomCreationsAndDeletions(100);
39     }
40 }
41
42 [Fact]
43 public static void CascadeUpdateTest()
44 {
45     var itself = _constants.Itself;
46     using (var scope = new TempLinksTestScope(useLog: true))
47     {
48         var links = scope.Links;
49
50         var l1 = links.Create();
51         var l2 = links.Create();
52
53         l2 = links.Update(l2, l2, l1, l2);
54
55         links.CreateAndUpdate(l2, itself);
56         links.CreateAndUpdate(l2, itself);
57
58         l2 = links.Update(l2, l1);
59
60         links.Delete(l2);
61
62         Global.Trash = links.Count();
63
64         links.Unsync.DisposeIfPossible(); // Close links to access log
65
66         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope.TempTransactionLogFilename);
67     }
68 }
69
70 [Fact]
71 public static void BasicTransactionLogTest()
72 {
73     using (var scope = new TempLinksTestScope(useLog: true))
74     {
75         var links = scope.Links;
76         var l1 = links.Create();
77         var l2 = links.Create();
78
79         Global.Trash = links.Update(l2, l2, l1, l2);
80
81         links.Delete(l1);
82
83         links.Unsync.DisposeIfPossible(); // Close links to access log
84
85         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope.TempTransactionLogFilename);
86     }
87 }
88
89 [Fact]
90 public static void TransactionAutoRevertedTest()
91 {
92     // Auto Reverted (Because no commit at transaction)
93     using (var scope = new TempLinksTestScope(useLog: true))
94     {
95         var links = scope.Links;
96         var transactionsLayer = (UInt64LinksTransactionsLayer)scope.MemoryAdapter;
97         using (var transaction = transactionsLayer.BeginTransaction())
98         {
99             var l1 = links.Create();
100             var l2 = links.Create();
101
102             links.Update(l2, l2, l1, l2);
103         }
104
105         Assert.Equal(0UL, links.Count());
106
107         links.Unsync.DisposeIfPossible();
108
109         var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope.TempTransactionLogFilename);
110         Assert.Single(transitions);
111     }
112 }

```

```

113 [Fact]
114 public static void TransactionUserCodeErrorNoDataSavedTest()
115 {
116     // User Code Error (Autoreverted), no data saved
117     var itself = _constants.Itself;
118
119     TempLinksTestScope lastScope = null;
120     try
121     {
122         using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
123             ↪ useLog: true))
124         {
125             var links = scope.Links;
126             var transactionsLayer = (UInt64LinksTransactionsLayer)((LinksDisposableDecor_
127             ↪ atorBase<ulong>)links.Unsync).Links;
128             using (var transaction = transactionsLayer.BeginTransaction())
129             {
130                 var l1 = links.CreateAndUpdate(itself, itself);
131                 var l2 = links.CreateAndUpdate(itself, itself);
132
133                 l2 = links.Update(l2, l2, l1, l2);
134
135                 links.CreateAndUpdate(l2, itself);
136                 links.CreateAndUpdate(l2, itself);
137
138                 //Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transi_
139                 ↪ tion>(scope.TempTransactionLogFilename);
140
141                 l2 = links.Update(l2, l1);
142
143                 links.Delete(l2);
144
145                 ExceptionThrower();
146
147                 transaction.Commit();
148             }
149             Global.Trash = links.Count();
150         }
151     } catch
152     {
153         Assert.False(lastScope == null);
154
155         var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(l_
156         ↪ astScope.TempTransactionLogFilename);
157
158         Assert.True(transitions.Length == 1 && transitions[0].Before.IsNull() &&
159         ↪ transitions[0].After.IsNull());
160
161         lastScope.DeleteFiles();
162     }
163 }
164 [Fact]
165 public static void TransactionUserCodeErrorSomeDataSavedTest()
166 {
167     // User Code Error (Autoreverted), some data saved
168     var itself = _constants.Itself;
169
170     TempLinksTestScope lastScope = null;
171     try
172     {
173         ulong l1;
174         ulong l2;
175
176         using (var scope = new TempLinksTestScope(useLog: true))
177         {
178             var links = scope.Links;
179             l1 = links.CreateAndUpdate(itself, itself);
180             l2 = links.CreateAndUpdate(itself, itself);
181
182             l2 = links.Update(l2, l2, l1, l2);
183
184             links.CreateAndUpdate(l2, itself);
185             links.CreateAndUpdate(l2, itself);
186
187             links.Unsync.DisposeIfPossible();

```

```

188         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(
189             ↪ scope.TempTransactionLogFilename);
190     }
191     using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
192         ↪ useLog: true))
193     {
194         var links = scope.Links;
195         var transactionsLayer = (UInt64LinksTransactionsLayer)links.Unsync;
196         using (var transaction = transactionsLayer.BeginTransaction())
197         {
198             l2 = links.Update(l2, l1);
199             links.Delete(l2);
200             ExceptionThrower();
201             transaction.Commit();
202         }
203         Global.Trash = links.Count();
204     }
205 }
206 }
207 }
208 }
209 catch
210 {
211     Assert.False(lastScope == null);
212     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(last
213         ↪ Scope.TempTransactionLogFilename);
214     lastScope.DeleteFiles();
215 }
216 }
217 }
218 }
219 [Fact]
220 public static void TransactionCommit()
221 {
222     var itself = _constants.Itself;
223     var tempDatabaseFilename = Path.GetTempFileName();
224     var tempTransactionLogFilename = Path.GetTempFileName();
225     // Commit
226     using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
227         ↪ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
228         ↪ tempTransactionLogFilename))
229     using (var links = new UInt64Links(memoryAdapter))
230     {
231         using (var transaction = memoryAdapter.BeginTransaction())
232         {
233             var l1 = links.CreateAndUpdate(itself, itself);
234             var l2 = links.CreateAndUpdate(itself, itself);
235             Global.Trash = links.Update(l2, l2, l1, l2);
236             links.Delete(l1);
237             transaction.Commit();
238         }
239         Global.Trash = links.Count();
240     }
241     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
242         ↪ sactionLogFilename);
243 }
244 }
245 }
246 }
247 }
248 [Fact]
249 public static void TransactionDamage()
250 {
251     var itself = _constants.Itself;
252     var tempDatabaseFilename = Path.GetTempFileName();
253     var tempTransactionLogFilename = Path.GetTempFileName();
254     // Commit
255     using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
256         ↪ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
257         ↪ tempTransactionLogFilename))

```

```

259 using (var links = new UInt64Links(memoryAdapter))
260 {
261     using (var transaction = memoryAdapter.BeginTransaction())
262     {
263         var l1 = links.CreateAndUpdate(itself, itself);
264         var l2 = links.CreateAndUpdate(itself, itself);
265
266         Global.Trash = links.Update(l2, l2, l1, l2);
267
268         links.Delete(l1);
269
270         transaction.Commit();
271     }
272
273     Global.Trash = links.Count();
274 }
275
276 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTransactionLogFilename);
277
278 // Damage database
279
280 FileHelpers.WriteFirst(tempTransactionLogFilename, new
    ↳ UInt64LinksTransactionsLayer.Transition(new UniqueTimestampFactory(), 555));
281
282 // Try load damaged database
283 try
284 {
285     // TODO: Fix
286     using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
        ↳ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
        ↳ tempTransactionLogFilename))
287     using (var links = new UInt64Links(memoryAdapter))
288     {
289         Global.Trash = links.Count();
290     }
291 }
292 catch (NotSupportedException ex)
293 {
294     Assert.True(ex.Message == "Database is damaged, autorecovery is not supported
        ↳ yet.");
295 }
296
297 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTransactionLogFilename);
298
299 File.Delete(tempDatabaseFilename);
300 File.Delete(tempTransactionLogFilename);
301 }
302
303 [Fact]
304 public static void Bug1Test()
305 {
306     var tempDatabaseFilename = Path.GetTempFileName();
307     var tempTransactionLogFilename = Path.GetTempFileName();
308
309     var itself = _constants.Itself;
310
311     // User Code Error (Autoreverted), some data saved
312     try
313     {
314         ulong l1;
315         ulong l2;
316
317         using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
            ↳ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
            ↳ tempTransactionLogFilename))
318         using (var links = new UInt64Links(memoryAdapter))
319         {
320             l1 = links.CreateAndUpdate(itself, itself);
321             l2 = links.CreateAndUpdate(itself, itself);
322
323             l2 = links.Update(l2, l2, l1, l2);
324
325             links.CreateAndUpdate(l2, itself);
326             links.CreateAndUpdate(l2, itself);
327         }
328     }

```

```

329         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp ↵
    ↵ TransactionLogFilename);
330
331     using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
    ↵ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
    ↵ tempTransactionLogFilename))
332     using (var links = new UInt64Links(memoryAdapter))
333     {
334         using (var transaction = memoryAdapter.BeginTransaction())
335         {
336             l2 = links.Update(l2, l1);
337
338             links.Delete(l2);
339
340             ExceptionThrower();
341
342             transaction.Commit();
343         }
344
345         Global.Trash = links.Count();
346     }
347 }
348 catch
349 {
350     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp ↵
    ↵ TransactionLogFilename);
351 }
352
353 File.Delete(tempDatabaseFilename);
354 File.Delete(tempTransactionLogFilename);
355 }
356
357 private static void ExceptionThrower() => throw new InvalidOperationException();
358
359 [Fact]
360 public static void PathsTest()
361 {
362     var source = _constants.SourcePart;
363     var target = _constants.TargetPart;
364
365     using (var scope = new TempLinksTestScope())
366     {
367         var links = scope.Links;
368         var l1 = links.CreatePoint();
369         var l2 = links.CreatePoint();
370
371         var r1 = links.GetByKeys(l1, source, target, source);
372         var r2 = links.CheckPathExistence(l2, l2, l2, l2);
373     }
374 }
375
376 [Fact]
377 public static void RecursiveStringFormattingTest()
378 {
379     using (var scope = new TempLinksTestScope(useSequences: true))
380     {
381         var links = scope.Links;
382         var sequences = scope.Sequences; // TODO: Auto use sequences on Sequences getter.
383
384         var a = links.CreatePoint();
385         var b = links.CreatePoint();
386         var c = links.CreatePoint();
387
388         var ab = links.CreateAndUpdate(a, b);
389         var cb = links.CreateAndUpdate(c, b);
390         var ac = links.CreateAndUpdate(a, c);
391
392         a = links.Update(a, c, b);
393         b = links.Update(b, a, c);
394         c = links.Update(c, a, b);
395
396         Debug.WriteLine(links.FormatStructure(ab, link => link.IsFullPoint(), true));
397         Debug.WriteLine(links.FormatStructure(cb, link => link.IsFullPoint(), true));
398         Debug.WriteLine(links.FormatStructure(ac, link => link.IsFullPoint(), true));
399
400         Assert.True(links.FormatStructure(cb, link => link.IsFullPoint(), true) ==
    ↵ "(5:(4:5 (6:5 4)) 6)");
401         Assert.True(links.FormatStructure(ac, link => link.IsFullPoint(), true) ==
    ↵ "(6:(5:(4:5 6) 6) 4)");

```

```

402     Assert.True(links.FormatStructure(ab, link => link.IsFullPoint(), true) ==
403         ↪ "(4:(5:4 (6:5 4)) 6)");
404
405     // TODO: Think how to build balanced syntax tree while formatting structure (eg.
406     ↪ "(4:(5:4 6) (6:5 4))" instead of "(4:(5:4 (6:5 4)) 6)")
407
408     Assert.True(sequences.SafeFormatSequence(cb, DefaultFormatter, false) ==
409         ↪ "{5}{5}{4}{6}");
410     Assert.True(sequences.SafeFormatSequence(ac, DefaultFormatter, false) ==
411         ↪ "{5}{6}{6}{4}");
412     Assert.True(sequences.SafeFormatSequence(ab, DefaultFormatter, false) ==
413         ↪ "{4}{5}{4}{6}");
414 }
415
416 private static void DefaultFormatter(StringBuilder sb, ulong link)
417 {
418     sb.Append(link.ToString());
419 }
420
421 #endregion
422
423 #region Performance
424
425 /*
426 public static void RunAllPerformanceTests()
427 {
428     try
429     {
430         links.TestLinksInSteps();
431     }
432     catch (Exception ex)
433     {
434         ex.WriteToConsole();
435     }
436
437     return;
438
439     try
440     {
441         //ThreadPool.SetMaxThreads(2, 2);
442
443         ↪ результат // Запускаем все тесты дважды, чтобы первоначальная инициализация не повлияла на
444
445         // Также это дополнительно помогает в отладке
446         // Увеличивает вероятность попадания информации в кэши
447         for (var i = 0; i < 10; i++)
448         {
449             //0 - 10 ГБ
450             //Каждые 100 МБ срез цифр
451
452             //links.TestGetSourceFunction();
453             //links.TestGetSourceFunctionInParallel();
454             //links.TestGetTargetFunction();
455             //links.TestGetTargetFunctionInParallel();
456             links.Create64BillionLinks();
457
458             links.TestRandomSearchFixed();
459             //links.Create64BillionLinksInParallel();
460             links.TestEachFunction();
461             //links.TestForeach();
462             //links.TestParallelForeach();
463         }
464
465         links.TestDeletionOfAllLinks();
466     }
467     catch (Exception ex)
468     {
469         ex.WriteToConsole();
470     }
471 }*/
472
473 /*
474 public static void TestLinksInSteps()
475 {
476     const long gibibyte = 1024 * 1024 * 1024;
477     const long mebibyte = 1024 * 1024;

```



```

475         var totalLinksToCreate = gibibyte /
↳ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
476         var linksStep = 102 * mebibyte /
↳ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
477
478         var creationMeasurements = new List<TimeSpan>();
479         var searchMeasurements = new List<TimeSpan>();
480         var deletionMeasurements = new List<TimeSpan>();
481
482         GetBaseRandomLoopOverhead(linksStep);
483         GetBaseRandomLoopOverhead(linksStep);
484
485         var stepLoopOverhead = GetBaseRandomLoopOverhead(linksStep);
486
487         ConsoleHelpers.Debug("Step loop overhead: {0}.", stepLoopOverhead);
488
489         var loops = totalLinksToCreate / linksStep;
490
491         for (int i = 0; i < loops; i++)
492         {
493             creationMeasurements.Add(Measure(() => links.RunRandomCreations(linksStep)));
494             searchMeasurements.Add(Measure(() => links.RunRandomSearches(linksStep)));
495
496             Console.WriteLine("\rC + S {0}/{1}", i + 1, loops);
497         }
498
499         ConsoleHelpers.Debug();
500
501         for (int i = 0; i < loops; i++)
502         {
503             deletionMeasurements.Add(Measure(() => links.RunRandomDeletions(linksStep)));
504
505             Console.WriteLine("\rD {0}/{1}", i + 1, loops);
506         }
507
508         ConsoleHelpers.Debug();
509
510         ConsoleHelpers.Debug("C S D");
511
512         for (int i = 0; i < loops; i++)
513         {
514             ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i],
↳ searchMeasurements[i], deletionMeasurements[i]);
515         }
516
517         ConsoleHelpers.Debug("C S D (no overhead)");
518
519         for (int i = 0; i < loops; i++)
520         {
521             ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i] - stepLoopOverhead,
↳ searchMeasurements[i] - stepLoopOverhead, deletionMeasurements[i] - stepLoopOverhead);
522         }
523
524         ConsoleHelpers.Debug("All tests done. Total links left in database: {0}.",
↳ links.Total);
525     }
526
527     private static void CreatePoints(this Platform.Links.Data.Core.Doublets.Links links, long
↳ amountToCreate)
528     {
529         for (long i = 0; i < amountToCreate; i++)
530             links.Create(0, 0);
531     }
532
533     private static TimeSpan GetBaseRandomLoopOverhead(long loops)
534     {
535         return Measure(() =>
536         {
537             ulong maxValue = RandomHelpers.DefaultFactory.NextUInt64();
538             ulong result = 0;
539             for (long i = 0; i < loops; i++)
540             {
541                 var source = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
542                 var target = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
543
544                 result += maxValue + source + target;
545             }
546             Global.Trash = result;
547         });

```

```

548 }
549 */
550
551 [Fact(Skip = "performance test")]
552 public static void GetSourceTest()
553 {
554     using (var scope = new TempLinksTestScope())
555     {
556         var links = scope.Links;
557         ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations.",
558             ↪ Iterations);
559
560         ulong counter = 0;
561
562         //var firstLink = links.First();
563         // Создаём одну связь, из которой будет производить считывание
564         var firstLink = links.Create();
565
566         var sw = Stopwatch.StartNew();
567
568         // Тестируем саму функцию
569         for (ulong i = 0; i < Iterations; i++)
570         {
571             counter += links.GetSource(firstLink);
572         }
573
574         var elapsedTime = sw.Elapsed;
575
576         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
577
578         // Удаляем связь, из которой производилось считывание
579         links.Delete(firstLink);
580
581         ConsoleHelpers.Debug(
582             "{0} Iterations of GetSource function done in {1} ({2} Iterations per
583             ↪ second), counter result: {3}",
584             Iterations, elapsedTime, (long)iterationsPerSecond, counter);
585     }
586
587 [Fact(Skip = "performance test")]
588 public static void GetSourceInParallel()
589 {
590     using (var scope = new TempLinksTestScope())
591     {
592         var links = scope.Links;
593         ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations in
594             ↪ parallel.", Iterations);
595
596         long counter = 0;
597
598         //var firstLink = links.First();
599         var firstLink = links.Create();
600
601         var sw = Stopwatch.StartNew();
602
603         // Тестируем саму функцию
604         Parallel.For(0, Iterations, x =>
605         {
606             Interlocked.Add(ref counter, (long)links.GetSource(firstLink));
607             //Interlocked.Increment(ref counter);
608         });
609
610         var elapsedTime = sw.Elapsed;
611
612         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
613
614         links.Delete(firstLink);
615
616         ConsoleHelpers.Debug(
617             "{0} Iterations of GetSource function done in {1} ({2} Iterations per
618             ↪ second), counter result: {3}",
619             Iterations, elapsedTime, (long)iterationsPerSecond, counter);
620     }
621 }
622
623 [Fact(Skip = "performance test")]
624 public static void TestGetTarget()
625 {

```

```

623 using (var scope = new TempLinksTestScope())
624 {
625     var links = scope.Links;
626     ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations.",
        ↪ Iterations);
627
628     ulong counter = 0;
629
630     //var firstLink = links.First();
631     var firstLink = links.Create();
632
633     var sw = Stopwatch.StartNew();
634
635     for (ulong i = 0; i < Iterations; i++)
636     {
637         counter += links.GetTarget(firstLink);
638     }
639
640     var elapsedTime = sw.Elapsed;
641
642     var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
643
644     links.Delete(firstLink);
645
646     ConsoleHelpers.Debug(
647         "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
        ↪ second), counter result: {3}",
        Iterations, elapsedTime, (long)iterationsPerSecond, counter);
648 }
649 }
650
651 [Fact(Skip = "performance test")]
652 public static void TestGetTargetInParallel()
653 {
654     using (var scope = new TempLinksTestScope())
655     {
656         var links = scope.Links;
657         ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations in
        ↪ parallel.", Iterations);
658
659         long counter = 0;
660
661         //var firstLink = links.First();
662         var firstLink = links.Create();
663
664         var sw = Stopwatch.StartNew();
665
666         Parallel.For(0, Iterations, x =>
667         {
668             Interlocked.Add(ref counter, (long)links.GetTarget(firstLink));
669             //Interlocked.Increment(ref counter);
670         });
671
672         var elapsedTime = sw.Elapsed;
673
674         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
675
676         links.Delete(firstLink);
677
678         ConsoleHelpers.Debug(
679             "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
        ↪ second), counter result: {3}",
        Iterations, elapsedTime, (long)iterationsPerSecond, counter);
680     }
681 }
682 }
683
684 // TODO: Заполнить базу данных перед тестом
685 /*
686 [Fact]
687 public void TestRandomSearchFixed()
688 {
689     var tempFilename = Path.GetTempFileName();
690
691     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
        ↪ DefaultLinksSizeStep))
692     {
693         long iterations = 64 * 1024 * 1024 /
694         ↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
695

```

```

696         ulong counter = 0;
697         var maxLink = links.Total;
698
699         ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.", iterations);
700
701         var sw = Stopwatch.StartNew();
702
703         for (var i = iterations; i > 0; i--)
704         {
705             var source =
↪ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
706             var target =
↪ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
707
708             counter += links.Search(source, target);
709         }
710
711         var elapsedTime = sw.Elapsed;
712
713         var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
714
715         ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
↪ Iterations per second), c: {3}", iterations, elapsedTime, (long)iterationsPerSecond,
↪ counter);
716     }
717
718     File.Delete(tempFilename);
719 }*/
720
721 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
722 public static void TestRandomSearchAll()
723 {
724     using (var scope = new TempLinksTestScope())
725     {
726         var links = scope.Links;
727         ulong counter = 0;
728
729         var maxLink = links.Count();
730
731         var iterations = links.Count();
732
733         ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.",
↪ links.Count());
734
735         var sw = Stopwatch.StartNew();
736
737         for (var i = iterations; i > 0; i--)
738         {
739             var linksAddressRange = new
↪ Range<ulong>(_constants.PossibleInnerReferencesRange.Minimum, maxLink);
740
741             var source = RandomHelpers.Default.NextUInt64(linksAddressRange);
742             var target = RandomHelpers.Default.NextUInt64(linksAddressRange);
743
744             counter += links.SearchOrDefault(source, target);
745         }
746
747         var elapsedTime = sw.Elapsed;
748
749         var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
750
751         ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
↪ Iterations per second), c: {3}",
↪ iterations, elapsedTime, (long)iterationsPerSecond, counter);
752     }
753 }
754
755 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
756 public static void TestEach()
757 {
758     using (var scope = new TempLinksTestScope())
759     {
760         var links = scope.Links;
761
762         var counter = new Counter<IList<ulong>, ulong>(links.Constants.Continue);
763
764         ConsoleHelpers.Debug("Testing Each function.");
765
766         var sw = Stopwatch.StartNew();
767
768

```

```

769         links.Each(counter.IncrementAndReturnTrue);
770
771         var elapsedTime = sw.Elapsed;
772
773         var linksPerSecond = counter.Count / elapsedTime.TotalSeconds;
774
775         ConsoleHelpers.Debug("{0} Iterations of Each's handler function done in {1} ({2}
↪         links per second)",
            counter, elapsedTime, (long)linksPerSecond);
776     }
777 }
778
779 /*
780 [Fact]
781 public static void TestForeach()
782 {
783     var tempFilename = Path.GetTempFileName();
784
785     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
↪     DefaultLinksSizeStep))
786     {
787         ulong counter = 0;
788
789         ConsoleHelpers.Debug("Testing foreach through links.");
790
791         var sw = Stopwatch.StartNew();
792
793         //foreach (var link in links)
794         //{
795             //    counter++;
796         //}
797
798         var elapsedTime = sw.Elapsed;
799
800         var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
801
802         ConsoleHelpers.Debug("{0} Iterations of Foreach's handler block done in {1} ({2}
↪     links per second)", counter, elapsedTime, (long)linksPerSecond);
803     }
804
805     File.Delete(tempFilename);
806 }
807 */
808
809 /*
810 [Fact]
811 public static void TestParallelForeach()
812 {
813     var tempFilename = Path.GetTempFileName();
814
815     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
↪     DefaultLinksSizeStep))
816     {
817         long counter = 0;
818
819         ConsoleHelpers.Debug("Testing parallel foreach through links.");
820
821         var sw = Stopwatch.StartNew();
822
823         //Parallel.ForEach((IEnumerable<ulong>)links, x =>
824         //{
825             //    Interlocked.Increment(ref counter);
826         //});
827
828         var elapsedTime = sw.Elapsed;
829
830         var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
831
832         ConsoleHelpers.Debug("{0} Iterations of Parallel Foreach's handler block done in
↪     {1} ({2} links per second)", counter, elapsedTime, (long)linksPerSecond);
833     }
834
835     File.Delete(tempFilename);
836 }
837 */
838
839 [Fact(Skip = "performance test")]
840 public static void Create64BillionLinks()
841 {
842
843

```

```

844 using (var scope = new TempLinksTestScope())
845 {
846     var links = scope.Links;
847     var linksBeforeTest = links.Count();
848
849     long linksToCreate = 64 * 1024 * 1024 /
850         ↳ 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)",
868         ↳ linksCreated, elapsedTime,
869         (long)linksPerSecond);
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 /
883             ↳ UInt64ResizableDirectMemoryLinks.LinkSizeInBytes;
884
885         ConsoleHelpers.Debug("Creating {0} links in parallel.", linksToCreate);
886
887         Parallel.For(0, linksToCreate, x => links.Create());
888
889         var elapsedTime = sw.Elapsed;
890
891         var linksCreated = links.Count() - linksBeforeTest;
892         var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
893
894         ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
895             ↳ linksCreated, elapsedTime,
896             (long)linksPerSecond);
897     }
898 }
899
900 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
901 public static void TestDeletionOfAllLinks()
902 {
903     using (var scope = new TempLinksTestScope())
904     {
905         var links = scope.Links;
906         var linksBeforeTest = links.Count();
907
908         ConsoleHelpers.Debug("Deleting all links");
909
910         var elapsedTime = Performance.Measure(links.DeleteAll);
911
912         var linksDeleted = linksBeforeTest - links.Count();
913         var linksPerSecond = linksDeleted / elapsedTime.TotalSeconds;
914
915         ConsoleHelpers.Debug("{0} links deleted in {1} ({2} links per second)",
916             ↳ linksDeleted, elapsedTime,
917             (long)linksPerSecond);
918     }
919 }
920
921 #endregion
922 }

```

./Platform.Data.Doublets.Tests/UnaryNumberConvertersTests.cs

```

1  using Xunit;
2  using Platform.Random;
3  using Platform.Data.Doublets.Numbers.Unary;
4
5  namespace Platform.Data.Doublets.Tests
6  {
7      public static class UnaryNumberConvertersTests
8      {
9          [Fact]
10         public static void ConvertersTest()
11         {
12             using (var scope = new TempLinksTestScope())
13             {
14                 const int N = 10;
15                 var links = scope.Links;
16                 var meaningRoot = links.CreatePoint();
17                 var one = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
18                 var powerOf2ToUnaryNumberConverter = new
19                     ↪ PowerOf2ToUnaryNumberConverter<ulong>(links, one);
20                 var toUnaryNumberConverter = new AddressToUnaryNumberConverter<ulong>(links,
21                     ↪ powerOf2ToUnaryNumberConverter);
22                 var random = new System.Random(0);
23                 ulong[] numbers = new ulong[N];
24                 ulong[] unaryNumbers = new ulong[N];
25                 for (int i = 0; i < N; i++)
26                 {
27                     numbers[i] = random.NextUInt64();
28                     unaryNumbers[i] = toUnaryNumberConverter.Convert(numbers[i]);
29                 }
30                 var fromUnaryNumberConverterUsingOrOperation = new
31                     ↪ UnaryNumberToAddressOrOperationConverter<ulong>(links,
32                     ↪ powerOf2ToUnaryNumberConverter);
33                 var fromUnaryNumberConverterUsingAddOperation = new
34                     ↪ UnaryNumberToAddressAddOperationConverter<ulong>(links, one);
35                 for (int i = 0; i < N; i++)
36                 {
37                     Assert.Equal(numbers[i],
38                         ↪ fromUnaryNumberConverterUsingOrOperation.Convert(unaryNumbers[i]));
39                     Assert.Equal(numbers[i],
40                         ↪ fromUnaryNumberConverterUsingAddOperation.Convert(unaryNumbers[i]));
41                 }
42             }
43         }
44     }
45 }

```

./Platform.Data.Doublets.Tests/UnicodeConvertersTests.cs

```

1  using Xunit;
2  using Platform.Interfaces;
3  using Platform.Memory;
4  using Platform.Reflection;
5  using Platform.Scopes;
6  using Platform.Data.Doublets.Incrementers;
7  using Platform.Data.Doublets.Numbers.Raw;
8  using Platform.Data.Doublets.Numbers.Unary;
9  using Platform.Data.Doublets.PropertyOperators;
10 using Platform.Data.Doublets.Sequences.Converters;
11 using Platform.Data.Doublets.Sequences.Indexes;
12 using Platform.Data.Doublets.Sequences.Walkers;
13 using Platform.Data.Doublets.Unicode;
14 using Platform.Data.Doublets.ResizableDirectMemory.Generic;
15
16 namespace Platform.Data.Doublets.Tests
17 {
18     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
29                     ↪ 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
      ↳ LinkToItsFrequencyNumberConverter<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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