

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  namespace Platform.Data.Doublets.Decorators
4  {
5      public class LinksCascadeUniquenessAndUsagesResolver<TLink> : LinksUniquenessResolver<TLink>
6      {
7          public LinksCascadeUniquenessAndUsagesResolver(ILinks<TLink> links) : base(links) { }
8
9          protected override TLink ResolveAddressChangeConflict(TLink oldLinkAddress, TLink
10             ↪ newLinkAddress)
11          {
12              Links.MergeUsages(oldLinkAddress, newLinkAddress);
13              return base.ResolveAddressChangeConflict(oldLinkAddress, newLinkAddress);
14          }
15     }

```

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

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  namespace Platform.Data.Doublets.Decorators
4  {
5      /// <remarks>
6      /// <para>Must be used in conjunction with NonNullContentsLinkDeletionResolver.</para>
7      /// <para>Должен использоваться вместе с NonNullContentsLinkDeletionResolver.</para>
8      /// </remarks>
9      public class LinksCascadeUsagesResolver<TLink> : LinksDecoratorBase<TLink>
10     {
11         public LinksCascadeUsagesResolver(ILinks<TLink> links) : base(links) { }
12
13         public override void Delete(TLink linkIndex)
14         {
15             this.DeleteAllUsages(linkIndex);
16             Links.Delete(linkIndex);
17         }
18     }
19 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Data.Constants;
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         public LinksCombinedConstants<TLink, TLink, int> Constants { get; }
12         protected LinksDecoratorBase(ILinks<TLink> links) : base(links) => Constants =
13             ↪ links.Constants;
14         public virtual TLink Count(IList<TLink> restriction) => Links.Count(restriction);
15         public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
16             ↪ => Links.Each(handler, restrictions);
17         public virtual TLink Create() => Links.Create();
18         public virtual TLink Update(IList<TLink> restrictions) => Links.Update(restrictions);
19         public virtual void Delete(TLink link) => Links.Delete(link);
20     }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Disposables;
4  using Platform.Data.Constants;
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         public LinksCombinedConstants<TLink, TLink, int> Constants { get; }
13
14         public ILinks<TLink> Links { get; }
15     }

```

```

16     protected LinksDisposableDecoratorBase(ILinks<TLink> links)
17     {
18         Links = links;
19         Constants = links.Constants;
20     }
21
22     public virtual TLink Count(IList<TLink> restriction) => Links.Count(restriction);
23
24     public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
25     ↪ => Links.Each(handler, restrictions);
26
27     public virtual TLink Create() => Links.Create();
28
29     public virtual TLink Update(IList<TLink> restrictions) => Links.Update(restrictions);
30
31     public virtual void Delete(TLink link) => Links.Delete(link);
32
33     protected override bool AllowMultipleDisposeCalls => true;
34
35     protected override void Dispose(bool manual, bool wasDisposed)
36     {
37         if (!wasDisposed)
38         {
39             Links.DisposeIfPossible();
40         }
41     }
42 }

```

./Platform.Data.Doublets/Decorators/LinksInnerReferenceExistenceValidator.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.Decorators
7  {
8      // TODO: Make LinksExternalReferenceValidator. A layer that checks each link to exist or to
9      ↪ be external (hybrid link's raw number).
10     public class LinksInnerReferenceExistenceValidator<TLink> : LinksDecoratorBase<TLink>
11     {
12         public LinksInnerReferenceExistenceValidator(ILinks<TLink> links) : base(links) { }
13
14         public override TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
15         {
16             Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
17             return Links.Each(handler, restrictions);
18         }
19
20         public override TLink Update(IList<TLink> restrictions)
21         {
22             // TODO: Possible values: null, ExistentLink or NonExistentHybrid(ExternalReference)
23             Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
24             return Links.Update(restrictions);
25         }
26
27         public override void Delete(TLink link)
28         {
29             Links.EnsureLinkExists(link, nameof(link));
30             Links.Delete(link);
31         }
32     }
33 }

```

./Platform.Data.Doublets/Decorators/LinksItselfConstantToSelfReferenceResolver.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.Decorators
7  {
8     public class LinksItselfConstantToSelfReferenceResolver<TLink> : LinksDecoratorBase<TLink>
9     {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11         ↪ EqualityComparer<TLink>.Default;
12
13         public LinksItselfConstantToSelfReferenceResolver(ILinks<TLink> links) : base(links) { }
14
15         public override TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)

```

```

15     {
16         var constants = Constants;
17         var itselfConstant = constants.Itself;
18         var indexPartConstant = constants.IndexPart;
19         var sourcePartConstant = constants.SourcePart;
20         var targetPartConstant = constants.TargetPart;
21         var restrictionsCount = restrictions.Count;
22         if (!_equalityComparer.Equals(constants.Any, itselfConstant)
23             && (((restrictionsCount > indexPartConstant) &&
24                 ↪ _equalityComparer.Equals(restrictions[indexPartConstant], itselfConstant))
25                 || ((restrictionsCount > sourcePartConstant) &&
26                     ↪ _equalityComparer.Equals(restrictions[sourcePartConstant], itselfConstant))
27                 || ((restrictionsCount > targetPartConstant) &&
28                     ↪ _equalityComparer.Equals(restrictions[targetPartConstant], itselfConstant))))
29             {
30                 // Itself constant is not supported for Each method right now, skipping execution
31                 return constants.Continue;
32             }
33         return Links.Each(handler, restrictions);
34     }
35 }

```

./Platform.Data.Doublets/Decorators/LinksNonExistentDependenciesCreator.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.Decorators
6 {
7     /// <remarks>
8     /// Not practical if newSource and newTarget are too big.
9     /// To be able to use practical version we should allow to create link at any specific
10     ↪ location inside ResizableDirectMemoryLinks.
11     /// This in turn will require to implement not a list of empty links, but a list of ranges
12     ↪ to store it more efficiently.
13     /// </remarks>
14     public class LinksNonExistentDependenciesCreator<TLink> : LinksDecoratorBase<TLink>
15     {
16         public LinksNonExistentDependenciesCreator(ILinks<TLink> links) : base(links) { }
17
18         public override TLink Update(IList<TLink> restrictions)
19         {
20             var constants = Constants;
21             Links.EnsureCreated(restrictions[constants.SourcePart],
22                 ↪ restrictions[constants.TargetPart]);
23             return Links.Update(restrictions);
24         }
25     }
26 }

```

./Platform.Data.Doublets/Decorators/LinksNullConstantToSelfReferenceResolver.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.Decorators
6 {
7     public class LinksNullConstantToSelfReferenceResolver<TLink> : LinksDecoratorBase<TLink>
8     {
9         public LinksNullConstantToSelfReferenceResolver(ILinks<TLink> links) : base(links) { }
10
11         public override TLink Create()
12         {
13             var link = Links.Create();
14             return Links.Update(link, link, link);
15         }
16
17         public override TLink Update(IList<TLink> restrictions) =>
18             ↪ Links.Update(Links.ResolveConstantAsSelfReference(Constants.Null, restrictions));
19     }
20 }

```

./Platform.Data.Doublets/Decorators/LinksUniquenessResolver.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.Decorators
6 {
7     public class LinksUniquenessResolver<TLink> : LinksDecoratorBase<TLink>
8     {
9         private static readonly EqualityComparer<TLink> _equalityComparer =
10             ⇨ EqualityComparer<TLink>.Default;
11
12         public LinksUniquenessResolver(ILinks<TLink> links) : base(links) { }
13
14         public override TLink Update(IList<TLink> restrictions)
15         {
16             var newLinkAddress = Links.SearchOrDefault(restrictions[Constants.SourcePart],
17                 ⇨ restrictions[Constants.TargetPart]);
18             if (_equalityComparer.Equals(newLinkAddress, default))
19             {
20                 return Links.Update(restrictions);
21             }
22             return ResolveAddressChangeConflict(restrictions[Constants.IndexPart],
23                 ⇨ newLinkAddress);
24         }
25
26         protected virtual TLink ResolveAddressChangeConflict(TLink oldLinkAddress, TLink
27             ⇨ newLinkAddress)
28         {
29             if (!_equalityComparer.Equals(oldLinkAddress, newLinkAddress) &&
30                 ⇨ Links.Exists(oldLinkAddress))
31             {
32                 Delete(oldLinkAddress);
33             }
34             return newLinkAddress;
35         }
36     }
37 }
```

./Platform.Data.Doublets/Decorators/LinksUniquenessValidator.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.Decorators
6 {
7     public class LinksUniquenessValidator<TLink> : LinksDecoratorBase<TLink>
8     {
9         public LinksUniquenessValidator(ILinks<TLink> links) : base(links) { }
10
11         public override TLink Update(IList<TLink> restrictions)
12         {
13             Links.EnsureDoesNotExists(restrictions[Constants.SourcePart],
14                 ⇨ restrictions[Constants.TargetPart]);
15             return Links.Update(restrictions);
16         }
17     }
18 }
```

./Platform.Data.Doublets/Decorators/LinksUsagesValidator.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.Decorators
6 {
7     public class LinksUsagesValidator<TLink> : LinksDecoratorBase<TLink>
8     {
9         public LinksUsagesValidator(ILinks<TLink> links) : base(links) { }
10
11         public override TLink Update(IList<TLink> restrictions)
12         {
13             Links.EnsureNoUsages(restrictions[Constants.IndexPart]);
14             return Links.Update(restrictions);
15         }
16
17         public override void Delete(TLink link)
18         {
19             Links.EnsureNoUsages(link);
20         }
21     }
22 }
```

```

20         Links.Delete(link);
21     }
22 }
23 }

```

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

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  namespace Platform.Data.Doublets.Decorators
4  {
5      public class NonNullContentsLinkDeletionResolver<TLink> : LinksDecoratorBase<TLink>
6      {
7          public NonNullContentsLinkDeletionResolver(ILinks<TLink> links) : base(links) { }
8
9          public override void Delete(TLink linkIndex)
10         {
11             Links.EnforceResetValues(linkIndex);
12             Links.Delete(linkIndex);
13         }
14     }
15 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Collections;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Decorators
8  {
9      /// <summary>
10     /// Представляет объект для работы с базой данных (файлом) в формате Links (массива связей).
11     /// </summary>
12     /// <remarks>
13     /// Возможные оптимизации:
14     /// Объединение в одном поле Source и Target с уменьшением до 32 бит.
15     ///     + меньше объём БД
16     ///     - меньше производительность
17     ///     - больше ограничение на количество связей в БД)
18     /// Ленивое хранение размеров поддеревьев (расчитываемое по мере использования БД)
19     ///     + меньше объём БД
20     ///     - больше сложность
21     ///
22     /// Текущее теоретическое ограничение на индекс связи, из-за использования 5 бит в размере
23     ↪ поддеревьев для AVL баланса и флагов нитей: 2 в степени(64 минус 5 равно 59 ) равно 576
24     ↪ 460 752 303 423 488
25     /// Желательно реализовать поддержку переключения между деревьями и битовыми индексами
26     ↪ (битовыми строками) - вариант матрицы (выстраиваемой лениво).
27     ///
28     /// Решить отключать ли проверки при компиляции под Release. Т.е. исключения будут
29     ↪ выбрасываться только при #if DEBUG
30     /// </remarks>
31     public class UInt64Links : LinksDisposableDecoratorBase<ulong>
32     {
33         public UInt64Links(ILinks<ulong> links) : base(links) { }
34
35         public override ulong Each(Func<IList<ulong>, ulong> handler, IList<ulong> restrictions)
36         {
37             this.EnsureLinkIsAnyOrExists(restrictions);
38             return Links.Each(handler, restrictions);
39         }
40
41         public override ulong Create() => Links.CreatePoint();
42
43         public override ulong Update(IList<ulong> restrictions)
44         {
45             var constants = Constants;
46             var nullConstant = constants.Null;
47             if (restrictions.IsNullOrEmpty())
48             {
49                 return nullConstant;
50             }
51             // TODO: Looks like this is a common type of exceptions linked with restrictions
52             ↪ support
53             if (restrictions.Count != 3)
54             {
55                 throw new NotSupportedException();
56             }
57         }
58     }
59 }

```

```

52     var indexPartConstant = constants.IndexPart;
53     var updatedLink = restrictions[indexPartConstant];
54     this.EnsureLinkExists(updatedLink,
55         ↪ $"{nameof(restrictions)}[{nameof(indexPartConstant)}]");
56     var sourcePartConstant = constants.SourcePart;
57     var newSource = restrictions[sourcePartConstant];
58     this.EnsureLinkIsItselfOrExists(newSource,
59         ↪ $"{nameof(restrictions)}[{nameof(sourcePartConstant)}]");
60     var targetPartConstant = constants.TargetPart;
61     var newTarget = restrictions[targetPartConstant];
62     this.EnsureLinkIsItselfOrExists(newTarget,
63         ↪ $"{nameof(restrictions)}[{nameof(targetPartConstant)}]");
64     var existedLink = nullConstant;
65     var itselfConstant = constants.Itself;
66     if (newSource != itselfConstant && newTarget != itselfConstant)
67     {
68         existedLink = this.SearchOrDefault(newSource, newTarget);
69     }
70     if (existedLink == nullConstant)
71     {
72         var before = Links.GetLink(updatedLink);
73         if (before[sourcePartConstant] != newSource || before[targetPartConstant] !=
74             ↪ newTarget)
75         {
76             Links.Update(updatedLink, newSource == itselfConstant ? updatedLink :
77                 ↪ newSource,
78                                     newTarget == itselfConstant ? updatedLink :
79                 ↪ newTarget);
80         }
81         return updatedLink;
82     }
83     else
84     {
85         return this.MergeAndDelete(updatedLink, existedLink);
86     }
87 }
88
89 public override void Delete(ulong linkIndex)
90 {
91     Links.EnsureLinkExists(linkIndex);
92     Links.EnforceResetValues(linkIndex);
93     this.DeleteAllUsages(linkIndex);
94     Links.Delete(linkIndex);
95 }
96 }

```

./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
16     ↪ by itself. But can cause creation (update from nothing) or deletion (update to nothing).
17     ///
18     /// TODO: Decide to change to IDoubletLinks or not to change. (Better to create
19     ↪ DefaultUniLinksBase, that contains logic itself and can be implemented using both
20     ↪ IDoubletLinks and ILinks.)
21     /// </remarks>
22     internal class UniLinks<TLink> : LinksDecoratorBase<TLink>, IUniLinks<TLink>
23     {
24         private static readonly EqualityComparer<TLink> _equalityComparer =
25             ↪ EqualityComparer<TLink>.Default;
26
27         public UniLinks(ILinks<TLink> links) : base(links) { }
28
29         private struct Transition
30         {
31             public IList<TLink> Before;

```

```

28     public IList<TLink> After;
29
30     public Transition(IList<TLink> before, IList<TLink> after)
31     {
32         Before = before;
33         After = after;
34     }
35 }
36
37 //public static readonly TLink NullConstant = Use<LinksCombinedConstants<TLink, TLink,
38     ↳ int>>.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     ///                if (!Memory.Each(handler, restriction))
94     ///                    return Constants.Break;
95     ///            }
96     ///        }
97     ///        else
98     ///        {
99     ///            Func<T, bool> handler = link =>
100     ///            {
101     ///                var matchedLink = Memory.GetLinkValue(link);
102     ///                var matchDecision = matchedHandler(matchedLink, matchedLink);
103     ///                return !Equals(matchDecision, Constants.Break);
104     ///            };

```

```

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;
162 //        };
163 //        if (!Memory.Each(handler, restriction))
164 //            return Constants.Break;
165 //    }
166 //    if (!matchedLinks.IsNullOrEmpty())
167 //    {
168 //        var totalMatchedLinks = matchedLinks.Count;
169 //        for (var i = 0; i < totalMatchedLinks; i++)
170 //        {

```



```

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         //     }
192     }
193     return Constants.Continue;
194 }

195 public TLink Trigger(IList<TLink> patternOrCondition, Func<IList<TLink>, TLink>
196     matchHandler, IList<TLink> substitution, Func<IList<TLink>, IList<TLink>, TLink>
197     substitutedHandler)
198 {
199     if (patternOrCondition.IsNullOrEmpty() && substitution.IsNullOrEmpty())
200     {
201         return Constants.Continue;
202     }
203     else if (patternOrCondition.EqualTo(substitution)) // Should be Each here TODO:
204     {
205         // Check if it is a correct condition
206         // Or it only applies to trigger without matchHandler.
207         throw new NotImplementedException();
208     }
209     else if (!substitution.IsNullOrEmpty()) // Creation
210     {
211         var before = ArrayPool<TLink>.Empty;
212         // Что должно означать False здесь? Остановиться (перестать идти) или пропустить
213         // (пройти мимо) или пустить (взять)?
214         if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
215             Constants.Break))
216         {
217             return Constants.Break;
218         }
219         var after = (IList<TLink>)substitution.ToArray();
220         if (_equalityComparer.Equals(after[0], default))
221         {
222             var newLink = Links.Create();
223             after[0] = newLink;
224         }
225         if (substitution.Count == 1)
226         {
227             after = Links.GetLink(substitution[0]);
228         }
229         else if (substitution.Count == 3)
230         {
231             Links.Update(after);
232         }
233         else
234         {
235             throw new NotSupportedException();
236         }
237         if (matchHandler != null)
238         {
239             return substitutedHandler(before, after);
240         }
241         return Constants.Continue;
242     }
243     else if (!patternOrCondition.IsNullOrEmpty()) // Deletion
244     {
245         if (patternOrCondition.Count == 1)

```

```

{
    var linkToDelete = patternOrCondition[0];
    var before = Links.GetLink(linkToDelete);
    if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
        ↪ Constants.Break))
    {
        return Constants.Break;
    }
    var after = ArrayPool<TLink>.Empty;
    Links.Update(linkToDelete, Constants.Null, Constants.Null);
    Links.Delete(linkToDelete);
    if (matchHandler != null)
    {
        return substitutionHandler(before, after);
    }
    return Constants.Continue;
}
else
{
    throw new NotSupportedException();
}
}
else // Replace / Update
{
    if (patternOrCondition.Count == 1) //-V3125
    {
        var linkToUpdate = patternOrCondition[0];
        var before = Links.GetLink(linkToUpdate);
        if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
            ↪ Constants.Break))
        {
            return Constants.Break;
        }
        var after = (IList<TLink>)substitution.ToArray(); //-V3125
        if (_equalityComparer.Equals(after[0], default))
        {
            after[0] = linkToUpdate;
        }
        if (substitution.Count == 1)
        {
            if (!_equalityComparer.Equals(substitution[0], linkToUpdate))
            {
                after = Links.GetLink(substitution[0]);
                Links.Update(linkToUpdate, Constants.Null, Constants.Null);
                Links.Delete(linkToUpdate);
            }
        }
        else if (substitution.Count == 3)
        {
            Links.Update(after);
        }
        else
        {
            throw new NotSupportedException();
        }
        if (matchHandler != null)
        {
            return substitutionHandler(before, after);
        }
        return Constants.Continue;
    }
    else
    {
        throw new NotSupportedException();
    }
}
}
}

/// <remarks>
/// IList[IList[IList[T]]]
/// |         |         |         |||
/// |         |         ----- |||
/// |         |         link   |||
/// |         -----      |||
/// |         change       |||
/// |-----              |||
/// |           changes     |||
/// </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 Platform.Reflection;

```

```

4 using Platform.Converters;
5 using Platform.Exceptions;
6
7 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9 namespace Platform.Data.Doublets
10 {
11     public class Hybrid<T>
12     {
13         public readonly T Value;
14         public bool IsNothing => Convert.ToInt64(To.Signed(Value)) == 0;
15         public bool IsInternal => Convert.ToInt64(To.Signed(Value)) > 0;
16         public bool IsExternal => Convert.ToInt64(To.Signed(Value)) < 0;
17         public long AbsoluteValue => Numbers.Math.Abs(Convert.ToInt64(To.Signed(Value)));
18
19         public Hybrid(T value)
20         {
21             Ensure.Always.IsUnsignedInteger<T>();
22             Value = value;
23         }
24
25         public Hybrid(object value) => Value = To.UnsignedAs<T>(Convert.ChangeType(value,
26             ↪ Type<T>.SignedVersion));
27
28         public Hybrid(object value, bool isExternal)
29         {
30             var signedType = Type<T>.SignedVersion;
31             var signedValue = Convert.ChangeType(value, signedType);
32             var abs = typeof(Numbers.Math).GetTypeInfo().GetMethod("Abs").MakeGenericMethod(signedType);
33             var negate = typeof(Numbers.Math).GetTypeInfo().GetMethod("Negate").MakeGenericMethod(signedType);
34             var absoluteValue = abs.Invoke(null, new[] { signedValue });
35             var resultValue = isExternal ? negate.Invoke(null, new[] { absoluteValue }) : absoluteValue;
36             Value = To.UnsignedAs<T>(resultValue);
37         }
38
39         public static implicit operator Hybrid<T>(T integer) => new Hybrid<T>(integer);
40         public static explicit operator Hybrid<T>(ulong integer) => new Hybrid<T>(integer);
41         public static explicit operator Hybrid<T>(long integer) => new Hybrid<T>(integer);
42         public static explicit operator Hybrid<T>(uint integer) => new Hybrid<T>(integer);
43         public static explicit operator Hybrid<T>(int integer) => new Hybrid<T>(integer);
44         public static explicit operator Hybrid<T>(ushort integer) => new Hybrid<T>(integer);
45         public static explicit operator Hybrid<T>(short integer) => new Hybrid<T>(integer);
46         public static explicit operator Hybrid<T>(byte integer) => new Hybrid<T>(integer);
47         public static explicit operator Hybrid<T>(sbyte integer) => new Hybrid<T>(integer);
48         public static implicit operator T(Hybrid<T> hybrid) => hybrid.Value;
49         public static explicit operator ulong(Hybrid<T> hybrid) =>
50             ↪ Convert.ToUInt64(hybrid.Value);
51         public static explicit operator long(Hybrid<T> hybrid) => hybrid.AbsoluteValue;
52         public static explicit operator uint(Hybrid<T> hybrid) => Convert.ToUInt32(hybrid.Value);
53         public static explicit operator int(Hybrid<T> hybrid) =>
54             ↪ Convert.ToInt32(hybrid.AbsoluteValue);
55         public static explicit operator ushort(Hybrid<T> hybrid) =>
56             ↪ Convert.ToUInt16(hybrid.Value);
57         public static explicit operator short(Hybrid<T> hybrid) =>
58             ↪ Convert.ToInt16(hybrid.AbsoluteValue);
59         public static explicit operator byte(Hybrid<T> hybrid) => Convert.ToByte(hybrid.Value);
60         public static explicit operator sbyte(Hybrid<T> hybrid) =>
61             ↪ Convert.ToSByte(hybrid.AbsoluteValue);
62
63
64
65
66
67
68
69
70
71
72
73

```

```

74         public override string ToString() => IsNothing ? default(T) == null ? "Nothing" :
           ↳ default(T).ToString() : IsExternal ? $"{<AbsoluteValue>}" : Value.ToString();
75     }
76 }

```

./Platform.Data.Doublets/ILinks.cs

```

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

```

```

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

```

```

131         return false;
132     }
133     if (!equalityComparer.Equals(next, source) && !equalityComparer.Equals(next,
134         ↪ target))
135     {
136         //throw new Exception(string.Format("Невозможно продолжить путь через
137         ↪ элемент пути {0}", next));
138         return false;
139     }
140     current = next;
141 }
142 return true;
143 }
144 /// <remarks>
145 /// Может потребовать дополнительного стека для PathElement's при использовании
146 ↪ SequenceWalker.
147 /// </remarks>
148 public static TLink GetByKeys<TLink>(this ILinks<TLink> links, TLink root, params int[]
149 ↪ path)
150 {
151     links.EnsureLinkExists(root, "root");
152     var currentLink = root;
153     for (var i = 0; i < path.Length; i++)
154     {
155         currentLink = links.GetLink(currentLink)[path[i]];
156     }
157     return currentLink;
158 }
159 public static TLink GetSquareMatrixSequenceElementByIndex<TLink>(this ILinks<TLink>
160 ↪ links, TLink root, ulong size, ulong index)
161 {
162     var constants = links.Constants;
163     var source = constants.SourcePart;
164     var target = constants.TargetPart;
165     if (!Numbers.Math.IsPowerOfTwo(size))
166     {
167         throw new ArgumentOutOfRangeException(nameof(size), "Sequences with sizes other
168         ↪ than powers of two are not supported.");
169     }
170     var path = new BitArray(BitConverter.GetBytes(index));
171     var length = Bit.GetLowestPosition(size);
172     links.EnsureLinkExists(root, "root");
173     var currentLink = root;
174     for (var i = length - 1; i >= 0; i--)
175     {
176         currentLink = links.GetLink(currentLink)[path[i] ? target : source];
177     }
178     return currentLink;
179 }
180 #endregion
181
182 /// <summary>
183 /// Возвращает индекс указанной связи.
184 /// </summary>
185 /// <param name="links">Хранилище связей.</param>
186 /// <param name="link">Связь представленная списком, состоящим из её адреса и
187 ↪ содержимого.</param>
188 /// <returns>Индекс начальной связи для указанной связи.</returns>
189 [MethodImpl(MethodImplOptions.AggressiveInlining)]
190 public static TLink GetIndex<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
191 ↪ link[links.Constants.IndexPart];
192
193 /// <summary>
194 /// Возвращает индекс начальной (Source) связи для указанной связи.
195 /// </summary>
196 /// <param name="links">Хранилище связей.</param>
197 /// <param name="link">Индекс связи.</param>
198 /// <returns>Индекс начальной связи для указанной связи.</returns>
199 [MethodImpl(MethodImplOptions.AggressiveInlining)]
200 public static TLink GetSource<TLink>(this ILinks<TLink> links, TLink link) =>
201 ↪ links.GetLink(link)[links.Constants.SourcePart];
202
203 /// <summary>
204 /// Возвращает индекс начальной (Source) связи для указанной связи.
205 /// </summary>

```

```

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

205
206 /// <summary>
207 /// Возвращает индекс конечной (Target) связи для указанной связи.
208 /// </summary>
209 /// <param name="links">Хранилище связей.</param>
210 /// <param name="link">Индекс связи.</param>
211 /// <returns>Индекс конечной связи для указанной связи.</returns>
212 [MethodImpl(MethodImplOptions.AggressiveInlining)]
213 public static TLink GetTarget<TLink>(this ILinks<TLink> links, TLink link) =>
    ↳ links.GetLink(link)[links.Constants.TargetPart];

214
215 /// <summary>
216 /// Возвращает индекс конечной (Target) связи для указанной связи.
217 /// </summary>
218 /// <param name="links">Хранилище связей.</param>
219 /// <param name="link">Связь представленная списком, состоящим из её адреса и
    ↳ содержимого.</param>
220 /// <returns>Индекс конечной связи для указанной связи.</returns>
221 [MethodImpl(MethodImplOptions.AggressiveInlining)]
222 public static TLink GetTarget<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
    ↳ link[links.Constants.TargetPart];

223
224 /// <summary>
225 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
    ↳ (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
    ↳ может иметь значения: Constants.Null - 0-я связь, обозначающая ссылку на пустоту,
    ↳ Any - отсутствие ограничения, 1..∞ конкретный адрес связи.</param>
230 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
    ↳ случае.</returns>
231 [MethodImpl(MethodImplOptions.AggressiveInlining)]
232 public static bool Each<TLink>(this ILinks<TLink> links, Func<IList<TLink>, TLink>
    ↳ handler, params TLink[] restrictions)
233 => EqualityComparer<TLink>.Default.Equals(links.Each(handler, restrictions),
    ↳ links.Constants.Continue);

234
235 /// <summary>
236 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
    ↳ (handler) для каждой подходящей связи.
237 /// </summary>
238 /// <param name="links">Хранилище связей.</param>
239 /// <param name="source">Значение, определяющее соответствующие шаблону связи.
    ↳ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве начала,
    ↳ Constants.Any - любое начало, 1..∞ конкретное начало)</param>
240 /// <param name="target">Значение, определяющее соответствующие шаблону связи.
    ↳ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве конца,
    ↳ Constants.Any - любой конец, 1..∞ конкретный конец)</param>
241 /// <param name="handler">Обработчик каждой подходящей связи.</param>
242 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
    ↳ случае.</returns>
243 [MethodImpl(MethodImplOptions.AggressiveInlining)]
244 public static bool Each<TLink>(this ILinks<TLink> links, TLink source, TLink target,
    ↳ Func<TLink, bool> handler)
245 {
246     var constants = links.Constants;
247     return links.Each(link => handler(link[constants.IndexPart]) ? constants.Continue :
    ↳ constants.Break, constants.Any, source, target);
248 }
249
250 /// <summary>
251 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
    ↳ (handler) для каждой подходящей связи.
252 /// </summary>
253 /// <param name="links">Хранилище связей.</param>

```



```

254  /// <param name="source">Значение, определяющее соответствующие шаблону связи.
255  → (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве начала,
256  → Constants.Any - любое начало, 1..∞ конкретное начало)</param>
257  /// <param name="target">Значение, определяющее соответствующие шаблону связи.
258  → (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве конца,
259  → Constants.Any - любой конец, 1..∞ конкретный конец)</param>
260  /// <param name="handler">Обработчик каждой подходящей связи.</param>
261  /// <returns>True, в случае если проход по связям не был прерван и False в обратном
262  → случае.</returns>
263  [MethodImpl(MethodImplOptions.AggressiveInlining)]
264  public static bool Each<TLink>(this ILinks<TLink> links, TLink source, TLink target,
265  → Func<IList<TLink>, TLink> handler)
266  {
267      var constants = links.Constants;
268      return links.Each(handler, constants.Any, source, target);
269  }
270
271  [MethodImpl(MethodImplOptions.AggressiveInlining)]
272  public static IList<IList<TLink>> All<TLink>(this ILinks<TLink> links, params TLink[]
273  → restrictions)
274  {
275      long arraySize = (Integer<TLink>)links.Count(restrictions);
276      var array = new IList<TLink>[arraySize];
277      if (arraySize > 0)
278      {
279          var filler = new ArrayFiller<IList<TLink>, TLink>(array,
280          → links.Constants.Continue);
281          links.Each(filler.AddAndReturnConstant, restrictions);
282      }
283      return array;
284  }
285
286  [MethodImpl(MethodImplOptions.AggressiveInlining)]
287  public static IList<TLink> AllIndices<TLink>(this ILinks<TLink> links, params TLink[]
288  → restrictions)
289  {
290      long arraySize = (Integer<TLink>)links.Count(restrictions);
291      var array = new TLink[arraySize];
292      if (arraySize > 0)
293      {
294          var filler = new ArrayFiller<TLink, TLink>(array, links.Constants.Continue);
295          links.Each(filler.AddFirstAndReturnConstant, restrictions);
296      }
297      return array;
298  }
299
300  /// <summary>
301  /// Возвращает значение, определяющее существует ли связь с указанными началом и концом
302  → в хранилище связей.
303  /// </summary>
304  /// <param name="links">Хранилище связей.</param>
305  /// <param name="source">Начало связи.</param>
306  /// <param name="target">Конец связи.</param>
307  /// <returns>Значение, определяющее существует ли связь.</returns>
308  [MethodImpl(MethodImplOptions.AggressiveInlining)]
309  public static bool Exists<TLink>(this ILinks<TLink> links, TLink source, TLink target)
310  → => Comparer<TLink>.Default.Compare(links.Count(links.Constants.Any, source, target),
311  → default) > 0;
312
313  #region Ensure
314  // TODO: May be move to EnsureExtensions or make it both there and here
315
316  [MethodImpl(MethodImplOptions.AggressiveInlining)]
317  public static void EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links, TLink
318  → reference, string argumentName)
319  {
320      if (links.IsInnerReference(reference) && !links.Exists(reference))
321      {
322          throw new ArgumentLinkDoesNotExistsException<TLink>(reference, argumentName);
323      }
324  }
325
326  [MethodImpl(MethodImplOptions.AggressiveInlining)]
327  public static void EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links,
328  → IList<TLink> restrictions, string argumentName)
329  {
330      for (int i = 0; i < restrictions.Count; i++)

```

```

317     {
318         links.EnsureInnerReferenceExists(restrictions[i], argumentName);
319     }
320 }
321
322 [MethodImpl(MethodImplOptions.AggressiveInlining)]
323 public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, IList<TLink>
    ↪ restrictions)
324 {
325     for (int i = 0; i < restrictions.Count; i++)
326     {
327         links.EnsureLinkIsAnyOrExists(restrictions[i], nameof(restrictions));
328     }
329 }
330
331 [MethodImpl(MethodImplOptions.AggressiveInlining)]
332 public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, TLink link,
    ↪ string argumentName)
333 {
334     var equalityComparer = EqualityComparer<TLink>.Default;
335     if (!equalityComparer.Equals(link, links.Constants.Any) && !links.Exists(link))
336     {
337         throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
338     }
339 }
340
341 [MethodImpl(MethodImplOptions.AggressiveInlining)]
342 public static void EnsureLinkIsItselfOrExists<TLink>(this ILinks<TLink> links, TLink
    ↪ link, string argumentName)
343 {
344     var equalityComparer = EqualityComparer<TLink>.Default;
345     if (!equalityComparer.Equals(link, links.Constants.Itself) && !links.Exists(link))
346     {
347         throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
348     }
349 }
350
351 /// <param name="links">Хранилище связей.</param>
352 [MethodImpl(MethodImplOptions.AggressiveInlining)]
353 public static void EnsureDoesNotExists<TLink>(this ILinks<TLink> links, TLink source,
    ↪ TLink target)
354 {
355     if (links.Exists(source, target))
356     {
357         throw new LinkWithSameValueAlreadyExistsException();
358     }
359 }
360
361 /// <param name="links">Хранилище связей.</param>
362 public static void EnsureNoUsages<TLink>(this ILinks<TLink> links, TLink link)
363 {
364     if (links.HasUsages(link))
365     {
366         throw new ArgumentLinkHasDependenciesException<TLink>(link);
367     }
368 }
369
370 /// <param name="links">Хранилище связей.</param>
371 public static void EnsureCreated<TLink>(this ILinks<TLink> links, params TLink[]
    ↪ addresses) => links.EnsureCreated(links.Create, addresses);
372
373 /// <param name="links">Хранилище связей.</param>
374 public static void EnsurePointsCreated<TLink>(this ILinks<TLink> links, params TLink[]
    ↪ addresses) => links.EnsureCreated(links.CreatePoint, addresses);
375
376 /// <param name="links">Хранилище связей.</param>
377 public static void EnsureCreated<TLink>(this ILinks<TLink> links, Func<TLink> creator,
    ↪ params TLink[] addresses)
378 {
379     var constants = links.Constants;
380     var nonExistentAddresses = new HashSet<ulong>(addresses.Where(x =>
    ↪ !links.Exists(x)).Select(x => (ulong)(Integer<TLink>)x));
381     if (nonExistentAddresses.Count > 0)
382     {
383         var max = nonExistentAddresses.Max();
384         // TODO: Эту верхнюю границу нужно разрешить переопределять (проверить
    ↪ применяется ли эта логика)
385         max = System.Math.Min(max, (Integer<TLink>)constants.MaxPossibleIndex);

```

```

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

```

```

456 public static TLink CreatePoint<TLink>(this ILinks<TLink> links)
457 {
458     var link = links.Create();
459     return links.Update(link, link, link);
460 }
461
462 /// <param name="links">Хранилище связей.</param>
463 [MethodImpl(MethodImplOptions.AggressiveInlining)]
464 public static TLink CreateAndUpdate<TLink>(this ILinks<TLink> links, TLink source, TLink
    ↪ target) => links.Update(links.Create(), source, target);
465
466 /// <summary>
467 /// Обновляет связь с указанными началом (Source) и концом (Target)
468 /// на связь с указанными началом (NewSource) и концом (NewTarget).
469 /// </summary>
470 /// <param name="links">Хранилище связей.</param>
471 /// <param name="link">Индекс обновляемой связи.</param>
472 /// <param name="newSource">Индекс связи, которая является началом связи, на которую
    ↪ выполняется обновление.</param>
473 /// <param name="newTarget">Индекс связи, которая является концом связи, на которую
    ↪ выполняется обновление.</param>
474 /// <returns>Индекс обновлённой связи.</returns>
475 [MethodImpl(MethodImplOptions.AggressiveInlining)]
476 public static TLink Update<TLink>(this ILinks<TLink> links, TLink link, TLink newSource,
    ↪ TLink newTarget) => links.Update(new Link<TLink>(link, newSource, newTarget));
477
478 /// <summary>
479 /// Обновляет связь с указанными началом (Source) и концом (Target)
480 /// на связь с указанными началом (NewSource) и концом (NewTarget).
481 /// </summary>
482 /// <param name="links">Хранилище связей.</param>
483 /// <param name="restrictions">Ограничения на содержимое связей. Каждое ограничение
    ↪ может иметь значения: Constants.Null - 0-я связь, обозначающая ссылку на пустоту,
    ↪ Itself - требование установить ссылку на себя, 1.. $\infty$  конкретный адрес другой
    ↪ связи.</param>
484 /// <returns>Индекс обновлённой связи.</returns>
485 [MethodImpl(MethodImplOptions.AggressiveInlining)]
486 public static TLink Update<TLink>(this ILinks<TLink> links, params TLink[] restrictions)
487 {
488     if (restrictions.Length == 2)
489     {
490         return links.MergeAndDelete(restrictions[0], restrictions[1]);
491     }
492     if (restrictions.Length == 4)
493     {
494         return links.UpdateOrCreateOrGet(restrictions[0], restrictions[1],
            ↪ restrictions[2], restrictions[3]);
495     }
496     else
497     {
498         return links.Update(restrictions);
499     }
500 }
501
502 [MethodImpl(MethodImplOptions.AggressiveInlining)]
503 public static IList<TLink> ResolveConstantAsSelfReference<TLink>(this ILinks<TLink>
    ↪ links, TLink constant, IList<TLink> restrictions)
504 {
505     var equalityComparer = EqualityComparer<TLink>.Default;
506     var constants = links.Constants;
507     var index = restrictions[constants.IndexPart];
508     var source = restrictions[constants.SourcePart];
509     var target = restrictions[constants.TargetPart];
510     source = equalityComparer.Equals(source, constant) ? index : source;
511     target = equalityComparer.Equals(target, constant) ? index : target;
512     return new Link<TLink>(index, source, target);
513 }
514
515 /// <summary>
516 /// Создаёт связь (если она не существовала), либо возвращает индекс существующей связи
    ↪ с указанными Source (началом) и Target (концом).
517 /// </summary>
518 /// <param name="links">Хранилище связей.</param>
519 /// <param name="source">Индекс связи, которая является началом на создаваемой
    ↪ связи.</param>
520 /// <param name="target">Индекс связи, которая является концом для создаваемой
    ↪ связи.</param>

```

```

521 /// <returns>Индекс связи, с указанным Source (началом) и Target (концом)</returns>
522 [MethodImpl(MethodImplOptions.AggressiveInlining)]
523 public static TLink GetOrCreate<TLink>(this ILinks<TLink> links, TLink source, TLink
    ↳ target)
524 {
525     var link = links.SearchOrDefault(source, target);
526     if (EqualityComparer<TLink>.Default.Equals(link, default))
527     {
528         link = links.CreateAndUpdate(source, target);
529     }
530     return link;
531 }
532
533 /// <summary>
534 /// Обновляет связь с указанными началом (Source) и концом (Target)
535 /// на связь с указанными началом (NewSource) и концом (NewTarget).
536 /// </summary>
537 /// <param name="links">Хранилище связей.</param>
538 /// <param name="source">Индекс связи, которая является началом обновляемой
    ↳ связи.</param>
539 /// <param name="target">Индекс связи, которая является концом обновляемой связи.</param>
540 /// <param name="newSource">Индекс связи, которая является началом связи, на которую
    ↳ выполняется обновление.</param>
541 /// <param name="newTarget">Индекс связи, которая является концом связи, на которую
    ↳ выполняется обновление.</param>
542 /// <returns>Индекс обновлённой связи.</returns>
543 [MethodImpl(MethodImplOptions.AggressiveInlining)]
544 public static TLink UpdateOrCreateOrGet<TLink>(this ILinks<TLink> links, TLink source,
    ↳ TLink target, TLink newSource, TLink newTarget)
545 {
546     var equalityComparer = EqualityComparer<TLink>.Default;
547     var link = links.SearchOrDefault(source, target);
548     if (equalityComparer.Equals(link, default))
549     {
550         return links.CreateAndUpdate(newSource, newTarget);
551     }
552     if (equalityComparer.Equals(newSource, source) && equalityComparer.Equals(newTarget,
    ↳ target))
553     {
554         return link;
555     }
556     return links.Update(link, newSource, newTarget);
557 }
558
559 /// <summary>Удаляет связь с указанными началом (Source) и концом (Target).</summary>
560 /// <param name="links">Хранилище связей.</param>
561 /// <param name="source">Индекс связи, которая является началом удаляемой связи.</param>
562 /// <param name="target">Индекс связи, которая является концом удаляемой связи.</param>
563 [MethodImpl(MethodImplOptions.AggressiveInlining)]
564 public static TLink DeleteIfExists<TLink>(this ILinks<TLink> links, TLink source, TLink
    ↳ target)
565 {
566     var link = links.SearchOrDefault(source, target);
567     if (!EqualityComparer<TLink>.Default.Equals(link, default))
568     {
569         links.Delete(link);
570         return link;
571     }
572     return default;
573 }
574
575 /// <summary>Удаляет несколько связей.</summary>
576 /// <param name="links">Хранилище связей.</param>
577 /// <param name="deletedLinks">Список адресов связей к удалению.</param>
578 [MethodImpl(MethodImplOptions.AggressiveInlining)]
579 public static void DeleteMany<TLink>(this ILinks<TLink> links, IList<TLink> deletedLinks)
580 {
581     for (int i = 0; i < deletedLinks.Count; i++)
582     {
583         links.Delete(deletedLinks[i]);
584     }
585 }
586
587 /// <remarks>Before execution of this method ensure that deleted link is detached (all
    ↳ values - source and target are reset to null) or it might enter into infinite
    ↳ recursion.</remarks>
588 public static void DeleteAllUsages<TLink>(this ILinks<TLink> links, TLink linkIndex)
589 {

```

```

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

```

```

660     {
661         var totalUsages = usagesAsSourceCount + usagesAsTargetCount;
662         if (totalUsages > 0)
663         {
664             var usages = ArrayPool.Allocate<TLink>(totalUsages);
665             var usagesFiller = new ArrayFiller<TLink, TLink>(usages,
666                 ↪ links.Constants.Continue);
667             var i = 0L;
668             if (usagesAsSourceCount > 0)
669             {
670                 links.Each(usagesFiller.AddFirstAndReturnConstant,
671                     ↪ usagesAsSourceQuery);
672                 for (; i < usagesAsSourceCount; i++)
673                 {
674                     var usage = usages[i];
675                     if (!equalityComparer.Equals(usage, oldLinkIndex))
676                     {
677                         links.Update(usage, newLinkIndex, links.GetTarget(usage));
678                     }
679                 }
680             }
681             if (usagesAsTargetCount > 0)
682             {
683                 links.Each(usagesFiller.AddFirstAndReturnConstant,
684                     ↪ usagesAsTargetQuery);
685                 for (; i < usages.Length; i++)
686                 {
687                     var usage = usages[i];
688                     if (!equalityComparer.Equals(usage, oldLinkIndex))
689                     {
690                         links.Update(usage, links.GetSource(usage), newLinkIndex);
691                     }
692                 }
693             }
694             ArrayPool.Free(usages);
695         }
696     }
697     return newLinkIndex;
698 }
699
700 /// <summary>
701 /// Replace one link with another (replaced link is deleted, children are updated or
702 /// ↪ deleted).
703 /// </summary>
704 [MethodImpl(MethodImplOptions.AggressiveInlining)]
705 public static TLink MergeAndDelete<TLink>(this ILinks<TLink> links, TLink oldLinkIndex,
706     ↪ TLink newLinkIndex)
707 {
708     var equalityComparer = EqualityComparer<TLink>.Default;
709     if (!equalityComparer.Equals(oldLinkIndex, newLinkIndex))
710     {
711         links.MergeUsages(oldLinkIndex, newLinkIndex);
712         links.Delete(oldLinkIndex);
713     }
714     return newLinkIndex;
715 }
716 }
717 }

```

./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)

```

```

17         : base(links)
18     {
19         _frequencyMarker = frequencyMarker;
20         _unaryOne = unaryOne;
21         _unaryNumberIncrementer = unaryNumberIncrementer;
22     }
23
24     public TLink Increment(TLink frequency)
25     {
26         if (_equalityComparer.Equals(frequency, default))
27         {
28             return Links.GetOrCreate(_unaryOne, _frequencyMarker);
29         }
30         var source = Links.GetSource(frequency);
31         var incrementedSource = _unaryNumberIncrementer.Increment(source);
32         return Links.GetOrCreate(incrementedSource, _frequencyMarker);
33     }
34 }
35 }

```

./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             {
28                 return Links.GetOrCreate(unaryNumber, _unaryOne);
29             }
30             else
31             {
32                 return Links.GetOrCreate(source, Increment(target));
33             }
34         }
35     }
36 }

```

./Platform.Data.Doublets/ISynchronizedLinks.cs

```

1  using Platform.Data.Constants;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets
6  {
7      public interface ISynchronizedLinks<TLink> : ISynchronizedLinks<TLink, ILinks<TLink>,
8          ⇨ LinksCombinedConstants<TLink, TLink, int>>, ILinks<TLink>
9      {
10     }
11 }

```

./Platform.Data.Doublets/Link.cs

```

1  using System;
2  using System.Collections;
3  using System.Collections.Generic;
4  using Platform.Exceptions;
5  using Platform.Ranges;
6  using Platform.Singletons;
7  using Platform.Collections.Lists;

```



```

8 using Platform.Data.Constants;
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 LinksCombinedConstants<bool, TLink, int> _constants =
22             ↪ Default<LinksCombinedConstants<bool, TLink, int>>.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         public Link(params TLink[] values)
33         {
34             Index = values.Length > _constants.IndexPart ? values[_constants.IndexPart] :
35                 ↪ _constants.Null;
36             Source = values.Length > _constants.SourcePart ? values[_constants.SourcePart] :
37                 ↪ _constants.Null;
38             Target = values.Length > _constants.TargetPart ? values[_constants.TargetPart] :
39                 ↪ _constants.Null;
40         }
41
42         public Link(IList<TLink> values)
43         {
44             Index = values.Count > _constants.IndexPart ? values[_constants.IndexPart] :
45                 ↪ _constants.Null;
46             Source = values.Count > _constants.SourcePart ? values[_constants.SourcePart] :
47                 ↪ _constants.Null;
48             Target = values.Count > _constants.TargetPart ? values[_constants.TargetPart] :
49                 ↪ _constants.Null;
50         }
51
52         public Link(TLink index, TLink source, TLink target)
53         {
54             Index = index;
55             Source = source;
56             Target = target;
57         }
58
59         public Link(TLink source, TLink target)
60             : this(_constants.Null, source, target)
61         {
62             Source = source;
63             Target = target;
64         }
65
66         public static Link<TLink> Create(TLink source, TLink target) => new Link<TLink>(source,
67             ↪ target);
68
69         public override int GetHashCode() => (Index, Source, Target).GetHashCode();
70
71         public bool IsNull() => _equalityComparer.Equals(Index, _constants.Null)
72             && _equalityComparer.Equals(Source, _constants.Null)
73             && _equalityComparer.Equals(Target, _constants.Null);
74
75         public override bool Equals(object other) => other is Link<TLink> &&
76             ↪ Equals((Link<TLink>)other);
77
78         public bool Equals(Link<TLink> other) => _equalityComparer.Equals(Index, other.Index)
79             && _equalityComparer.Equals(Source, other.Source)
80             && _equalityComparer.Equals(Target, other.Target);
81
82         public static string ToString(TLink index, TLink source, TLink target) => $"({index}:
83             ↪ {source}->{target})";
84
85         public static string ToString(TLink source, TLink target) => $"({source}->{target})";
86
87         public static implicit operator TLink[] (Link<TLink> link) => link.ToArray();

```

```

77
78 public static implicit operator Link<TLink>(TLink[] linkArray) => new
    ↳ Link<TLink>(linkArray);
79
80 public override string ToString() => _equalityComparer.Equals(Index, _constants.Null) ?
    ↳ ToString(Source, Target) : ToString(Index, Source, Target);
81
82 #region IList
83
84 public int Count => Length;
85
86 public bool IsReadOnly => true;
87
88 public TLink this[int index]
89 {
90     get
91     {
92         Ensure.Always.ArgumentInRange(index, new Range<int>(0, Length - 1),
    ↳ nameof(index));
93         if (index == _constants.IndexPart)
94         {
95             return Index;
96         }
97         if (index == _constants.SourcePart)
98         {
99             return Source;
100         }
101         if (index == _constants.TargetPart)
102         {
103             return Target;
104         }
105         throw new NotSupportedException(); // Impossible path due to
    ↳ Ensure.ArgumentInRange
106     }
107     set => throw new NotSupportedException();
108 }
109
110 IEnumerator IEnumerable.GetEnumerator() => GetEnumerator();
111
112 public IEnumerator<TLink> GetEnumerator()
113 {
114     yield return Index;
115     yield return Source;
116     yield return Target;
117 }
118
119 public void Add(TLink item) => throw new NotSupportedException();
120
121 public void Clear() => throw new NotSupportedException();
122
123 public bool Contains(TLink item) => IndexOf(item) >= 0;
124
125 public void CopyTo(TLink[] array, int arrayIndex)
126 {
127     Ensure.Always.ArgumentNotNull(array, nameof(array));
128     Ensure.Always.ArgumentInRange(arrayIndex, new Range<int>(0, array.Length - 1),
    ↳ nameof(arrayIndex));
129     if (arrayIndex + Length > array.Length)
130     {
131         throw new InvalidOperationException();
132     }
133     array[arrayIndex++] = Index;
134     array[arrayIndex++] = Source;
135     array[arrayIndex] = Target;
136 }
137
138 public bool Remove(TLink item) => Throw.A.NotSupportedExceptionAndReturn<bool>();
139
140 public int IndexOf(TLink item)
141 {
142     if (_equalityComparer.Equals(Index, item))
143     {
144         return _constants.IndexPart;
145     }
146     if (_equalityComparer.Equals(Source, item))
147     {
148         return _constants.SourcePart;
149     }
150     if (_equalityComparer.Equals(Target, item))

```

```

151         {
152             return _constants.TargetPart;
153         }
154         return -1;
155     }
156
157     public void Insert(int index, TLink item) => throw new NotSupportedException();
158
159     public void RemoveAt(int index) => throw new NotSupportedException();
160
161     #endregion
162 }
163 }

```

./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/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/ResizableDirectMemoryLinks.cs

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

```

3 using System.Runtime.CompilerServices;
4 using System.Runtime.InteropServices;
5 using Platform.Disposables;
6 using Platform.Singletons;
7 using Platform.Collections.Arrays;
8 using Platform.Numbers;
9 using Platform.Unsafe;
10 using Platform.Memory;
11 using Platform.Data.Exceptions;
12 using Platform.Data.Constants;
13 using static Platform.Numbers.Arithmetic;
14
15 #pragma warning disable 0649
16 #pragma warning disable 169
17 #pragma warning disable 618
18 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
19
20 // ReSharper disable StaticMemberInGenericType
21 // ReSharper disable BuiltInTypeReferenceStyle
22 // ReSharper disable MemberCanBePrivate.Local
23 // ReSharper disable UnusedMember.Local
24
25 namespace Platform.Data.Doublets.ResizableDirectMemory
26 {
27     public partial class ResizableDirectMemoryLinks<TLink> : DisposableBase, ILinks<TLink>
28     {
29         private static readonly EqualityComparer<TLink> _equalityComparer =
30             ↳ EqualityComparer<TLink>.Default;
31         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
32
33         /// <summary>Возвращает размер одной связи в байтах.</summary>
34         public static readonly int LinkSizeInBytes = Structure<Link>.Size;
35
36         public static readonly int LinkHeaderSizeInBytes = Structure<LinkHeader>.Size;
37
38         public static readonly long DefaultLinksSizeStep = LinkSizeInBytes * 1024 * 1024;
39
40         private struct Link
41         {
42             public static readonly int SourceOffset = Marshal.OffsetOf(typeof(Link),
43                 ↳ nameof(Source)).ToInt32();
44             public static readonly int TargetOffset = Marshal.OffsetOf(typeof(Link),
45                 ↳ nameof(Target)).ToInt32();
46             public static readonly int LeftAsSourceOffset = Marshal.OffsetOf(typeof(Link),
47                 ↳ nameof(LeftAsSource)).ToInt32();
48             public static readonly int RightAsSourceOffset = Marshal.OffsetOf(typeof(Link),
49                 ↳ nameof(RightAsSource)).ToInt32();
50             public static readonly int SizeAsSourceOffset = Marshal.OffsetOf(typeof(Link),
51                 ↳ nameof(SizeAsSource)).ToInt32();
52             public static readonly int LeftAsTargetOffset = Marshal.OffsetOf(typeof(Link),
53                 ↳ nameof(LeftAsTarget)).ToInt32();
54             public static readonly int RightAsTargetOffset = Marshal.OffsetOf(typeof(Link),
55                 ↳ nameof(RightAsTarget)).ToInt32();
56             public static readonly int SizeAsTargetOffset = Marshal.OffsetOf(typeof(Link),
57                 ↳ nameof(SizeAsTarget)).ToInt32();
58
59             public TLink Source;
60             public TLink Target;
61             public TLink LeftAsSource;
62             public TLink RightAsSource;
63             public TLink SizeAsSource;
64             public TLink LeftAsTarget;
65             public TLink RightAsTarget;
66             public TLink SizeAsTarget;
67
68             [MethodImpl(MethodImplOptions.AggressiveInlining)]
69             public static TLink GetSource(IntPtr pointer) => (pointer +
70                 ↳ SourceOffset).GetValue<TLink>();
71             [MethodImpl(MethodImplOptions.AggressiveInlining)]
72             public static TLink GetTarget(IntPtr pointer) => (pointer +
73                 ↳ TargetOffset).GetValue<TLink>();
74             [MethodImpl(MethodImplOptions.AggressiveInlining)]
75             public static TLink GetLeftAsSource(IntPtr pointer) => (pointer +
76                 ↳ LeftAsSourceOffset).GetValue<TLink>();
77             [MethodImpl(MethodImplOptions.AggressiveInlining)]
78             public static TLink GetRightAsSource(IntPtr pointer) => (pointer +
79                 ↳ RightAsSourceOffset).GetValue<TLink>();
80             [MethodImpl(MethodImplOptions.AggressiveInlining)]
81             public static TLink GetSizeAsSource(IntPtr pointer) => (pointer +
82                 ↳ SizeAsSourceOffset).GetValue<TLink>();

```

```

69     [MethodImpl(MethodImplOptions.AggressiveInlining)]
70     public static TLink GetLeftAsTarget(IntPtr pointer) => (pointer +
    ↪ LeftAsTargetOffset).GetValue<TLink>();
71     [MethodImpl(MethodImplOptions.AggressiveInlining)]
72     public static TLink GetRightAsTarget(IntPtr pointer) => (pointer +
    ↪ RightAsTargetOffset).GetValue<TLink>();
73     [MethodImpl(MethodImplOptions.AggressiveInlining)]
74     public static TLink GetSizeAsTarget(IntPtr pointer) => (pointer +
    ↪ SizeAsTargetOffset).GetValue<TLink>();
75
76     [MethodImpl(MethodImplOptions.AggressiveInlining)]
77     public static void SetSource(IntPtr pointer, TLink value) => (pointer +
    ↪ SourceOffset).SetValue(value);
78     [MethodImpl(MethodImplOptions.AggressiveInlining)]
79     public static void SetTarget(IntPtr pointer, TLink value) => (pointer +
    ↪ TargetOffset).SetValue(value);
80     [MethodImpl(MethodImplOptions.AggressiveInlining)]
81     public static void SetLeftAsSource(IntPtr pointer, TLink value) => (pointer +
    ↪ LeftAsSourceOffset).SetValue(value);
82     [MethodImpl(MethodImplOptions.AggressiveInlining)]
83     public static void SetRightAsSource(IntPtr pointer, TLink value) => (pointer +
    ↪ RightAsSourceOffset).SetValue(value);
84     [MethodImpl(MethodImplOptions.AggressiveInlining)]
85     public static void SetSizeAsSource(IntPtr pointer, TLink value) => (pointer +
    ↪ SizeAsSourceOffset).SetValue(value);
86     [MethodImpl(MethodImplOptions.AggressiveInlining)]
87     public static void SetLeftAsTarget(IntPtr pointer, TLink value) => (pointer +
    ↪ LeftAsTargetOffset).SetValue(value);
88     [MethodImpl(MethodImplOptions.AggressiveInlining)]
89     public static void SetRightAsTarget(IntPtr pointer, TLink value) => (pointer +
    ↪ RightAsTargetOffset).SetValue(value);
90     [MethodImpl(MethodImplOptions.AggressiveInlining)]
91     public static void SetSizeAsTarget(IntPtr pointer, TLink value) => (pointer +
    ↪ SizeAsTargetOffset).SetValue(value);
92 }
93
94 private struct LinksHeader
95 {
96     public static readonly int AllocatedLinksOffset =
    ↪ Marshal.OffsetOf<typeof(LinksHeader), nameof(AllocatedLinks)>().ToInt32();
97     public static readonly int ReservedLinksOffset =
    ↪ Marshal.OffsetOf<typeof(LinksHeader), nameof(ReservedLinks)>().ToInt32();
98     public static readonly int FreeLinksOffset = Marshal.OffsetOf<typeof(LinksHeader),
    ↪ nameof(FreeLinks)>().ToInt32();
99     public static readonly int FirstFreeLinkOffset =
    ↪ Marshal.OffsetOf<typeof(LinksHeader), nameof(FirstFreeLink)>().ToInt32();
100    public static readonly int FirstAsSourceOffset =
    ↪ Marshal.OffsetOf<typeof(LinksHeader), nameof(FirstAsSource)>().ToInt32();
101    public static readonly int FirstAsTargetOffset =
    ↪ Marshal.OffsetOf<typeof(LinksHeader), nameof(FirstAsTarget)>().ToInt32();
102    public static readonly int LastFreeLinkOffset =
    ↪ Marshal.OffsetOf<typeof(LinksHeader), nameof(LastFreeLink)>().ToInt32();
103
104    public TLink AllocatedLinks;
105    public TLink ReservedLinks;
106    public TLink FreeLinks;
107    public TLink FirstFreeLink;
108    public TLink FirstAsSource;
109    public TLink FirstAsTarget;
110    public TLink LastFreeLink;
111    public TLink Reserved8;
112
113    [MethodImpl(MethodImplOptions.AggressiveInlining)]
114    public static TLink GetAllocatedLinks(IntPtr pointer) => (pointer +
    ↪ AllocatedLinksOffset).GetValue<TLink>();
115    [MethodImpl(MethodImplOptions.AggressiveInlining)]
116    public static TLink GetReservedLinks(IntPtr pointer) => (pointer +
    ↪ ReservedLinksOffset).GetValue<TLink>();
117    [MethodImpl(MethodImplOptions.AggressiveInlining)]
118    public static TLink GetFreeLinks(IntPtr pointer) => (pointer +
    ↪ FreeLinksOffset).GetValue<TLink>();
119    [MethodImpl(MethodImplOptions.AggressiveInlining)]
120    public static TLink GetFirstFreeLink(IntPtr pointer) => (pointer +
    ↪ FirstFreeLinkOffset).GetValue<TLink>();
121    [MethodImpl(MethodImplOptions.AggressiveInlining)]
122    public static TLink GetFirstAsSource(IntPtr pointer) => (pointer +
    ↪ FirstAsSourceOffset).GetValue<TLink>();

```

```

123     [MethodImpl(MethodImplOptions.AggressiveInlining)]
124     public static TLink GetFirstAsTarget(IntPtr pointer) => (pointer +
    ↪ FirstAsTargetOffset).GetValue<TLink>();
125     [MethodImpl(MethodImplOptions.AggressiveInlining)]
126     public static TLink GetLastFreeLink(IntPtr pointer) => (pointer +
    ↪ LastFreeLinkOffset).GetValue<TLink>();
127
128     [MethodImpl(MethodImplOptions.AggressiveInlining)]
129     public static IntPtr GetFirstAsSourcePointer(IntPtr pointer) => pointer +
    ↪ FirstAsSourceOffset;
130     [MethodImpl(MethodImplOptions.AggressiveInlining)]
131     public static IntPtr GetFirstAsTargetPointer(IntPtr pointer) => pointer +
    ↪ FirstAsTargetOffset;
132
133     [MethodImpl(MethodImplOptions.AggressiveInlining)]
134     public static void SetAllocatedLinks(IntPtr pointer, TLink value) => (pointer +
    ↪ AllocatedLinksOffset).SetValue(value);
135     [MethodImpl(MethodImplOptions.AggressiveInlining)]
136     public static void SetReservedLinks(IntPtr pointer, TLink value) => (pointer +
    ↪ ReservedLinksOffset).SetValue(value);
137     [MethodImpl(MethodImplOptions.AggressiveInlining)]
138     public static void SetFreeLinks(IntPtr pointer, TLink value) => (pointer +
    ↪ FreeLinksOffset).SetValue(value);
139     [MethodImpl(MethodImplOptions.AggressiveInlining)]
140     public static void SetFirstFreeLink(IntPtr pointer, TLink value) => (pointer +
    ↪ FirstFreeLinkOffset).SetValue(value);
141     [MethodImpl(MethodImplOptions.AggressiveInlining)]
142     public static void SetFirstAsSource(IntPtr pointer, TLink value) => (pointer +
    ↪ FirstAsSourceOffset).SetValue(value);
143     [MethodImpl(MethodImplOptions.AggressiveInlining)]
144     public static void SetFirstAsTarget(IntPtr pointer, TLink value) => (pointer +
    ↪ FirstAsTargetOffset).SetValue(value);
145     [MethodImpl(MethodImplOptions.AggressiveInlining)]
146     public static void SetLastFreeLink(IntPtr pointer, TLink value) => (pointer +
    ↪ LastFreeLinkOffset).SetValue(value);
147 }
148
149 private readonly long _memoryReservationStep;
150
151 private readonly IResizableDirectMemory _memory;
152 private IntPtr _header;
153 private IntPtr _links;
154
155 private LinksTargetsTreeMethods _targetsTreeMethods;
156 private LinksSourcesTreeMethods _sourcesTreeMethods;
157
158 // TODO: Возможно чтобы гарантированно проверять на то, является ли связь удалённой,
    ↪ нужно использовать не список а дерево, так как так можно быстрее проверить на
    ↪ наличие связи внутри
159 private UnusedLinksListMethods _unusedLinksListMethods;
160
161 /// <summary>
162 /// Возвращает общее число связей находящихся в хранилище.
163 /// </summary>
164 private TLink Total => Subtract(LinksHeader.GetAllocatedLinks(_header),
    ↪ LinksHeader.GetFreeLinks(_header));
165
166 public LinksCombinedConstants<TLink, TLink, int> Constants { get; }
167
168 public ResizableDirectMemoryLinks(string address)
169     : this(address, DefaultLinksSizeStep)
170 {
171 }
172
173 /// <summary>
174 /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
    ↪ минимальным шагом расширения базы данных.
175 /// </summary>
176 /// <param name="address">Полный путь к файлу базы данных.</param>
177 /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
    ↪ байтах.</param>
178 public ResizableDirectMemoryLinks(string address, long memoryReservationStep)
179     : this(new FileMappedResizableDirectMemory(address, memoryReservationStep),
    ↪ memoryReservationStep)
180 {
181 }
182
183 public ResizableDirectMemoryLinks(IResizableDirectMemory memory)

```

```

184         : this(memory, DefaultLinksSizeStep)
185     {
186     }
187
188     public ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
189     ↪ memoryReservationStep)
190     {
191         Constants = Default<LinksCombinedConstants<TLink, TLink, int>>.Instance;
192         _memory = memory;
193         _memoryReservationStep = memoryReservationStep;
194         if (memory.ReservedCapacity < memoryReservationStep)
195         {
196             memory.ReservedCapacity = memoryReservationStep;
197         }
198         SetPointers(_memory);
199         // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
200         _memory.UsedCapacity = ((long)(Integer<TLink>)LinksHeader.GetAllocatedLinks(_header)
201         ↪ * LinkSizeInBytes) + LinkHeaderSizeInBytes;
202         // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
203         LinksHeader.SetReservedLinks(_header, (Integer<TLink>)((_memory.ReservedCapacity -
204         ↪ LinkHeaderSizeInBytes) / LinkSizeInBytes));
205     }
206
207     [MethodImpl(MethodImplOptions.AggressiveInlining)]
208     public TLink Count(IList<TLink> restrictions)
209     {
210         // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
211         if (restrictions.Count == 0)
212         {
213             return Total;
214         }
215         if (restrictions.Count == 1)
216         {
217             var index = restrictions[Constants.IndexPart];
218             if (_equalityComparer.Equals(index, Constants.Any))
219             {
220                 return Total;
221             }
222             return Exists(index) ? Integer<TLink>.One : Integer<TLink>.Zero;
223         }
224         if (restrictions.Count == 2)
225         {
226             var index = restrictions[Constants.IndexPart];
227             var value = restrictions[1];
228             if (_equalityComparer.Equals(index, Constants.Any))
229             {
230                 if (_equalityComparer.Equals(value, Constants.Any))
231                 {
232                     return Total; // Any - как отсутствие ограничения
233                 }
234                 return Add(_sourcesTreeMethods.CountUsages(value),
235                 ↪ _targetsTreeMethods.CountUsages(value));
236             }
237             else
238             {
239                 if (!Exists(index))
240                 {
241                     return Integer<TLink>.Zero;
242                 }
243                 if (_equalityComparer.Equals(value, Constants.Any))
244                 {
245                     return Integer<TLink>.One;
246                 }
247                 var storedLinkValue = GetLinkUnsafe(index);
248                 if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), value) ||
249                 ↪ _equalityComparer.Equals(Link.GetTarget(storedLinkValue), value))
250                 {
251                     return Integer<TLink>.One;
252                 }
253                 return Integer<TLink>.Zero;
254             }
255         }
256         if (restrictions.Count == 3)
257         {
258             var index = restrictions[Constants.IndexPart];
259             var source = restrictions[Constants.SourcePart];
260             var target = restrictions[Constants.TargetPart];

```



```

258 if (_equalityComparer.Equals(index, Constants.Any))
259 {
260     if (_equalityComparer.Equals(source, Constants.Any) &&
        ↳ _equalityComparer.Equals(target, Constants.Any))
261     {
262         return Total;
263     }
264     else if (_equalityComparer.Equals(source, Constants.Any))
265     {
266         return _targetsTreeMethods.CountUsages(target);
267     }
268     else if (_equalityComparer.Equals(target, Constants.Any))
269     {
270         return _sourcesTreeMethods.CountUsages(source);
271     }
272     else //if(source != Any && target != Any)
273     {
274         // Эквивалент Exists(source, target) => Count(Any, source, target) > 0
275         var link = _sourcesTreeMethods.Search(source, target);
276         return _equalityComparer.Equals(link, Constants.Null) ?
            ↳ Integer<TLink>.Zero : Integer<TLink>.One;
277     }
278 }
279 else
280 {
281     if (!Exists(index))
282     {
283         return Integer<TLink>.Zero;
284     }
285     if (_equalityComparer.Equals(source, Constants.Any) &&
        ↳ _equalityComparer.Equals(target, Constants.Any))
286     {
287         return Integer<TLink>.One;
288     }
289     var storedLinkValue = GetLinkUnsafe(index);
290     if (!_equalityComparer.Equals(source, Constants.Any) &&
        ↳ !_equalityComparer.Equals(target, Constants.Any))
291     {
292         if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), source) &&
293             ↳ _equalityComparer.Equals(Link.GetTarget(storedLinkValue), target))
294         {
295             return Integer<TLink>.One;
296         }
297         return Integer<TLink>.Zero;
298     }
299     var value = default(TLink);
300     if (_equalityComparer.Equals(source, Constants.Any))
301     {
302         value = target;
303     }
304     if (_equalityComparer.Equals(target, Constants.Any))
305     {
306         value = source;
307     }
308     if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), value) ||
309         ↳ _equalityComparer.Equals(Link.GetTarget(storedLinkValue), value))
310     {
311         return Integer<TLink>.One;
312     }
313     return Integer<TLink>.Zero;
314 }
315 }
316 throw new NotSupportedException("Другие размеры и способы ограничений не
        ↳ поддерживаются.");
317 }
318
319 [MethodImpl(MethodImplOptions.AggressiveInlining)]
320 public TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
321 {
322     if (restrictions.Count == 0)
323     {
324         for (TLink link = Integer<TLink>.One; _comparer.Compare(link,
            ↳ (Integer<TLink>)LinksHeader.GetAllocatedLinks(_header)) <= 0; link =
            ↳ Increment(link))
325         {
326             if (Exists(link) && _equalityComparer.Equals(handler(GetLinkStruct(link)),
            ↳ Constants.Break))
327             {

```

```

328         return Constants.Break;
329     }
330 }
331
332     return Constants.Continue;
333 }
334 if (restrictions.Count == 1)
335 {
336     var index = restrictions[Constants.IndexPart];
337     if (_equalityComparer.Equals(index, Constants.Any))
338     {
339         return Each(handler, ArrayPool<TLink>.Empty);
340     }
341     if (!Exists(index))
342     {
343         return Constants.Continue;
344     }
345     return handler(GetLinkStruct(index));
346 }
347 if (restrictions.Count == 2)
348 {
349     var index = restrictions[Constants.IndexPart];
350     var value = restrictions[1];
351     if (_equalityComparer.Equals(index, Constants.Any))
352     {
353         if (_equalityComparer.Equals(value, Constants.Any))
354         {
355             return Each(handler, ArrayPool<TLink>.Empty);
356         }
357         if (_equalityComparer.Equals(Each(handler, new[] { index, value,
358             ↪ Constants.Any }), Constants.Break))
359         {
360             return Constants.Break;
361         }
362         return Each(handler, new[] { index, Constants.Any, value });
363     }
364     else
365     {
366         if (!Exists(index))
367         {
368             return Constants.Continue;
369         }
370         if (_equalityComparer.Equals(value, Constants.Any))
371         {
372             return handler(GetLinkStruct(index));
373         }
374         var storedLinkValue = GetLinkUnsafe(index);
375         if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), value) ||
376             _equalityComparer.Equals(Link.GetTarget(storedLinkValue), value))
377         {
378             return handler(GetLinkStruct(index));
379         }
380         return Constants.Continue;
381     }
382 }
383 if (restrictions.Count == 3)
384 {
385     var index = restrictions[Constants.IndexPart];
386     var source = restrictions[Constants.SourcePart];
387     var target = restrictions[Constants.TargetPart];
388     if (_equalityComparer.Equals(index, Constants.Any))
389     {
390         if (_equalityComparer.Equals(source, Constants.Any) &&
391             ↪ _equalityComparer.Equals(target, Constants.Any))
392         {
393             return Each(handler, ArrayPool<TLink>.Empty);
394         }
395         else if (_equalityComparer.Equals(source, Constants.Any))
396         {
397             return _targetsTreeMethods.EachUsage(target, handler);
398         }
399         else if (_equalityComparer.Equals(target, Constants.Any))
400         {
401             return _sourcesTreeMethods.EachUsage(source, handler);
402         }
403         else //if(source != Any && target != Any)
404         {
405             var link = _sourcesTreeMethods.Search(source, target);

```

```

404         return _equalityComparer.Equals(link, Constants.Null) ?
           ↳ Constants.Continue : handler(GetLinkStruct(link));
405     }
406 }
407 else
408 {
409     if (!Exists(index))
410     {
411         return Constants.Continue;
412     }
413     if (_equalityComparer.Equals(source, Constants.Any) &&
           ↳ _equalityComparer.Equals(target, Constants.Any))
414     {
415         return handler(GetLinkStruct(index));
416     }
417     var storedLinkValue = GetLinkUnsafe(index);
418     if (!_equalityComparer.Equals(source, Constants.Any) &&
           ↳ !_equalityComparer.Equals(target, Constants.Any))
419     {
420         if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), source) &&
               ↳ _equalityComparer.Equals(Link.GetTarget(storedLinkValue), target))
421         {
422             return handler(GetLinkStruct(index));
423         }
424         return Constants.Continue;
425     }
426     var value = default(TLink);
427     if (_equalityComparer.Equals(source, Constants.Any))
428     {
429         value = target;
430     }
431     if (_equalityComparer.Equals(target, Constants.Any))
432     {
433         value = source;
434     }
435     if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), value) ||
           ↳ _equalityComparer.Equals(Link.GetTarget(storedLinkValue), value))
436     {
437         return handler(GetLinkStruct(index));
438     }
439     return Constants.Continue;
440 }
441 }
442 }
443 throw new NotSupportedException("Другие размеры и способы ограничений не
444     ↳ поддерживаются.");
445 }
446
447 /// <remarks>
448 /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
449     ↳ в другом месте (но не в менеджере памяти, а в логике Links)
450 /// </remarks>
451 [MethodImpl(MethodImplOptions.AggressiveInlining)]
452 public TLink Update(ICollection<TLink> values)
453 {
454     var linkIndex = values[Constants.IndexPart];
455     var link = GetLinkUnsafe(linkIndex);
456     // Будет корректно работать только в том случае, если пространство выделенной связи
457     ↳ предварительно заполнено нулями
458     if (!_equalityComparer.Equals(Link.GetSource(link), Constants.Null))
459     {
460         _sourcesTreeMethods.Detach(LinksHeader.GetFirstAsSourcePointer(_header),
461             ↳ linkIndex);
462     }
463     if (!_equalityComparer.Equals(Link.GetTarget(link), Constants.Null))
464     {
465         _targetsTreeMethods.Detach(LinksHeader.GetFirstAsTargetPointer(_header),
466             ↳ linkIndex);
467     }
468     Link.SetSource(link, values[Constants.SourcePart]);
469     Link.SetTarget(link, values[Constants.TargetPart]);
470     if (!_equalityComparer.Equals(Link.GetSource(link), Constants.Null))
471     {
472         _sourcesTreeMethods.Attach(LinksHeader.GetFirstAsSourcePointer(_header),
473             ↳ linkIndex);
474     }
475     if (!_equalityComparer.Equals(Link.GetTarget(link), Constants.Null))
476     {
477         _targetsTreeMethods.Attach(LinksHeader.GetFirstAsTargetPointer(_header),
478             ↳ linkIndex);
479     }
480 }

```

```

472         _targetsTreeMethods.Attach(LinksHeader.GetFirstAsTargetPointer(_header),
473         ↪ linkIndex);
474     }
475     return linkIndex;
476 }
477 [MethodImpl(MethodImplOptions.AggressiveInlining)]
478 public Link<TLink> GetLinkStruct(TLink linkIndex)
479 {
480     var link = GetLinkUnsafe(linkIndex);
481     return new Link<TLink>(linkIndex, Link.GetSource(link), Link.GetTarget(link));
482 }
483 [MethodImpl(MethodImplOptions.AggressiveInlining)]
484 private IntPtr GetLinkUnsafe(TLink linkIndex) => _links.GetElement(LinkSizeInBytes,
485     ↪ linkIndex);
486
487 /// <remarks>
488 /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
489 ↪ пространство
490 /// </remarks>
491 public TLink Create()
492 {
493     var freeLink = LinksHeader.GetFirstFreeLink(_header);
494     if (!_equalityComparer.Equals(freeLink, Constants.Null))
495     {
496         _unusedLinksListMethods.Detach(freeLink);
497     }
498     else
499     {
500         if (_comparer.Compare(LinksHeader.GetAllocatedLinks(_header),
501             ↪ Constants.MaxPossibleIndex) > 0)
502         {
503             throw new
504                 ↪ LinksLimitReachedException((Integer<TLink>)Constants.MaxPossibleIndex);
505         }
506         if (_comparer.Compare(LinksHeader.GetAllocatedLinks(_header),
507             ↪ Decrement(LinksHeader.GetReservedLinks(_header))) >= 0)
508         {
509             _memory.ReservedCapacity += _memory.ReservationStep;
510             SetPointers(_memory);
511             LinksHeader.SetReservedLinks(_header,
512                 ↪ (Integer<TLink>)(_memory.ReservedCapacity / LinkSizeInBytes));
513         }
514         LinksHeader.SetAllocatedLinks(_header,
515             ↪ Increment(LinksHeader.GetAllocatedLinks(_header)));
516         _memory.UsedCapacity += LinkSizeInBytes;
517         freeLink = LinksHeader.GetAllocatedLinks(_header);
518     }
519     return freeLink;
520 }
521
522 public void Delete(TLink link)
523 {
524     if (_comparer.Compare(link, LinksHeader.GetAllocatedLinks(_header)) < 0)
525     {
526         _unusedLinksListMethods.AttachAsFirst(link);
527     }
528     else if (_equalityComparer.Equals(link, LinksHeader.GetAllocatedLinks(_header)))
529     {
530         LinksHeader.SetAllocatedLinks(_header,
531             ↪ Decrement(LinksHeader.GetAllocatedLinks(_header)));
532         _memory.UsedCapacity -= LinkSizeInBytes;
533         // Убираем все связи, находящиеся в списке свободных в конце файла, до тех пор,
534         ↪ пока не дойдём до первой существующей связи
535         // Позволяет оптимизировать количество выделенных связей (AllocatedLinks)
536         while ((_comparer.Compare(LinksHeader.GetAllocatedLinks(_header),
537             ↪ Integer<TLink>.Zero) > 0) &&
538             ↪ IsUnusedLink(LinksHeader.GetAllocatedLinks(_header)))
539         {
540             _unusedLinksListMethods.Detach(LinksHeader.GetAllocatedLinks(_header));
541             LinksHeader.SetAllocatedLinks(_header,
542                 ↪ Decrement(LinksHeader.GetAllocatedLinks(_header)));
543             _memory.UsedCapacity -= LinkSizeInBytes;
544         }
545     }
546 }

```

```

537     /// <remarks>
538     /// TODO: Возможно это должно быть событием, вызываемым из IMemory, в том случае, если
539     /// ↪ адрес реально поменялся
540     ///
541     /// Указатель this.links может быть в том же месте,
542     /// так как 0-я связь не используется и имеет такой же размер как Header,
543     /// поэтому header размещается в том же месте, что и 0-я связь
544     /// </remarks>
545     private void SetPointers(IDirectMemory memory)
546     {
547         if (memory == null)
548         {
549             _links = IntPtr.Zero;
550             _header = _links;
551             _unusedLinksListMethods = null;
552             _targetsTreeMethods = null;
553             _unusedLinksListMethods = null;
554         }
555         else
556         {
557             _links = memory.Pointer;
558             _header = _links;
559             _sourcesTreeMethods = new LinksSourcesTreeMethods(this);
560             _targetsTreeMethods = new LinksTargetsTreeMethods(this);
561             _unusedLinksListMethods = new UnusedLinksListMethods(_links, _header);
562         }
563     }
564     [MethodImpl(MethodImplOptions.AggressiveInlining)]
565     private bool Exists(TLink link)
566     => (_comparer.Compare(link, Constants.MinPossibleIndex) >= 0)
567     && (_comparer.Compare(link, LinksHeader.GetAllocatedLinks(_header)) <= 0)
568     && !IsUnusedLink(link);
569
570     [MethodImpl(MethodImplOptions.AggressiveInlining)]
571     private bool IsUnusedLink(TLink link)
572     => _equalityComparer.Equals(LinksHeader.GetFirstFreeLink(_header), link)
573     || (_equalityComparer.Equals(Link.GetSizeAsSource(GetLinkUnsafe(link)),
574     ↪ Constants.Null)
575     && !_equalityComparer.Equals(Link.GetSource(GetLinkUnsafe(link)), Constants.Null));
576
577     #region DisposableBase
578     protected override bool AllowMultipleDisposeCalls => true;
579
580     protected override void Dispose(bool manual, bool wasDisposed)
581     {
582         if (!wasDisposed)
583         {
584             SetPointers(null);
585             _memory.DisposeIfPossible();
586         }
587     }
588
589     #endregion
590 }
591 }

```

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

```

1  using System;
2  using Platform.Unsafe;
3  using Platform.Collections.Methods.Lists;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.ResizableDirectMemory
8  {
9      partial class ResizableDirectMemoryLinks<TLink>
10     {
11         private class UnusedLinksListMethods : CircularDoublyLinkedListMethods<TLink>
12         {
13             private readonly IntPtr _links;
14             private readonly IntPtr _header;
15
16             public UnusedLinksListMethods(IntPtr links, IntPtr header)
17             {
18                 _links = links;
19                 _header = header;
20             }
21         }
22     }
23 }

```

```

22     protected override TLink GetFirst() => (_header +
    ↪ LinksHeader.FirstFreeLinkOffset).GetValue<TLink>();
23
24     protected override TLink GetLast() => (_header +
    ↪ LinksHeader.LastFreeLinkOffset).GetValue<TLink>();
25
26     protected override TLink GetPrevious(TLink element) =>
    ↪ (_links.GetElement(LinkSizeInBytes, element) +
    ↪ Link.SourceOffset).GetValue<TLink>();
27
28     protected override TLink GetNext(TLink element) =>
    ↪ (_links.GetElement(LinkSizeInBytes, element) +
    ↪ Link.TargetOffset).GetValue<TLink>();
29
30     protected override TLink GetSize() => (_header +
    ↪ LinksHeader.FreeLinksOffset).GetValue<TLink>();
31
32     protected override void SetFirst(TLink element) => (_header +
    ↪ LinksHeader.FirstFreeLinkOffset).SetValue(element);
33
34     protected override void SetLast(TLink element) => (_header +
    ↪ LinksHeader.LastFreeLinkOffset).SetValue(element);
35
36     protected override void SetPrevious(TLink element, TLink previous) =>
    ↪ (_links.GetElement(LinkSizeInBytes, element) +
    ↪ Link.SourceOffset).SetValue(previous);
37
38     protected override void SetNext(TLink element, TLink next) =>
    ↪ (_links.GetElement(LinkSizeInBytes, element) + Link.TargetOffset).SetValue(next);
39
40     protected override void SetSize(TLink size) => (_header +
    ↪ LinksHeader.FreeLinksOffset).SetValue(size);
41 }
42 }
43 }

```

./Platform.Data.Doublets/ResizableDirectMemory/ResizableDirectMemoryLinks.TreeMethods.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.Unsafe;
7  using Platform.Collections.Methods.Trees;
8  using Platform.Data.Constants;
9
10 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
11
12 namespace Platform.Data.Doublets.ResizableDirectMemory
13 {
14     partial class ResizableDirectMemoryLinks<TLink>
15     {
16         private abstract class LinksTreeMethodsBase :
17             ↪ SizedAndThreadedAVLBalancedTreeMethods<TLink>
18         {
19             private readonly ResizableDirectMemoryLinks<TLink> _memory;
20             private readonly LinksCombinedConstants<TLink, TLink, int> _constants;
21             protected readonly IntPtr Links;
22             protected readonly IntPtr Header;
23
24             LinksTreeMethodsBase(ResizableDirectMemoryLinks<TLink> memory)
25             {
26                 Links = memory._links;
27                 Header = memory._header;
28                 _memory = memory;
29                 _constants = memory.Constants;
30             }
31
32             [MethodImpl(MethodImplOptions.AggressiveInlining)]
33             protected abstract TLink GetTreeRoot();
34
35             [MethodImpl(MethodImplOptions.AggressiveInlining)]
36             protected abstract TLink GetBasePartValue(TLink link);
37
38             public TLink this[TLink index]
39             {
40                 get
41                 {
42                     var root = GetTreeRoot();
43                     if (GreaterOrEqualThan(index, GetSize(root)))

```

```

43     {
44         return GetZero();
45     }
46     while (!EqualToZero(root))
47     {
48         var left = GetLeftOrDefault(root);
49         var leftSize = GetSizeOrZero(left);
50         if (LessThan(index, leftSize))
51         {
52             root = left;
53             continue;
54         }
55         if (IsEquals(index, leftSize))
56         {
57             return root;
58         }
59         root = GetRightOrDefault(root);
60         index = Subtract(index, Increment(leftSize));
61     }
62     return GetZero(); // TODO: Impossible situation exception (only if tree
        ↳ structure broken)
63 }
64 }
65
66 // TODO: Return indices range instead of references count
67 public TLink CountUsages(TLink link)
68 {
69     var root = GetTreeRoot();
70     var total = GetSize(root);
71     var totalRightIgnore = GetZero();
72     while (!EqualToZero(root))
73     {
74         var @base = GetBasePartValue(root);
75         if (LessOrEqualThan(@base, link))
76         {
77             root = GetRightOrDefault(root);
78         }
79         else
80         {
81             totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
82             root = GetLeftOrDefault(root);
83         }
84     }
85     root = GetTreeRoot();
86     var totalLeftIgnore = GetZero();
87     while (!EqualToZero(root))
88     {
89         var @base = GetBasePartValue(root);
90         if (GreaterOrEqualThan(@base, link))
91         {
92             root = GetLeftOrDefault(root);
93         }
94         else
95         {
96             totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
97             root = GetRightOrDefault(root);
98         }
99     }
100     return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
101 }
102
103 public TLink EachUsage(TLink link, Func<IList<TLink>, TLink> handler)
104 {
105     var root = GetTreeRoot();
106     if (EqualToZero(root))
107     {
108         return _constants.Continue;
109     }
110     TLink first = GetZero(), current = root;
111     while (!EqualToZero(current))
112     {
113         var @base = GetBasePartValue(current);
114         if (GreaterOrEqualThan(@base, link))
115         {
116             if (IsEquals(@base, link))
117             {
118                 first = current;
119             }

```

```

120         }
121         current = GetLeftOrDefault(current);
122     }
123     else
124     {
125         current = GetRightOrDefault(current);
126     }
127 }
128 if (!EqualToZero(first))
129 {
130     current = first;
131     while (true)
132     {
133         if (IsEquals(handler(_memory.GetLinkStruct(current)), _constants.Break))
134         {
135             return _constants.Break;
136         }
137         current = GetNext(current);
138         if (EqualToZero(current) || !IsEquals(GetBasePartValue(current), link))
139         {
140             break;
141         }
142     }
143 }
144 return _constants.Continue;
145 }
146
147 protected override void PrintNodeValue(TLink node, StringBuilder sb)
148 {
149     sb.Append(' ');
150     sb.Append((Links.GetElement(LinkSizeInBytes, node) +
151         ↳ Link.SourceOffset).GetValue<TLink>());
152     sb.Append('-');
153     sb.Append('>');
154     sb.Append((Links.GetElement(LinkSizeInBytes, node) +
155         ↳ Link.TargetOffset).GetValue<TLink>());
156 }
157
158 private class LinksSourcesTreeMethods : LinksTreeMethodsBase
159 {
160     public LinksSourcesTreeMethods(ResizableDirectMemoryLinks<TLink> memory)
161         : base(memory)
162     {
163     }
164
165     protected override IntPtr GetLeftPointer(TLink node) =>
166         ↳ Links.GetElement(LinkSizeInBytes, node) + Link.LeftAsSourceOffset;
167
168     protected override IntPtr GetRightPointer(TLink node) =>
169         ↳ Links.GetElement(LinkSizeInBytes, node) + Link.RightAsSourceOffset;
170
171     protected override TLink GetLeftValue(TLink node) =>
172         ↳ (Links.GetElement(LinkSizeInBytes, node) +
173         ↳ Link.LeftAsSourceOffset).GetValue<TLink>();
174
175     protected override TLink GetRightValue(TLink node) =>
176         ↳ (Links.GetElement(LinkSizeInBytes, node) +
177         ↳ Link.RightAsSourceOffset).GetValue<TLink>();
178
179     protected override TLink GetSize(TLink node)
180     {
181         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
182             ↳ Link.SizeAsSourceOffset).GetValue<TLink>();
183         return Bit.PartialRead(previousValue, 5, -5);
184     }
185
186     protected override void SetLeft(TLink node, TLink left) =>
187         ↳ (Links.GetElement(LinkSizeInBytes, node) +
188         ↳ Link.LeftAsSourceOffset).SetValue(left);
189
190     protected override void SetRight(TLink node, TLink right) =>
191         ↳ (Links.GetElement(LinkSizeInBytes, node) +
192         ↳ Link.RightAsSourceOffset).SetValue(right);
193
194     protected override void SetSize(TLink node, TLink size)
195     {

```



```

184     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
185         ↪ Link.SizeAsSourceOffset).GetValue<TLink>();
186     (Links.GetElement(LinkSizeInBytes, node) +
187         ↪ Link.SizeAsSourceOffset).SetValue(Bit.PartialWrite(previousValue, size, 5,
188         ↪ -5));
189 }
190
191 protected override bool GetLeftIsChild(TLink node)
192 {
193     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
194         ↪ Link.SizeAsSourceOffset).GetValue<TLink>();
195     return (Integer<TLink>)Bit.PartialRead(previousValue, 4, 1);
196 }
197
198 protected override void SetLeftIsChild(TLink node, bool value)
199 {
200     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
201         ↪ Link.SizeAsSourceOffset).GetValue<TLink>();
202     var modified = Bit.PartialWrite(previousValue, (TLink)(Integer<TLink>)value, 4,
203         ↪ 1);
204     (Links.GetElement(LinkSizeInBytes, node) +
205         ↪ Link.SizeAsSourceOffset).SetValue(modified);
206 }
207
208 protected override bool GetRightIsChild(TLink node)
209 {
210     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
211         ↪ Link.SizeAsSourceOffset).GetValue<TLink>();
212     return (Integer<TLink>)Bit.PartialRead(previousValue, 3, 1);
213 }
214
215 protected override void SetRightIsChild(TLink node, bool value)
216 {
217     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
218         ↪ Link.SizeAsSourceOffset).GetValue<TLink>();
219     var modified = Bit.PartialWrite(previousValue, (TLink)(Integer<TLink>)value, 3,
220         ↪ 1);
221     (Links.GetElement(LinkSizeInBytes, node) +
222         ↪ Link.SizeAsSourceOffset).SetValue(modified);
223 }
224
225 protected override sbyte GetBalance(TLink node)
226 {
227     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
228         ↪ Link.SizeAsSourceOffset).GetValue<TLink>();
229     var value = (ulong)(Integer<TLink>)Bit.PartialRead(previousValue, 0, 3);
230     var unpackedValue = (sbyte)((value & 4) > 0 ? ((value & 4) << 5) | value & 3 |
231         ↪ 124 : value & 3);
232     return unpackedValue;
233 }
234
235 protected override void SetBalance(TLink node, sbyte value)
236 {
237     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
238         ↪ Link.SizeAsSourceOffset).GetValue<TLink>();
239     var packagedValue = (TLink)(Integer<TLink>)((((byte)value >> 5) & 4) | value &
240         ↪ 3);
241     modified = Bit.PartialWrite(previousValue, packagedValue, 0, 3);
242     (Links.GetElement(LinkSizeInBytes, node) +
243         ↪ Link.SizeAsSourceOffset).SetValue(modified);
244 }
245
246 protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
247 {
248     var firstSource = (Links.GetElement(LinkSizeInBytes, first) +
249         ↪ Link.SourceOffset).GetValue<TLink>();
250     var secondSource = (Links.GetElement(LinkSizeInBytes, second) +
251         ↪ Link.SourceOffset).GetValue<TLink>();
252     return LessThan(firstSource, secondSource) ||
253         (IsEquals(firstSource, secondSource) &&
254         ↪ LessThan((Links.GetElement(LinkSizeInBytes, first) +
255         ↪ Link.TargetOffset).GetValue<TLink>(),
256         ↪ (Links.GetElement(LinkSizeInBytes, second) +
257         ↪ Link.TargetOffset).GetValue<TLink>()));
258 }

```

```

238     protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
239     {
240         var firstSource = (Links.GetElement(LinkSizeInBytes, first) +
241             ↪ Link.SourceOffset).GetValue<TLink>();
242         var secondSource = (Links.GetElement(LinkSizeInBytes, second) +
243             ↪ Link.SourceOffset).GetValue<TLink>();
244         return GreaterThan(firstSource, secondSource) ||
245             (IsEquals(firstSource, secondSource) &&
246             ↪ GreaterThan((Links.GetElement(LinkSizeInBytes, first) +
247             ↪ Link.TargetOffset).GetValue<TLink>(),
248             ↪ (Links.GetElement(LinkSizeInBytes, second) +
249             ↪ Link.TargetOffset).GetValue<TLink>()));
250     }
251
252     protected override TLink GetTreeRoot() => (Header +
253     ↪ LinksHeader.FirstAsSourceOffset).GetValue<TLink>();
254
255     protected override TLink GetBasePartValue(TLink link) =>
256     ↪ (Links.GetElement(LinkSizeInBytes, link) + Link.SourceOffset).GetValue<TLink>();
257
258     /// <summary>
259     /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
260     ↪ (концом)
261     /// по дереву (индексу) связей, отсортированному по Source, а затем по Target.
262     /// </summary>
263     /// <param name="source">Индекс связи, которая является началом на искомой
264     ↪ связи.</param>
265     /// <param name="target">Индекс связи, которая является концом на искомой
266     ↪ связи.</param>
267     /// <returns>Индекс искомой связи.</returns>
268     public TLink Search(TLink source, TLink target)
269     {
270         var root = GetTreeRoot();
271         while (!EqualToZero(root))
272         {
273             var rootSource = (Links.GetElement(LinkSizeInBytes, root) +
274             ↪ Link.SourceOffset).GetValue<TLink>();
275             var rootTarget = (Links.GetElement(LinkSizeInBytes, root) +
276             ↪ Link.TargetOffset).GetValue<TLink>();
277             if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
278             ↪ node.Key < root.Key
279             {
280                 root = GetLeftOrDefault(root);
281             }
282             else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget))
283             ↪ // node.Key > root.Key
284             {
285                 root = GetRightOrDefault(root);
286             }
287             else // node.Key == root.Key
288             {
289                 return root;
290             }
291         }
292         return GetZero();
293     }
294
295     [MethodImpl(MethodImplOptions.AggressiveInlining)]
296     private bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget, TLink
297     ↪ secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) ||
298     ↪ (IsEquals(firstSource, secondSource) && LessThan(firstTarget, secondTarget));
299
300     [MethodImpl(MethodImplOptions.AggressiveInlining)]
301     private bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget, TLink
302     ↪ secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) ||
303     ↪ (IsEquals(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget));
304 }
305
306 private class LinksTargetsTreeMethods : LinksTreeMethodsBase
307 {
308     public LinksTargetsTreeMethods(ResizableDirectMemoryLinks<TLink> memory)
309     : base(memory)
310     {
311     }
312 }
313
314 protected override IntPtr GetLeftPointer(TLink node) =>
315     ↪ Links.GetElement(LinkSizeInBytes, node) + Link.LeftAsTargetOffset;

```

```

295
296     protected override IntPtr GetRightPointer(TLink node) =>
297         ↳ Links.GetElement(LinkSizeInBytes, node) + Link.RightAsTargetOffset;
298
299     protected override TLink GetLeftValue(TLink node) =>
300         ↳ (Links.GetElement(LinkSizeInBytes, node) +
301         ↳ Link.LeftAsTargetOffset).GetValue<TLink>();
302
303     protected override TLink GetRightValue(TLink node) =>
304         ↳ (Links.GetElement(LinkSizeInBytes, node) +
305         ↳ Link.RightAsTargetOffset).GetValue<TLink>();
306
307     protected override TLink GetSize(TLink node)
308     {
309         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
310         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
311         return Bit.PartialRead(previousValue, 5, -5);
312     }
313
314     protected override void SetLeft(TLink node, TLink left) =>
315         ↳ (Links.GetElement(LinkSizeInBytes, node) +
316         ↳ Link.LeftAsTargetOffset).SetValue(left);
317
318     protected override void SetRight(TLink node, TLink right) =>
319         ↳ (Links.GetElement(LinkSizeInBytes, node) +
320         ↳ Link.RightAsTargetOffset).SetValue(right);
321
322     protected override void SetSize(TLink node, TLink size)
323     {
324         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
325         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
326         (Links.GetElement(LinkSizeInBytes, node) +
327         ↳ Link.SizeAsTargetOffset).SetValue(Bit.PartialWrite(previousValue, size, 5,
328         ↳ -5));
329     }
330
331     protected override bool GetLeftIsChild(TLink node)
332     {
333         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
334         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
335         return (Integer<TLink>)Bit.PartialRead(previousValue, 4, 1);
336     }
337
338     protected override void SetLeftIsChild(TLink node, bool value)
339     {
340         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
341         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
342         var modified = Bit.PartialWrite(previousValue, (TLink)(Integer<TLink>)value, 4,
343         ↳ 1);
344         (Links.GetElement(LinkSizeInBytes, node) +
345         ↳ Link.SizeAsTargetOffset).SetValue(modified);
346     }
347
348     protected override bool GetRightIsChild(TLink node)
349     {
350         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
351         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
352         return (Integer<TLink>)Bit.PartialRead(previousValue, 3, 1);
353     }
354
355     protected override void SetRightIsChild(TLink node, bool value)
356     {
357         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
358         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
359         var modified = Bit.PartialWrite(previousValue, (TLink)(Integer<TLink>)value, 3,
360         ↳ 1);
361         (Links.GetElement(LinkSizeInBytes, node) +
362         ↳ Link.SizeAsTargetOffset).SetValue(modified);
363     }
364
365     protected override sbyte GetBalance(TLink node)
366     {
367         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
368         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
369         var value = (ulong)(Integer<TLink>)Bit.PartialRead(previousValue, 0, 3);
370         var unpackedValue = (sbyte)((value & 4) > 0 ? ((value & 4) << 5) | value & 3 |
371         ↳ 124 : value & 3);
372     }

```

```

349         return unpackedValue;
350     }
351
352     protected override void SetBalance(TLink node, sbyte value)
353     {
354         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
355             ↪ Link.SizeAsTargetOffset).GetValue<TLink>();
356         var packagedValue = (TLink)(Integer<TLink>)((((byte)value >> 5) & 4) | value &
357             ↪ 3);
358         var modified = Bit.PartialWrite(previousValue, packagedValue, 0, 3);
359         (Links.GetElement(LinkSizeInBytes, node) +
360             ↪ Link.SizeAsTargetOffset).SetValue(modified);
361     }
362
363     protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
364     {
365         var firstTarget = (Links.GetElement(LinkSizeInBytes, first) +
366             ↪ Link.TargetOffset).GetValue<TLink>();
367         var secondTarget = (Links.GetElement(LinkSizeInBytes, second) +
368             ↪ Link.TargetOffset).GetValue<TLink>();
369         return LessThan(firstTarget, secondTarget) ||
370             (IsEquals(firstTarget, secondTarget) &&
371             ↪ LessThan((Links.GetElement(LinkSizeInBytes, first) +
372             ↪ Link.SourceOffset).GetValue<TLink>(),
373             ↪ (Links.GetElement(LinkSizeInBytes, second) +
374             ↪ Link.SourceOffset).GetValue<TLink>()));
375     }
376
377     protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
378     {
379         var firstTarget = (Links.GetElement(LinkSizeInBytes, first) +
380             ↪ Link.TargetOffset).GetValue<TLink>();
381         var secondTarget = (Links.GetElement(LinkSizeInBytes, second) +
382             ↪ Link.TargetOffset).GetValue<TLink>();
383         return GreaterThan(firstTarget, secondTarget) ||
384             (IsEquals(firstTarget, secondTarget) &&
385             ↪ GreaterThan((Links.GetElement(LinkSizeInBytes, first) +
386             ↪ Link.SourceOffset).GetValue<TLink>(),
387             ↪ (Links.GetElement(LinkSizeInBytes, second) +
388             ↪ Link.SourceOffset).GetValue<TLink>()));
389     }
390
391     protected override TLink GetTreeRoot() => (Header +
392         ↪ LinksHeader.FirstAsTargetOffset).GetValue<TLink>();
393
394     protected override TLink GetBasePartValue(TLink link) =>
395         ↪ (Links.GetElement(LinkSizeInBytes, link) + Link.TargetOffset).GetValue<TLink>();
396 }
397
398 }
399
400 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Disposables;
5  using Platform.Collections.Arrays;
6  using Platform.Singletons;
7  using Platform.Memory;
8  using Platform.Data.Exceptions;
9  using Platform.Data.Constants;
10
11  #pragma warning disable 0649
12  #pragma warning disable 169
13  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
14
15  // ReSharper disable BuiltInTypeReferenceStyle
16
17  //#define ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
18
19  namespace Platform.Data.Doublets.ResizableDirectMemory
20  {
21      using id = UInt64;
22
23      public unsafe partial class UInt64ResizableDirectMemoryLinks : DisposableBase, ILinks<id>
24      {
25          /// <summary>Возвращает размер одной связи в байтах.</summary>
26          /// <remarks>
27          /// Используется только во вне класса, не рекомендуется использовать внутри.

```

```

28     /// Так как во вне не обязательно будет доступен unsafe C#.
29     /// </remarks>
30     public static readonly int LinkSizeInBytes = sizeof(Link);
31
32     public static readonly long DefaultLinksSizeStep = LinkSizeInBytes * 1024 * 1024;
33
34     private struct Link
35     {
36         public id Source;
37         public id Target;
38         public id LeftAsSource;
39         public id RightAsSource;
40         public id SizeAsSource;
41         public id LeftAsTarget;
42         public id RightAsTarget;
43         public id SizeAsTarget;
44     }
45
46     private struct LinksHeader
47     {
48         public id AllocatedLinks;
49         public id ReservedLinks;
50         public id FreeLinks;
51         public id FirstFreeLink;
52         public id FirstAsSource;
53         public id FirstAsTarget;
54         public id LastFreeLink;
55         public id Reserved8;
56     }
57
58     private readonly long _memoryReservationStep;
59
60     private readonly IResizableDirectMemory _memory;
61     private LinksHeader* _header;
62     private Link* _links;
63
64     private LinksTargetsTreeMethods _targetsTreeMethods;
65     private LinksSourcesTreeMethods _sourcesTreeMethods;
66
67     // TODO: Возможно чтобы гарантированно проверять на то, является ли связь удалённой,
68     // → нужно использовать не список а дерево, так как так можно быстрее проверить на
69     // → наличие связи внутри
70     private UnusedLinksListMethods _unusedLinksListMethods;
71
72     /// <summary>
73     /// Возвращает общее число связей находящихся в хранилище.
74     /// </summary>
75     private id Total => _header->AllocatedLinks - _header->FreeLinks;
76
77     // TODO: Дать возможность переопределять в конструкторе
78     public LinksCombinedConstants<id, id, int> Constants { get; }
79
80     public UInt64ResizableDirectMemoryLinks(string address) : this(address,
81     → DefaultLinksSizeStep) { }
82
83     /// <summary>
84     /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
85     → минимальным шагом расширения базы данных.
86     /// </summary>
87     /// <param name="address">Полный путь к файлу базы данных.</param>
88     /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
89     → байтах.</param>
90     public UInt64ResizableDirectMemoryLinks(string address, long memoryReservationStep) :
91     → this(new FileMappedResizableDirectMemory(address, memoryReservationStep),
92     → memoryReservationStep) { }
93
94     public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory) : this(memory,
95     → DefaultLinksSizeStep) { }
96
97     public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
98     → memoryReservationStep)
99     {
100         Constants = Default<LinksCombinedConstants<id, id, int>>.Instance;
101         _memory = memory;
102         _memoryReservationStep = memoryReservationStep;
103         if (memory.ReservedCapacity < memoryReservationStep)
104         {
105             memory.ReservedCapacity = memoryReservationStep;
106         }
107         SetPointers(_memory);
108         // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks

```

```

_memory.UsedCapacity = ((long)_header->AllocatedLinks * sizeof(Link)) +
    ↳ sizeof(LinksHeader);
// Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
_header->ReservedLinks = (id)((_memory.ReservedCapacity - sizeof(LinksHeader)) /
    ↳ sizeof(Link));
}

[MethodImpl(MethodImplOptions.AggressiveInlining)]
public id Count(IList<id> restrictions)
{
    // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
    if (restrictions.Count == 0)
    {
        return Total;
    }
    if (restrictions.Count == 1)
    {
        var index = restrictions[Constants.IndexPart];
        if (index == Constants.Any)
        {
            return Total;
        }
        return Exists(index) ? 1UL : 0UL;
    }
    if (restrictions.Count == 2)
    {
        var index = restrictions[Constants.IndexPart];
        var value = restrictions[1];
        if (index == Constants.Any)
        {
            if (value == Constants.Any)
            {
                return Total; // Any - как отсутствие ограничения
            }
            return _sourcesTreeMethods.CountUsages(value)
                + _targetsTreeMethods.CountUsages(value);
        }
        else
        {
            if (!Exists(index))
            {
                return 0;
            }
            if (value == Constants.Any)
            {
                return 1;
            }
            var storedLinkValue = GetLinkUnsafe(index);
            if (storedLinkValue->Source == value ||
                storedLinkValue->Target == value)
            {
                return 1;
            }
            return 0;
        }
    }
    if (restrictions.Count == 3)
    {
        var index = restrictions[Constants.IndexPart];
        var source = restrictions[Constants.SourcePart];
        var target = restrictions[Constants.TargetPart];
        if (index == Constants.Any)
        {
            if (source == Constants.Any && target == Constants.Any)
            {
                return Total;
            }
            else if (source == Constants.Any)
            {
                return _targetsTreeMethods.CountUsages(target);
            }
            else if (target == Constants.Any)
            {
                return _sourcesTreeMethods.CountUsages(source);
            }
            else //if(source != Any && target != Any)
            {
                // Эквивалент Exists(source, target) => Count(Any, source, target) > 0
            }
        }
    }
}

```

```

176         var link = _sourcesTreeMethods.Search(source, target);
177         return link == Constants.Null ? OUL : IUL;
178     }
179 }
180 else
181 {
182     if (!Exists(index))
183     {
184         return 0;
185     }
186     if (source == Constants.Any && target == Constants.Any)
187     {
188         return 1;
189     }
190     var storedLinkValue = GetLinkUnsafe(index);
191     if (source != Constants.Any && target != Constants.Any)
192     {
193         if (storedLinkValue->Source == source &&
194             storedLinkValue->Target == target)
195         {
196             return 1;
197         }
198         return 0;
199     }
200     var value = default(id);
201     if (source == Constants.Any)
202     {
203         value = target;
204     }
205     if (target == Constants.Any)
206     {
207         value = source;
208     }
209     if (storedLinkValue->Source == value ||
210         storedLinkValue->Target == value)
211     {
212         return 1;
213     }
214     return 0;
215 }
216 }
217 throw new NotSupportedException("Другие размеры и способы ограничений не
    ↳ поддерживаются.");
218 }
219
220 [MethodImpl(MethodImplOptions.AggressiveInlining)]
221 public id Each(Func<IList<id>, id> handler, IList<id> restrictions)
222 {
223     if (restrictions.Count == 0)
224     {
225         for (id link = 1; link <= _header->AllocatedLinks; link++)
226         {
227             if (Exists(link))
228             {
229                 if (handler(GetLinkStruct(link)) == Constants.Break)
230                 {
231                     return Constants.Break;
232                 }
233             }
234         }
235         return Constants.Continue;
236     }
237     if (restrictions.Count == 1)
238     {
239         var index = restrictions[Constants.IndexPart];
240         if (index == Constants.Any)
241         {
242             return Each(handler, ArrayPool<ulong>.Empty);
243         }
244         if (!Exists(index))
245         {
246             return Constants.Continue;
247         }
248         return handler(GetLinkStruct(index));
249     }
250     if (restrictions.Count == 2)
251     {
252         var index = restrictions[Constants.IndexPart];
253         var value = restrictions[1];

```

```

254 if (index == Constants.Any)
255 {
256     if (value == Constants.Any)
257     {
258         return Each(handler, ArrayPool<ulong>.Empty);
259     }
260     if (Each(handler, new[] { index, value, Constants.Any }) == Constants.Break)
261     {
262         return Constants.Break;
263     }
264     return Each(handler, new[] { index, Constants.Any, value });
265 }
266 else
267 {
268     if (!Exists(index))
269     {
270         return Constants.Continue;
271     }
272     if (value == Constants.Any)
273     {
274         return handler(GetLinkStruct(index));
275     }
276     var storedLinkValue = GetLinkUnsafe(index);
277     if (storedLinkValue->Source == value ||
278         storedLinkValue->Target == value)
279     {
280         return handler(GetLinkStruct(index));
281     }
282     return Constants.Continue;
283 }
284 }
285 if (restrictions.Count == 3)
286 {
287     var index = restrictions[Constants.IndexPart];
288     var source = restrictions[Constants.SourcePart];
289     var target = restrictions[Constants.TargetPart];
290     if (index == Constants.Any)
291     {
292         if (source == Constants.Any && target == Constants.Any)
293         {
294             return Each(handler, ArrayPool<ulong>.Empty);
295         }
296         else if (source == Constants.Any)
297         {
298             return _targetsTreeMethods.EachReference(target, handler);
299         }
300         else if (target == Constants.Any)
301         {
302             return _sourcesTreeMethods.EachReference(source, handler);
303         }
304         else //if(source != Any && target != Any)
305         {
306             var link = _sourcesTreeMethods.Search(source, target);
307             return link == Constants.Null ? Constants.Continue :
308                 ↪ handler(GetLinkStruct(link));
309         }
310     }
311     else
312     {
313         if (!Exists(index))
314         {
315             return Constants.Continue;
316         }
317         if (source == Constants.Any && target == Constants.Any)
318         {
319             return handler(GetLinkStruct(index));
320         }
321         var storedLinkValue = GetLinkUnsafe(index);
322         if (source != Constants.Any && target != Constants.Any)
323         {
324             if (storedLinkValue->Source == source &&
325                 storedLinkValue->Target == target)
326             {
327                 return handler(GetLinkStruct(index));
328             }
329             return Constants.Continue;
330         }
331         var value = default(id);

```



```

331         if (source == Constants.Any)
332         {
333             value = target;
334         }
335         if (target == Constants.Any)
336         {
337             value = source;
338         }
339         if (storedLinkValue->Source == value ||
340             storedLinkValue->Target == value)
341         {
342             return handler(GetLinkStruct(index));
343         }
344         return Constants.Continue;
345     }
346 }
347 throw new NotSupportedException("Другие размеры и способы ограничений не
    ↳ поддерживаются.");
348 }
349
350 /// <remarks>
351 /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
    ↳ в другом месте (но не в менеджере памяти, а в логике Links)
352 /// </remarks>
353 [MethodImpl(MethodImplOptions.AggressiveInlining)]
354 public id Update(IList<id> values)
355 {
356     var linkIndex = values[Constants.IndexPart];
357     var link = GetLinkUnsafe(linkIndex);
358     // Будет корректно работать только в том случае, если пространство выделенной связи
    ↳ предварительно заполнено нулями
359     if (link->Source != Constants.Null)
360     {
361         _sourcesTreeMethods.Detach(new IntPtr(&_header->FirstAsSource), linkIndex);
362     }
363     if (link->Target != Constants.Null)
364     {
365         _targetsTreeMethods.Detach(new IntPtr(&_header->FirstAsTarget), linkIndex);
366     }
367 #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
368     var leftTreeSize = _sourcesTreeMethods.GetSize(new IntPtr(&_header->FirstAsSource));
369     var rightTreeSize = _targetsTreeMethods.GetSize(new IntPtr(&_header->FirstAsTarget));
370     if (leftTreeSize != rightTreeSize)
371     {
372         throw new Exception("One of the trees is broken.");
373     }
374 #endif
375     link->Source = values[Constants.SourcePart];
376     link->Target = values[Constants.TargetPart];
377     if (link->Source != Constants.Null)
378     {
379         _sourcesTreeMethods.Attach(new IntPtr(&_header->FirstAsSource), linkIndex);
380     }
381     if (link->Target != Constants.Null)
382     {
383         _targetsTreeMethods.Attach(new IntPtr(&_header->FirstAsTarget), linkIndex);
384     }
385 #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
386     leftTreeSize = _sourcesTreeMethods.GetSize(new IntPtr(&_header->FirstAsSource));
387     rightTreeSize = _targetsTreeMethods.GetSize(new IntPtr(&_header->FirstAsTarget));
388     if (leftTreeSize != rightTreeSize)
389     {
390         throw new Exception("One of the trees is broken.");
391     }
392 #endif
393     return linkIndex;
394 }
395
396 [MethodImpl(MethodImplOptions.AggressiveInlining)]
397 private IList<id> GetLinkStruct(id linkIndex)
398 {
399     var link = GetLinkUnsafe(linkIndex);
400     return new UInt64Link(linkIndex, link->Source, link->Target);
401 }
402
403 [MethodImpl(MethodImplOptions.AggressiveInlining)]
404 private Link* GetLinkUnsafe(id linkIndex) => &_links[linkIndex];
405

```

```

406 /// <remarks>
407 /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
408   ↳ пространство
409 /// </remarks>
410 public id Create()
411 {
412     var freeLink = _header->FirstFreeLink;
413     if (freeLink != Constants.Null)
414     {
415         _unusedLinksListMethods.Detach(freeLink);
416     }
417     else
418     {
419         if (_header->AllocatedLinks > Constants.MaxPossibleIndex)
420         {
421             throw new LinksLimitReachedException(Constants.MaxPossibleIndex);
422         }
423         if (_header->AllocatedLinks >= _header->ReservedLinks - 1)
424         {
425             _memory.ReservedCapacity += _memory.ReservationStep;
426             SetPointers(_memory);
427             _header->ReservedLinks = (id)(_memory.ReservedCapacity / sizeof(Link));
428         }
429         _header->AllocatedLinks++;
430         _memory.UsedCapacity += sizeof(Link);
431         freeLink = _header->AllocatedLinks;
432     }
433     return freeLink;
434 }
435 public void Delete(id link)
436 {
437     if (link < _header->AllocatedLinks)
438     {
439         _unusedLinksListMethods.AttachAsFirst(link);
440     }
441     else if (link == _header->AllocatedLinks)
442     {
443         _header->AllocatedLinks--;
444         _memory.UsedCapacity -= sizeof(Link);
445         // Убираем все связи, находящиеся в списке свободных в конце файла, до тех пор,
446         // пока не дойдём до первой существующей связи
447         // Позволяет оптимизировать количество выделенных связей (AllocatedLinks)
448         while (_header->AllocatedLinks > 0 && IsUnusedLink(_header->AllocatedLinks))
449         {
450             _unusedLinksListMethods.Detach(_header->AllocatedLinks);
451             _header->AllocatedLinks--;
452             _memory.UsedCapacity -= sizeof(Link);
453         }
454     }
455 }
456 /// <remarks>
457 /// TODO: Возможно это должно быть событием, вызываемым из IMemory, в том случае, если
458   ↳ адрес реально поменялся
459 ///
460 /// Указатель this.links может быть в том же месте,
461 /// так как 0-я связь не используется и имеет такой же размер как Header,
462 /// поэтому header размещается в том же месте, что и 0-я связь
463 /// </remarks>
464 private void SetPointers(IResizableDirectMemory memory)
465 {
466     if (memory == null)
467     {
468         _header = null;
469         _links = null;
470         _unusedLinksListMethods = null;
471         _targetsTreeMethods = null;
472         _unusedLinksListMethods = null;
473     }
474     else
475     {
476         _header = (LinksHeader*)(void*)memory.Pointer;
477         _links = (Link*)(void*)memory.Pointer;
478         _sourcesTreeMethods = new LinksSourcesTreeMethods(this);
479         _targetsTreeMethods = new LinksTargetsTreeMethods(this);
480         _unusedLinksListMethods = new UnusedLinksListMethods(_links, _header);
481     }
482 }

```

```

482     [MethodImpl(MethodImplOptions.AggressiveInlining)]
483     private bool Exists(id link) => link >= Constants.MinPossibleIndex && link <=
484         ↪ _header->AllocatedLinks && !IsUnusedLink(link);
485
486     [MethodImpl(MethodImplOptions.AggressiveInlining)]
487     private bool IsUnusedLink(id link) => _header->FirstFreeLink == link
488         || (_links[link].SizeAsSource == Constants.Null &&
489             ↪ _links[link].Source != Constants.Null);
489
490     #region Disposable
491
492     protected override bool AllowMultipleDisposeCalls => true;
493
494     protected override void Dispose(bool manual, bool wasDisposed)
495     {
496         if (!wasDisposed)
497         {
498             SetPointers(null);
499             _memory.DisposeIfPossible();
500         }
501     }
502
503     #endregion
504 }
505 }

```

```

./Platform.Data.Doublets/ResizableDirectMemory/UInt64ResizableDirectMemoryLinks.ListMethods.cs
1  using Platform.Collections.Methods.Lists;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.ResizableDirectMemory
6  {
7      unsafe partial class UInt64ResizableDirectMemoryLinks
8      {
9          private class UnusedLinksListMethods : CircularDoublyLinkedListMethods<ulong>
10         {
11             private readonly Link* _links;
12             private readonly LinksHeader* _header;
13
14             public UnusedLinksListMethods(Link* links, LinksHeader* header)
15             {
16                 _links = links;
17                 _header = header;
18             }
19
20             protected override ulong GetFirst() => _header->FirstFreeLink;
21
22             protected override ulong GetLast() => _header->LastFreeLink;
23
24             protected override ulong GetPrevious(ulong element) => _links[element].Source;
25
26             protected override ulong GetNext(ulong element) => _links[element].Target;
27
28             protected override ulong GetSize() => _header->FreeLinks;
29
30             protected override void SetFirst(ulong element) => _header->FirstFreeLink = element;
31
32             protected override void SetLast(ulong element) => _header->LastFreeLink = element;
33
34             protected override void SetPrevious(ulong element, ulong previous) =>
35                 ↪ _links[element].Source = previous;
36
37             protected override void SetNext(ulong element, ulong next) => _links[element].Target
38                 ↪ = next;
39
40             protected override void SetSize(ulong size) => _header->FreeLinks = size;
41         }
42     }
43 }

```

```

./Platform.Data.Doublets/ResizableDirectMemory/UInt64ResizableDirectMemoryLinks.TreeMethods.cs
1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using System.Text;
5  using Platform.Collections.Methods.Trees;
6  using Platform.Data.Constants;
7

```

```

8  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets.ResizableDirectMemory
11 {
12     unsafe partial class UInt64ResizableDirectMemoryLinks
13     {
14         private abstract class LinksTreeMethodsBase :
15             ↳ SizedAndThreadedAVLBalancedTreeMethods<ulong>
16         {
17             private readonly UInt64ResizableDirectMemoryLinks _memory;
18             private readonly LinksCombinedConstants<ulong, ulong, int> _constants;
19             protected readonly Link* Links;
20             protected readonly LinksHeader* Header;
21
22             protected LinksTreeMethodsBase(UInt64ResizableDirectMemoryLinks memory)
23             {
24                 Links = memory._links;
25                 Header = memory._header;
26                 _memory = memory;
27                 _constants = memory.Constants;
28             }
29
30             [MethodImpl(MethodImplOptions.AggressiveInlining)]
31             protected abstract ulong GetTreeRoot();
32
33             [MethodImpl(MethodImplOptions.AggressiveInlining)]
34             protected abstract ulong GetBasePartValue(ulong link);
35
36             public ulong this[ulong index]
37             {
38                 get
39                 {
40                     var root = GetTreeRoot();
41                     if (index >= GetSize(root))
42                     {
43                         return 0;
44                     }
45                     while (root != 0)
46                     {
47                         var left = GetLeftOrDefault(root);
48                         var leftSize = GetSizeOrZero(left);
49                         if (index < leftSize)
50                         {
51                             root = left;
52                             continue;
53                         }
54                         if (index == leftSize)
55                         {
56                             return root;
57                         }
58                         root = GetRightOrDefault(root);
59                         index -= leftSize + 1;
60                     }
61                     return 0; // TODO: Impossible situation exception (only if tree structure
62                     ↳ broken)
63                 }
64             }
65
66             // TODO: Return indices range instead of references count
67             public ulong CountUsages(ulong link)
68             {
69                 var root = GetTreeRoot();
70                 var total = GetSize(root);
71                 var totalRightIgnore = 0UL;
72                 while (root != 0)
73                 {
74                     var @base = GetBasePartValue(root);
75                     if (@base <= link)
76                     {
77                         root = GetRightOrDefault(root);
78                     }
79                     else
80                     {
81                         totalRightIgnore += GetRightSize(root) + 1;
82                         root = GetLeftOrDefault(root);
83                     }
84                 }
85                 root = GetTreeRoot();
86                 var totalLeftIgnore = 0UL;
87                 while (root != 0)

```

```

86     {
87         var @base = GetBasePartValue(root);
88         if (@base >= link)
89         {
90             root = GetLeftOrDefault(root);
91         }
92         else
93         {
94             totalLeftIgnore += GetLeftSize(root) + 1;
95             root = GetRightOrDefault(root);
96         }
97     }
98     return total - totalRightIgnore - totalLeftIgnore;
99 }
100
101 public ulong EachReference(ulong link, Func<IList<ulong>, ulong> handler)
102 {
103     var root = GetTreeRoot();
104     if (root == 0)
105     {
106         return _constants.Continue;
107     }
108     ulong first = 0, current = root;
109     while (current != 0)
110     {
111         var @base = GetBasePartValue(current);
112         if (@base >= link)
113         {
114             if (@base == link)
115             {
116                 first = current;
117             }
118             current = GetLeftOrDefault(current);
119         }
120         else
121         {
122             current = GetRightOrDefault(current);
123         }
124     }
125     if (first != 0)
126     {
127         current = first;
128         while (true)
129         {
130             if (handler(_memory.GetLinkStruct(current)) == _constants.Break)
131             {
132                 return _constants.Break;
133             }
134             current = GetNext(current);
135             if (current == 0 || GetBasePartValue(current) != link)
136             {
137                 break;
138             }
139         }
140     }
141     return _constants.Continue;
142 }
143
144 protected override void PrintNodeValue(ulong node, StringBuilder sb)
145 {
146     sb.Append(' ');
147     sb.Append(Links[node].Source);
148     sb.Append('-');
149     sb.Append('>');
150     sb.Append(Links[node].Target);
151 }
152
153 private class LinksSourcesTreeMethods : LinksTreeMethodsBase
154 {
155     public LinksSourcesTreeMethods(UInt64ResizableDirectMemoryLinks memory)
156         : base(memory)
157     {
158     }
159
160     protected override IntPtr GetLeftPointer(ulong node) => new
161         ↳ IntPtr(&Links[node].LeftAsSource);
162

```

```

163     protected override IntPtr GetRightPointer(ulong node) => new
164         ↳ IntPtr(&Links[node].RightAsSource);
165
166     protected override ulong GetLeftValue(ulong node) => Links[node].LeftAsSource;
167
168     protected override ulong GetRightValue(ulong node) => Links[node].RightAsSource;
169
170     protected override ulong GetSize(ulong node)
171     {
172         var previousValue = Links[node].SizeAsSource;
173         //return Math.PartialRead(previousValue, 5, -5);
174         return (previousValue & 4294967264) >> 5;
175     }
176
177     protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsSource
178         ↳ = left;
179
180     protected override void SetRight(ulong node, ulong right) =>
181         ↳ Links[node].RightAsSource = right;
182
183     protected override void SetSize(ulong node, ulong size)
184     {
185         var previousValue = Links[node].SizeAsSource;
186         //var modified = Math.PartialWrite(previousValue, size, 5, -5);
187         var modified = (previousValue & 31) | ((size & 134217727) << 5);
188         Links[node].SizeAsSource = modified;
189     }
190
191     protected override bool GetLeftIsChild(ulong node)
192     {
193         var previousValue = Links[node].SizeAsSource;
194         //return (Integer)Math.PartialRead(previousValue, 4, 1);
195         return (previousValue & 16) >> 4 == 1UL;
196     }
197
198     protected override void SetLeftIsChild(ulong node, bool value)
199     {
200         var previousValue = Links[node].SizeAsSource;
201         //var modified = Math.PartialWrite(previousValue, (ulong)(Integer)value, 4, 1);
202         var modified = (previousValue & 4294967279) | ((value ? 1UL : 0UL) << 4);
203         Links[node].SizeAsSource = modified;
204     }
205
206     protected override bool GetRightIsChild(ulong node)
207     {
208         var previousValue = Links[node].SizeAsSource;
209         //return (Integer)Math.PartialRead(previousValue, 3, 1);
210         return (previousValue & 8) >> 3 == 1UL;
211     }
212
213     protected override void SetRightIsChild(ulong node, bool value)
214     {
215         var previousValue = Links[node].SizeAsSource;
216         //var modified = Math.PartialWrite(previousValue, (ulong)(Integer)value, 3, 1);
217         var modified = (previousValue & 4294967287) | ((value ? 1UL : 0UL) << 3);
218         Links[node].SizeAsSource = modified;
219     }
220
221     protected override sbyte GetBalance(ulong node)
222     {
223         var previousValue = Links[node].SizeAsSource;
224         //var value = Math.PartialRead(previousValue, 0, 3);
225         var value = previousValue & 7;
226         var unpackedValue = (sbyte)((value & 4) > 0 ? ((value & 4) << 5) | value & 3 |
227             ↳ 124 : value & 3);
228         return unpackedValue;
229     }
230
231     protected override void SetBalance(ulong node, sbyte value)
232     {
233         var previousValue = Links[node].SizeAsSource;
234         var packagedValue = (ulong)((((byte)value >> 5) & 4) | value & 3);
235         //var modified = Math.PartialWrite(previousValue, packagedValue, 0, 3);
236         var modified = (previousValue & 4294967288) | (packagedValue & 7);
237         Links[node].SizeAsSource = modified;
238     }
239
240     protected override bool FirstIsToTheLeftOfSecond(ulong first, ulong second)
241         => Links[first].Source < Links[second].Source ||

```

```

238         (Links[first].Source == Links[second].Source && Links[first].Target <
239             ↳ Links[second].Target);
240
241     protected override bool FirstIsToTheRightOfSecond(ulong first, ulong second)
242     => Links[first].Source > Links[second].Source ||
243         (Links[first].Source == Links[second].Source && Links[first].Target >
244             ↳ Links[second].Target);
245
246     protected override ulong GetTreeRoot() => Header->FirstAsSource;
247
248     protected override ulong GetBasePartValue(ulong link) => Links[link].Source;
249
250     /// <summary>
251     /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
252     ///     ↳ (концом)
253     /// по дереву (индексу) связей, отсортированному по Source, а затем по Target.
254     /// </summary>
255     /// <param name="source">Индекс связи, которая является началом на искомой
256     ///     ↳ связи.</param>
257     /// <param name="target">Индекс связи, которая является концом на искомой
258     ///     ↳ связи.</param>
259     /// <returns>Индекс искомой связи.</returns>
260     public ulong Search(ulong source, ulong target)
261     {
262         var root = Header->FirstAsSource;
263         while (root != 0)
264         {
265             var rootSource = Links[root].Source;
266             var rootTarget = Links[root].Target;
267             if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
268                 ↳ node.Key < root.Key
269             {
270                 root = GetLeftOrDefault(root);
271             }
272             else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget))
273                 ↳ // node.Key > root.Key
274             {
275                 root = GetRightOrDefault(root);
276             }
277             else // node.Key == root.Key
278             {
279                 return root;
280             }
281         }
282         return 0;
283     }
284
285     [MethodImpl(MethodImplOptions.AggressiveInlining)]
286     private static bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
287         ↳ ulong secondSource, ulong secondTarget)
288     => firstSource < secondSource || (firstSource == secondSource && firstTarget <
289         ↳ secondTarget);
290
291     [MethodImpl(MethodImplOptions.AggressiveInlining)]
292     private static bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
293         ↳ ulong secondSource, ulong secondTarget)
294     => firstSource > secondSource || (firstSource == secondSource && firstTarget >
295         ↳ secondTarget);
296
297     [MethodImpl(MethodImplOptions.AggressiveInlining)]
298     protected override void ClearNode(ulong node)
299     {
300         Links[node].LeftAsSource = OUL;
301         Links[node].RightAsSource = OUL;
302         Links[node].SizeAsSource = OUL;
303     }
304
305     [MethodImpl(MethodImplOptions.AggressiveInlining)]
306     protected override ulong GetZero() => OUL;
307
308     [MethodImpl(MethodImplOptions.AggressiveInlining)]
309     protected override ulong GetOne() => 1UL;
310
311     [MethodImpl(MethodImplOptions.AggressiveInlining)]
312     protected override ulong GetTwo() => 2UL;
313
314     [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

304     protected override bool ValueEqualToZero(IntPtr pointer) =>
305         ↪ *(ulong*)pointer.ToPointer() == 0UL;
306
307     [MethodImpl(MethodImplOptions.AggressiveInlining)]
308     protected override bool EqualToZero(ulong value) => value == 0UL;
309
310     [MethodImpl(MethodImplOptions.AggressiveInlining)]
311     protected override bool IsEquals(ulong first, ulong second) => first == second;
312
313     [MethodImpl(MethodImplOptions.AggressiveInlining)]
314     protected override bool GreaterThanZero(ulong value) => value > 0UL;
315
316     [MethodImpl(MethodImplOptions.AggressiveInlining)]
317     protected override bool GreaterThan(ulong first, ulong second) => first > second;
318
319     [MethodImpl(MethodImplOptions.AggressiveInlining)]
320     protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >=
321         ↪ second;
322
323     [MethodImpl(MethodImplOptions.AggressiveInlining)]
324     protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0
325         ↪ is always true for ulong
326
327     [MethodImpl(MethodImplOptions.AggressiveInlining)]
328     protected override bool LessOrEqualThanZero(ulong value) => value == 0; // value is
329         ↪ always >= 0 for ulong
330
331     [MethodImpl(MethodImplOptions.AggressiveInlining)]
332     protected override bool LessOrEqualThan(ulong first, ulong second) => first <=
333         ↪ second;
334
335     [MethodImpl(MethodImplOptions.AggressiveInlining)]
336     protected override bool LessThanZero(ulong value) => false; // value < 0 is always
337         ↪ false for ulong
338
339     [MethodImpl(MethodImplOptions.AggressiveInlining)]
340     protected override bool LessThan(ulong first, ulong second) => first < second;
341
342     [MethodImpl(MethodImplOptions.AggressiveInlining)]
343     protected override ulong Increment(ulong value) => ++value;
344
345     [MethodImpl(MethodImplOptions.AggressiveInlining)]
346     protected override ulong Decrement(ulong value) => --value;
347
348     [MethodImpl(MethodImplOptions.AggressiveInlining)]
349     protected override ulong Add(ulong first, ulong second) => first + second;
350
351     [MethodImpl(MethodImplOptions.AggressiveInlining)]
352     protected override ulong Subtract(ulong first, ulong second) => first - second;
353 }
354
355 private class LinksTargetsTreeMethods : LinksTreeMethodsBase
356 {
357     public LinksTargetsTreeMethods(UInt64ResizableDirectMemoryLinks memory)
358         : base(memory)
359     {
360     }
361
362     //protected override IntPtr GetLeft(ulong node) => new
363     ↪ IntPtr(&Links[node].LeftAsTarget);
364
365     //protected override IntPtr GetRight(ulong node) => new
366     ↪ IntPtr(&Links[node].RightAsTarget);
367
368     //protected override ulong GetSize(ulong node) => Links[node].SizeAsTarget;
369
370     //protected override void SetLeft(ulong node, ulong left) =>
371     ↪ Links[node].LeftAsTarget = left;
372
373     //protected override void SetRight(ulong node, ulong right) =>
374     ↪ Links[node].RightAsTarget = right;
375
376     //protected override void SetSize(ulong node, ulong size) =>
377     ↪ Links[node].SizeAsTarget = size;
378
379     protected override IntPtr GetLeftPointer(ulong node) => new
380     ↪ IntPtr(&Links[node].LeftAsTarget);
381
382     protected override IntPtr GetRightPointer(ulong node) => new
383     ↪ IntPtr(&Links[node].RightAsTarget);
384
385     protected override ulong GetSize(ulong node) => Links[node].SizeAsTarget;
386
387     protected override void SetLeft(ulong node, ulong left) =>
388     ↪ Links[node].LeftAsTarget = left;
389
390     protected override void SetRight(ulong node, ulong right) =>
391     ↪ Links[node].RightAsTarget = right;
392
393     protected override void SetSize(ulong node, ulong size) =>
394     ↪ Links[node].SizeAsTarget = size;
395 }

```



```

370     protected override IntPtr GetRightPointer(ulong node) => new
371         ↳ IntPtr(&Links[node].RightAsTarget);
372
373     protected override ulong GetLeftValue(ulong node) => Links[node].LeftAsTarget;
374
375     protected override ulong GetRightValue(ulong node) => Links[node].RightAsTarget;
376
377     protected override ulong GetSize(ulong node)
378     {
379         var previousValue = Links[node].SizeAsTarget;
380         //return Math.PartialRead(previousValue, 5, -5);
381         return (previousValue & 4294967264) >> 5;
382     }
383
384     protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsTarget
385         ↳ = left;
386
387     protected override void SetRight(ulong node, ulong right) =>
388         ↳ Links[node].RightAsTarget = right;
389
390     protected override void SetSize(ulong node, ulong size)
391     {
392         var previousValue = Links[node].SizeAsTarget;
393         //var modified = Math.PartialWrite(previousValue, size, 5, -5);
394         var modified = (previousValue & 31) | ((size & 134217727) << 5);
395         Links[node].SizeAsTarget = modified;
396     }
397
398     protected override bool GetLeftIsChild(ulong node)
399     {
400         var previousValue = Links[node].SizeAsTarget;
401         //return (Integer)Math.PartialRead(previousValue, 4, 1);
402         return (previousValue & 16) >> 4 == 1UL;
403         // TODO: Check if this is possible to use
404         //var nodeSize = GetSize(node);
405         //var left = GetLeftValue(node);
406         //var leftSize = GetSizeOrZero(left);
407         //return leftSize > 0 && nodeSize > leftSize;
408     }
409
410     protected override void SetLeftIsChild(ulong node, bool value)
411     {
412         var previousValue = Links[node].SizeAsTarget;
413         //var modified = Math.PartialWrite(previousValue, (ulong)(Integer)value, 4, 1);
414         var modified = (previousValue & 4294967279) | ((value ? 1UL : 0UL) << 4);
415         Links[node].SizeAsTarget = modified;
416     }
417
418     protected override bool GetRightIsChild(ulong node)
419     {
420         var previousValue = Links[node].SizeAsTarget;
421         //return (Integer)Math.PartialRead(previousValue, 3, 1);
422         return (previousValue & 8) >> 3 == 1UL;
423         // TODO: Check if this is possible to use
424         //var nodeSize = GetSize(node);
425         //var right = GetRightValue(node);
426         //var rightSize = GetSizeOrZero(right);
427         //return rightSize > 0 && nodeSize > rightSize;
428     }
429
430     protected override void SetRightIsChild(ulong node, bool value)
431     {
432         var previousValue = Links[node].SizeAsTarget;
433         //var modified = Math.PartialWrite(previousValue, (ulong)(Integer)value, 3, 1);
434         var modified = (previousValue & 4294967287) | ((value ? 1UL : 0UL) << 3);
435         Links[node].SizeAsTarget = modified;
436     }
437
438     protected override sbyte GetBalance(ulong node)
439     {
440         var previousValue = Links[node].SizeAsTarget;
441         //var value = Math.PartialRead(previousValue, 0, 3);
442         var value = previousValue & 7;
443         var unpackedValue = (sbyte)((value & 4) > 0 ? ((value & 4) << 5) | value & 3 |
444             ↳ 124 : value & 3);
445         return unpackedValue;
446     }

```

```

444     protected override void SetBalance(ulong node, sbyte value)
445     {
446         var previousValue = Links[node].SizeAsTarget;
447         var packagedValue = (ulong)((((byte)value >> 5) & 4) | value & 3);
448         //var modified = Math.PartialWrite(previousValue, packagedValue, 0, 3);
449         var modified = (previousValue & 4294967288) | (packagedValue & 7);
450         Links[node].SizeAsTarget = modified;
451     }
452
453     protected override bool FirstIsToTheLeftOfSecond(ulong first, ulong second)
454     => Links[first].Target < Links[second].Target ||
455         (Links[first].Target == Links[second].Target && Links[first].Source <
456             Links[second].Source);
457
458     protected override bool FirstIsToTheRightOfSecond(ulong first, ulong second)
459     => Links[first].Target > Links[second].Target ||
460         (Links[first].Target == Links[second].Target && Links[first].Source >
461             Links[second].Source);
462
463     protected override ulong GetTreeRoot() => Header->FirstAsTarget;
464
465     protected override ulong GetBasePartValue(ulong link) => Links[link].Target;
466
467     [MethodImpl(MethodImplOptions.AggressiveInlining)]
468     protected override void ClearNode(ulong node)
469     {
470         Links[node].LeftAsTarget = OUL;
471         Links[node].RightAsTarget = OUL;
472         Links[node].SizeAsTarget = OUL;
473     }
474 }

```

./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(ICollection<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             // Keep creating layer after layer
33             while (length > 2)
34             {
35                 HalveSequence(sequence, sequence, length);
36                 length = (length / 2) + (length % 2);
37             }
38             return Links.GetOrCreate(sequence[0], sequence[1]);
39         }
40
41         private void HalveSequence(ICollection<TLink> destination, ICollection<TLink> source, int length)
42         {
43             var loopedLength = length - (length % 2);
44             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.Constants;
9  using Platform.Data.Doublets.Sequences.Frequencies.Cache;
10
11 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
12
13 namespace Platform.Data.Doublets.Sequences.Converters
14 {
15     /// <remarks>
16     /// TODO: Возможно будет лучше если алгоритм будет выполняться полностью изолированно от
17     ///     ↳ Links на этапе сжатия.
18     ///     А именно будет создаваться временный список пар необходимых для выполнения сжатия, в
19     ///     ↳ таком случае тип значения элемента массива может быть любым, как char так и ulong.
20     ///     Как только список/словарь пар был выявлен можно разом выполнить создание всех этих
21     ///     ↳ пар, а так же разом выполнить замену.
22     /// </remarks>
23     public class CompressingConverter<TLink> : LinksListToSequenceConverterBase<TLink>
24     {
25         private static readonly LinksCombinedConstants<bool, TLink, long> _constants =
26             ↳ Default<LinksCombinedConstants<bool, TLink, long>>.Instance;
27         private static readonly EqualityComparer<TLink> _equalityComparer =
28             ↳ EqualityComparer<TLink>.Default;
29         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
30
31         private readonly IConverter<IList<TLink>, TLink> _baseConverter;
32         private readonly LinkFrequenciesCache<TLink> _doubletFrequenciesCache;
33         private readonly TLink _minFrequencyToCompress;
34         private readonly bool _doInitialFrequenciesIncrement;
35         private Doublet<TLink> _maxDoublet;
36         private LinkFrequency<TLink> _maxDoubletData;
37
38         private struct HalfDoublet
39         {
40             public TLink Element;
41             public LinkFrequency<TLink> DoubletData;
42
43             public HalfDoublet(TLink element, LinkFrequency<TLink> doubletData)
44             {
45                 Element = element;
46                 DoubletData = doubletData;
47             }
48
49             public override string ToString() => $"{Element}: ({DoubletData})";
50         }
51
52         public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
53             ↳ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache)
54             : this(links, baseConverter, doubletFrequenciesCache, Integer<TLink>.One, true)
55         {
56         }
57
58         public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
59             ↳ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, bool
60             ↳ doInitialFrequenciesIncrement)
61             : this(links, baseConverter, doubletFrequenciesCache, Integer<TLink>.One,
62                 ↳ doInitialFrequenciesIncrement)
63         {
64         }
65
66         public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
67             ↳ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, TLink
68             ↳ minFrequencyToCompress, bool doInitialFrequenciesIncrement)

```

```

58         : base(links)
59     {
60         _baseConverter = baseConverter;
61         _doubletFrequenciesCache = doubletFrequenciesCache;
62         if (_comparer.Compare(minFrequencyToCompress, Integer<TLink>.One) < 0)
63         {
64             minFrequencyToCompress = Integer<TLink>.One;
65         }
66         _minFrequencyToCompress = minFrequencyToCompress;
67         _doInitialFrequenciesIncrement = doInitialFrequenciesIncrement;
68         ResetMaxDoublet();
69     }
70
71     public override TLink Convert(ICollection<TLink> source) =>
72     {
73         // <remarks>
74         // Original algorithm idea: https://en.wikipedia.org/wiki/Byte_pair_encoding .
75         // Faster version (doublets' frequencies dictionary is not recreated).
76         // </remarks>
77         private ICollection<TLink> Compress(ICollection<TLink> sequence)
78         {
79             if (sequence.IsNullOrEmpty())
80             {
81                 return null;
82             }
83             if (sequence.Count == 1)
84             {
85                 return sequence;
86             }
87             if (sequence.Count == 2)
88             {
89                 return new[] { Links.GetOrCreate(sequence[0], sequence[1]) };
90             }
91             // TODO: arraypool with min size (to improve cache locality) or stackalloc with Sigil
92             var copy = new HalfDoublet[sequence.Count];
93             Doublet<TLink> doublet = default;
94             for (var i = 1; i < sequence.Count; i++)
95             {
96                 doublet.Source = sequence[i - 1];
97                 doublet.Target = sequence[i];
98                 LinkFrequency<TLink> data;
99                 if (_doInitialFrequenciesIncrement)
100                 {
101                     data = _doubletFrequenciesCache.IncrementFrequency(ref doublet);
102                 }
103                 else
104                 {
105                     data = _doubletFrequenciesCache.GetFrequency(ref doublet);
106                     if (data == null)
107                     {
108                         throw new NotSupportedException("If you ask not to increment
109                             ↪ frequencies, it is expected that all frequencies for the sequence
110                             ↪ are prepared.");
111                     }
112                 }
113                 copy[i - 1].Element = sequence[i - 1];
114                 copy[i - 1].DoubletData = data;
115                 UpdateMaxDoublet(ref doublet, data);
116             }
117             copy[sequence.Count - 1].Element = sequence[sequence.Count - 1];
118             copy[sequence.Count - 1].DoubletData = new LinkFrequency<TLink>();
119             if (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
120             {
121                 var newLength = ReplaceDoublets(copy);
122                 sequence = new TLink[newLength];
123                 for (int i = 0; i < newLength; i++)
124                 {
125                     sequence[i] = copy[i].Element;
126                 }
127             }
128             return sequence;
129         }
130     }
131
132     // <remarks>
133     // Original algorithm idea: https://en.wikipedia.org/wiki/Byte_pair_encoding
134     // </remarks>
135     private int ReplaceDoublets(HalfDoublet[] copy)
136     {

```

```

134     var oldLength = copy.Length;
135     var newLength = copy.Length;
136     while (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
137     {
138         var maxDoubletSource = _maxDoublet.Source;
139         var maxDoubletTarget = _maxDoublet.Target;
140         if (_equalityComparer.Equals(_maxDoubletData.Link, _constants.Null))
141         {
142             _maxDoubletData.Link = Links.GetOrCreate(maxDoubletSource, maxDoubletTarget);
143         }
144         var maxDoubletReplacementLink = _maxDoubletData.Link;
145         oldLength--;
146         var oldLengthMinusTwo = oldLength - 1;
147         // Substitute all usages
148         int w = 0, r = 0; // (r == read, w == write)
149         for (; r < oldLength; r++)
150         {
151             if (_equalityComparer.Equals(copy[r].Element, maxDoubletSource) &&
152                 ↪ _equalityComparer.Equals(copy[r + 1].Element, maxDoubletTarget))
153             {
154                 if (r > 0)
155                 {
156                     var previous = copy[w - 1].Element;
157                     copy[w - 1].DoubletData.DecrementFrequency();
158                     copy[w - 1].DoubletData =
159                         ↪ _doubletFrequenciesCache.IncrementFrequency(previous,
160                             ↪ maxDoubletReplacementLink);
161                 }
162                 if (r < oldLengthMinusTwo)
163                 {
164                     var next = copy[r + 2].Element;
165                     copy[r + 1].DoubletData.DecrementFrequency();
166                     copy[w].DoubletData = _doubletFrequenciesCache.IncrementFrequency(max
167                         ↪ xDoubletReplacementLink,
168                         ↪ next);
169                 }
170                 copy[w++].Element = maxDoubletReplacementLink;
171                 r++;
172                 newLength--;
173             }
174             else
175             {
176                 copy[w++] = copy[r];
177             }
178         }
179         if (w < newLength)
180         {
181             copy[w] = copy[r];
182         }
183         oldLength = newLength;
184         ResetMaxDoublet();
185         UpdateMaxDoublet(copy, newLength);
186     }
187     return newLength;
188 }
189
190 [MethodImpl(MethodImplOptions.AggressiveInlining)]
191 private void ResetMaxDoublet()
192 {
193     _maxDoublet = new Doublet<TLink>();
194     _maxDoubletData = new LinkFrequency<TLink>();
195 }
196
197 [MethodImpl(MethodImplOptions.AggressiveInlining)]
198 private void UpdateMaxDoublet(HalfDoublet[] copy, int length)
199 {
200     Doublet<TLink> doublet = default;
201     for (var i = 1; i < length; i++)
202     {
203         doublet.Source = copy[i - 1].Element;
204         doublet.Target = copy[i].Element;
205         UpdateMaxDoublet(ref doublet, copy[i - 1].DoubletData);
206     }
207 }
208
209 [MethodImpl(MethodImplOptions.AggressiveInlining)]
210 private void UpdateMaxDoublet(ref Doublet<TLink> doublet, LinkFrequency<TLink> data)
211 {
212     var frequency = data.Frequency;

```

```

208     var maxFrequency = _maxDoubletData.Frequency;
209     //if (frequency > _minFrequencyToCompress && (maxFrequency < frequency ||
    ↪ (maxFrequency == frequency && doublet.Source + doublet.Target < /* gives better
    ↪ compression string data (and gives collisions quickly) */ _maxDoublet.Source +
    ↪ _maxDoublet.Target)))
210     if (_comparer.Compare(frequency, _minFrequencyToCompress) > 0 &&
211         (_comparer.Compare(maxFrequency, frequency) < 0 ||
    ↪ (_equalityComparer.Equals(maxFrequency, frequency) &&
    ↪ _comparer.Compare(Arithmetic.Add(doublet.Source, doublet.Target),
    ↪ Arithmetic.Add(_maxDoublet.Source, _maxDoublet.Target)) > 0))) /* gives
    ↪ better stability and better compression on sequent data and even on random
    ↪ numbers data (but gives collisions anyway) */
212     {
213         _maxDoublet = doublet;
214         _maxDoubletData = data;
215     }
216 }
217 }
218 }

```

./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>,
    ↪ TLink>
9      {
10         protected readonly ILinks<TLink> Links;
11         public LinksListToSequenceConverterBase(ILinks<TLink> links) => Links = links;
12         public abstract TLink Convert(IList<TLink> source);
13     }
14 }

```

./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 =
    ↪ EqualityComparer<TLink>.Default;
12         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
13
14         private readonly IConverter<IList<TLink>> _sequenceToItsLocalElementLevelsConverter;
15
16         public OptimalVariantConverter(ILinks<TLink> links, IConverter<IList<TLink>>
    ↪ sequenceToItsLocalElementLevelsConverter) : base(links)
17         => _sequenceToItsLocalElementLevelsConverter =
    ↪ sequenceToItsLocalElementLevelsConverter;
18
19         public override TLink Convert(IList<TLink> sequence)
20         {
21             var length = sequence.Count;
22             if (length == 1)
23             {
24                 return sequence[0];
25             }
26             var links = Links;
27             if (length == 2)
28             {
29                 return links.GetOrCreate(sequence[0], sequence[1]);
30             }
31             sequence = sequence.ToArray();
32             var levels = _sequenceToItsLocalElementLevelsConverter.Convert(sequence);
33             while (length > 2)
34             {
35                 var levelRepeat = 1;
36                 var currentLevel = levels[0];
37                 var previousLevel = levels[0];
38                 var skipOnce = false;

```

```

39     var w = 0;
40     for (var i = 1; i < length; i++)
41     {
42         if (_equalityComparer.Equals(currentLevel, levels[i]))
43         {
44             levelRepeat++;
45             skipOnce = false;
46             if (levelRepeat == 2)
47             {
48                 sequence[w] = links.GetOrCreate(sequence[i - 1], sequence[i]);
49                 var newLevel = i >= length - 1 ?
50                     GetPreviousLowerThanCurrentOrCurrent(previousLevel,
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     return links.GetOrCreate(sequence[0], sequence[1]);
94 }
95 private static TLink GetGreatestNeighbourLowerThanCurrentOrCurrent(TLink previous, TLink
96 ↪ current, TLink next)
97 {
98     return _comparer.Compare(previous, next) > 0
99         ? _comparer.Compare(previous, current) < 0 ? previous : current
100         : _comparer.Compare(next, current) < 0 ? next : current;
101 }
102 private static TLink GetNextLowerThanCurrentOrCurrent(TLink current, TLink next) =>
103 ↪ _comparer.Compare(next, current) < 0 ? next : current;
104 private static TLink GetPreviousLowerThanCurrentOrCurrent(TLink previous, TLink current)
105 ↪ => _comparer.Compare(previous, current) < 0 ? previous : current;
106 }

```

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

```

./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)
17         {
18             _links = links;
19             _sequenceMarkerLink = sequenceMarkerLink;
20         }
21
22         public bool IsMatched(TLink sequenceCandidate)
23             ↳ => _equalityComparer.Equals(_links.GetSource(sequenceCandidate), _sequenceMarkerLink)
24                 || !_equalityComparer.Equals(_links.SearchOrDefault(_sequenceMarkerLink,
25                     ↳ sequenceCandidate), _links.Constants.Null);
26     }
27 }

```


./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.Sequences;
12 using Platform.Data.Doublets.Unicode;
13
14 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
15
16 namespace Platform.Data.Doublets.Sequences
17 {
18     public class DuplicateSegmentsProvider<TLink> :
19         ↳ DictionaryBasedDuplicateSegmentsWalkerBase<TLink>,
20         ↳ IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
21     {
22         private readonly ILinks<TLink> _links;
23         private readonly ISequences<TLink> _sequences;
24         private HashSet<KeyValuePair<IList<TLink>, IList<TLink>>> _groups;
25         private BitString _visited;
26
27         private class ItemEquilityComparer : IEqualityComparer<KeyValuePair<IList<TLink>,
28             ↳ IList<TLink>>>
29         {
30             private readonly IListEqualityComparer<TLink> _listComparer;
31             public ItemEquilityComparer() => _listComparer =
32                 ↳ Default<IListEqualityComparer<TLink>>.Instance;
33             public bool Equals(KeyValuePair<IList<TLink>, IList<TLink>> left,
34                 ↳ KeyValuePair<IList<TLink>, IList<TLink>> right) =>
35                 ↳ _listComparer.Equals(left.Key, right.Key) && _listComparer.Equals(left.Value,
36                 ↳ right.Value);
37             public int GetHashCode(KeyValuePair<IList<TLink>, IList<TLink>> pair) =>
38                 ↳ (_listComparer.GetHashCode(pair.Key),
39                 ↳ _listComparer.GetHashCode(pair.Value)).GetHashCode();
40         }
41
42         private class ItemComparer : IComparer<KeyValuePair<IList<TLink>, IList<TLink>>>
43         {
44             private readonly IListComparer<TLink> _listComparer;
45
46             public ItemComparer() => _listComparer = Default<IListComparer<TLink>>.Instance;
47
48             public int Compare(KeyValuePair<IList<TLink>, IList<TLink>> left,
49                 ↳ KeyValuePair<IList<TLink>, IList<TLink>> right)
50             {
51                 var intermediateResult = _listComparer.Compare(left.Key, right.Key);
52                 if (intermediateResult == 0)
53                 {
54                     intermediateResult = _listComparer.Compare(left.Value, right.Value);
55                 }
56                 return intermediateResult;
57             }
58         }
59
60         public DuplicateSegmentsProvider(ILinks<TLink> links, ISequences<TLink> sequences)
61             : base(minimumStringSegmentLength: 2)
62         {
63             _links = links;
64             _sequences = sequences;
65         }
66
67         public IList<KeyValuePair<IList<TLink>, IList<TLink>>> Get()
68         {
69             _groups = new HashSet<KeyValuePair<IList<TLink>,
70                 ↳ IList<TLink>>>(Default<ItemEquilityComparer>.Instance);
71             var count = _links.Count();
72             _visited = new BitString((long)(Integer<TLink>)count + 1);
73             _links.Each(link =>
74             {
75                 var linkIndex = _links.GetIndex(link);
76                 var linkBitIndex = (long)(Integer<TLink>)linkIndex;
77                 if (!_visited.Get(linkBitIndex))
78                 {
79                     var sequenceElements = new List<TLink>();
80                     _sequences.EachPart(sequenceElements.AddAndReturnTrue, linkIndex);
81                     if (sequenceElements.Count > 2)
82                     {

```

```

72         WalkAll(sequenceElements);
73     }
74 }
75 return _links.Constants.Continue;
76 });
77 var resultList = _groups.ToList();
78 var comparer = Default<ItemComparer>.Instance;
79 resultList.Sort(comparer);
80 #if DEBUG
81 foreach (var item in resultList)
82 {
83     PrintDuplicates(item);
84 }
85 #endif
86 return resultList;
87 }
88
89 protected override Segment<TLink> CreateSegment(IList<TLink> elements, int offset, int
↪ length) => new Segment<TLink>(elements, offset, length);
90
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(),
↪ duplicates));
97     }
98 }
99
100 private List<TLink> CollectDuplicatesForSegment(Segment<TLink> segment)
101 {
102     var duplicates = new List<TLink>();
103     var readAsElement = new HashSet<TLink>();
104     _sequences.Each(sequence =>
105     {
106         duplicates.Add(sequence);
107         readAsElement.Add(sequence);
108         return true; // Continue
109     }, segment);
110     if (duplicates.Any(x => _visited.Get((Integer<TLink>)x)))
111     {
112         return new List<TLink>();
113     }
114     foreach (var duplicate in duplicates)
115     {
116         var duplicateBitIndex = (long)(Integer<TLink>)duplicate;
117         _visited.Set(duplicateBitIndex);
118     }
119     if (_sequences is Sequences sequencesExperiments)
120     {
121         var partiallyMatched = sequencesExperiments.GetAllPartiallyMatchingSequences4((H
↪
↪ ashSet<ulong>)(object)readAsElement,
↪ (IList<ulong>)segment);
122         foreach (var partiallyMatchedSequence in partiallyMatched)
123         {
124             TLink sequenceIndex = (Integer<TLink>)partiallyMatchedSequence;
125             duplicates.Add(sequenceIndex);
126         }
127     }
128     duplicates.Sort();
129     return duplicates;
130 }
131
132 private void PrintDuplicates(KeyValuePair<IList<TLink>, IList<TLink>> duplicatesItem)
133 {
134     if (!(_links is ILinks<ulong> ulongLinks))
135     {
136         return;
137     }
138     var duplicatesKey = duplicatesItem.Key;
139     var keyString = UnicodeMap.FromLinksToString((IList<ulong>)duplicatesKey);
140     Console.WriteLine($"> {keyString} ({string.Join(", ", duplicatesKey)}");
141     var duplicatesList = duplicatesItem.Value;
142     for (int i = 0; i < duplicatesList.Count; i++)
143     {
144         ulong sequenceIndex = (Integer<TLink>)duplicatesList[i];

```

```

145         var formattedSequenceStructure = ulongLinks.FormatStructure(sequenceIndex, x =>
            ↳ Point<ulong>.IsPartialPoint(x), (sb, link) => _ =
            ↳ UnicodeMap.IsCharLink(link.Index) ?
            ↳ sb.Append(UnicodeMap.FromLinkToChar(link.Index)) : sb.Append(link.Index));
146         Console.WriteLine(formattedSequenceStructure);
147         var sequenceString = UnicodeMap.FromSequenceLinkToString(sequenceIndex,
            ↳ ulongLinks);
148         Console.WriteLine(sequenceString);
149     }
150     Console.WriteLine();
151 }
152 }
153 }

```

./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         {
49             for (var i = 1; i < sequence.Count; i++)
50             {
51                 IncrementFrequency(sequence[i - 1], sequence[i]);
52             }
53         }
54
55         [MethodImpl(MethodImplOptions.AggressiveInlining)]
56         public LinkFrequency<TLink> IncrementFrequency(TLink source, TLink target)
57         {
58             var doublet = new Doublet<TLink>(source, target);
59             return IncrementFrequency(ref doublet);
60         }
61
62         public void PrintFrequencies(IList<TLink> sequence)
63         {
64             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         }
89         _doubletsCache.Add(doublet, data);
90     }
91     return data;
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             //else
115             //{
116             //     if (value.Frequency > 0)
117             //     {
118             //         var frequency = value.Frequency;
119             //         linkIndex = _createLink(entry.Key.Source, entry.Key.Target);
120             //         var count = _countLinkFrequency(linkIndex);
121             //         if ((frequency > count && frequency - count > 1) || (count > frequency
122             //             ↪ && count - frequency > 1))
123             //             throw new Exception("Frequencies validation failed.");
124             //     }
125             // }
126         }
127     }
128 }
129
130 }
131
132 }

```

./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))
20             {
21                 return default;
22             }
23             return base.Count();
24         }
25     }
26 }

```

./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 }
55 }

```

./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             _markedSequenceMatcher = markedSequenceMatcher;
17         }
18
19         public TLink Count(TLink argument) => new
20             ↪ TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
21             ↪ _markedSequenceMatcher, argument).Count();
22     }
23 }

```

./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> :
9         ↪ TotalSequenceSymbolFrequencyOneOffCounter<TLink>
10    {
11        private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
12
13        public TotalMarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
14            ↪ ICriterionMatcher<TLink> markedSequenceMatcher, TLink symbol)
15            : base(links, symbol)
16            => _markedSequenceMatcher = markedSequenceMatcher;
17
18        protected override void CountSequenceSymbolFrequency(TLink link)
19        {
20            var symbolFrequencyCounter = new
21                ↪ MarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
22                ↪ _markedSequenceMatcher, link, _symbol);
23            _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
24        }
25    }
26 }

```

./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
12            ↪ TotalSequenceSymbolFrequencyOneOffCounter<TLink>(_links, symbol).Count();
13    }
14 }

```

./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 =
12            ↪ EqualityComparer<TLink>.Default;
13        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
14
15        protected readonly ILinks<TLink> _links;
16        protected readonly TLink _symbol;
17        protected readonly HashSet<TLink> _visits;
18        protected TLink _total;
19
20        public TotalSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink symbol)
21        {
22            _links = links;
23            _symbol = symbol;
24            _visits = new HashSet<TLink>();
25            _total = default;
26        }
27
28        public TLink Count()
29        {
30            if (_comparer.Compare(_total, default) > 0 || _visits.Count > 0)
31            {
32                return _total;
33            }
34            CountCore(_symbol);
35            return _total;
36        }
37
38        private void CountCore(TLink link)
39        {
40            var any = _links.Constants.Any;
41            if (_equalityComparer.Equals(_links.Count(any, link), default))
42            {
43                CountSequenceSymbolFrequency(link);
44            }
45        }
46    }
47 }

```



```

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)
37         {
38             TLink height;
39             var heightValue = _propertyOperator.GetValue(sequence, _heightPropertyMarker);
40             if (_equalityComparer.Equals(heightValue, default))
41             {
42                 height = _baseHeightProvider.Get(sequence);
43                 heightValue = _addressToUnaryNumberConverter.Convert(height);
44                 _propertyOperator.SetValue(sequence, _heightPropertyMarker, heightValue);
45             }
46             else
47             {
48                 height = _unaryNumberToAddressConverter.Convert(heightValue);
49             }
50             return height;
51         }
52     }
53 }

```

```
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/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(ICollection<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             }
25             for (; i >= 1; i--)
26             {
27                 _cache.IncrementFrequency(sequence[i - 1], sequence[i]);
28             }
29             return indexed;
30         }
31
32         private bool IsIndexedWithIncrement(TLink source, TLink target)
33         {
34             var frequency = _cache.GetFrequency(source, target);
35             if (frequency == null)
36             {
37                 return false;
38             }
39             return frequency > 0;
40         }
41     }
42 }
```

```

32     {
33         return false;
34     }
35     var indexed = !_equalityComparer.Equals(frequency.Frequency, default);
36     if (indexed)
37     {
38         _cache.IncrementFrequency(source, target);
39     }
40     return indexed;
41 }
42
43 public bool MightContain(ICollection<TLink> sequence)
44 {
45     var indexed = true;
46     var i = sequence.Count;
47     while (--i >= 1 && (indexed = IsIndexed(sequence[i - 1], sequence[i]))) { }
48     return indexed;
49 }
50
51 private bool IsIndexed(TLink source, TLink target)
52 {
53     var frequency = _cache.GetFrequency(source, target);
54     if (frequency == null)
55     {
56         return false;
57     }
58     return !_equalityComparer.Equals(frequency.Frequency, default);
59 }
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(ICollection<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(ICollection<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 }

```

```

45     private void Increment(TLink link)
46     {
47         var previousFrequency = _frequencyPropertyOperator.Get(link);
48         var frequency = _frequencyIncrementer.Increment(previousFrequency);
49         _frequencyPropertyOperator.Set(link, frequency);
50     }
51 }
52 }

```

./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 =
            ↪ EqualityComparer<TLink>.Default;
10
11         private readonly ISynchronizedLinks<TLink> _links;
12
13         public SynchronizedSequenceIndex(ISynchronizedLinks<TLink> links) => _links = links;
14
15         public bool Add(IList<TLink> sequence)
16         {
17             var indexed = true;
18             var i = sequence.Count;
19             var links = _links.Unsync;
20             _links.SyncRoot.ExecuteReadOperation(() =>
21             {
22                 while (--i >= 1 && (indexed =
23                     ↪ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
24                     ↪ sequence[i]), default))) { }
25             });
26             if (!indexed)
27             {
28                 _links.SyncRoot.ExecuteWriteOperation(() =>
29                 {
30                     for (; i >= 1; i--)
31                     {
32                         links.GetOrCreate(sequence[i - 1], sequence[i]);
33                     }
34                 });
35             }
36             return indexed;
37         }
38
39         public bool MightContain(IList<TLink> sequence)
40         {
41             var links = _links.Unsync;
42             return _links.SyncRoot.ExecuteReadOperation(() =>
43             {
44                 var indexed = true;
45                 var i = sequence.Count;
46                 while (--i >= 1 && (indexed =
47                     ↪ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
48                     ↪ sequence[i]), default))) { }
49                 return indexed;
50             });
51         }
52     }
53 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Linq;
4  using System.Runtime.CompilerServices;
5  using Platform.Collections;
6  using Platform.Collections.Lists;
7  using Platform.Threading.Synchronization;
8  using Platform.Singletons;
9  using LinkIndex = System.UInt64;
10 using Platform.Data.Constants;
11 using Platform.Data.Sequences;
12 using Platform.Data.Doublets.Sequences.Walkers;
13 using Platform.Collections.Stacks;
14
15 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
16
17 namespace Platform.Data.Doublets.Sequences
18 {
19     /// <summary>
20     /// Представляет коллекцию последовательностей связей.
21     /// </summary>
22     /// <remarks>
23     /// Обязательно реализовать атомарность каждого публичного метода.
24     ///
25     /// TODO:
26     ///
27     /// !!! Повышение вероятности повторного использования групп (подпоследовательностей),
28     /// через естественную группировку по unicode типам, все whitespace вместе, все символы
29     /// вместе, все числа вместе и т.п.
30     /// + использовать ровно сбалансированный вариант, чтобы уменьшать вложенность (глубину
31     /// графа)
32     ///

```

```

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 : ISequences<ulong> // IList<string>, IList<ulong[]> (после
54  ↪ завершения реализации Sequences)
55  {
56      private static readonly LinksCombinedConstants<bool, ulong, long> _constants =
57      ↪ Default<LinksCombinedConstants<bool, ulong, long>>.Instance;
58
59      /// <summary>Возвращает значение ulong, обозначающее любое количество связей.</summary>
60      public const ulong ZeroOrMany = ulong.MaxValue;
61
62      public SequencesOptions<ulong> Options;
63      public readonly SynchronizedLinks<ulong> Links;
64      public readonly ISynchronization Sync;
65
66      public Sequences(SynchronizedLinks<ulong> links)
67      : this(links, new SequencesOptions<ulong>())
68      {
69      }
70
71      public Sequences(SynchronizedLinks<ulong> links, SequencesOptions<ulong> options)
72      {
73          Links = links;
74          Sync = links.SyncRoot;
75          Options = options;
76
77          Options.ValidateOptions();
78          Options.InitOptions(Links);
79      }
80
81      public bool IsSequence(ulong sequence)
82      {
83          return Sync.ExecuteReadOperation(() =>
84          {
85              if (Options.UseSequenceMarker)
86              {
87                  return Options.MarkedSequenceMatcher.IsMatched(sequence);
88              }
89              return !Links.Unsync.IsPartialPoint(sequence);
90          });
91      }
92
93      [MethodImpl(MethodImplOptions.AggressiveInlining)]
94      private ulong GetSequenceByElements(ulong sequence)
95      {
96          if (Options.UseSequenceMarker)
97          {
98              return Links.SearchOrDefault(Options.SequenceMarkerLink, sequence);
99          }
100          return sequence;
101      }
102
103      private ulong GetSequenceElements(ulong sequence)
104      {
105          if (Options.UseSequenceMarker)
106          {

```

```

105     var linkContents = new UInt64Link(Links.GetLink(sequence));
106     if (linkContents.Source == Options.SequenceMarkerLink)
107     {
108         return linkContents.Target;
109     }
110     if (linkContents.Target == Options.SequenceMarkerLink)
111     {
112         return linkContents.Source;
113     }
114 }
115 return sequence;
116 }
117
118 #region Count
119
120 public ulong Count(params ulong[] sequence)
121 {
122     if (sequence.Length == 0)
123     {
124         return Links.Count(_constants.Any, Options.SequenceMarkerLink, _constants.Any);
125     }
126     if (sequence.Length == 1) // Первая связь это адрес
127     {
128         if (sequence[0] == _constants.Null)
129         {
130             return 0;
131         }
132         if (sequence[0] == _constants.Any)
133         {
134             return Count();
135         }
136         if (Options.UseSequenceMarker)
137         {
138             return Links.Count(_constants.Any, Options.SequenceMarkerLink, sequence[0]);
139         }
140         return Links.Exists(sequence[0]) ? 1UL : 0;
141     }
142     throw new NotImplementedException();
143 }
144
145 private ulong CountUsages(params ulong[] restrictions)
146 {
147     if (restrictions.Length == 0)
148     {
149         return 0;
150     }
151     if (restrictions.Length == 1) // Первая связь это адрес
152     {
153         if (restrictions[0] == _constants.Null)
154         {
155             return 0;
156         }
157         if (Options.UseSequenceMarker)
158         {
159             var elementsLink = GetSequenceElements(restrictions[0]);
160             var sequenceLink = GetSequenceByElements(elementsLink);
161             if (sequenceLink != _constants.Null)
162             {
163                 return Links.Count(sequenceLink) + Links.Count(elementsLink) - 1;
164             }
165             return Links.Count(elementsLink);
166         }
167         return Links.Count(restrictions[0]);
168     }
169     throw new NotImplementedException();
170 }
171
172 #endregion
173
174 #region Create
175
176 public ulong Create(params ulong[] sequence)
177 {
178     return Sync.ExecuteWriteOperation(() =>
179     {
180         if (sequence.IsNullOrEmpty())
181         {
182             return _constants.Null;
183         }

```

```

184         Links.EnsureEachLinkExists(sequence);
185         return CreateCore(sequence);
186     });
187 }
188
189 private ulong CreateCore(params ulong[] sequence)
190 {
191     if (Options.UseIndex)
192     {
193         Options.Index.Add(sequence);
194     }
195     var sequenceRoot = default(ulong);
196     if (Options.EnforceSingleSequenceVersionOnWriteBasedOnExisting)
197     {
198         var matches = Each(sequence);
199         if (matches.Count > 0)
200         {
201             sequenceRoot = matches[0];
202         }
203     }
204     else if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew)
205     {
206         return CompactCore(sequence);
207     }
208     if (sequenceRoot == default)
209     {
210         sequenceRoot = Options.LinksToSequenceConverter.Convert(sequence);
211     }
212     if (Options.UseSequenceMarker)
213     {
214         Links.Unsync.CreateAndUpdate(Options.SequenceMarkerLink, sequenceRoot);
215     }
216     return sequenceRoot; // Возвращаем корень последовательности (т.е. сами элементы)
217 }
218
219 #endregion
220
221 #region Each
222
223 public List<ulong> Each(params ulong[] sequence)
224 {
225     var results = new List<ulong>();
226     Each(results.AddAndReturnTrue, sequence);
227     return results;
228 }
229
230 public bool Each(Func<ulong, bool> handler, IList<ulong> sequence)
231 {
232     return Sync.ExecuteReadOperation(() =>
233     {
234         if (sequence.IsNullOrEmpty())
235         {
236             return true;
237         }
238         Links.EnsureEachLinkIsAnyOrExists(sequence);
239         if (sequence.Count == 1)
240         {
241             var link = sequence[0];
242             if (link == _constants.Any)
243             {
244                 return Links.Unsync.Each(_constants.Any, _constants.Any, handler);
245             }
246             return handler(link);
247         }
248         if (sequence.Count == 2)
249         {
250             return Links.Unsync.Each(sequence[0], sequence[1], handler);
251         }
252         if (Options.UseIndex && !Options.Index.MightContain(sequence))
253         {
254             return false;
255         }
256         return EachCore(handler, sequence);
257     });
258 }
259
260 private bool EachCore(Func<ulong, bool> handler, IList<ulong> sequence)
261 {
262     var matcher = new Matcher(this, sequence, new HashSet<LinkIndex>(), handler);

```



```

263 // TODO: Find out why matcher.HandleFullMatched executed twice for the same sequence
264 ↪ Id.
265 Func<ulong, bool> innerHandler = Options.UseSequenceMarker ? (Func<ulong,
266 ↪ bool>)matcher.HandleFullMatchedSequence : matcher.HandleFullMatched;
267 //if (sequence.Length >= 2)
268 if (!StepRight(innerHandler, sequence[0], sequence[1]))
269 {
270     return false;
271 }
272 var last = sequence.Count - 2;
273 for (var i = 1; i < last; i++)
274 {
275     if (!PartialStepRight(innerHandler, sequence[i], sequence[i + 1]))
276     {
277         return false;
278     }
279 }
280 if (sequence.Count >= 3)
281 {
282     if (!StepLeft(innerHandler, sequence[sequence.Count - 2],
283 ↪ sequence[sequence.Count - 1]))
284     {
285         return false;
286     }
287 }
288 return true;
289 }
290
291 private bool PartialStepRight(Func<ulong, bool> handler, ulong left, ulong right)
292 {
293     return Links.Unsync.Each(_constants.Any, left, doublet =>
294     {
295         if (!StepRight(handler, doublet, right))
296         {
297             return false;
298         }
299         if (left != doublet)
300         {
301             return PartialStepRight(handler, doublet, right);
302         }
303     });
304     return true;
305 }
306
307 private bool StepRight(Func<ulong, bool> handler, ulong left, ulong right) =>
308 ↪ Links.Unsync.Each(left, _constants.Any, rightStep => TryStepRightUp(handler, right,
309 ↪ rightStep));
310
311 private bool TryStepRightUp(Func<ulong, bool> handler, ulong right, ulong stepFrom)
312 {
313     var upStep = stepFrom;
314     var firstSource = Links.Unsync.GetTarget(upStep);
315     while (firstSource != right && firstSource != upStep)
316     {
317         upStep = firstSource;
318         firstSource = Links.Unsync.GetSource(upStep);
319     }
320     if (firstSource == right)
321     {
322         return handler(stepFrom);
323     }
324     return true;
325 }
326
327 private bool StepLeft(Func<ulong, bool> handler, ulong left, ulong right) =>
328 ↪ Links.Unsync.Each(_constants.Any, right, leftStep => TryStepLeftUp(handler, left,
329 ↪ leftStep));
330
331 private bool TryStepLeftUp(Func<ulong, bool> handler, ulong left, ulong stepFrom)
332 {
333     var upStep = stepFrom;
334     var firstTarget = Links.Unsync.GetSource(upStep);
335     while (firstTarget != left && firstTarget != upStep)
336     {
337         upStep = firstTarget;
338         firstTarget = Links.Unsync.GetTarget(upStep);
339     }
340     if (firstTarget == left)
341     {

```

```

335         return handler(stepFrom);
336     }
337     return true;
338 }
339
340 #endregion
341
342 #region Update
343
344 public ulong Update(ulong[] sequence, ulong[] newSequence)
345 {
346     if (sequence.IsNullOrEmpty() && newSequence.IsNullOrEmpty())
347     {
348         return _constants.Null;
349     }
350     if (sequence.IsNullOrEmpty())
351     {
352         return Create(newSequence);
353     }
354     if (newSequence.IsNullOrEmpty())
355     {
356         Delete(sequence);
357         return _constants.Null;
358     }
359     return Sync.ExecuteWriteOperation(() =>
360     {
361         Links.EnsureEachLinkIsAnyOrExists(sequence);
362         Links.EnsureEachLinkExists(newSequence);
363         return UpdateCore(sequence, newSequence);
364     });
365 }
366
367 private ulong UpdateCore(ulong[] sequence, ulong[] newSequence)
368 {
369     ulong bestVariant;
370     if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew &&
371         ↪ !sequence.EqualTo(newSequence))
372     {
373         bestVariant = CompactCore(newSequence);
374     }
375     else
376     {
377         bestVariant = CreateCore(newSequence);
378     }
379     // TODO: Check all options only ones before loop execution
380     // Возможно нужно две версии Each, возвращающий фактические последовательности и с
381     ↪ маркером,
382     // или возможно даже возвращать и тот и тот вариант. С другой стороны все варианты
383     ↪ можно получить имея только фактические последовательности.
384     foreach (var variant in Each(sequence))
385     {
386         if (variant != bestVariant)
387         {
388             UpdateOneCore(variant, bestVariant);
389         }
390     }
391     return bestVariant;
392 }
393
394 private void UpdateOneCore(ulong sequence, ulong newSequence)
395 {
396     if (Options.UseGarbageCollection)
397     {
398         var sequenceElements = GetSequenceElements(sequence);
399         var sequenceElementsContents = new UInt64Link(Links.GetLink(sequenceElements));
400         var sequenceLink = GetSequenceByElements(sequenceElements);
401         var newSequenceElements = GetSequenceElements(newSequence);
402         var newSequenceLink = GetSequenceByElements(newSequenceElements);
403         if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
404         {
405             if (sequenceLink != _constants.Null)
406             {
407                 Links.Unsync.MergeUsages(sequenceLink, newSequenceLink);
408             }
409             Links.Unsync.MergeUsages(sequenceElements, newSequenceElements);
410         }
411         ClearGarbage(sequenceElementsContents.Source);
412         ClearGarbage(sequenceElementsContents.Target);
413     }
414 }

```

```

411     else
412     {
413         if (Options.UseSequenceMarker)
414         {
415             var sequenceElements = GetSequenceElements(sequence);
416             var sequenceLink = GetSequenceByElements(sequenceElements);
417             var newSequenceElements = GetSequenceElements(newSequence);
418             var newSequenceLink = GetSequenceByElements(newSequenceElements);
419             if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
420             {
421                 if (sequenceLink != _constants.Null)
422                 {
423                     Links.Unsync.MergeUsages(sequenceLink, newSequenceLink);
424                 }
425                 Links.Unsync.MergeUsages(sequenceElements, newSequenceElements);
426             }
427         }
428     }
429     else
430     {
431         if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
432         {
433             Links.Unsync.MergeUsages(sequence, newSequence);
434         }
435     }
436 }
437
438 #endregion
439
440 #region Delete
441
442 public void Delete(params ulong[] sequence)
443 {
444     Sync.ExecuteWriteOperation(() =>
445     {
446         // TODO: Check all options only ones before loop execution
447         foreach (var linkToDelete in Each(sequence))
448         {
449             DeleteOneCore(linkToDelete);
450         }
451     });
452 }
453
454 private void DeleteOneCore(ulong link)
455 {
456     if (Options.UseGarbageCollection)
457     {
458         var sequenceElements = GetSequenceElements(link);
459         var sequenceElementsContents = new UInt64Link(Links.GetLink(sequenceElements));
460         var sequenceLink = GetSequenceByElements(sequenceElements);
461         if (Options.UseCascadeDelete || CountUsages(link) == 0)
462         {
463             if (sequenceLink != _constants.Null)
464             {
465                 Links.Unsync.Delete(sequenceLink);
466             }
467             Links.Unsync.Delete(link);
468         }
469         ClearGarbage(sequenceElementsContents.Source);
470         ClearGarbage(sequenceElementsContents.Target);
471     }
472     else
473     {
474         if (Options.UseSequenceMarker)
475         {
476             var sequenceElements = GetSequenceElements(link);
477             var sequenceLink = GetSequenceByElements(sequenceElements);
478             if (Options.UseCascadeDelete || CountUsages(link) == 0)
479             {
480                 if (sequenceLink != _constants.Null)
481                 {
482                     Links.Unsync.Delete(sequenceLink);
483                 }
484                 Links.Unsync.Delete(link);
485             }
486         }
487         else
488         {

```

```

489         if (Options.UseCascadeDelete || CountUsages(link) == 0)
490         {
491             Links.Unsync.Delete(link);
492         }
493     }
494 }
495 }
496
497 #endregion
498
499 #region Compactification
500
501 /// <remarks>
502 /// bestVariant можно выбирать по максимальному числу использований,
503 /// но балансированный позволяет гарантировать уникальность (если есть возможность,
504 /// гарантировать его использование в других местах).
505 ///
506 /// Получается этот метод должен игнорировать Options.EnforceSingleSequenceVersionOnWrite
507 /// </remarks>
508 public ulong Compact(params ulong[] sequence)
509 {
510     return Sync.ExecuteWriteOperation(() =>
511     {
512         if (sequence.IsNullOrEmpty())
513         {
514             return _constants.Null;
515         }
516         Links.EnsureEachLinkExists(sequence);
517         return CompactCore(sequence);
518     });
519 }
520
521 [MethodImpl(MethodImplOptions.AggressiveInlining)]
522 private ulong CompactCore(params ulong[] sequence) => UpdateCore(sequence, sequence);
523
524 #endregion
525
526 #region Garbage Collection
527
528 /// <remarks>
529 /// TODO: Добавить дополнительный обработчик / событие CanBeDeleted которое можно
530 ///     ↪ определить извне или в унаследованном классе
531 /// </remarks>
532 [MethodImpl(MethodImplOptions.AggressiveInlining)]
533 private bool IsGarbage(ulong link) => link != Options.SequenceMarkerLink &&
534     ↪ !Links.Unsync.IsPartialPoint(link) && Links.Count(link) == 0;
535
536 private void ClearGarbage(ulong link)
537 {
538     if (IsGarbage(link))
539     {
540         var contents = new UInt64Link(Links.GetLink(link));
541         Links.Unsync.Delete(link);
542         ClearGarbage(contents.Source);
543         ClearGarbage(contents.Target);
544     }
545 }
546
547 #endregion
548
549 #region Walkers
550
551 public bool EachPart(Func<ulong, bool> handler, ulong sequence)
552 {
553     return Sync.ExecuteReadOperation(() =>
554     {
555         var links = Links.Unsync;
556         foreach (var part in Options.Walker.Walk(sequence))
557         {
558             if (!handler(part))
559             {
560                 return false;
561             }
562         }
563         return true;
564     });
565 }
566
567 public class Matcher : RightSequenceWalker<ulong>
568 {

```

```

567 private readonly Sequences _sequences;
568 private readonly IList<LinkIndex> _patternSequence;
569 private readonly HashSet<LinkIndex> _linksInSequence;
570 private readonly HashSet<LinkIndex> _results;
571 private readonly Func<ulong, bool> _stopableHandler;
572 private readonly HashSet<ulong> _readAsElements;
573 private int _filterPosition;
574
575 public Matcher(Sequences sequences, IList<LinkIndex> patternSequence,
    ↳ HashSet<LinkIndex> results, Func<LinkIndex, bool> stopableHandler,
    ↳ HashSet<LinkIndex> readAsElements = null)
    : base(sequences.Links.Unsync, new DefaultStack<ulong>())
{
    _sequences = sequences;
    _patternSequence = patternSequence;
    _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
    ↳ _constants.Any && x != ZeroOrMany));
    _results = results;
    _stopableHandler = stopableHandler;
    _readAsElements = readAsElements;
}

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586
protected override bool IsElement(ulong link) => base.IsElement(link) ||
    ↳ (_readAsElements != null && _readAsElements.Contains(link)) ||
    ↳ _linksInSequence.Contains(link);

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640
public bool FullMatch(LinkIndex sequenceToMatch)
{
    _filterPosition = 0;
    foreach (var part in Walk(sequenceToMatch))
    {
        if (!FullMatchCore(part))
        {
            break;
        }
    }
    return _filterPosition == _patternSequence.Count;
}

private bool FullMatchCore(LinkIndex element)
{
    if (_filterPosition == _patternSequence.Count)
    {
        _filterPosition = -2; // Длиннее чем нужно
        return false;
    }
    if (_patternSequence[_filterPosition] != _constants.Any
        && element != _patternSequence[_filterPosition])
    {
        _filterPosition = -1;
        return false; // Начинается/Продолжается иначе
    }
    _filterPosition++;
    return true;
}

public void AddFullMatchedToResults(ulong sequenceToMatch)
{
    if (FullMatch(sequenceToMatch))
    {
        _results.Add(sequenceToMatch);
    }
}

public bool HandleFullMatched(ulong sequenceToMatch)
{
    if (FullMatch(sequenceToMatch) && _results.Add(sequenceToMatch))
    {
        return _stopableHandler(sequenceToMatch);
    }
    return true;
}

public bool HandleFullMatchedSequence(ulong sequenceToMatch)
{
    var sequence = _sequences.GetSequenceByElements(sequenceToMatch);
    if (sequence != _constants.Null && FullMatch(sequenceToMatch) &&
        ↳ _results.Add(sequenceToMatch))
    {
        return _stopableHandler(sequence);
    }
}

```

```

641     }
642     return true;
643 }
644
645 /// <remarks>
646 /// TODO: Add support for LinksConstants.Any
647 /// </remarks>
648 public bool PartialMatch(LinkIndex sequenceToMatch)
649 {
650     _filterPosition = -1;
651     foreach (var part in Walk(sequenceToMatch))
652     {
653         if (!PartialMatchCore(part))
654         {
655             break;
656         }
657     }
658     return _filterPosition == _patternSequence.Count - 1;
659 }
660
661 private bool PartialMatchCore(LinkIndex element)
662 {
663     if (_filterPosition == (_patternSequence.Count - 1))
664     {
665         return false; // Нашлось
666     }
667     if (_filterPosition >= 0)
668     {
669         if (element == _patternSequence[_filterPosition + 1])
670         {
671             _filterPosition++;
672         }
673         else
674         {
675             _filterPosition = -1;
676         }
677     }
678     if (_filterPosition < 0)
679     {
680         if (element == _patternSequence[0])
681         {
682             _filterPosition = 0;
683         }
684     }
685     return true; // Ищем дальше
686 }
687
688 public void AddPartialMatchedToResults(ulong sequenceToMatch)
689 {
690     if (PartialMatch(sequenceToMatch))
691     {
692         _results.Add(sequenceToMatch);
693     }
694 }
695
696 public bool HandlePartialMatched(ulong sequenceToMatch)
697 {
698     if (PartialMatch(sequenceToMatch))
699     {
700         return _stopableHandler(sequenceToMatch);
701     }
702     return true;
703 }
704
705 public void AddAllPartialMatchedToResults(IEnumerable<ulong> sequencesToMatch)
706 {
707     foreach (var sequenceToMatch in sequencesToMatch)
708     {
709         if (PartialMatch(sequenceToMatch))
710         {
711             _results.Add(sequenceToMatch);
712         }
713     }
714 }
715
716 public void AddAllPartialMatchedToResultsAndReadAsElements(IEnumerable<ulong>
717 ↪ sequencesToMatch)
718 {
719     foreach (var sequenceToMatch in sequencesToMatch)

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```

719         {
720             if (PartialMatch(sequenceToMatch))
721             {
722                 _readAsElements.Add(sequenceToMatch);
723                 _results.Add(sequenceToMatch);
724             }
725         }
726     }
727 }
728
729 #endregion
730 }
731 }

```

./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.EnsureEachLinkExists(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)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);

```

```

64     var right = CreateAllVariants2Core(sequence, splitter + 1, stopAt);
65     for (var i = 0; i < left.Length; i++)
66     {
67         for (var j = 0; j < right.Length; j++)
68         {
69             var variant = Links.Unsync.CreateAndUpdate(left[i], right[j]);
70             if (variant == _constants.Null)
71             {
72                 throw new NotImplementedException("Creation cancellation is not
73                     ↳ implemented.");
74             }
75             variants[last++] = variant;
76         }
77     }
78     return variants;
79 }
80
81 public List<ulong> CreateAllVariants1(params ulong[] sequence)
82 {
83     return Sync.ExecuteWriteOperation(() =>
84     {
85         if (sequence.IsNullOrEmpty())
86         {
87             return new List<ulong>();
88         }
89         Links.Unsync.EnsureEachLinkExists(sequence);
90         if (sequence.Length == 1)
91         {
92             return new List<ulong> { sequence[0] };
93         }
94         var results = new List<ulong>((int)Numbers.Math.Catalan(sequence.Length));
95         return CreateAllVariants1Core(sequence, results);
96     });
97 }
98
99 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

```



```

139     Each1(link =>
140     {
141         if (!visitedLinks.Contains(link))
142         {
143             visitedLinks.Add(link); // изучить почему случаются повторы
144         }
145         return true;
146     }, sequence);
147     return visitedLinks;
148 }
149
150 private void Each1(Func<ulong, bool> handler, params ulong[] sequence)
151 {
152     if (sequence.Length == 2)
153     {
154         Links.Unsync.Each(sequence[0], sequence[1], handler);
155     }
156     else
157     {
158         var innerSequenceLength = sequence.Length - 1;
159         for (var li = 0; li < innerSequenceLength; li++)
160         {
161             var left = sequence[li];
162             var right = sequence[li + 1];
163             if (left == 0 && right == 0)
164             {
165                 continue;
166             }
167             var linkIndex = li;
168             ulong[] innerSequence = null;
169             Links.Unsync.Each(left, right, doublet =>
170             {
171                 if (innerSequence == null)
172                 {
173                     innerSequence = new ulong[innerSequenceLength];
174                     for (var isi = 0; isi < linkIndex; isi++)
175                     {
176                         innerSequence[isi] = sequence[isi];
177                     }
178                     for (var isi = linkIndex + 1; isi < innerSequenceLength; isi++)
179                     {
180                         innerSequence[isi] = sequence[isi + 1];
181                     }
182                 }
183                 innerSequence[linkIndex] = doublet;
184                 Each1(handler, innerSequence);
185                 return _constants.Continue;
186             });
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         if (!visitedLinks.Contains(link))
197         {
198             visitedLinks.Add(link); // изучить почему случаются повторы
199         }
200         return true;
201     }, sequence);
202     return visitedLinks;
203 }
204
205 public void EachPart(Func<ulong, bool> handler, params ulong[] sequence)
206 {
207     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
208     EachPartCore(link =>
209     {
210         if (!visitedLinks.Contains(link))
211         {
212             visitedLinks.Add(link); // изучить почему случаются повторы
213             return handler(link);
214         }
215         return true;
216     }, sequence);
217 }

```

```

218
219 private void EachPartCore(Func<ulong, bool> handler, params ulong[] sequence)
220 {
221     if (sequence.IsNullOrEmpty())
222     {
223         return;
224     }
225     Links.EnsureEachLinkIsAnyOrExists(sequence);
226     if (sequence.Length == 1)
227     {
228         var link = sequence[0];
229         if (link > 0)
230         {
231             handler(link);
232         }
233         else
234         {
235             Links.Each(_constants.Any, _constants.Any, handler);
236         }
237     }
238     else if (sequence.Length == 2)
239     {
240         // _links.Each(sequence[0], sequence[1], handler);
241         //   o_|      x_o ...
242         // x_|      |___|
243         Links.Each(sequence[1], _constants.Any, doublet =>
244         {
245             var match = Links.SearchOrDefault(sequence[0], doublet);
246             if (match != _constants.Null)
247             {
248                 handler(match);
249             }
250             return true;
251         });
252         // |_x      ... x_o
253         // |_o      |___|
254         Links.Each(_constants.Any, sequence[0], doublet =>
255         {
256             var match = Links.SearchOrDefault(doublet, sequence[1]);
257             if (match != 0)
258             {
259                 handler(match);
260             }
261             return true;
262         });
263         //           . _x o _
264         //           |___|
265         PartialStepRight(x => handler(x), sequence[0], sequence[1]);
266     }
267     else
268     {
269         // TODO: Implement other variants
270         return;
271     }
272 }
273
274 private void PartialStepRight(Action<ulong> handler, ulong left, ulong right)
275 {
276     Links.Unsync.Each(_constants.Any, left, doublet =>
277     {
278         StepRight(handler, doublet, right);
279         if (left != doublet)
280         {
281             PartialStepRight(handler, doublet, right);
282         }
283         return true;
284     });
285 }
286
287 private void StepRight(Action<ulong> handler, ulong left, ulong right)
288 {
289     Links.Unsync.Each(left, _constants.Any, rightStep =>
290     {
291         TryStepRightUp(handler, right, rightStep);
292         return true;
293     });
294 }
295
296 private void TryStepRightUp(Action<ulong> handler, ulong right, ulong stepFrom)

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297 {
298     var upStep = stepFrom;
299     var firstSource = Links.Unsync.GetTarget(upStep);
300     while (firstSource != right && firstSource != upStep)
301     {
302         upStep = firstSource;
303         firstSource = Links.Unsync.GetSource(upStep);
304     }
305     if (firstSource == right)
306     {
307         handler(stepFrom);
308     }
309 }
310
311 // TODO: Test
312 private void PartialStepLeft(Action<ulong> handler, ulong left, ulong right)
313 {
314     Links.Unsync.Each(right, _constants.Any, doublet =>
315     {
316         StepLeft(handler, left, doublet);
317         if (right != doublet)
318         {
319             PartialStepLeft(handler, left, doublet);
320         }
321         return true;
322     });
323 }
324
325 private void StepLeft(Action<ulong> handler, ulong left, ulong right)
326 {
327     Links.Unsync.Each(_constants.Any, right, leftStep =>
328     {
329         TryStepLeftUp(handler, left, leftStep);
330         return true;
331     });
332 }
333
334 private void TryStepLeftUp(Action<ulong> handler, ulong left, ulong stepFrom)
335 {
336     var upStep = stepFrom;
337     var firstTarget = Links.Unsync.GetSource(upStep);
338     while (firstTarget != left && firstTarget != upStep)
339     {
340         upStep = firstTarget;
341         firstTarget = Links.Unsync.GetTarget(upStep);
342     }
343     if (firstTarget == left)
344     {
345         handler(stepFrom);
346     }
347 }
348
349 private bool StartsWith(ulong sequence, ulong link)
350 {
351     var upStep = sequence;
352     var firstSource = Links.Unsync.GetSource(upStep);
353     while (firstSource != link && firstSource != upStep)
354     {
355         upStep = firstSource;
356         firstSource = Links.Unsync.GetSource(upStep);
357     }
358     return firstSource == link;
359 }
360
361 private bool EndsWith(ulong sequence, ulong link)
362 {
363     var upStep = sequence;
364     var lastTarget = Links.Unsync.GetTarget(upStep);
365     while (lastTarget != link && lastTarget != upStep)
366     {
367         upStep = lastTarget;
368         lastTarget = Links.Unsync.GetTarget(upStep);
369     }
370     return lastTarget == link;
371 }
372
373 public List<ulong> GetAllMatchingSequences0(params ulong[] sequence)
374 {
375     return Sync.ExecuteReadOperation(() =>

```

```

376 {
377     var results = new List<ulong>();
378     if (sequence.Length > 0)
379     {
380         Links.EnsureEachLinkExists(sequence);
381         var firstElement = sequence[0];
382         if (sequence.Length == 1)
383         {
384             results.Add(firstElement);
385             return results;
386         }
387         if (sequence.Length == 2)
388         {
389             var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
390             if (doublet != _constants.Null)
391             {
392                 results.Add(doublet);
393             }
394             return results;
395         }
396         var linksInSequence = new HashSet<ulong>(sequence);
397         void handler(ulong result)
398         {
399             var filterPosition = 0;
400             StopableSequenceWalker.WalkRight(result, Links.Unsync.GetSource,
401                 ↪ Links.Unsync.GetTarget,
402                 x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
403                 ↪ x =>
404                 {
405                     if (filterPosition == sequence.Length)
406                     {
407                         filterPosition = -2; // Длиннее чем нужно
408                         return false;
409                     }
410                     if (x != sequence[filterPosition])
411                     {
412                         filterPosition = -1;
413                         return false; // Начинается иначе
414                     }
415                     filterPosition++;
416                     return true;
417                 });
418             if (filterPosition == sequence.Length)
419             {
420                 results.Add(result);
421             }
422         }
423         if (sequence.Length >= 2)
424         {
425             StepRight(handler, sequence[0], sequence[1]);
426         }
427         var last = sequence.Length - 2;
428         for (var i = 1; i < last; i++)
429         {
430             PartialStepRight(handler, sequence[i], sequence[i + 1]);
431         }
432         if (sequence.Length >= 3)
433         {
434             StepLeft(handler, sequence[sequence.Length - 2],
435                 ↪ sequence[sequence.Length - 1]);
436         }
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.EnsureEachLinkExists(sequence);
450             var firstElement = sequence[0];
451             if (sequence.Length == 1)
452             {

```

```

451         results.Add(firstElement);
452         return results;
453     }
454     if (sequence.Length == 2)
455     {
456         var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
457         if (doublet != _constants.Null)
458         {
459             results.Add(doublet);
460         }
461         return results;
462     }
463     var matcher = new Matcher(this, sequence, results, null);
464     if (sequence.Length >= 2)
465     {
466         StepRight(matcher.AddFullMatchedToResults, sequence[0], sequence[1]);
467     }
468     var last = sequence.Length - 2;
469     for (var i = 1; i < last; i++)
470     {
471         PartialStepRight(matcher.AddFullMatchedToResults, sequence[i],
472             ↪ sequence[i + 1]);
473     }
474     if (sequence.Length >= 3)
475     {
476         StepLeft(matcher.AddFullMatchedToResults, sequence[sequence.Length - 2],
477             ↪ sequence[sequence.Length - 1]);
478     }
479     return results;
480 }
481
482 public const int MaxSequenceFormatSize = 200;
483
484 public string FormatSequence(LinkIndex sequenceLink, params LinkIndex[] knownElements)
485     ↪ => FormatSequence(sequenceLink, (sb, x) => sb.Append(x), true, knownElements);
486
487 public string FormatSequence(LinkIndex sequenceLink, Action<StringBuilder, LinkIndex>
488     ↪ elementToString, bool insertComma, params LinkIndex[] knownElements) =>
489     ↪ Links.SyncRoot.ExecuteReadOperation(() => FormatSequence(Links.Unsync, sequenceLink,
490     ↪ elementToString, insertComma, knownElements));
491
492 private string FormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
493     ↪ Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
494     ↪ LinkIndex[] knownElements)
495 {
496     var linksInSequence = new HashSet<ulong>(knownElements);
497     //var entered = new HashSet<ulong>();
498     var sb = new StringBuilder();
499     sb.Append('{');
500     if (links.Exists(sequenceLink))
501     {
502         StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
503             x => linksInSequence.Contains(x) || links.IsPartialPoint(x), element => //
504             ↪ entered.AddAndReturnVoid, x => { }, entered.DoNotContains
505         {
506             if (insertComma && sb.Length > 1)
507             {
508                 sb.Append(',');
509             }
510             //if (entered.Contains(element))
511             //{
512             //    sb.Append('{');
513             //    elementToString(sb, element);
514             //    sb.Append('}');
515             //}
516             //else
517             elementToString(sb, element);
518             if (sb.Length < MaxSequenceFormatSize)
519             {
520                 return true;
521             }
522             sb.Append(insertComma ? ", ..." : "...");
523             return false;
524         }
525     }
526     sb.Append('}');

```

```

520     return sb.ToString();
521 }
522
523 public string SafeFormatSequence(LinkIndex sequenceLink, params LinkIndex[]
    ↪ knownElements) => SafeFormatSequence(sequenceLink, (sb, x) => sb.Append(x), true,
    ↪ knownElements);
524
525 public string SafeFormatSequence(LinkIndex sequenceLink, Action<StringBuilder,
    ↪ LinkIndex> elementToString, bool insertComma, params LinkIndex[] knownElements) =>
    ↪ Links.SyncRoot.ExecuteReadOperation(() => SafeFormatSequence(Links.Unsync,
    ↪ sequenceLink, elementToString, insertComma, knownElements));
526
527 private string SafeFormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
    ↪ Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
    ↪ LinkIndex[] knownElements)
528 {
529     var linksInSequence = new HashSet<ulong>(knownElements);
530     var entered = new HashSet<ulong>();
531     var sb = new StringBuilder();
532     sb.Append('{');
533     if (links.Exists(sequenceLink))
534     {
535         StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
536             x => linksInSequence.Contains(x) || links.IsFullPoint(x),
537             ↪ entered.AddAndReturnVoid, x => { }, entered.DoNotContains, element =>
538             {
539                 if (insertComma && sb.Length > 1)
540                 {
541                     sb.Append(',');
542                 }
543                 if (entered.Contains(element))
544                 {
545                     sb.Append('{');
546                     elementToString(sb, element);
547                     sb.Append('}');
548                 }
549                 else
550                 {
551                     elementToString(sb, element);
552                 }
553                 if (sb.Length < MaxSequenceFormatSize)
554                 {
555                     return true;
556                 }
557                 sb.Append(insertComma ? ", ..." : "...");
558                 return false;
559             });
560     }
561     sb.Append('}');
562     return sb.ToString();
563 }
564
565 public List<ulong> GetAllPartiallyMatchingSequences0(params ulong[] sequence)
566 {
567     return Sync.ExecuteReadOperation(() =>
568     {
569         if (sequence.Length > 0)
570         {
571             Links.EnsureEachLinkExists(sequence);
572             var results = new HashSet<ulong>();
573             for (var i = 0; i < sequence.Length; i++)
574             {
575                 AllUsagesCore(sequence[i], results);
576             }
577             var filteredResults = new List<ulong>();
578             var linksInSequence = new HashSet<ulong>(sequence);
579             foreach (var result in results)
580             {
581                 var filterPosition = -1;
582                 StopableSequenceWalker.WalkRight(result, Links.Unsync.GetSource,
583                     ↪ Links.Unsync.GetTarget,
584                     x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
585                     ↪ x =>
586                     {
587                         if (filterPosition == (sequence.Length - 1))
588                         {
589                             return false;
590                         }
591                     }
592                 );
593                 filteredResults.Add(result);
594             }
595             return filteredResults;
596         }
597         return new List<ulong>();
598     });
599 }

```

```

588         if (filterPosition >= 0)
589         {
590             if (x == sequence[filterPosition + 1])
591             {
592                 filterPosition++;
593             }
594             else
595             {
596                 return false;
597             }
598         }
599         if (filterPosition < 0)
600         {
601             if (x == sequence[0])
602             {
603                 filterPosition = 0;
604             }
605         }
606         return true;
607     });
608     if (filterPosition == (sequence.Length - 1))
609     {
610         filteredResults.Add(result);
611     }
612 }
613 return filteredResults;
614 }
615 return new List<ulong>();
616 });
617 }
618
619 public HashSet<ulong> GetAllPartiallyMatchingSequences1(params ulong[] sequence)
620 {
621     return Sync.ExecuteReadOperation(() =>
622     {
623         if (sequence.Length > 0)
624         {
625             Links.EnsureEachLinkExists(sequence);
626             var results = new HashSet<ulong>();
627             for (var i = 0; i < sequence.Length; i++)
628             {
629                 AllUsagesCore(sequence[i], results);
630             }
631             var filteredResults = new HashSet<ulong>();
632             var matcher = new Matcher(this, sequence, filteredResults, null);
633             matcher.AddAllPartialMatchedToResults(results);
634             return filteredResults;
635         }
636         return new HashSet<ulong>();
637     });
638 }
639
640 public bool GetAllPartiallyMatchingSequences2(Func<ulong, bool> handler, params ulong[]
641 → sequence)
642 {
643     return Sync.ExecuteReadOperation(() =>
644     {
645         if (sequence.Length > 0)
646         {
647             Links.EnsureEachLinkExists(sequence);
648
649             var results = new HashSet<ulong>();
650             var filteredResults = new HashSet<ulong>();
651             var matcher = new Matcher(this, sequence, filteredResults, handler);
652             for (var i = 0; i < sequence.Length; i++)
653             {
654                 if (!AllUsagesCore1(sequence[i], results, matcher.HandlePartialMatched))
655                 {
656                     return false;
657                 }
658             }
659             return true;
660         }
661         return true;
662     });
663 }
664
665 //public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
666 //{

```

```

666 // return Sync.ExecuteReadOperation(() =>
667 // {
668 //     if (sequence.Length > 0)
669 //     {
670 //         _links.EnsureEachLinkIsAnyOrExists(sequence);
671
672 //         var firstResults = new HashSet<ulong>();
673 //         var lastResults = new HashSet<ulong>();
674
675 //         var first = sequence.First(x => x != LinksConstants.Any);
676 //         var last = sequence.Last(x => x != LinksConstants.Any);
677
678 //         AllUsagesCore(first, firstResults);
679 //         AllUsagesCore(last, lastResults);
680
681 //         firstResults.IntersectWith(lastResults);
682
683 //         //for (var i = 0; i < sequence.Length; i++)
684 //         //    AllUsagesCore(sequence[i], results);
685
686 //         var filteredResults = new HashSet<ulong>();
687 //         var matcher = new Matcher(this, sequence, filteredResults, null);
688 //         matcher.AddAllPartialMatchedToResults(firstResults);
689 //         return filteredResults;
690 //     }
691
692 //     return new HashSet<ulong>();
693 // });
694 //}

```

```

695
696 public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
697 {
698     return Sync.ExecuteReadOperation(() =>
699     {
700         if (sequence.Length > 0)
701         {
702             Links.EnsureEachLinkIsAnyOrExists(sequence);
703             var firstResults = new HashSet<ulong>();
704             var lastResults = new HashSet<ulong>();
705             var first = sequence.First(x => x != _constants.Any);
706             var last = sequence.Last(x => x != _constants.Any);
707             AllUsagesCore(first, firstResults);
708             AllUsagesCore(last, lastResults);
709             firstResults.IntersectWith(lastResults);
710             //for (var i = 0; i < sequence.Length; i++)
711             //    AllUsagesCore(sequence[i], results);
712             var filteredResults = new HashSet<ulong>();
713             var matcher = new Matcher(this, sequence, filteredResults, null);
714             matcher.AddAllPartialMatchedToResults(firstResults);
715             return filteredResults;
716         }
717         return new HashSet<ulong>();
718     });
719 }

```

```

720
721 public HashSet<ulong> GetAllPartiallyMatchingSequences4(HashSet<ulong> readAsElements,
722 → IList<ulong> sequence)
723 {
724     return Sync.ExecuteReadOperation(() =>
725     {
726         if (sequence.Count > 0)
727         {
728             Links.EnsureEachLinkExists(sequence);
729             var results = new HashSet<LinkIndex>();
730             //var nextResults = new HashSet<ulong>();
731             //for (var i = 0; i < sequence.Length; i++)
732             //{
733             //    AllUsagesCore(sequence[i], nextResults);
734             //    if (results.IsNullOrEmpty())
735             //    {
736             //        results = nextResults;
737             //        nextResults = new HashSet<ulong>();
738             //    }
739             //    else
740             //    {
741             //        results.IntersectWith(nextResults);
742             //        nextResults.Clear();
743             //    }
744             //}

```



```

743     //}
744     var collector1 = new AllUsagesCollector1(Links.Unsync, results);
745     collector1.Collect(Links.Unsync.GetLink(sequence[0]));
746     var next = new HashSet<ulong>();
747     for (var i = 1; i < sequence.Count; i++)
748     {
749         var collector = new AllUsagesCollector1(Links.Unsync, next);
750         collector.Collect(Links.Unsync.GetLink(sequence[i]));
751
752         results.IntersectWith(next);
753         next.Clear();
754     }
755     var filteredResults = new HashSet<ulong>();
756     var matcher = new Matcher(this, sequence, filteredResults, null,
757         ↪ readAsElements);
758     matcher.AddAllPartialMatchedToResultsAndReadAsElements(results.OrderBy(x =>
759         ↪ x)); // OrderBy is a Hack
760     return filteredResults;
761 }
762 return new HashSet<ulong>();
763 });
764 }
765 // Does not work
766 public HashSet<ulong> GetAllPartiallyMatchingSequences5(HashSet<ulong> readAsElements,
767     ↪ params ulong[] sequence)
768 {
769     var visited = new HashSet<ulong>();
770     var results = new HashSet<ulong>();
771     var matcher = new Matcher(this, sequence, visited, x => { results.Add(x); return
772         ↪ true; }, readAsElements);
773     var last = sequence.Length - 1;
774     for (var i = 0; i < last; i++)
775     {
776         PartialStepRight(matcher.PartialMatch, sequence[i], sequence[i + 1]);
777     }
778     return results;
779 }
780 public List<ulong> GetAllPartiallyMatchingSequences(params ulong[] sequence)
781 {
782     return Sync.ExecuteReadOperation(() =>
783     {
784         if (sequence.Length > 0)
785         {
786             Links.EnsureEachLinkExists(sequence);
787             //var firstElement = sequence[0];
788             //if (sequence.Length == 1)
789             //{
790                 //results.Add(firstElement);
791                 //return results;
792             //}
793             //if (sequence.Length == 2)
794             //{
795                 //var doublet = _links.SearchCore(firstElement, sequence[1]);
796                 //if (doublet != Doublets.Links.Null)
797                 //    results.Add(doublet);
798                 //return results;
799             //}
800             //var lastElement = sequence[sequence.Length - 1];
801             //Func<ulong, bool> handler = x =>
802             //{
803                 //if (StartsWith(x, firstElement) && EndsWith(x, lastElement))
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             //    throw new NotImplementedException(); // all sequences, containing
817             ↪ this element?

```

```

814         //////////////////////////////////////////////////
815         //////////////////////////////////////////////////if (sequence.Length == 2)
816         //////////////////////////////////////////////////{
817         //////////////////////////////////////////////////    var results = new List<ulong>();
818         //////////////////////////////////////////////////    PartialStepRight(results.Add, sequence[0], sequence[1]);
819         //////////////////////////////////////////////////    return results;
820         //////////////////////////////////////////////////}
821         //////////////////////////////////////////////////var matches = new List<List<ulong>>();
822         //////////////////////////////////////////////////var last = sequence.Length - 1;
823         //////////////////////////////////////////////////for (var i = 0; i < last; i++)
824         //////////////////////////////////////////////////{
825         //////////////////////////////////////////////////    var results = new List<ulong>();
826         //////////////////////////////////////////////////    //StepRight(results.Add, sequence[i], sequence[i + 1]);
827         //////////////////////////////////////////////////    PartialStepRight(results.Add, sequence[i], sequence[i + 1]);
828         //////////////////////////////////////////////////    if (results.Count > 0)
829         //////////////////////////////////////////////////        matches.Add(results);
830         //////////////////////////////////////////////////    else
831         //////////////////////////////////////////////////        return results;
832         //////////////////////////////////////////////////    if (matches.Count == 2)
833         //////////////////////////////////////////////////    {
834         //////////////////////////////////////////////////        var merged = new List<ulong>();
835         //////////////////////////////////////////////////        for (var j = 0; j < matches[0].Count; j++)
836         //////////////////////////////////////////////////            for (var k = 0; k < matches[1].Count; k++)
837         //////////////////////////////////////////////////                CloseInnerConnections(merged.Add, matches[0][j],
838         ↪ matches[1][k]);
839         //////////////////////////////////////////////////        if (merged.Count > 0)
840         //////////////////////////////////////////////////            matches = new List<List<ulong>> { merged };
841         //////////////////////////////////////////////////        else
842         //////////////////////////////////////////////////            return new List<ulong>();
843         //////////////////////////////////////////////////    }
844         //////////////////////////////////////////////////}
845         //////////////////////////////////////////////////if (matches.Count > 0)
846         //////////////////////////////////////////////////{
847         //////////////////////////////////////////////////    var usages = new HashSet<ulong>();
848         //////////////////////////////////////////////////    for (int i = 0; i < sequence.Length; i++)
849         //////////////////////////////////////////////////    {
850         //////////////////////////////////////////////////        AllUsagesCore(sequence[i], usages);
851         //////////////////////////////////////////////////    }
852         //////////////////////////////////////////////////    //for (int i = 0; i < matches[0].Count; i++)
853         //////////////////////////////////////////////////    //    AllUsagesCore(matches[0][i], usages);
854         //////////////////////////////////////////////////    //usages.UnionWith(matches[0]);
855         //////////////////////////////////////////////////    return usages.ToList();
856         //////////////////////////////////////////////////}
857         var firstLinkUsages = new HashSet<ulong>();
858         AllUsagesCore(sequence[0], firstLinkUsages);
859         firstLinkUsages.Add(sequence[0]);
860         //var previousMatchings = firstLinkUsages.ToList(); //new List<ulong>() {
861         ↪ sequence[0] }; // or all sequences, containing this element?
862         //return GetAllPartiallyMatchingSequencesCore(sequence, firstLinkUsages,
863         ↪ 1).ToList();
864         var results = new HashSet<ulong>();
865         foreach (var match in GetAllPartiallyMatchingSequencesCore(sequence,
866         ↪ firstLinkUsages, 1))
867         {
868             AllUsagesCore(match, results);
869         }
870         return results.ToList();
871     }
872     return new List<ulong>();
873 });
874 }
875
876 /// <remarks>
877 /// TODO: Может потребоваться ограничение на уровень глубины рекурсии
878 /// </remarks>
879 public HashSet<ulong> AllUsages(ulong link)
880 {
881     return Sync.ExecuteReadOperation(() =>
882     {
883         var usages = new HashSet<ulong>();
884         AllUsagesCore(link, usages);
885         return usages;
886     });
887 }
888
889 // При сборе всех использований (последовательностей) можно сохранять обратный путь к
890 ↪ той связи с которой начинался поиск (STTTSSSTT),

```

```

886 // причём достаточно одного бита для хранения перехода влево или вправо
887 private void AllUsagesCore(ulong link, HashSet<ulong> usages)
888 {
889     bool handler(ulong doublet)
890     {
891         if (usages.Add(doublet))
892         {
893             AllUsagesCore(doublet, usages);
894         }
895         return true;
896     }
897     Links.Unsync.Each(link, _constants.Any, handler);
898     Links.Unsync.Each(_constants.Any, link, handler);
899 }
900
901 public HashSet<ulong> AllBottomUsages(ulong link)
902 {
903     return Sync.ExecuteReadOperation(() =>
904     {
905         var visits = new HashSet<ulong>();
906         var usages = new HashSet<ulong>();
907         AllBottomUsagesCore(link, visits, usages);
908         return usages;
909     });
910 }
911
912 private void AllBottomUsagesCore(ulong link, HashSet<ulong> visits, HashSet<ulong>
↪ usages)
913 {
914     bool handler(ulong doublet)
915     {
916         if (visits.Add(doublet))
917         {
918             AllBottomUsagesCore(doublet, visits, usages);
919         }
920         return true;
921     }
922     if (Links.Unsync.Count(_constants.Any, link) == 0)
923     {
924         usages.Add(link);
925     }
926     else
927     {
928         Links.Unsync.Each(link, _constants.Any, handler);
929         Links.Unsync.Each(_constants.Any, link, handler);
930     }
931 }
932
933 public ulong CalculateTotalSymbolFrequencyCore(ulong symbol)
934 {
935     if (Options.UseSequenceMarker)
936     {
937         var counter = new TotalMarkedSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
↪ Options.MarkedSequenceMatcher, symbol);
938         return counter.Count();
939     }
940     else
941     {
942         var counter = new TotalSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
↪ symbol);
943         return counter.Count();
944     }
945 }
946
947 private bool AllUsagesCore1(ulong link, HashSet<ulong> usages, Func<ulong, bool>
↪ outerHandler)
948 {
949     bool handler(ulong doublet)
950     {
951         if (usages.Add(doublet))
952         {
953             if (!outerHandler(doublet))
954             {
955                 return false;
956             }
957             if (!AllUsagesCore1(doublet, usages, outerHandler))
958             {
959                 return false;

```

```

960     }
961     }
962     return true;
963 }
964 return Links.Unsync.Each(link, _constants.Any, handler)
965     && Links.Unsync.Each(_constants.Any, link, handler);
966 }
967
968 public void CalculateAllUsages(ulong[] totals)
969 {
970     var calculator = new AllUsagesCalculator(Links, totals);
971     calculator.Calculate();
972 }
973
974 public void CalculateAllUsages2(ulong[] totals)
975 {
976     var calculator = new AllUsagesCalculator2(Links, totals);
977     calculator.Calculate();
978 }
979
980 private class AllUsagesCalculator
981 {
982     private readonly SynchronizedLinks<ulong> _links;
983     private readonly ulong[] _totals;
984
985     public AllUsagesCalculator(SynchronizedLinks<ulong> links, ulong[] totals)
986     {
987         _links = links;
988         _totals = totals;
989     }
990
991     public void Calculate() => _links.Each(_constants.Any, _constants.Any,
992         ↪ CalculateCore);
993
994     private bool CalculateCore(ulong link)
995     {
996         if (_totals[link] == 0)
997         {
998             var total = 1UL;
999             _totals[link] = total;
1000             var visitedChildren = new HashSet<ulong>();
1001             bool linkCalculator(ulong child)
1002             {
1003                 if (link != child && visitedChildren.Add(child))
1004                 {
1005                     total += _totals[child] == 0 ? 1 : _totals[child];
1006                 }
1007                 return true;
1008             }
1009             _links.Unsync.Each(link, _constants.Any, linkCalculator);
1010             _links.Unsync.Each(_constants.Any, link, linkCalculator);
1011             _totals[link] = total;
1012         }
1013         return true;
1014     }
1015 }
1016
1017 private class AllUsagesCalculator2
1018 {
1019     private readonly SynchronizedLinks<ulong> _links;
1020     private readonly ulong[] _totals;
1021
1022     public AllUsagesCalculator2(SynchronizedLinks<ulong> links, ulong[] totals)
1023     {
1024         _links = links;
1025         _totals = totals;
1026     }
1027
1028     public void Calculate() => _links.Each(_constants.Any, _constants.Any,
1029         ↪ CalculateCore);
1030
1031     private bool IsElement(ulong link)
1032     {
1033         // _linksInSequence.Contains(link) ||
1034         return _links.Unsync.GetTarget(link) == link || _links.Unsync.GetSource(link) ==
1035             ↪ link;
1036     }
1037
1038     private bool CalculateCore(ulong link)

```

```

1036 {
1037     // TODO: Проработать защиту от заикливания
1038     // Основано на SequenceWalker.WalkLeft
1039     Func<ulong, ulong> getSource = _links.Unsync.GetSource;
1040     Func<ulong, ulong> getTarget = _links.Unsync.GetTarget;
1041     Func<ulong, bool> isElement = IsElement;
1042     void visitLeaf(ulong parent)
1043     {
1044         if (link != parent)
1045         {
1046             _totals[parent]++;
1047         }
1048     }
1049     void visitNode(ulong parent)
1050     {
1051         if (link != parent)
1052         {
1053             _totals[parent]++;
1054         }
1055     }
1056     var stack = new Stack();
1057     var element = link;
1058     if (isElement(element))
1059     {
1060         visitLeaf(element);
1061     }
1062     else
1063     {
1064         while (true)
1065         {
1066             if (isElement(element))
1067             {
1068                 if (stack.Count == 0)
1069                 {
1070                     break;
1071                 }
1072                 element = stack.Pop();
1073                 var source = getSource(element);
1074                 var target = getTarget(element);
1075                 // Обработка элемента
1076                 if (isElement(target))
1077                 {
1078                     visitLeaf(target);
1079                 }
1080                 if (isElement(source))
1081                 {
1082                     visitLeaf(source);
1083                 }
1084                 element = source;
1085             }
1086             else
1087             {
1088                 stack.Push(element);
1089                 visitNode(element);
1090                 element = getTarget(element);
1091             }
1092         }
1093     }
1094     _totals[link]++;
1095     return true;
1096 }
1097
1098 private class AllUsagesCollector
1099 {
1100     private readonly ILinks<ulong> _links;
1101     private readonly HashSet<ulong> _usages;
1102
1103     public AllUsagesCollector(ILinks<ulong> links, HashSet<ulong> usages)
1104     {
1105         _links = links;
1106         _usages = usages;
1107     }
1108
1109     public bool Collect(ulong link)
1110     {
1111         if (_usages.Add(link))
1112         {
1113             _links.Each(link, _constants.Any, Collect);
1114         }
1115     }
1116 }

```

```

1115         _links.Each(_constants.Any, link, Collect);
1116     }
1117     return true;
1118 }
1119 }
1120
1121 private class AllUsagesCollector1
1122 {
1123     private readonly ILinks<ulong> _links;
1124     private readonly HashSet<ulong> _usages;
1125     private readonly ulong _continue;
1126
1127     public AllUsagesCollector1(ILinks<ulong> links, HashSet<ulong> usages)
1128     {
1129         _links = links;
1130         _usages = usages;
1131         _continue = _links.Constants.Continue;
1132     }
1133
1134     public ulong Collect(IList<ulong> link)
1135     {
1136         var linkIndex = _links.GetIndex(link);
1137         if (_usages.Add(linkIndex))
1138         {
1139             _links.Each(Collect, _constants.Any, linkIndex);
1140         }
1141         return _continue;
1142     }
1143 }
1144
1145 private class AllUsagesCollector2
1146 {
1147     private readonly ILinks<ulong> _links;
1148     private readonly BitString _usages;
1149
1150     public AllUsagesCollector2(ILinks<ulong> links, BitString usages)
1151     {
1152         _links = links;
1153         _usages = usages;
1154     }
1155
1156     public bool Collect(ulong link)
1157     {
1158         if (_usages.Add((long)link))
1159         {
1160             _links.Each(link, _constants.Any, Collect);
1161             _links.Each(_constants.Any, link, Collect);
1162         }
1163         return true;
1164     }
1165 }
1166
1167 private class AllUsagesIntersectingCollector
1168 {
1169     private readonly SynchronizedLinks<ulong> _links;
1170     private readonly HashSet<ulong> _intersectWith;
1171     private readonly HashSet<ulong> _usages;
1172     private readonly HashSet<ulong> _enter;
1173
1174     public AllUsagesIntersectingCollector(SynchronizedLinks<ulong> links, HashSet<ulong>
↪ intersectWith, HashSet<ulong> usages)
1175     {
1176         _links = links;
1177         _intersectWith = intersectWith;
1178         _usages = usages;
1179         _enter = new HashSet<ulong>(); // защита от зацикливания
1180     }
1181
1182     public bool Collect(ulong link)
1183     {
1184         if (_enter.Add(link))
1185         {
1186             if (_intersectWith.Contains(link))
1187             {
1188                 _usages.Add(link);
1189             }
1190             _links.Unsync.Each(link, _constants.Any, Collect);
1191             _links.Unsync.Each(_constants.Any, link, Collect);
1192         }
1193         return true;

```

```

1194     }
1195 }
1196
1197 private void CloseInnerConnections(Action<ulong> handler, ulong left, ulong right)
1198 {
1199     TryStepLeftUp(handler, left, right);
1200     TryStepRightUp(handler, right, left);
1201 }
1202
1203 private void AllCloseConnections(Action<ulong> handler, ulong left, ulong right)
1204 {
1205     // Direct
1206     if (left == right)
1207     {
1208         handler(left);
1209     }
1210     var doublet = Links.Unsync.SearchOrDefault(left, right);
1211     if (doublet != _constants.Null)
1212     {
1213         handler(doublet);
1214     }
1215     // Inner
1216     CloseInnerConnections(handler, left, right);
1217     // Outer
1218     StepLeft(handler, left, right);
1219     StepRight(handler, left, right);
1220     PartialStepRight(handler, left, right);
1221     PartialStepLeft(handler, left, right);
1222 }
1223
1224 private HashSet<ulong> GetAllPartiallyMatchingSequencesCore(ulong[] sequence,
1225     ↪ HashSet<ulong> previousMatchings, long startAt)
1226 {
1227     if (startAt >= sequence.Length) // ?
1228     {
1229         return previousMatchings;
1230     }
1231     var secondLinkUsages = new HashSet<ulong>();
1232     AllUsagesCore(sequence[startAt], secondLinkUsages);
1233     secondLinkUsages.Add(sequence[startAt]);
1234     var matchings = new HashSet<ulong>();
1235     //for (var i = 0; i < previousMatchings.Count; i++)
1236     foreach (var secondLinkUsage in secondLinkUsages)
1237     {
1238         foreach (var previousMatching in previousMatchings)
1239         {
1240             //AllCloseConnections(matchings.AddAndReturnVoid, previousMatching,
1241             ↪ secondLinkUsage);
1242             StepRight(matchings.AddAndReturnVoid, previousMatching, secondLinkUsage);
1243             TryStepRightUp(matchings.AddAndReturnVoid, secondLinkUsage,
1244             ↪ previousMatching);
1245             //PartialStepRight(matchings.AddAndReturnVoid, secondLinkUsage,
1246             ↪ sequence[startAt]); // почему-то эта ошибочная запись приводит к
1247             ↪ желаемым результатам.
1248             PartialStepRight(matchings.AddAndReturnVoid, previousMatching,
1249             ↪ secondLinkUsage);
1250         }
1251     }
1252     if (matchings.Count == 0)
1253     {
1254         return matchings;
1255     }
1256     return GetAllPartiallyMatchingSequencesCore(sequence, matchings, startAt + 1); // ??
1257 }
1258
1259 private static void EnsureEachLinkIsAnyOrZeroOrManyOrExists(SynchronizedLinks<ulong>
1260     ↪ links, params ulong[] sequence)
1261 {
1262     if (sequence == null)
1263     {
1264         return;
1265     }
1266     for (var i = 0; i < sequence.Length; i++)
1267     {
1268         if (sequence[i] != _constants.Any && sequence[i] != ZeroOrMany &&
1269             ↪ !links.Exists(sequence[i]))
1270         {
1271

```

```

1263         throw new ArgumentException<ulong>(sequence[i],
1264             ↪ $"patternSequence[{i}]");
1265     }
1266 }
1267
1268 // Pattern Matching -> Key To Triggers
1269 public HashSet<ulong> MatchPattern(params ulong[] patternSequence)
1270 {
1271     return Sync.ExecuteReadOperation(() =>
1272     {
1273         patternSequence = Simplify(patternSequence);
1274         if (patternSequence.Length > 0)
1275         {
1276             EnsureEachLinkIsAnyOrZeroOrManyOrExists(Links, patternSequence);
1277             var uniqueSequenceElements = new HashSet<ulong>();
1278             for (var i = 0; i < patternSequence.Length; i++)
1279             {
1280                 if (patternSequence[i] != _constants.Any && patternSequence[i] !=
1281                     ↪ ZeroOrMany)
1282                 {
1283                     uniqueSequenceElements.Add(patternSequence[i]);
1284                 }
1285             }
1286             var results = new HashSet<ulong>();
1287             foreach (var uniqueSequenceElement in uniqueSequenceElements)
1288             {
1289                 AllUsagesCore(uniqueSequenceElement, results);
1290             }
1291             var filteredResults = new HashSet<ulong>();
1292             var matcher = new PatternMatcher(this, patternSequence, filteredResults);
1293             matcher.AddAllPatternMatchedToResults(results);
1294             return filteredResults;
1295         }
1296         return new HashSet<ulong>();
1297     });
1298 }
1299
1300 // Найти все возможные связи между указанным списком связей.
1301 // Находит связи между всеми указанными связями в любом порядке.
1302 // TODO: решить что делать с повторами (когда одни и те же элементы встречаются
1303 ↪ несколько раз в последовательности)
1304 public HashSet<ulong> GetAllConnections(params ulong[] linksToConnect)
1305 {
1306     return Sync.ExecuteReadOperation(() =>
1307     {
1308         var results = new HashSet<ulong>();
1309         if (linksToConnect.Length > 0)
1310         {
1311             Links.EnsureEachLinkExists(linksToConnect);
1312             AllUsagesCore(linksToConnect[0], results);
1313             for (var i = 1; i < linksToConnect.Length; i++)
1314             {
1315                 var next = new HashSet<ulong>();
1316                 AllUsagesCore(linksToConnect[i], next);
1317                 results.IntersectWith(next);
1318             }
1319             return results;
1320         }
1321     });
1322 }
1323
1324 public HashSet<ulong> GetAllConnections1(params ulong[] linksToConnect)
1325 {
1326     return Sync.ExecuteReadOperation(() =>
1327     {
1328         var results = new HashSet<ulong>();
1329         if (linksToConnect.Length > 0)
1330         {
1331             Links.EnsureEachLinkExists(linksToConnect);
1332             var collector1 = new AllUsagesCollector(Links.Unsync, results);
1333             collector1.Collect(linksToConnect[0]);
1334             var next = new HashSet<ulong>();
1335             for (var i = 1; i < linksToConnect.Length; i++)
1336             {
1337                 var collector = new AllUsagesCollector(Links.Unsync, next);
1338                 collector.Collect(linksToConnect[i]);
1339                 results.IntersectWith(next);
1340             }
1341         }
1342     });
1343 }

```



```

1338         next.Clear();
1339     }
1340 }
1341 return results;
1342 });
1343 }
1344
1345 public HashSet<ulong> GetAllConnections2(params ulong[] linksToConnect)
1346 {
1347     return Sync.ExecuteReadOperation(() =>
1348     {
1349         var results = new HashSet<ulong>();
1350         if (linksToConnect.Length > 0)
1351         {
1352             Links.EnsureEachLinkExists(linksToConnect);
1353             var collector1 = new AllUsagesCollector(Links, results);
1354             collector1.Collect(linksToConnect[0]);
1355             //AllUsagesCore(linksToConnect[0], results);
1356             for (var i = 1; i < linksToConnect.Length; i++)
1357             {
1358                 var next = new HashSet<ulong>();
1359                 var collector = new AllUsagesIntersectingCollector(Links, results, next);
1360                 collector.Collect(linksToConnect[i]);
1361                 //AllUsagesCore(linksToConnect[i], next);
1362                 //results.IntersectWith(next);
1363                 results = next;
1364             }
1365         }
1366         return results;
1367     });
1368 }
1369
1370 public List<ulong> GetAllConnections3(params ulong[] linksToConnect)
1371 {
1372     return Sync.ExecuteReadOperation(() =>
1373     {
1374         var results = new BitString((long)Links.Unsync.Count() + 1); // new
1375         ↪ BitArray((int)_links.Total + 1);
1376         if (linksToConnect.Length > 0)
1377         {
1378             Links.EnsureEachLinkExists(linksToConnect);
1379             var collector1 = new AllUsagesCollector2(Links.Unsync, results);
1380             collector1.Collect(linksToConnect[0]);
1381             for (var i = 1; i < linksToConnect.Length; i++)
1382             {
1383                 var next = new BitString((long)Links.Unsync.Count() + 1); //new
1384                 ↪ BitArray((int)_links.Total + 1);
1385                 var collector = new AllUsagesCollector2(Links.Unsync, next);
1386                 collector.Collect(linksToConnect[i]);
1387                 results = results.And(next);
1388             }
1389             return results.GetSetUInt64Indices();
1390         }
1391     });
1392 }
1393
1394 private static ulong[] Simplify(ulong[] sequence)
1395 {
1396     // Считаем новый размер последовательности
1397     long newLength = 0;
1398     var zeroOrManyStepped = false;
1399     for (var i = 0; i < sequence.Length; i++)
1400     {
1401         if (sequence[i] == ZeroOrMany)
1402         {
1403             if (zeroOrManyStepped)
1404             {
1405                 continue;
1406             }
1407             zeroOrManyStepped = true;
1408         }
1409         else
1410         {
1411             //if (zeroOrManyStepped) Is it efficient?
1412             zeroOrManyStepped = false;
1413             newLength++;
1414         }
1415     }
1416 }

```

```

1414 // Строим новую последовательность
1415 zeroOrManyStepped = false;
1416 var newSequence = new ulong[newLength];
1417 long j = 0;
1418 for (var i = 0; i < sequence.Length; i++)
1419 {
1420     //var current = zeroOrManyStepped;
1421     //zeroOrManyStepped = patternSequence[i] == zeroOrMany;
1422     //if (current && zeroOrManyStepped)
1423     //    continue;
1424     //var newZeroOrManyStepped = patternSequence[i] == zeroOrMany;
1425     //if (zeroOrManyStepped && newZeroOrManyStepped)
1426     //    continue;
1427     //zeroOrManyStepped = newZeroOrManyStepped;
1428     if (sequence[i] == ZeroOrMany)
1429     {
1430         if (zeroOrManyStepped)
1431         {
1432             continue;
1433         }
1434         zeroOrManyStepped = true;
1435     }
1436     else
1437     {
1438         //if (zeroOrManyStepped) Is it efficient?
1439         zeroOrManyStepped = false;
1440     }
1441     newSequence[j++] = sequence[i];
1442 }
1443 return newSequence;
1444 }
1445
1446 public static void TestSimplify()
1447 {
1448     var sequence = new ulong[] { ZeroOrMany, ZeroOrMany, 2, 3, 4, ZeroOrMany,
1449     ↪ ZeroOrMany, ZeroOrMany, 4, ZeroOrMany, ZeroOrMany, ZeroOrMany };
1450     var simplifiedSequence = Simplify(sequence);
1451 }
1452
1453 public List<ulong> GetSimilarSequences() => new List<ulong>();
1454
1455 public void Prediction()
1456 {
1457     //_links
1458     //_sequences
1459 }
1460
1461 #region From Triplets
1462
1463 //public static void DeleteSequence(Link sequence)
1464 //{
1465 //}
1466
1467 public List<ulong> CollectMatchingSequences(ulong[] links)
1468 {
1469     if (links.Length == 1)
1470     {
1471         throw new Exception("Подпоследовательности с одним элементом не
1472         ↪ поддерживаются.");
1473     }
1474     var leftBound = 0;
1475     var rightBound = links.Length - 1;
1476     var left = links[leftBound++];
1477     var right = links[rightBound--];
1478     var results = new List<ulong>();
1479     CollectMatchingSequences(left, leftBound, links, right, rightBound, ref results);
1480     return results;
1481 }
1482
1483 private void CollectMatchingSequences(ulong leftLink, int leftBound, ulong[]
1484 ↪ 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)

```

```

1490     {
1491         for (var i = elements.Length - 1; i >= 0; i--)
1492         {
1493             var element = elements[i];
1494             if (element != 0)
1495             {
1496                 CollectMatchingSequences(element, leftBound + 1, middleLinks,
1497                     ↪ rightLink, rightBound, ref results);
1498             }
1499         }
1500     }
1501     else
1502     {
1503         for (var i = elements.Length - 1; i >= 0; i--)
1504         {
1505             var element = elements[i];
1506             if (element != 0)
1507             {
1508                 results.Add(element);
1509             }
1510         }
1511     }
1512     else
1513     {
1514         var nextRightLink = middleLinks[rightBound];
1515         var elements = GetLeftElements(rightLink, nextRightLink);
1516         if (leftBound <= rightBound)
1517         {
1518             for (var i = elements.Length - 1; i >= 0; i--)
1519             {
1520                 var element = elements[i];
1521                 if (element != 0)
1522                 {
1523                     CollectMatchingSequences(leftLink, leftBound, middleLinks,
1524                         ↪ elements[i], rightBound - 1, ref results);
1525                 }
1526             }
1527         }
1528         else
1529         {
1530             for (var i = elements.Length - 1; i >= 0; i--)
1531             {
1532                 var element = elements[i];
1533                 if (element != 0)
1534                 {
1535                     results.Add(element);
1536                 }
1537             }
1538         }
1539     }
1540 }
1541 public ulong[] GetRightElements(ulong startLink, ulong rightLink)
1542 {
1543     var result = new ulong[5];
1544     TryStepRight(startLink, rightLink, result, 0);
1545     Links.Each(_constants.Any, startLink, couple =>
1546     {
1547         if (couple != startLink)
1548         {
1549             if (TryStepRight(couple, rightLink, result, 2))
1550             {
1551                 return false;
1552             }
1553         }
1554         return true;
1555     });
1556     if (Links.GetTarget(Links.GetTarget(startLink)) == rightLink)
1557     {
1558         result[4] = startLink;
1559     }
1560     return result;
1561 }
1562 public bool TryStepRight(ulong startLink, ulong rightLink, ulong[] result, int offset)
1563 {
1564     var added = 0;

```

```

1566 Links.Each(startLink, _constants.Any, couple =>
1567 {
1568     if (couple != startLink)
1569     {
1570         var coupleTarget = Links.GetTarget(couple);
1571         if (coupleTarget == rightLink)
1572         {
1573             result[offset] = couple;
1574             if (++added == 2)
1575             {
1576                 return false;
1577             }
1578         }
1579         else if (Links.GetSource(coupleTarget) == rightLink) // coupleTarget.Linker
1580             ↪ == Net.And &&
1581         {
1582             result[offset + 1] = couple;
1583             if (++added == 2)
1584             {
1585                 return false;
1586             }
1587         }
1588     }
1589     return true;
1590 });
1591 return added > 0;
1592 }
1593
1594 public ulong[] GetLeftElements(ulong startLink, ulong leftLink)
1595 {
1596     var result = new ulong[5];
1597     TryStepLeft(startLink, leftLink, result, 0);
1598     Links.Each(startLink, _constants.Any, couple =>
1599     {
1600         if (couple != startLink)
1601         {
1602             if (TryStepLeft(couple, leftLink, result, 2))
1603             {
1604                 return false;
1605             }
1606         }
1607         return true;
1608     });
1609     if (Links.GetSource(Links.GetSource(leftLink)) == startLink)
1610     {
1611         result[4] = leftLink;
1612     }
1613     return result;
1614 }
1615
1616 public bool TryStepLeft(ulong startLink, ulong leftLink, ulong[] result, int offset)
1617 {
1618     var added = 0;
1619     Links.Each(_constants.Any, startLink, couple =>
1620     {
1621         if (couple != startLink)
1622         {
1623             var coupleSource = Links.GetSource(couple);
1624             if (coupleSource == leftLink)
1625             {
1626                 result[offset] = couple;
1627                 if (++added == 2)
1628                 {
1629                     return false;
1630                 }
1631             }
1632             else if (Links.GetTarget(coupleSource) == leftLink) // coupleSource.Linker
1633                 ↪ == Net.And &&
1634             {
1635                 result[offset + 1] = couple;
1636                 if (++added == 2)
1637                 {
1638                     return false;
1639                 }
1640             }
1641         }
1642     });
1643     return added > 0;

```

```

1643     }
1644
1645     #endregion
1646
1647     #region Walkers
1648
1649     public class PatternMatcher : RightSequenceWalker<ulong>
1650     {
1651         private readonly Sequences _sequences;
1652         private readonly ulong[] _patternSequence;
1653         private readonly HashSet<LinkIndex> _linksInSequence;
1654         private readonly HashSet<LinkIndex> _results;
1655
1656         #region Pattern Match
1657
1658         enum PatternBlockType
1659         {
1660             Undefined,
1661             Gap,
1662             Elements
1663         }
1664
1665         struct PatternBlock
1666         {
1667             public PatternBlockType Type;
1668             public long Start;
1669             public long Stop;
1670         }
1671
1672         private readonly List<PatternBlock> _pattern;
1673         private int _patternPosition;
1674         private long _sequencePosition;
1675
1676         #endregion
1677
1678         public PatternMatcher(Sequences sequences, LinkIndex[] patternSequence,
1679             ↳ HashSet<LinkIndex> results)
1680             : base(sequences.Links.Unsync, new DefaultStack<ulong>())
1681         {
1682             _sequences = sequences;
1683             _patternSequence = patternSequence;
1684             _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
1685                 ↳ _constants.Any && x != ZeroOrMany));
1686             _results = results;
1687             _pattern = CreateDetailedPattern();
1688
1689             protected override bool IsElement(ulong link) => _linksInSequence.Contains(link) ||
1690                 ↳ base.IsElement(link);
1691
1692             public bool PatternMatch(LinkIndex sequenceToMatch)
1693             {
1694                 _patternPosition = 0;
1695                 _sequencePosition = 0;
1696                 foreach (var part in Walk(sequenceToMatch))
1697                 {
1698                     if (!PatternMatchCore(part))
1699                     {
1700                         break;
1701                     }
1702                 }
1703                 return _patternPosition == _pattern.Count || (_patternPosition == _pattern.Count
1704                     ↳ - 1 && _pattern[_patternPosition].Start == 0);
1705             }
1706
1707             private List<PatternBlock> CreateDetailedPattern()
1708             {
1709                 var pattern = new List<PatternBlock>();
1710                 var patternBlock = new PatternBlock();
1711                 for (var i = 0; i < _patternSequence.Length; i++)
1712                 {
1713                     if (patternBlock.Type == PatternBlockType.Undefined)
1714                     {
1715                         if (_patternSequence[i] == _constants.Any)
1716                         {
1717                             patternBlock.Type = PatternBlockType.Gap;
1718                             patternBlock.Start = 1;
1719                             patternBlock.Stop = 1;
1720                         }
1721                         else if (_patternSequence[i] == ZeroOrMany)
1722                         {

```

```

1720         patternBlock.Type = PatternBlockType.Gap;
1721         patternBlock.Start = 0;
1722         patternBlock.Stop = long.MaxValue;
1723     }
1724     else
1725     {
1726         patternBlock.Type = PatternBlockType.Elements;
1727         patternBlock.Start = i;
1728         patternBlock.Stop = i;
1729     }
1730 }
1731 else if (patternBlock.Type == PatternBlockType.Elements)
1732 {
1733     if (_patternSequence[i] == _constants.Any)
1734     {
1735         pattern.Add(patternBlock);
1736         patternBlock = new PatternBlock
1737         {
1738             Type = PatternBlockType.Gap,
1739             Start = 1,
1740             Stop = 1
1741         };
1742     }
1743     else if (_patternSequence[i] == ZeroOrMany)
1744     {
1745         pattern.Add(patternBlock);
1746         patternBlock = new PatternBlock
1747         {
1748             Type = PatternBlockType.Gap,
1749             Start = 0,
1750             Stop = long.MaxValue
1751         };
1752     }
1753     else
1754     {
1755         patternBlock.Stop = i;
1756     }
1757 }
1758 else // patternBlock.Type == PatternBlockType.Gap
1759 {
1760     if (_patternSequence[i] == _constants.Any)
1761     {
1762         patternBlock.Start++;
1763         if (patternBlock.Stop < patternBlock.Start)
1764         {
1765             patternBlock.Stop = patternBlock.Start;
1766         }
1767     }
1768     else if (_patternSequence[i] == ZeroOrMany)
1769     {
1770         patternBlock.Stop = long.MaxValue;
1771     }
1772     else
1773     {
1774         pattern.Add(patternBlock);
1775         patternBlock = new PatternBlock
1776         {
1777             Type = PatternBlockType.Elements,
1778             Start = i,
1779             Stop = i
1780         };
1781     }
1782 }
1783 }
1784 if (patternBlock.Type != PatternBlockType.Undefined)
1785 {
1786     pattern.Add(patternBlock);
1787 }
1788 return pattern;
1789 }
1790
1791 // match: search for regexp anywhere in text
1792 //int match(char* regexp, char* text)
1793 //{
1794 //    do
1795 //    {
1796 //    } while (*text++ != '\0');
1797 //    return 0;
1798 //}
1799

```

```

1800 // matchhere: search for regexp at beginning of text
1801 //int matchhere(char* regexp, char* text)
1802 //{
1803 //    if (regexp[0] == '\0')
1804 //        return 1;
1805 //    if (regexp[1] == '*')
1806 //        return matchstar(regexp[0], regexp + 2, text);
1807 //    if (regexp[0] == '$' && regexp[1] == '\0')
1808 //        return *text == '\0';
1809 //    if (*text != '\0' && (regexp[0] == '.' || regexp[0] == *text))
1810 //        return matchhere(regexp + 1, text + 1);
1811 //    return 0;
1812 //}
1813
1814 // matchstar: search for c*regexp at beginning of text
1815 //int matchstar(int c, char* regexp, char* text)
1816 //{
1817 //    do
1818 //    { /* a * matches zero or more instances */
1819 //        if (matchhere(regexp, text))
1820 //            return 1;
1821 //    } while (*text != '\0' && (*text++ == c || c == '.'));
1822 //    return 0;
1823 //}
1824
1825 //private void GetNextPatternElement(out LinkIndex element, out long mininumGap, out
1826 //    long maximumGap)
1827 //{
1828 //    mininumGap = 0;
1829 //    maximumGap = 0;
1830 //    element = 0;
1831 //    for (; _patternPosition < _patternSequence.Length; _patternPosition++)
1832 //    {
1833 //        if (_patternSequence[_patternPosition] == Doublets.Links.Null)
1834 //            mininumGap++;
1835 //        else if (_patternSequence[_patternPosition] == ZeroOrMany)
1836 //            maximumGap = long.MaxValue;
1837 //        else
1838 //            break;
1839 //    }
1840 //    if (maximumGap < mininumGap)
1841 //        maximumGap = mininumGap;
1842 //}
1843
1844 private bool PatternMatchCore(LinkIndex element)
1845 {
1846     if (_patternPosition >= _pattern.Count)
1847     {
1848         _patternPosition = -2;
1849         return false;
1850     }
1851     var currentPatternBlock = _pattern[_patternPosition];
1852     if (currentPatternBlock.Type == PatternBlockType.Gap)
1853     {
1854         //var currentMatchingBlockLength = (_sequencePosition -
1855         //    _lastMatchedBlockPosition);
1856         if (_sequencePosition < currentPatternBlock.Start)
1857         {
1858             _sequencePosition++;
1859             return true; // Двигаемся дальше
1860         }
1861         // Это последний блок
1862         if (_pattern.Count == _patternPosition + 1)
1863         {
1864             _patternPosition++;
1865             _sequencePosition = 0;
1866             return false; // Полное соответствие
1867         }
1868         else
1869         {
1870             if (_sequencePosition > currentPatternBlock.Stop)
1871             {
1872                 return false; // Соответствие невозможно
1873             }
1874             var nextPatternBlock = _pattern[_patternPosition + 1];
1875             if (_patternSequence[nextPatternBlock.Start] == element)
1876             {

```

```

1876         if (nextPatternBlock.Start < nextPatternBlock.Stop)
1877         {
1878             _patternPosition++;
1879             _sequencePosition = 1;
1880         }
1881         else
1882         {
1883             _patternPosition += 2;
1884             _sequencePosition = 0;
1885         }
1886     }
1887 }
1888 }
1889 else // currentPatternBlock.Type == PatternBlockType.Elements
1890 {
1891     var patternElementPosition = currentPatternBlock.Start + _sequencePosition;
1892     if (_patternSequence[patternElementPosition] != element)
1893     {
1894         return false; // Соответствие невозможно
1895     }
1896     if (patternElementPosition == currentPatternBlock.Stop)
1897     {
1898         _patternPosition++;
1899         _sequencePosition = 0;
1900     }
1901     else
1902     {
1903         _sequencePosition++;
1904     }
1905 }
1906 return true;
1907 //if (_patternSequence[_patternPosition] != element)
1908 //    return false;
1909 //else
1910 //{
1911 //    _sequencePosition++;
1912 //    _patternPosition++;
1913 //    return true;
1914 //}
1915 ///////
1916 //if (_filterPosition == _patternSequence.Length)
1917 //{
1918 //    _filterPosition = -2; // Длиннее чем нужно
1919 //    return false;
1920 //}
1921 //if (element != _patternSequence[_filterPosition])
1922 //{
1923 //    _filterPosition = -1;
1924 //    return false; // Начинается иначе
1925 //}
1926 //_filterPosition++;
1927 //if (_filterPosition == (_patternSequence.Length - 1))
1928 //    return false;
1929 //if (_filterPosition >= 0)
1930 //{
1931 //    if (element == _patternSequence[_filterPosition + 1])
1932 //        _filterPosition++;
1933 //    else
1934 //        return false;
1935 //}
1936 //if (_filterPosition < 0)
1937 //{
1938 //    if (element == _patternSequence[0])
1939 //        _filterPosition = 0;
1940 //}
1941 }
1942 }
1943 public void AddAllPatternMatchedToResults(IEnumerable<ulong> sequencesToMatch)
1944 {
1945     foreach (var sequenceToMatch in sequencesToMatch)
1946     {
1947         if (PatternMatch(sequenceToMatch))
1948         {
1949             _results.Add(sequenceToMatch);
1950         }
1951     }
1952 }
1953 }
1954

```



```

1955         #endregion
1956     }
1957 }

```

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

```

1  using Platform.Collections.Lists;
2  using Platform.Data.Sequences;
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.Sequences
8  {
9      public static class SequencesExtensions
10     {
11         public static TLink Create<TLink>(this ISequences<TLink> sequences, IList<TLink[]>
12             ↪ groupedSequence)
13         {
14             var finalSequence = new TLink[groupedSequence.Count];
15             for (var i = 0; i < finalSequence.Length; i++)
16             {
17                 var part = groupedSequence[i];
18                 finalSequence[i] = part.Length == 1 ? part[0] : sequences.Create(part);
19             }
20             return sequences.Create(finalSequence);
21         }
22
23         public static IList<TLink> ToList<TLink>(this ISequences<TLink> sequences, TLink
24             ↪ sequence)
25         {
26             var list = new List<TLink>();
27             sequences.EachPart(list.AddAndReturnTrue, sequence);
28             return list;
29         }
30     }
31 }

```

./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
37         // TODO: Реализовать компактификацию при чтении
38         //public bool EnforceSingleSequenceVersionOnRead { get; set; }
39         //public bool UseRequestMarker { get; set; }
40         //public bool StoreRequestResults { get; set; }
41     }
42 }

```

```

40 public void InitOptions(ISynchronizedLinks<TLink> links)
41 {
42     if (UseSequenceMarker)
43     {
44         if (_equalityComparer.Equals(SequenceMarkerLink, links.Constants.Null))
45         {
46             SequenceMarkerLink = links.CreatePoint();
47         }
48         else
49         {
50             if (!links.Exists(SequenceMarkerLink))
51             {
52                 var link = links.CreatePoint();
53                 if (!_equalityComparer.Equals(link, SequenceMarkerLink))
54                 {
55                     throw new InvalidOperationException("Cannot recreate sequence marker
56                                     ↪ link.");
57                 }
58             }
59             if (MarkedSequenceMatcher == null)
60             {
61                 MarkedSequenceMatcher = new MarkedSequenceCriterionMatcher<TLink>(links,
62                                     ↪ SequenceMarkerLink);
63             }
64             var balancedVariantConverter = new BalancedVariantConverter<TLink>(links);
65             if (UseCompression)
66             {
67                 if (LinksToSequenceConverter == null)
68                 {
69                     ICounter<TLink, TLink> totalSequenceSymbolFrequencyCounter;
70                     if (UseSequenceMarker)
71                     {
72                         totalSequenceSymbolFrequencyCounter = new
73                             ↪ TotalMarkedSequenceSymbolFrequencyCounter<TLink>(links,
74                             ↪ MarkedSequenceMatcher);
75                     }
76                     else
77                     {
78                         totalSequenceSymbolFrequencyCounter = new
79                             ↪ TotalSequenceSymbolFrequencyCounter<TLink>(links);
80                     }
81                     var doubletFrequenciesCache = new LinkFrequenciesCache<TLink>(links,
82                                     ↪ totalSequenceSymbolFrequencyCounter);
83                     var compressingConverter = new CompressingConverter<TLink>(links,
84                                     ↪ balancedVariantConverter, doubletFrequenciesCache);
85                     LinksToSequenceConverter = compressingConverter;
86                 }
87             }
88             else
89             {
90                 if (LinksToSequenceConverter == null)
91                 {
92                     LinksToSequenceConverter = balancedVariantConverter;
93                 }
94             }
95             if (UseIndex && Index == null)
96             {
97                 Index = new SequenceIndex<TLink>(links);
98             }
99             if (Walker == null)
100             {
101                 Walker = new RightSequenceWalker<TLink>(links, new DefaultStack<TLink>());
102             }
103         }
104     }
105 }
106
107 public void ValidateOptions()
108 {
109     if (UseGarbageCollection && !UseSequenceMarker)
110     {
111         throw new NotSupportedException("To use garbage collection UseSequenceMarker
112                                     ↪ option must be on.");
113     }
114 }
115 }

```

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

```

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

```

```

19         if (IsElement(element))
20         {
21             yield return element;
22         }
23         else
24         {
25             while (true)
26             {
27                 if (IsElement(element))
28                 {
29                     if (_stack.IsEmpty)
30                     {
31                         break;
32                     }
33                     element = _stack.Pop();
34                     foreach (var output in WalkContents(element))
35                     {
36                         yield return output;
37                     }
38                     element = GetNextElementAfterPop(element);
39                 }
40                 else
41                 {
42                     _stack.Push(element);
43                     element = GetNextElementAfterPush(element);
44                 }
45             }
46         }
47     }
48
49     [MethodImpl(MethodImplOptions.AggressiveInlining)]
50     protected virtual bool IsElement(TLink elementLink) => Links.IsPartialPoint(elementLink);
51
52     [MethodImpl(MethodImplOptions.AggressiveInlining)]
53     protected abstract TLink GetNextElementAfterPop(TLink element);
54
55     [MethodImpl(MethodImplOptions.AggressiveInlining)]
56     protected abstract TLink GetNextElementAfterPush(TLink element);
57
58     [MethodImpl(MethodImplOptions.AggressiveInlining)]
59     protected abstract IEnumerable<TLink> WalkContents(TLink element);
60 }
61 }

```

./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();

```

```

35         var previousTop = _links.GetSource(top);
36         _links.Update(_stack, GetStackMarker(), previousTop);
37         _links.Delete(top);
38     }
39     return element;
40 }
41
42 public void Push(TLink element) => _links.Update(_stack, GetStackMarker(),
    ↪ _links.GetOrCreate(GetTop(), element));
43 }
44 }

```

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

```

```

43
44     //     return SyncRoot.ExecuteReadOperation(restriction, matchedHandler, substitution,
45     ↪     substitutedHandler, Unsync.Trigger);
46     //}
47 }

```

./Platform.Data.Doublets/UInt64Link.cs

```

1  using System;
2  using System.Collections;
3  using System.Collections.Generic;
4  using Platform.Exceptions;
5  using Platform.Ranges;
6  using Platform.Singletons;
7  using Platform.Collections.Lists;
8  using Platform.Data.Constants;
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 UInt64Link : IEquatable<UInt64Link>, IReadOnlyList<ulong>, IList<ulong>
18     {
19         private static readonly LinksCombinedConstants<bool, ulong, int> _constants =
20             ↪ Default<LinksCombinedConstants<bool, ulong, int>>.Instance;
21
22         private const int Length = 3;
23
24         public readonly ulong Index;
25         public readonly ulong Source;
26         public readonly ulong Target;
27
28         public static readonly UInt64Link Null = new UInt64Link();
29
30         public UInt64Link(params ulong[] values)
31         {
32             Index = values.Length > _constants.IndexPart ? values[_constants.IndexPart] :
33             ↪ _constants.Null;
34             Source = values.Length > _constants.SourcePart ? values[_constants.SourcePart] :
35             ↪ _constants.Null;
36             Target = values.Length > _constants.TargetPart ? values[_constants.TargetPart] :
37             ↪ _constants.Null;
38         }
39
40         public UInt64Link(IList<ulong> values)
41         {
42             Index = values.Count > _constants.IndexPart ? values[_constants.IndexPart] :
43             ↪ _constants.Null;
44             Source = values.Count > _constants.SourcePart ? values[_constants.SourcePart] :
45             ↪ _constants.Null;
46             Target = values.Count > _constants.TargetPart ? values[_constants.TargetPart] :
47             ↪ _constants.Null;
48         }
49
50         public UInt64Link(ulong index, ulong source, ulong target)
51         {
52             Index = index;
53             Source = source;
54             Target = target;
55         }
56
57         public UInt64Link(ulong source, ulong target)
58             : this(_constants.Null, source, target)
59         {
60             Source = source;
61             Target = target;
62         }
63
64         public static UInt64Link Create(ulong source, ulong target) => new UInt64Link(source,
65             ↪ target);
66
67         public override int GetHashCode() => (Index, Source, Target).GetHashCode();
68
69         public bool IsNull() => Index == _constants.Null
70             && Source == _constants.Null
71             && Target == _constants.Null;
72     }
73 }

```



```

65     public override bool Equals(object other) => other is UInt64Link &&
        ↳ Equals((UInt64Link)other);
66
67     public bool Equals(UInt64Link other) => Index == other.Index
68                                         && Source == other.Source
69                                         && Target == other.Target;
70
71     public static string ToString(ulong index, ulong source, ulong target) => $"{index}:
        ↳ {source}->{target}";
72
73     public static string ToString(ulong source, ulong target) => $"{source}->{target}";
74
75     public static implicit operator ulong[] (UInt64Link link) => link.ToArray();
76
77     public static implicit operator UInt64Link(ulong[] linkArray) => new
        ↳ UInt64Link(linkArray);
78
79     public override string ToString() => Index == _constants.Null ? ToString(Source, Target)
        ↳ : ToString(Index, Source, Target);
80
81     #region IList
82
83     public ulong this[int index]
84     {
85         get
86         {
87             Ensure.Always.ArgumentInRange(index, new Range<int>(0, Length - 1),
            ↳ nameof(index));
88             if (index == _constants.IndexPart)
89             {
90                 return Index;
91             }
92             if (index == _constants.SourcePart)
93             {
94                 return Source;
95             }
96             if (index == _constants.TargetPart)
97             {
98                 return Target;
99             }
100             throw new NotSupportedException(); // Impossible path due to
            ↳ Ensure.ArgumentInRange
101         }
102         set => throw new NotSupportedException();
103     }
104
105     public int Count => Length;
106
107     public bool IsReadOnly => true;
108
109     IEnumerator IEnumerable.GetEnumerator() => GetEnumerator();
110
111     public IEnumerator<ulong> GetEnumerator()
112     {
113         yield return Index;
114         yield return Source;
115         yield return Target;
116     }
117
118     public void Add(ulong item) => throw new NotSupportedException();
119
120     public void Clear() => throw new NotSupportedException();
121
122     public bool Contains(ulong item) => IndexOf(item) >= 0;
123
124     public void CopyTo(ulong[] array, int arrayIndex)
125     {
126         Ensure.Always.ArgumentNotNull(array, nameof(array));
127         Ensure.Always.ArgumentInRange(arrayIndex, new Range<int>(0, array.Length - 1),
            ↳ nameof(arrayIndex));
128         if (arrayIndex + Length > array.Length)
129         {
130             throw new ArgumentException();
131         }
132         array[arrayIndex++] = Index;
133         array[arrayIndex++] = Source;
134         array[arrayIndex] = Target;
135     }
136

```

```

137     public bool Remove(ulong item) => Throw.A.NotSupportedExceptionAndReturn<bool>();
138
139     public int IndexOf(ulong item)
140     {
141         if (Index == item)
142         {
143             return _constants.IndexPart;
144         }
145         if (Source == item)
146         {
147             return _constants.SourcePart;
148         }
149         if (Target == item)
150         {
151             return _constants.TargetPart;
152         }
153
154         return -1;
155     }
156
157     public void Insert(int index, ulong item) => throw new NotSupportedException();
158
159     public void RemoveAt(int index) => throw new NotSupportedException();
160
161     #endregion
162 }
163 }

```

./Platform.Data.Doublets/UInt64LinkExtensions.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 UInt64LinkExtensions
6      {
7          public static bool IsFullPoint(this UInt64Link link) => Point<ulong>.IsFullPoint(link);
8          public static bool IsPartialPoint(this UInt64Link link) =>
9              ↪ Point<ulong>.IsPartialPoint(link);
10     }
11 }

```

./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.Constants;
6  using Platform.Data.Exceptions;
7  using Platform.Data.Doublets.Unicode;
8
9  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
10
11 namespace Platform.Data.Doublets
12 {
13     public static class UInt64LinksExtensions
14     {
15         public static readonly LinksCombinedConstants<bool, ulong, int> Constants =
16             ↪ Default<LinksCombinedConstants<bool, ulong, int>>.Instance;
17
18         public static void UseUnicode(this ILinks<ulong> links) => UnicodeMap.InitNew(links);
19
20         public static void EnsureEachLinkExists(this ILinks<ulong> links, IList<ulong> sequence)
21         {
22             if (sequence == null)
23             {
24                 return;
25             }
26             for (var i = 0; i < sequence.Count; i++)
27             {
28                 if (!links.Exists(sequence[i]))
29                 {
30                     throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
31                         ↪ $"sequence[{i}]");
32                 }
33             }
34
35             public static void EnsureEachLinkIsAnyOrExists(this ILinks<ulong> links, IList<ulong>
36                 ↪ sequence)
37             {

```

```

36     if (sequence == null)
37     {
38         return;
39     }
40     for (var i = 0; i < sequence.Count; i++)
41     {
42         if (sequence[i] != Constants.Any && !links.Exists(sequence[i]))
43         {
44             throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
45                 ↪ $"sequence[{i}]");
46         }
47     }
48 }
49 public static bool AnyLinkIsAny(this ILinks<ulong> links, params ulong[] sequence)
50 {
51     if (sequence == null)
52     {
53         return false;
54     }
55     var constants = links.Constants;
56     for (var i = 0; i < sequence.Length; i++)
57     {
58         if (sequence[i] == constants.Any)
59         {
60             return true;
61         }
62     }
63     return false;
64 }
65
66 public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
67     ↪ Func<UInt64Link, bool> isElement, bool renderIndex = false, bool renderDebug = false)
68 {
69     var sb = new StringBuilder();
70     var visited = new HashSet<ulong>();
71     links.AppendStructure(sb, visited, linkIndex, isElement, (innerSb, link) =>
72         ↪ innerSb.Append(link.Index), renderIndex, renderDebug);
73     return sb.ToString();
74 }
75
76 public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
77     ↪ Func<UInt64Link, bool> isElement, Action<StringBuilder, UInt64Link> appendElement,
78     ↪ bool renderIndex = false, bool renderDebug = false)
79 {
80     var sb = new StringBuilder();
81     var visited = new HashSet<ulong>();
82     links.AppendStructure(sb, visited, linkIndex, isElement, appendElement, renderIndex,
83         ↪ renderDebug);
84     return sb.ToString();
85 }
86
87 public static void AppendStructure(this ILinks<ulong> links, StringBuilder sb,
88     ↪ HashSet<ulong> visited, ulong linkIndex, Func<UInt64Link, bool> isElement,
89     ↪ Action<StringBuilder, UInt64Link> appendElement, bool renderIndex = false, bool
90     ↪ renderDebug = false)
91 {
92     if (sb == null)
93     {
94         throw new ArgumentNullException(nameof(sb));
95     }
96     if (linkIndex == Constants.Null || linkIndex == Constants.Any || linkIndex ==
97         ↪ Constants.Itself)
98     {
99         return;
100     }
101     if (links.Exists(linkIndex))
102     {
103         if (visited.Add(linkIndex))
104         {
105             sb.Append('(');
106             var link = new UInt64Link(links.GetLink(linkIndex));
107             if (renderIndex)
108             {
109                 sb.Append(link.Index);
110                 sb.Append(':');
111             }
112             if (link.Source == link.Index)

```

```

104         {
105             sb.Append(link.Index);
106         }
107         else
108         {
109             var source = new UInt64Link(links.GetLink(link.Source));
110             if (isElement(source))
111             {
112                 appendElement(sb, source);
113             }
114             else
115             {
116                 links.AppendStructure(sb, visited, source.Index, isElement,
117                     ↪ appendElement, renderIndex);
118             }
119             sb.Append(' ');
120             if (link.Target == link.Index)
121             {
122                 sb.Append(link.Index);
123             }
124             else
125             {
126                 var target = new UInt64Link(links.GetLink(link.Target));
127                 if (isElement(target))
128                 {
129                     appendElement(sb, target);
130                 }
131                 else
132                 {
133                     links.AppendStructure(sb, visited, target.Index, isElement,
134                         ↪ appendElement, renderIndex);
135                 }
136             }
137             sb.Append(')');
138         }
139         else
140         {
141             if (renderDebug)
142             {
143                 sb.Append('*');
144             }
145             sb.Append(linkIndex);
146         }
147     }
148     else
149     {
150         if (renderDebug)
151         {
152             sb.Append('~');
153         }
154         sb.Append(linkIndex);
155     }
156 }
157 }

```

./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
14 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
15
16 namespace Platform.Data.Doublets
17 {
18     public class UInt64LinksTransactionsLayer : LinksDisposableDecoratorBase //-V3073
19     {
20         /// <remarks>
21         /// Альтернативные варианты хранения трансформации (элемента транзакции):

```

```

22     ///
23     /// private enum TransitionType
24     /// {
25     ///     Creation,
26     ///     UpdateOf,
27     ///     UpdateTo,
28     ///     Deletion
29     /// }
30     ///
31     /// private struct Transition
32     /// {
33     ///     public ulong TransactionId;
34     ///     public UniqueTimestamp Timestamp;
35     ///     public TransactionItemType Type;
36     ///     public Link Source;
37     ///     public Link Linker;
38     ///     public Link Target;
39     /// }
40     ///
41     /// Или
42     ///
43     /// public struct TransitionHeader
44     /// {
45     ///     public ulong TransactionIdCombined;
46     ///     public ulong TimestampCombined;
47     ///
48     ///     public ulong TransactionId
49     ///     {
50     ///         get
51     ///         {
52     ///             return (ulong) mask & TransactionIdCombined;
53     ///         }
54     ///     }
55     ///
56     ///     public UniqueTimestamp Timestamp
57     ///     {
58     ///         get
59     ///         {
60     ///             return (UniqueTimestamp)mask & TransactionIdCombined;
61     ///         }
62     ///     }
63     ///
64     ///     public TransactionItemType Type
65     ///     {
66     ///         get
67     ///         {
68     ///             // Использовать по одному биту из TransactionId и Timestamp,
69     ///             // для значения в 2 бита, которое представляет тип операции
70     ///             throw new NotImplementedException();
71     ///         }
72     ///     }
73     /// }
74     ///
75     /// private struct Transition
76     /// {
77     ///     public TransitionHeader Header;
78     ///     public Link Source;
79     ///     public Link Linker;
80     ///     public Link Target;
81     /// }
82     ///
83     /// </remarks>
84     public struct Transition
85     {
86         public static readonly long Size = Structure<Transition>.Size;
87
88         public readonly ulong TransactionId;
89         public readonly UInt64Link Before;
90         public readonly UInt64Link After;
91         public readonly Timestamp Timestamp;
92
93         public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
94         ↪ transactionId, UInt64Link before, UInt64Link after)
95         {
96             TransactionId = transactionId;
97             Before = before;
98             After = after;
99             Timestamp = uniqueTimestampFactory.Create();

```

```

99     }
100
101     public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
    ↪ transactionId, UInt64Link before)
102         : this(uniqueTimestampFactory, transactionId, before, default)
103     {
104     }
105
106     public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong transactionId
    ↪ : this(uniqueTimestampFactory, transactionId, default, default)
107     {
108     }
109
110
111     public override string ToString() => $"{Timestamp} {TransactionId}: {Before} =>
    ↪ {After}";
112 }
113
114 /// <remarks>
115 /// Другие варианты реализации транзакций (атомарности):
116 /// 1. Разделение хранения значения связи ((Source Target) или (Source Linker
    ↪ Target)) и индексов.
117 /// 2. Хранение трансформаций/операций в отдельном хранилище Links, но дополнительно
    ↪ потребуется решить вопрос
118 /// со ссылками на внешние идентификаторы, или как-то иначе решить вопрос с
    ↪ пересечениями идентификаторов.
119 ///
120 /// Где хранить промежуточный список транзакций?
121 ///
122 /// В оперативной памяти:
123 /// Минусы:
124 /// 1. Может усложнить систему, если она будет функционировать самостоятельно,
125 /// так как нужно отдельно выделять память под список трансформаций.
126 /// 2. Выделенной оперативной памяти может не хватить, в том случае,
127 /// если транзакция использует слишком много трансформаций.
128 /// -> Можно использовать жёсткий диск для слишком длинных транзакций.
129 /// -> Максимальный размер списка трансформаций можно ограничить / задать
    ↪ константой.
130 /// 3. При подтверждении транзакции (Commit) все трансформации записываются разом
    ↪ создавая задержку.
131 ///
132 /// На жёстком диске:
133 /// Минусы:
134 /// 1. Длительный отклик, на запись каждой трансформации.
135 /// 2. Лог транзакций дополнительно наполняется отменёнными транзакциями.
136 /// -> Это может решаться упаковкой/исключением дублирующих операций.
137 /// -> Также это может решаться тем, что короткие транзакции вообще
138 /// не будут записываться в случае отката.
139 /// 3. Перед тем как выполнять отмену операций транзакции нужно дождаться пока все
    ↪ операции (трансформации)
140 /// будут записаны в лог.
141 ///
142 /// </remarks>
143 public class Transaction : DisposableBase
144 {
145     private readonly Queue<Transition> _transitions;
146     private readonly UInt64LinksTransactionsLayer _layer;
147     public bool IsCommitted { get; private set; }
148     public bool IsReverted { get; private set; }
149
150     public Transaction(UInt64LinksTransactionsLayer layer)
151     {
152         _layer = layer;
153         if (_layer._currentTransactionId != 0)
154         {
155             throw new NotSupportedException("Nested transactions not supported.");
156         }
157         IsCommitted = false;
158         IsReverted = false;
159         _transitions = new Queue<Transition>();
160         SetCurrentTransaction(layer, this);
161     }
162
163     public void Commit()
164     {
165         EnsureTransactionAllowsWriteOperations(this);
166         while (_transitions.Count > 0)
167         {
168             var transition = _transitions.Dequeue();

```

```

169         _layer._transitions.Enqueue(transition);
170     }
171     _layer._lastCommittedTransactionId = _layer._currentTransactionId;
172     IsCommitted = true;
173 }
174
175 private void Revert()
176 {
177     EnsureTransactionAllowsWriteOperations(this);
178     var transitionsToRevert = new Transition[_transitions.Count];
179     _transitions.CopyTo(transitionsToRevert, 0);
180     for (var i = transitionsToRevert.Length - 1; i >= 0; i--)
181     {
182         _layer.RevertTransition(transitionsToRevert[i]);
183     }
184     IsReverted = true;
185 }
186
187 public static void SetCurrentTransaction(UInt64LinksTransactionsLayer layer,
188 ↪ Transaction transaction)
189 {
190     layer._currentTransactionId = layer._lastCommittedTransactionId + 1;
191     layer._currentTransactionTransitions = transaction._transitions;
192     layer._currentTransaction = transaction;
193 }
194
195 public static void EnsureTransactionAllowsWriteOperations(Transaction transaction)
196 {
197     if (transaction.IsReverted)
198     {
199         throw new InvalidOperationException("Transation is reverted.");
200     }
201     if (transaction.IsCommitted)
202     {
203         throw new InvalidOperationException("Transation is committed.");
204     }
205 }
206
207 protected override void Dispose(bool manual, bool wasDisposed)
208 {
209     if (!wasDisposed && _layer != null && !_layer.IsDisposed)
210     {
211         if (!IsCommitted && !IsReverted)
212         {
213             Revert();
214         }
215         _layer.ResetCurrentTransation();
216     }
217 }
218
219 public static readonly TimeSpan DefaultPushDelay = TimeSpan.FromSeconds(0.1);
220
221 private readonly string _logAddress;
222 private readonly FileStream _log;
223 private readonly Queue<Transition> _transitions;
224 private readonly UniqueTimestampFactory _uniqueTimestampFactory;
225 private Task _transitionsPusher;
226 private Transition _lastCommittedTransition;
227 private ulong _currentTransactionId;
228 private Queue<Transition> _currentTransactionTransitions;
229 private Transaction _currentTransaction;
230 private ulong _lastCommittedTransactionId;
231
232 public UInt64LinksTransactionsLayer(ILinks<ulong> links, string logAddress)
233     : base(links)
234 {
235     if (string.IsNullOrEmpty(logAddress))
236     {
237         throw new ArgumentNullException(nameof(logAddress));
238     }
239     // В первой строке файла хранится последняя закомиченная транзакция.
240     // При запуске это используется для проверки удачного закрытия файла лога.
241     // In the first line of the file the last committed transaction is stored.
242     // On startup, this is used to check that the log file is successfully closed.
243     var lastCommittedTransition = FileHelpers.ReadFirstOrDefault<Transition>(logAddress);
244     var lastWrittenTransition = FileHelpers.ReadLastOrDefault<Transition>(logAddress);
245     if (!lastCommittedTransition.Equals(lastWrittenTransition))
246     {

```

```

247         Dispose();
248         throw new NotSupportedException("Database is damaged, autorecovery is not
        ↳ supported yet.");
249     }
250     if (lastCommittedTransition.Equals(default(Transition)))
251     {
252         FileHelpers.WriteFirst(logAddress, lastCommittedTransition);
253     }
254     _lastCommittedTransition = lastCommittedTransition;
255     // TODO: Think about a better way to calculate or store this value
256     var allTransitions = FileHelpers.ReadAll<Transition>(logAddress);
257     _lastCommittedTransactionId = allTransitions.Max(x => x.TransactionId);
258     _uniqueTimestampFactory = new UniqueTimestampFactory();
259     _logAddress = logAddress;
260     _log = FileHelpers.Append(logAddress);
261     _transitions = new Queue<Transition>();
262     _transitionsPusher = new Task(TransitionsPusher);
263     _transitionsPusher.Start();
264 }
265
266 public IList<ulong> GetLinkValue(ulong link) => Links.GetLink(link);
267
268 public override ulong Create()
269 {
270     var createdLinkIndex = Links.Create();
271     var createdLink = new UInt64Link(Links.GetLink(createdLinkIndex));
272     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↳ default, createdLink));
273     return createdLinkIndex;
274 }
275
276 public override ulong Update(IList<ulong> parts)
277 {
278     var linkIndex = parts[Constants.IndexPart];
279     var beforeLink = new UInt64Link(Links.GetLink(linkIndex));
280     linkIndex = Links.Update(parts);
281     var afterLink = new UInt64Link(Links.GetLink(linkIndex));
282     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↳ beforeLink, afterLink));
283     return linkIndex;
284 }
285
286 public override void Delete(ulong link)
287 {
288     var deletedLink = new UInt64Link(Links.GetLink(link));
289     Links.Delete(link);
290     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↳ deletedLink, default));
291 }
292
293 [MethodImpl(MethodImplOptions.AggressiveInlining)]
294 private Queue<Transition> GetCurrentTransitions() => _currentTransactionTransitions ??
    ↳ _transitions;
295
296 private void CommitTransition(Transition transition)
297 {
298     if (_currentTransaction != null)
299     {
300         Transaction.EnsureTransactionAllowsWriteOperations(_currentTransaction);
301     }
302     var transitions = GetCurrentTransitions();
303     transitions.Enqueue(transition);
304 }
305
306 private void RevertTransition(Transition transition)
307 {
308     if (transition.After.IsNull()) // Revert Deletion with Creation
309     {
310         Links.Create();
311     }
312     else if (transition.Before.IsNull()) // Revert Creation with Deletion
313     {
314         Links.Delete(transition.After.Index);
315     }
316     else // Revert Update
317     {
318         Links.Update(new[] { transition.After.Index, transition.Before.Source,
        ↳ transition.Before.Target });

```



```

319     }
320 }
321
322 private void ResetCurrentTransation()
323 {
324     _currentTransactionId = 0;
325     _currentTransactionTransitions = null;
326     _currentTransaction = null;
327 }
328
329 private void PushTransitions()
330 {
331     if (_log == null || _transitions == null)
332     {
333         return;
334     }
335     for (var i = 0; i < _transitions.Count; i++)
336     {
337         var transition = _transitions.Dequeue();
338
339         _log.Write(transition);
340         _lastCommitedTransition = transition;
341     }
342 }
343
344 private void TransitionsPusher()
345 {
346     while (!IsDisposed && _transitionsPusher != null)
347     {
348         Thread.Sleep(DefaultPushDelay);
349         PushTransitions();
350     }
351 }
352
353 public Transaction BeginTransaction() => new Transaction(this);
354
355 private void DisposeTransitions()
356 {
357     try
358     {
359         var pusher = _transitionsPusher;
360         if (pusher != null)
361         {
362             _transitionsPusher = null;
363             pusher.Wait();
364         }
365         if (_transitions != null)
366         {
367             PushTransitions();
368         }
369         _log.DisposeIfPossible();
370         FileHelpers.WriteFirst(_logAddress, _lastCommitedTransition);
371     }
372     catch
373     {
374     }
375 }
376
377 #region DisposalBase
378
379 protected override void Dispose(bool manual, bool wasDisposed)
380 {
381     if (!wasDisposed)
382     {
383         DisposeTransitions();
384     }
385     base.Dispose(manual, wasDisposed);
386 }
387
388 #endregion
389 }
390 }

```

./Platform.Data.Doublets/UnaryNumbers/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.UnaryNumbers
9 {
10     public class AddressToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
        ↳ IConverter<TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
            ↳ EqualityComparer<TLink>.Default;
13
14         private readonly IConverter<int, TLink> _powerOf2ToUnaryNumberConverter;
15
16         public AddressToUnaryNumberConverter(ILinks<TLink> links, IConverter<int, TLink>
            ↳ powerOf2ToUnaryNumberConverter) : base(links) => _powerOf2ToUnaryNumberConverter =
            ↳ powerOf2ToUnaryNumberConverter;
17
18         public TLink Convert(TLink sourceAddress)
19         {
20             var number = sourceAddress;
21             var nullConstant = Links.Constants.Null;
22             var one = Integer<TLink>.One;
23             var target = nullConstant;
24             for (int i = 0; !_equalityComparer.Equals(number, default) && i <
                ↳ Type<TLink>.BitsLength; i++)
25             {
26                 if (_equalityComparer.Equals(Arithmetic.And(number, one), one))
27                 {
28                     target = _equalityComparer.Equals(target, nullConstant)
29                         ? _powerOf2ToUnaryNumberConverter.Convert(i)
30                         : Links.GetOrCreate(_powerOf2ToUnaryNumberConverter.Convert(i), target);
31                 }
32                 number = (Integer<TLink>)((ulong)(Integer<TLink>)number >> 1); // Should be
                    ↳ Bit.ShiftRight(number, 1)
33             }
34             return target;
35         }
36     }
37 }

```

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

```

```

40     }
41 }
42 }

```

./Platform.Data.Doublets/UnaryNumbers/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.UnaryNumbers
9  {
10     public class PowerOf2ToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
        ↳ IConverter<int, TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
        ↳ EqualityComparer<TLink>.Default;
13
14         private readonly TLink[] _unaryNumberPowersOf2;
15
16         public PowerOf2ToUnaryNumberConverter(ILinks<TLink> links, TLink one) : base(links)
17         {
18             _unaryNumberPowersOf2 = new TLink[64];
19             _unaryNumberPowersOf2[0] = one;
20         }
21
22         public TLink Convert(int power)
23         {
24             Ensure.Always.ArgumentInRange(power, new Range<int>(0, _unaryNumberPowersOf2.Length
        ↳ - 1), nameof(power));
25             if (!_equalityComparer.Equals(_unaryNumberPowersOf2[power], default))
26             {
27                 return _unaryNumberPowersOf2[power];
28             }
29             var previousPowerOf2 = Convert(power - 1);
30             var powerOf2 = Links.GetOrCreate(previousPowerOf2, previousPowerOf2);
31             _unaryNumberPowersOf2[power] = powerOf2;
32             return powerOf2;
33         }
34     }
35 }

```

./Platform.Data.Doublets/UnaryNumbers/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.UnaryNumbers
9  {
10     public class UnaryNumberToAddressAddOperationConverter<TLink> : LinksOperatorBase<TLink>,
        ↳ IConverter<TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
        ↳ EqualityComparer<TLink>.Default;
13
14         private Dictionary<TLink, TLink> _unaryToUInt64;
15         private readonly TLink _unaryOne;
16
17         public UnaryNumberToAddressAddOperationConverter(ILinks<TLink> links, TLink unaryOne)
        ↳ : base(links)
18         {
19             _unaryOne = unaryOne;
20             InitUnaryToUInt64();
21         }
22
23         private void InitUnaryToUInt64()
24         {
25             var one = Integer<TLink>.One;
26             _unaryToUInt64 = new Dictionary<TLink, TLink>
27             {
28                 { _unaryOne, one }
29             };
30             var unary = _unaryOne;
31             var number = one;
32             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/UnaryNumbers/UnaryNumberToAddressOrOperationConverter.cs

```

1  using System.Collections.Generic;
2  using Platform.Interfaces;
3  using Platform.Reflection;
4  using Platform.Numbers;
5  using System.Runtime.CompilerServices;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets.UnaryNumbers
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 < Type<TLink>.BitsLength; i++)
25             {
26                 _unaryNumberPowerOf2Indicies.Add(powerOf2ToUnaryNumberConverter.Convert(i), i);
27             }
28         }
29
30         public TLink Convert(TLink sourceNumber)
31         {
32             var nullConstant = Links.Constants.Null;
33             var source = sourceNumber;
34             var target = nullConstant;
35             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 =
    ↪ (Integer<TLink>)((Integer<TLink>)target | 1UL << powerOf2Index); // Should be
    ↪ Math.Or(target, Math.ShiftLeft(One, powerOf2Index))
54 }
55 }

```

./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> _addressToUnaryNumberConverter;
12         private readonly TLink _unicodeSymbolMarker;
13
14         public CharToUnicodeSymbolConverter(ILinks<TLink> links, IConverter<TLink>
15             ↪ addressToUnaryNumberConverter, TLink unicodeSymbolMarker) : base(links)
16         {
17             _addressToUnaryNumberConverter = addressToUnaryNumberConverter;
18             _unicodeSymbolMarker = unicodeSymbolMarker;
19
20         public TLink Convert(char source)
21         {
22             var unaryNumber = _addressToUnaryNumberConverter.Convert((Integer<TLink>)source);
23             return Links.GetOrCreate(unaryNumber, _unicodeSymbolMarker);
24         }
25     }
26 }

```

./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 }

```

```

22     }
23
24     public TLink Convert(string source)
25     {
26         var elements = new List<TLink>();
27         for (int i = 0; i < source.Length; i++)
28         {
29             elements.Add(_charToUnicodeSymbolConverter.Convert(source[i]));
30         }
31         _index.Add(elements);
32         var sequence = _listToSequenceLinkConverter.Convert(elements);
33         return Links.GetOrCreate(sequence, _unicodeSequenceMarker);
34     }
35 }
36 }

```

./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 }
60
61 // 0 - null link
62 // 1 - nil character (0 character)
63 // ...
64 // 65536 (0(1) + 65535 = 65536 possible values)

```

```

62 [MethodImpl(MethodImplOptions.AggressiveInlining)]
63 public static ulong FromCharToLink(char character) => (ulong)character + 1;
64
65 [MethodImpl(MethodImplOptions.AggressiveInlining)]
66 public static char FromLinkToChar(ulong link) => (char)(link - 1);
67
68 [MethodImpl(MethodImplOptions.AggressiveInlining)]
69 public static bool IsCharLink(ulong link) => link <= MapSize;
70
71 public static string FromLinksToString(IList<ulong> linksList)
72 {
73     var sb = new StringBuilder();
74     for (int i = 0; i < linksList.Count; i++)
75     {
76         sb.Append(FromLinkToChar(linksList[i]));
77     }
78     return sb.ToString();
79 }
80
81 public static string FromSequenceLinkToString(ulong link, ILinks<ulong> links)
82 {
83     var sb = new StringBuilder();
84     if (links.Exists(link))
85     {
86         StopableSequenceWalker.WalkRight(link, links.GetSource, links.GetTarget,
87             x => x <= MapSize || links.GetSource(x) == x || links.GetTarget(x) == x,
88             ↪ element =>
89             {
90                 sb.Append(FromLinkToChar(element));
91                 return true;
92             });
93     }
94     return sb.ToString();
95 }
96
97 public static ulong[] FromCharsToLinkArray(char[] chars) => FromCharsToLinkArray(chars,
98     ↪ chars.Length);
99
100 public static ulong[] FromCharsToLinkArray(char[] chars, int count)
101 {
102     // char array to ulong array
103     var linksSequence = new ulong[count];
104     for (var i = 0; i < count; i++)
105     {
106         linksSequence[i] = FromCharToLink(chars[i]);
107     }
108     return linksSequence;
109 }
110
111 public static ulong[] FromStringToLinkArray(string sequence)
112 {
113     // char array to ulong array
114     var linksSequence = new ulong[sequence.Length];
115     for (var i = 0; i < sequence.Length; i++)
116     {
117         linksSequence[i] = FromCharToLink(sequence[i]);
118     }
119     return linksSequence;
120 }
121
122 public static List<ulong[]> FromStringToLinkArrayGroups(string sequence)
123 {
124     var result = new List<ulong[]>();
125     var offset = 0;
126     while (offset < sequence.Length)
127     {
128         var currentCategory = CharUnicodeInfo.GetUnicodeCategory(sequence[offset]);
129         var relativeLength = 1;
130         var absoluteLength = offset + relativeLength;
131         while (absoluteLength < sequence.Length &&
132             currentCategory ==
133             ↪ CharUnicodeInfo.GetUnicodeCategory(sequence[absoluteLength]))
134         {
135             relativeLength++;
136             absoluteLength++;
137         }
138         // char array to ulong array
139         var innerSequence = new ulong[relativeLength];
140         var maxLength = offset + relativeLength;

```

```

138         for (var i = offset; i < maxLength; i++)
139         {
140             innerSequence[i - offset] = FromCharToLink(sequence[i]);
141         }
142         result.Add(innerSequence);
143         offset += relativeLength;
144     }
145     return result;
146 }
147
148 public static List<ulong[]> FromLinkArrayToLinkArrayGroups(ulong[] array)
149 {
150     var result = new List<ulong[]>();
151     var offset = 0;
152     while (offset < array.Length)
153     {
154         var relativeLength = 1;
155         if (array[offset] <= LastCharLink)
156         {
157             var currentCategory =
158                 ↪ CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(array[offset]));
159             var absoluteLength = offset + relativeLength;
160             while (absoluteLength < array.Length &&
161                 array[absoluteLength] <= LastCharLink &&
162                 currentCategory == CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(
163                     ↪ array[absoluteLength])))
164             {
165                 relativeLength++;
166                 absoluteLength++;
167             }
168         }
169         else
170         {
171             var absoluteLength = offset + relativeLength;
172             while (absoluteLength < array.Length && array[absoluteLength] > LastCharLink)
173             {
174                 relativeLength++;
175                 absoluteLength++;
176             }
177             // copy array
178             var innerSequence = new ulong[relativeLength];
179             var maxLength = offset + relativeLength;
180             for (var i = offset; i < maxLength; i++)
181             {
182                 innerSequence[i - offset] = array[i];
183             }
184             result.Add(innerSequence);
185             offset += relativeLength;
186         }
187     }
188     return result;
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 Platform.Interfaces;
2 using Platform.Numbers;
3 using System;
4 using System.Collections.Generic;
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 UnicodeSymbolToCharConverter<TLink> : LinksOperatorBase<TLink>,
11         ↳ IConverter<TLink, char>
12     {
13         private readonly IConverter<TLink> _unaryNumberToAddressConverter;
14         private readonly ICriterionMatcher<TLink> _unicodeSymbolCriterionMatcher;
15
16         public UnicodeSymbolToCharConverter(ILinks<TLink> links, IConverter<TLink>
17             ↳ unaryNumberToAddressConverter, ICriterionMatcher<TLink>
18             ↳ unicodeSymbolCriterionMatcher) : base(links)
19         {
20             _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
21         }
22     }
23 }

```

```

18         _unicodeSymbolCriterionMatcher = unicodeSymbolCriterionMatcher;
19     }
20
21     public char Convert(TLink source)
22     {
23         if (!_unicodeSymbolCriterionMatcher.IsMatched(source))
24         {
25             throw new ArgumentOutOfRangeException(nameof(source), source, "Specified link is
                ↳ not a unicode symbol.");
26         }
27         return (char)(ushort)(Integer<TLink>)_unaryNumberToAddressConverter.Convert(Links.Ge
                ↳ tSource(source));
28     }
29 }
30 }

```

./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         protected 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 GreaterOrEqualPerfomanceTest()
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             });

```



```

69     Assert.True(equalityComparer.Equals(link.Index, linkAddress));
70     Assert.True(equalityComparer.Equals(link.Source, constants.Null));
71     Assert.True(equalityComparer.Equals(link.Target, constants.Null));
72
73     Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.One));
74
75     // Get first link
76     setter = new Setter<T>(constants.Null);
77     links.Each(constants.Any, constants.Any, setter.SetAndReturnFalse);
78
79     Assert.True(equalityComparer.Equals(setter.Result, linkAddress));
80
81     // Update link to reference itself
82     links.Update(linkAddress, linkAddress, linkAddress);
83
84     link = new Link<T>(links.GetLink(linkAddress));
85
86     Assert.True(equalityComparer.Equals(link.Source, linkAddress));
87     Assert.True(equalityComparer.Equals(link.Target, linkAddress));
88
89     // Update link to reference null (prepare for delete)
90     var updated = links.Update(linkAddress, constants.Null, constants.Null);
91
92     Assert.True(equalityComparer.Equals(updated, linkAddress));
93
94     link = new Link<T>(links.GetLink(linkAddress));
95
96     Assert.True(equalityComparer.Equals(link.Source, constants.Null));
97     Assert.True(equalityComparer.Equals(link.Target, constants.Null));
98
99     // Delete link
100    links.Delete(linkAddress);
101
102    Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.Zero));
103
104    setter = new Setter<T>(constants.Null);
105    links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);
106
107    Assert.True(equalityComparer.Equals(setter.Result, constants.Null));
108 }
109
110 [Fact]
111 public static void UInt64RawNumbersCRUDTest()
112 {
113     using (var scope = new Scope<Types<HeapResizableDirectMemory,
114         ↳ ResizableDirectMemoryLinks<ulong>>>())
115     {
116         scope.Use<ILinks<ulong>>().TestRawNumbersCRUDOperations();
117     }
118 }
119
120 [Fact]
121 public static void UInt32RawNumbersCRUDTest()
122 {
123     using (var scope = new Scope<Types<HeapResizableDirectMemory,
124         ↳ ResizableDirectMemoryLinks<uint>>>())
125     {
126         scope.Use<ILinks<uint>>().TestRawNumbersCRUDOperations();
127     }
128 }
129
130 [Fact]
131 public static void UInt16RawNumbersCRUDTest()
132 {
133     using (var scope = new Scope<Types<HeapResizableDirectMemory,
134         ↳ ResizableDirectMemoryLinks<ushort>>>())
135     {
136         scope.Use<ILinks<ushort>>().TestRawNumbersCRUDOperations();
137     }
138 }
139
140 [Fact]
141 public static void UInt8RawNumbersCRUDTest()
142 {
143     using (var scope = new Scope<Types<HeapResizableDirectMemory,
144         ↳ ResizableDirectMemoryLinks<byte>>>())
145     {
146         scope.Use<ILinks<byte>>().TestRawNumbersCRUDOperations();
147     }
148 }

```

```

144 }
145
146 private static void TestRawNumbersCRUDOperations<T>(this ILinks<T> links)
147 {
148     // Constants
149     var constants = links.Constants;
150     var equalityComparer = EqualityComparer<T>.Default;
151
152     var h106E = new Hybrid<T>(106L, isExternal: true);
153     var h107E = new Hybrid<T>(-char.ConvertFromUtf32(107)[0]);
154     var h108E = new Hybrid<T>(-108L);
155
156     Assert.Equal(106L, h106E.AbsoluteValue);
157     Assert.Equal(107L, h107E.AbsoluteValue);
158     Assert.Equal(108L, h108E.AbsoluteValue);
159
160     // Create Link (External -> External)
161     var linkAddress1 = links.Create();
162
163     links.Update(linkAddress1, h106E, h108E);
164
165     var link1 = new Link<T>(links.GetLink(linkAddress1));
166
167     Assert.True(equalityComparer.Equals(link1.Source, h106E));
168     Assert.True(equalityComparer.Equals(link1.Target, h108E));
169
170     // Create Link (Internal -> External)
171     var linkAddress2 = links.Create();
172
173     links.Update(linkAddress2, linkAddress1, h108E);
174
175     var link2 = new Link<T>(links.GetLink(linkAddress2));
176
177     Assert.True(equalityComparer.Equals(link2.Source, linkAddress1));
178     Assert.True(equalityComparer.Equals(link2.Target, h108E));
179
180     // Create Link (Internal -> Internal)
181     var linkAddress3 = links.Create();
182
183     links.Update(linkAddress3, linkAddress1, linkAddress2);
184
185     var link3 = new Link<T>(links.GetLink(linkAddress3));
186
187     Assert.True(equalityComparer.Equals(link3.Source, linkAddress1));
188     Assert.True(equalityComparer.Equals(link3.Target, linkAddress2));
189
190     // Search for created link
191     var setter1 = new Setter<T>(constants.Null);
192     links.Each(h106E, h108E, setter1.SetAndReturnFalse);
193
194     Assert.True(equalityComparer.Equals(setter1.Result, linkAddress1));
195
196     // Search for nonexistent link
197     var setter2 = new Setter<T>(constants.Null);
198     links.Each(h106E, h107E, setter2.SetAndReturnFalse);
199
200     Assert.True(equalityComparer.Equals(setter2.Result, constants.Null));
201
202     // Update link to reference null (prepare for delete)
203     var updated = links.Update(linkAddress3, constants.Null, constants.Null);
204
205     Assert.True(equalityComparer.Equals(updated, linkAddress3));
206
207     link3 = new Link<T>(links.GetLink(linkAddress3));
208
209     Assert.True(equalityComparer.Equals(link3.Source, constants.Null));
210     Assert.True(equalityComparer.Equals(link3.Target, constants.Null));
211
212     // Delete link
213     links.Delete(linkAddress3);
214
215     Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.Two));
216
217     var setter3 = new Setter<T>(constants.Null);
218     links.Each(constants.Any, constants.Any, setter3.SetAndReturnTrue);
219
220     Assert.True(equalityComparer.Equals(setter3.Result, linkAddress2));
221 }
222
223 // TODO: Test layers

```

```
224     }
225 }
```

./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 EqualsPerformanceTest()
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
```



```

50
51         var createPoint = random.NextBoolean();
52
53         if (linksCount > 2 && createPoint)
54         {
55             var linksAddressRange = new Range<ulong>(1, linksCount);
56             var source = random.NextUInt64(linksAddressRange);
57             var target = random.NextUInt64(linksAddressRange); //-V3086
58
59             var resultLink = links.CreateAndUpdate(source, target);
60             if (resultLink > linksCount)
61             {
62                 created++;
63             }
64         }
65         else
66         {
67             links.Create();
68             created++;
69         }
70     }
71
72     Assert.True(created == (int)links.Count());
73
74     for (var i = 0; i < N; i++)
75     {
76         var link = (ulong)i + 1;
77         if (links.Exists(link))
78         {
79             links.Delete(link);
80             deleted++;
81         }
82     }
83
84     Assert.True(links.Count() == 0);
85 }
86
87 }
88
89 [Fact]
90 public static void CascadeUpdateTest()
91 {
92     var itself = _constants.Itself;
93
94     using (var scope = new TempLinksTestScope(useLog: true))
95     {
96         var links = scope.Links;
97
98         var l1 = links.Create();
99         var l2 = links.Create();
100
101         l2 = links.Update(l2, l2, l1, l2);
102
103         links.CreateAndUpdate(l2, itself);
104         links.CreateAndUpdate(l2, itself);
105
106         l2 = links.Update(l2, l1);
107
108         links.Delete(l2);
109
110         Global.Trash = links.Count();
111
112         links.Unsync.DisposeIfPossible(); // Close links to access log
113
114         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope ↵
            e.TempTransactionLogFilename);
115     }
116 }
117
118 [Fact]
119 public static void BasicTransactionLogTest()
120 {
121     using (var scope = new TempLinksTestScope(useLog: true))
122     {
123         var links = scope.Links;
124         var l1 = links.Create();
125         var l2 = links.Create();
126
127         Global.Trash = links.Update(l2, l2, l1, l2);
128

```



```

129         links.Delete(l1);
130
131         links.Unsync.DisposeIfPossible(); // Close links to access log
132
133         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope ↵
            ↵ e.TempTransactionLogFilename);
134     }
135 }
136
137 [Fact]
138 public static void TransactionAutoRevertedTest()
139 {
140     // Auto Reverted (Because no commit at transaction)
141     using (var scope = new TempLinksTestScope(useLog: true))
142     {
143         var links = scope.Links;
144         var transactionsLayer = (UInt64LinksTransactionsLayer)scope.MemoryAdapter;
145         using (var transaction = transactionsLayer.BeginTransaction())
146         {
147             var l1 = links.Create();
148             var l2 = links.Create();
149
150             links.Update(l2, l2, l1, l2);
151         }
152
153         Assert.Equal(0UL, links.Count());
154
155         links.Unsync.DisposeIfPossible();
156
157         var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(s ↵
            ↵ cope.TempTransactionLogFilename);
158         Assert.Single(transitions);
159     }
160 }
161
162 [Fact]
163 public static void TransactionUserCodeErrorNoDataSavedTest()
164 {
165     // User Code Error (Autoreverted), no data saved
166     var itself = _constants.Itself;
167
168     TempLinksTestScope lastScope = null;
169     try
170     {
171         using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false, ↵
            ↵ useLog: true))
172         {
173             var links = scope.Links;
174             var transactionsLayer = (UInt64LinksTransactionsLayer)((LinksDisposableDecor ↵
            ↵ atorBase<ulong>)links.Unsync).Links;
175             using (var transaction = transactionsLayer.BeginTransaction())
176             {
177                 var l1 = links.CreateAndUpdate(itself, itself);
178                 var l2 = links.CreateAndUpdate(itself, itself);
179
180                 l2 = links.Update(l2, l2, l1, l2);
181
182                 links.CreateAndUpdate(l2, itself);
183                 links.CreateAndUpdate(l2, itself);
184
185                 //Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transi ↵
            ↵ tion>(scope.TempTransactionLogFilename);
186
187                 l2 = links.Update(l2, l1);
188
189                 links.Delete(l2);
190
191                 ExceptionThrower();
192
193                 transaction.Commit();
194             }
195
196             Global.Trash = links.Count();
197         }
198     }
199     catch
200     {
201         Assert.False(lastScope == null);
202     }

```

```

203         var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(l
204         ↪ astScope.TempTransactionLogFilename);
205
206         Assert.True(transitions.Length == 1 && transitions[0].Before.IsNull() &&
207         ↪ transitions[0].After.IsNull());
208
209         lastScope.DeleteFiles();
210     }
211 }
212
213 [Fact]
214 public static void TransactionUserCodeErrorSomeDataSavedTest()
215 {
216     // User Code Error (Autoreverted), some data saved
217     var itself = _constants.Itself;
218
219     TempLinksTestScope lastScope = null;
220     try
221     {
222         ulong l1;
223         ulong l2;
224
225         using (var scope = new TempLinksTestScope(useLog: true))
226         {
227             var links = scope.Links;
228             l1 = links.CreateAndUpdate(itself, itself);
229             l2 = links.CreateAndUpdate(itself, itself);
230
231             l2 = links.Update(l2, l2, l1, l2);
232
233             links.CreateAndUpdate(l2, itself);
234             links.CreateAndUpdate(l2, itself);
235
236             links.Unsync.DisposeIfPossible();
237
238             Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(
239             ↪ scope.TempTransactionLogFilename);
240         }
241
242         using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
243         ↪ useLog: true))
244         {
245             var links = scope.Links;
246             var transactionsLayer = (UInt64LinksTransactionsLayer)links.Unsync;
247             using (var transaction = transactionsLayer.BeginTransaction())
248             {
249                 l2 = links.Update(l2, l1);
250
251                 links.Delete(l2);
252
253                 ExceptionThrower();
254
255                 transaction.Commit();
256             }
257
258             Global.Trash = links.Count();
259         }
260     }
261     catch
262     {
263         Assert.False(lastScope == null);
264
265         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(last
266         ↪ Scope.TempTransactionLogFilename);
267
268         lastScope.DeleteFiles();
269     }
270 }
271
272 [Fact]
273 public static void TransactionCommit()
274 {
275     var itself = _constants.Itself;
276
277     var tempDatabaseFilename = Path.GetTempFileName();
278     var tempTransactionLogFilename = Path.GetTempFileName();
279
280     // Commit

```

```

276 using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
    ↳ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
    ↳ tempTransactionLogFilename))
277 using (var links = new UInt64Links(memoryAdapter))
278 {
279     using (var transaction = memoryAdapter.BeginTransaction())
280     {
281         var l1 = links.CreateAndUpdate(itself, itself);
282         var l2 = links.CreateAndUpdate(itself, itself);
283
284         Global.Trash = links.Update(l2, l2, l1, l2);
285
286         links.Delete(l1);
287
288         transaction.Commit();
289     }
290
291     Global.Trash = links.Count();
292 }
293
294 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
    ↳ sactionLogFilename);
295 }
296
297 [Fact]
298 public static void TransactionDamage()
299 {
300     var itself = _constants.Itself;
301
302     var tempDatabaseFilename = Path.GetTempFileName();
303     var tempTransactionLogFilename = Path.GetTempFileName();
304
305     // Commit
306     using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
    ↳ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
    ↳ tempTransactionLogFilename))
307     using (var links = new UInt64Links(memoryAdapter))
308     {
309         using (var transaction = memoryAdapter.BeginTransaction())
310         {
311             var l1 = links.CreateAndUpdate(itself, itself);
312             var l2 = links.CreateAndUpdate(itself, itself);
313
314             Global.Trash = links.Update(l2, l2, l1, l2);
315
316             links.Delete(l1);
317
318             transaction.Commit();
319         }
320
321         Global.Trash = links.Count();
322     }
323
324     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
    ↳ sactionLogFilename);
325
326     // Damage database
327
328     FileHelpers.WriteFirst(tempTransactionLogFilename, new
    ↳ UInt64LinksTransactionsLayer.Transition(new UniqueTimestampFactory(), 555));
329
330     // Try load damaged database
331     try
332     {
333         // TODO: Fix
334         using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
    ↳ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
    ↳ tempTransactionLogFilename))
335         using (var links = new UInt64Links(memoryAdapter))
336         {
337             Global.Trash = links.Count();
338         }
339     }
340     catch (NotSupportedException ex)
341     {
342         Assert.True(ex.Message == "Database is damaged, autorecovery is not supported
    ↳ yet.");
343     }

```

```

344     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
345     ↪ sactionLogFilename);
346
347     File.Delete(tempDatabaseFilename);
348     File.Delete(tempTransactionLogFilename);
349 }
350
351 [Fact]
352 public static void Bug1Test()
353 {
354     var tempDatabaseFilename = Path.GetTempFileName();
355     var tempTransactionLogFilename = Path.GetTempFileName();
356
357     var itself = _constants.Itself;
358
359     // User Code Error (Autoreverted), some data saved
360     try
361     {
362         ulong l1;
363         ulong l2;
364
365         using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
366         ↪ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
367         ↪ tempTransactionLogFilename))
368         using (var links = new UInt64Links(memoryAdapter))
369         {
370             l1 = links.CreateAndUpdate(itself, itself);
371             l2 = links.CreateAndUpdate(itself, itself);
372
373             l2 = links.Update(l2, l2, l1, l2);
374
375             links.CreateAndUpdate(l2, itself);
376             links.CreateAndUpdate(l2, itself);
377         }
378
379         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
380         ↪ TransactionLogFilename);
381
382         using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
383         ↪ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
384         ↪ tempTransactionLogFilename))
385         using (var links = new UInt64Links(memoryAdapter))
386         {
387             using (var transaction = memoryAdapter.BeginTransaction())
388             {
389                 l2 = links.Update(l2, l1);
390
391                 links.Delete(l2);
392
393                 ExceptionThrower();
394
395                 transaction.Commit();
396             }
397
398             Global.Trash = links.Count();
399         }
400     }
401     catch
402     {
403         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
404         ↪ TransactionLogFilename);
405     }
406
407     File.Delete(tempDatabaseFilename);
408     File.Delete(tempTransactionLogFilename);
409 }
410
411 private static void ExceptionThrower()
412 {
413     throw new Exception();
414 }
415
416 [Fact]
417 public static void PathsTest()
418 {
419     var source = _constants.SourcePart;
420     var target = _constants.TargetPart;

```

```

416     using (var scope = new TempLinksTestScope())
417     {
418         var links = scope.Links;
419         var l1 = links.CreatePoint();
420         var l2 = links.CreatePoint();
421
422         var r1 = links.GetByKeys(l1, source, target, source);
423         var r2 = links.CheckPathExistence(l2, l2, l2, l2);
424     }
425 }
426
427 [Fact]
428 public static void RecursiveStringFormattingTest()
429 {
430     using (var scope = new TempLinksTestScope(useSequences: true))
431     {
432         var links = scope.Links;
433         var sequences = scope.Sequences; // TODO: Auto use sequences on Sequences getter.
434
435         var a = links.CreatePoint();
436         var b = links.CreatePoint();
437         var c = links.CreatePoint();
438
439         var ab = links.CreateAndUpdate(a, b);
440         var cb = links.CreateAndUpdate(c, b);
441         var ac = links.CreateAndUpdate(a, c);
442
443         a = links.Update(a, c, b);
444         b = links.Update(b, a, c);
445         c = links.Update(c, a, b);
446
447         Debug.WriteLine(links.FormatStructure(ab, link => link.IsFullPoint(), true));
448         Debug.WriteLine(links.FormatStructure(cb, link => link.IsFullPoint(), true));
449         Debug.WriteLine(links.FormatStructure(ac, link => link.IsFullPoint(), true));
450
451         Assert.True(links.FormatStructure(cb, link => link.IsFullPoint(), true) ==
452             ↳ "(5:(4:5 (6:5 4)) 6)");
453         Assert.True(links.FormatStructure(ac, link => link.IsFullPoint(), true) ==
454             ↳ "(6:(5:(4:5 6) 6) 4)");
455         Assert.True(links.FormatStructure(ab, link => link.IsFullPoint(), true) ==
456             ↳ "(4:(5:4 (6:5 4)) 6)");
457
458         // TODO: Think how to build balanced syntax tree while formatting structure (eg.
459         ↳ "(4:(5:4 6) (6:5 4))" instead of "(4:(5:4 (6:5 4)) 6)"
460
461         Assert.True(sequences.SafeFormatSequence(cb, DefaultFormatter, false) ==
462             ↳ "{{5}{5}{4}{6}}");
463         Assert.True(sequences.SafeFormatSequence(ac, DefaultFormatter, false) ==
464             ↳ "{{5}{6}{6}{4}}");
465         Assert.True(sequences.SafeFormatSequence(ab, DefaultFormatter, false) ==
466             ↳ "{{4}{5}{4}{6}}");
467     }
468 }
469
470 private static void DefaultFormatter(StringBuilder sb, ulong link)
471 {
472     sb.Append(link.ToString());
473 }
474
475 #endregion
476
477 #region Performance
478
479 /*
480 public static void RunAllPerformanceTests()
481 {
482     try
483     {
484         links.TestLinksInSteps();
485     }
486     catch (Exception ex)
487     {
488         ex.WriteToConsole();
489     }
490
491     return;
492
493     try
494     {

```

```

488         //ThreadPool.SetMaxThreads(2, 2);
489
490         // Запускаем все тесты дважды, чтобы первоначальная инициализация не повлияла на
↪ результат
491         // Также это дополнительно помогает в отладке
492         // Увеличивает вероятность попадания информации в кэши
493         for (var i = 0; i < 10; i++)
494         {
495             //0 - 10 ГБ
496             //Каждые 100 МБ срез цифр
497
498             //links.TestGetSourceFunction();
499             //links.TestGetSourceFunctionInParallel();
500             //links.TestGetTargetFunction();
501             //links.TestGetTargetFunctionInParallel();
502             links.Create64BillionLinks();
503
504             links.TestRandomSearchFixed();
505             //links.Create64BillionLinksInParallel();
506             links.TestEachFunction();
507             //links.TestForeach();
508             //links.TestParallelForeach();
509         }
510
511         links.TestDeletionOfAllLinks();
512
513     }
514     catch (Exception ex)
515     {
516         ex.WriteToConsole();
517     }
518 }*/
519
520 /*
521 public static void TestLinksInSteps()
522 {
523     const long gibibyte = 1024 * 1024 * 1024;
524     const long mebibyte = 1024 * 1024;
525
526     var totalLinksToCreate = gibibyte /
↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
527     var linksStep = 102 * mebibyte /
↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
528
529     var creationMeasurements = new List<TimeSpan>();
530     var searchMeasurements = new List<TimeSpan>();
531     var deletionMeasurements = new List<TimeSpan>();
532
533     GetBaseRandomLoopOverhead(linksStep);
534     GetBaseRandomLoopOverhead(linksStep);
535
536     var stepLoopOverhead = GetBaseRandomLoopOverhead(linksStep);
537
538     ConsoleHelpers.Debug("Step loop overhead: {0}.", stepLoopOverhead);
539
540     var loops = totalLinksToCreate / linksStep;
541
542     for (int i = 0; i < loops; i++)
543     {
544         creationMeasurements.Add(Measure(() => links.RunRandomCreations(linksStep)));
545         searchMeasurements.Add(Measure(() => links.RunRandomSearches(linksStep)));
546
547         Console.WriteLine("\rC + S {0}/{1}", i + 1, loops);
548     }
549
550     ConsoleHelpers.Debug();
551
552     for (int i = 0; i < loops; i++)
553     {
554         deletionMeasurements.Add(Measure(() => links.RunRandomDeletions(linksStep)));
555
556         Console.WriteLine("\rD {0}/{1}", i + 1, loops);
557     }
558
559     ConsoleHelpers.Debug();
560
561     ConsoleHelpers.Debug("C S D");
562
563     for (int i = 0; i < loops; i++)
564     {

```

```

565         ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i],
↪ searchMeasurements[i], deletionMeasurements[i]);
566     }
567
568     ConsoleHelpers.Debug("C S D (no overhead)");
569
570     for (int i = 0; i < loops; i++)
571     {
572         ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i] - stepLoopOverhead,
↪ searchMeasurements[i] - stepLoopOverhead, deletionMeasurements[i] - stepLoopOverhead);
573     }
574
575     ConsoleHelpers.Debug("All tests done. Total links left in database: {0}.",
↪ links.Total);
576 }
577
578 private static void CreatePoints(this Platform.Links.Data.Core.Doublets.Links links, long
↪ amountToCreate)
579 {
580     for (long i = 0; i < amountToCreate; i++)
581         links.Create(0, 0);
582 }
583
584 private static TimeSpan GetBaseRandomLoopOverhead(long loops)
585 {
586     return Measure(() =>
587     {
588         ulong maxValue = RandomHelpers.DefaultFactory.NextUInt64();
589         ulong result = 0;
590         for (long i = 0; i < loops; i++)
591         {
592             var source = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
593             var target = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
594
595             result += maxValue + source + target;
596         }
597         Global.Trash = result;
598     });
599 }
600 */
601
602 [Fact(Skip = "performance test")]
603 public static void GetSourceTest()
604 {
605     using (var scope = new TempLinksTestScope())
606     {
607         var links = scope.Links;
608         ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations.",
↪ Iterations);
609
610         ulong counter = 0;
611
612         //var firstLink = links.First();
613         // Создаём одну связь, из которой будет производить считывание
614         var firstLink = links.Create();
615
616         var sw = Stopwatch.StartNew();
617
618         // Тестируем саму функцию
619         for (ulong i = 0; i < Iterations; i++)
620         {
621             counter += links.GetSource(firstLink);
622         }
623
624         var elapsedTime = sw.Elapsed;
625
626         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
627
628         // Удаляем связь, из которой производилось считывание
629         links.Delete(firstLink);
630
631         ConsoleHelpers.Debug(
632             "{0} Iterations of GetSource function done in {1} ({2} Iterations per
↪ second), counter result: {3}",
633             Iterations, elapsedTime, (long)iterationsPerSecond, counter);
634     }
635 }
636
637 [Fact(Skip = "performance test")]

```

```

638 public static void GetSourceInParallel()
639 {
640     using (var scope = new TempLinksTestScope())
641     {
642         var links = scope.Links;
643         ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations in
        ↳ parallel.", Iterations);
644
645         long counter = 0;
646
647         //var firstLink = links.First();
648         var firstLink = links.Create();
649
650         var sw = Stopwatch.StartNew();
651
652         // Тестируем саму функцию
653         Parallel.For(0, Iterations, x =>
654         {
655             Interlocked.Add(ref counter, (long)links.GetSource(firstLink));
656             //Interlocked.Increment(ref counter);
657         });
658
659         var elapsedTime = sw.Elapsed;
660
661         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
662
663         links.Delete(firstLink);
664
665         ConsoleHelpers.Debug(
666             "{0} Iterations of GetSource function done in {1} ({2} Iterations per
        ↳ second), counter result: {3}",
        Iterations, elapsedTime, (long)iterationsPerSecond, counter);
667     }
668 }
669
670 [Fact(Skip = "performance test")]
671 public static void TestGetTarget()
672 {
673     using (var scope = new TempLinksTestScope())
674     {
675         var links = scope.Links;
676         ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations.",
        ↳ Iterations);
677
678         ulong counter = 0;
679
680         //var firstLink = links.First();
681         var firstLink = links.Create();
682
683         var sw = Stopwatch.StartNew();
684
685         for (ulong i = 0; i < Iterations; i++)
686         {
687             counter += links.GetTarget(firstLink);
688         }
689
690         var elapsedTime = sw.Elapsed;
691
692         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
693
694         links.Delete(firstLink);
695
696         ConsoleHelpers.Debug(
697             "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
        ↳ second), counter result: {3}",
        Iterations, elapsedTime, (long)iterationsPerSecond, counter);
698     }
699 }
700
701 [Fact(Skip = "performance test")]
702 public static void TestGetTargetInParallel()
703 {
704     using (var scope = new TempLinksTestScope())
705     {
706         var links = scope.Links;
707         ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations in
        ↳ parallel.", Iterations);
708
709         long counter = 0;
710
711
712

```



```

713         //var firstLink = links.First();
714         var firstLink = links.Create();
715
716         var sw = Stopwatch.StartNew();
717
718         Parallel.For(0, Iterations, x =>
719         {
720             Interlocked.Add(ref counter, (long)links.GetTarget(firstLink));
721             //Interlocked.Increment(ref counter);
722         });
723
724         var elapsedTime = sw.Elapsed;
725
726         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
727
728         links.Delete(firstLink);
729
730         ConsoleHelpers.Debug(
731             "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
              ↪ second), counter result: {3}",
732             Iterations, elapsedTime, (long)iterationsPerSecond, counter);
733     }
734 }
735
736 // TODO: Заполнить базу данных перед тестом
737 /*
738 [Fact]
739 public void TestRandomSearchFixed()
740 {
741     var tempFilename = Path.GetTempFileName();
742
743     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
744 ↪ DefaultLinksSizeStep))
745     {
746         long iterations = 64 * 1024 * 1024 /
747 ↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
748
749         ulong counter = 0;
750         var maxLink = links.Total;
751
752         ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.", iterations);
753
754         var sw = Stopwatch.StartNew();
755
756         for (var i = iterations; i > 0; i--)
757         {
758             var source =
759 ↪ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
760             var target =
761 ↪ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
762
763             counter += links.Search(source, target);
764         }
765
766         var elapsedTime = sw.Elapsed;
767
768         var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
769
770         ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
771 ↪ Iterations per second), c: {3}", iterations, elapsedTime, (long)iterationsPerSecond,
772 ↪ counter);
773     }
774
775     File.Delete(tempFilename);
776 }*/
777
778 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
779 public static void TestRandomSearchAll()
780 {
781     using (var scope = new TempLinksTestScope())
782     {
783         var links = scope.Links;
784         ulong counter = 0;
785
786         var maxLink = links.Count();
787
788         var iterations = links.Count();
789
790         ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.",
791 ↪ links.Count());

```

```

785
786     var sw = Stopwatch.StartNew();
787
788     for (var i = iterations; i > 0; i--)
789     {
790         var linksAddressRange = new Range<ulong>(_constants.MinPossibleIndex,
791             ↪ maxLink);
792
793         var source = RandomHelpers.Default.NextUInt64(linksAddressRange);
794         var target = RandomHelpers.Default.NextUInt64(linksAddressRange);
795
796         counter += links.SearchOrDefault(source, target);
797     }
798
799     var elapsedTime = sw.Elapsed;
800
801     var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
802
803     ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
804         ↪ Iterations per second), c: {3}",
805         iterations, elapsedTime, (long)iterationsPerSecond, counter);
806 }
807
808 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
809 public static void TestEach()
810 {
811     using (var scope = new TempLinksTestScope())
812     {
813         var links = scope.Links;
814
815         var counter = new Counter<IList<ulong>, ulong>(links.Constants.Continue);
816
817         ConsoleHelpers.Debug("Testing Each function.");
818
819         var sw = Stopwatch.StartNew();
820
821         links.Each(counter.IncrementAndReturnTrue);
822
823         var elapsedTime = sw.Elapsed;
824
825         var linksPerSecond = counter.Count / elapsedTime.TotalSeconds;
826
827         ConsoleHelpers.Debug("{0} Iterations of Each's handler function done in {1} ({2}
828             ↪ links per second)",
829             counter, elapsedTime, (long)linksPerSecond);
830     }
831 }
832
833 /*
834 [Fact]
835 public static void TestForeach()
836 {
837     var tempFilename = Path.GetTempFileName();
838
839     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
840         ↪ DefaultLinksSizeStep))
841     {
842         ulong counter = 0;
843
844         ConsoleHelpers.Debug("Testing foreach through links.");
845
846         var sw = Stopwatch.StartNew();
847
848         //foreach (var link in links)
849         //{
850             //    counter++;
851         //}
852
853         var elapsedTime = sw.Elapsed;
854
855         var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
856
857         ConsoleHelpers.Debug("{0} Iterations of Foreach's handler block done in {1} ({2}
858             ↪ links per second)", counter, elapsedTime, (long)linksPerSecond);
859     }
860
861     File.Delete(tempFilename);
862 }
863 */

```

```

860
861     /*
862     [Fact]
863     public static void TestParallelForeach()
864     {
865         var tempFilename = Path.GetTempFileName();
866
867         using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
↪ DefaultLinksSizeStep))
868         {
869             long counter = 0;
870
871             ConsoleHelpers.Debug("Testing parallel foreach through links.");
872
873             var sw = Stopwatch.StartNew();
874
875             //Parallel.ForEach((IEnumerable<ulong>)links, x =>
876             //{
877             //    Interlocked.Increment(ref counter);
878             //});
879
880             var elapsedTime = sw.Elapsed;
881
882             var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
883
884             ConsoleHelpers.Debug("{0} Iterations of Parallel Foreach's handler block done in
↪ {1} ({2} links per second)", counter, elapsedTime, (long)linksPerSecond);
885         }
886
887         File.Delete(tempFilename);
888     }
889     */
890
891     [Fact(Skip = "performance test")]
892     public static void Create64BillionLinks()
893     {
894         using (var scope = new TempLinksTestScope())
895         {
896             var links = scope.Links;
897             var linksBeforeTest = links.Count();
898
899             long linksToCreate = 64 * 1024 * 1024 /
↪ UInt64ResizableDirectMemoryLinks.LinkSizeInBytes;
900
901             ConsoleHelpers.Debug("Creating {0} links.", linksToCreate);
902
903             var elapsedTime = Performance.Measure(() =>
904             {
905                 for (long i = 0; i < linksToCreate; i++)
906                 {
907                     links.Create();
908                 }
909             });
910
911             var linksCreated = links.Count() - linksBeforeTest;
912             var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
913
914             ConsoleHelpers.Debug("Current links count: {0}.", links.Count());
915
916             ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
↪ linksCreated, elapsedTime,
917                 (long)linksPerSecond);
918         }
919     }
920
921     [Fact(Skip = "performance test")]
922     public static void Create64BillionLinksInParallel()
923     {
924         using (var scope = new TempLinksTestScope())
925         {
926             var links = scope.Links;
927             var linksBeforeTest = links.Count();
928
929             var sw = Stopwatch.StartNew();
930
931             long linksToCreate = 64 * 1024 * 1024 /
↪ UInt64ResizableDirectMemoryLinks.LinkSizeInBytes;
932
933

```

```

934     ConsoleHelpers.Debug("Creating {0} links in parallel.", linksToCreate);
935
936     Parallel.For(0, linksToCreate, x => links.Create());
937
938     var elapsedTime = sw.Elapsed;
939
940     var linksCreated = links.Count() - linksBeforeTest;
941     var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
942
943     ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
944         ↪ linksCreated, elapsedTime,
945         (long)linksPerSecond);
946 }
947
948 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
949 public static void TestDeletionOfAllLinks()
950 {
951     using (var scope = new TempLinksTestScope())
952     {
953         var links = scope.Links;
954         var linksBeforeTest = links.Count();
955
956         ConsoleHelpers.Debug("Deleting all links");
957
958         var elapsedTime = Performance.Measure(links.DeleteAll);
959
960         var linksDeleted = linksBeforeTest - links.Count();
961         var linksPerSecond = linksDeleted / elapsedTime.TotalSeconds;
962
963         ConsoleHelpers.Debug("{0} links deleted in {1} ({2} links per second)",
964             ↪ linksDeleted, elapsedTime,
965             (long)linksPerSecond);
966     }
967 }
968 #endregion
969 }
970 }

```

./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.UnaryNumbers;
15
16 namespace Platform.Data.Doublets.Tests
17 {
18     public static class OptimalVariantSequenceTests
19     {
20         private const string SequenceExample = "зеленела зелёная зелень";
21
22         [Fact]
23         public static void LinksBasedFrequencyStoredOptimalVariantSequenceTest()
24         {
25             using (var scope = new TempLinksTestScope(useSequences: false))
26             {
27                 var links = scope.Links;
28                 var constants = links.Constants;
29
30                 links.UseUnicode();
31
32                 var sequence = UnicodeMap.FromStringToLinkArray(SequenceExample);
33
34                 var meaningRoot = links.CreatePoint();
35                 var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
36                 var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
37                 var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
38                     ↪ constants.Itself);

```

```

39     var unaryNumberToAddressConverter = new
    ↪     UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
40     var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
41     var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
    ↪     frequencyMarker, unaryOne, unaryNumberIncrementer);
42     var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
    ↪     frequencyPropertyMarker, frequencyMarker);
43     var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
    ↪     frequencyPropertyOperator, frequencyIncrementer);
44     var linkToItsFrequencyNumberConverter = new
    ↪     LinkToItsFrequencyNumberConverter<ulong>(links, frequencyPropertyOperator,
    ↪     unaryNumberToAddressConverter);
45     var sequenceToItsLocalElementLevelsConverter = new
    ↪     SequenceToItsLocalElementLevelsConverter<ulong>(links,
    ↪     linkToItsFrequencyNumberConverter);
46     var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
    ↪     sequenceToItsLocalElementLevelsConverter);

47
48     var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
    ↪     Walker = new LeveledSequenceWalker<ulong>(links) });
49
50     ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
    ↪     index, optimalVariantConverter);
51 }
52 }
53
54 [Fact]
55 public static void DictionaryBasedFrequencyStoredOptimalVariantSequenceTest()
56 {
57     using (var scope = new TempLinksTestScope(useSequences: false))
58     {
59         var links = scope.Links;
60
61         links.UseUnicode();
62
63         var sequence = UnicodeMap.FromStringToLinkArray(SequenceExample);
64
65         var linksToFrequencies = new Dictionary<ulong, ulong>();
66
67         var totalSequenceSymbolFrequencyCounter = new
    ↪     TotalSequenceSymbolFrequencyCounter<ulong>(links);
68
69         var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
    ↪     totalSequenceSymbolFrequencyCounter);
70
71         var index = new
    ↪     CachedFrequencyIncrementingSequenceIndex<ulong>(linkFrequenciesCache);
72         var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<ulong>(linkFrequenciesCache);
73
74         var sequenceToItsLocalElementLevelsConverter = new
    ↪     SequenceToItsLocalElementLevelsConverter<ulong>(links,
    ↪     linkToItsFrequencyNumberConverter);
75         var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
    ↪     sequenceToItsLocalElementLevelsConverter);
76
77         var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
    ↪     Walker = new LeveledSequenceWalker<ulong>(links) });
78
79         ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
    ↪     index, optimalVariantConverter);
80     }
81 }
82
83 private static void ExecuteTest(Sequences.Sequences sequences, ulong[] sequence,
    ↪     SequenceToItsLocalElementLevelsConverter<ulong>
    ↪     sequenceToItsLocalElementLevelsConverter, ISequenceIndex<ulong> index,
    ↪     OptimalVariantConverter<ulong> optimalVariantConverter)
84 {
85     index.Add(sequence);
86
87     var optimalVariant = optimalVariantConverter.Convert(sequence);
88
89     var readSequence1 = sequences.ToList(optimalVariant);
90
91     Assert.True(sequence.SequenceEqual(readSequence1));
92 }
93 }

```

```
94 }
```

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

```
1 using System;
2 using System.Collections.Generic;
3 using System.Diagnostics;
4 using System.Linq;
5 using Xunit;
6 using Platform.Data.Sequences;
7 using Platform.Data.Doublets.Sequences.Converters;
8 using Platform.Data.Doublets.Sequences.Walkers;
9 using Platform.Data.Doublets.Sequences;
10
11 namespace Platform.Data.Doublets.Tests
12 {
13     public static class ReadSequenceTests
14     {
15         [Fact]
16         public static void ReadSequenceTest()
17         {
18             const long sequenceLength = 2000;
19
20             using (var scope = new TempLinksTestScope(useSequences: false))
21             {
22                 var links = scope.Links;
23                 var sequences = new Sequences.Sequences(links, new SequencesOptions() {
24                     ↪ Walker = new LeveledSequenceWalker(links) });;;;
25
26                 var sequence = new ulong[sequenceLength];
27                 for (var i = 0; i < sequenceLength; i++)
28                 {
29                     sequence[i] = links.Create();
30                 }
31
32                 var balancedVariantConverter = new BalancedVariantConverter(links);
33
34                 var sw1 = Stopwatch.StartNew();
35                 var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();
36
37                 var sw2 = Stopwatch.StartNew();
38                 var readSequence1 = sequences.ToList(balancedVariant); sw2.Stop();
39
40                 var sw3 = Stopwatch.StartNew();
41                 var readSequence2 = new List();
42                 SequenceWalker.WalkRight(balancedVariant,
43                                         links.GetSource,
44                                         links.GetTarget,
45                                         links.IsPartialPoint,
46                                         readSequence2.Add);
47                 sw3.Stop();
48
49                 Assert.True(sequence.SequenceEqual(readSequence1));
50                 Assert.True(sequence.SequenceEqual(readSequence2));
51
52                 // Assert.True(sw2.Elapsed < sw3.Elapsed);
53
54                 Console.WriteLine($"Stack-based walker: {sw3.Elapsed}, Level-based reader:
55                     ↪ {sw2.Elapsed}");
56
57                 for (var i = 0; i < sequenceLength; i++)
58                 {
59                     links.Delete(sequence[i]);
60                 }
61             }
62         }
63     }
64 }
```

```
./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.Constants;
6 using Platform.Data.Doublets.ResizableDirectMemory;
7
8 namespace Platform.Data.Doublets.Tests
9 {
10     public static class ResizableDirectMemoryLinksTests
```

```

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

```

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

```

1 using Xunit;
2 using Platform.Scopes;
3 using Platform.Memory;
4 using Platform.Data.Doublets.ResizableDirectMemory;
5 using Platform.Data.Doublets.Decorators;
6
7 namespace Platform.Data.Doublets.Tests
8 {
9     public static class ScopeTests
10     {
11         [Fact]
12         public static void SingleDependencyTest()
13         {
14             using (var scope = new Scope())
15             {
16                 scope.IncludeAssemblyOf<IMemory>();
17             }
18         }
19     }
20 }

```

```

17         var instance = scope.Use<IDirectMemory>();
18         Assert.IsType<HeapResizableDirectMemory>(instance);
19     }
20 }
21
22 [Fact]
23 public static void CascadeDependencyTest()
24 {
25     using (var scope = new Scope())
26     {
27         scope.Include<TemporaryFileMappedResizableDirectMemory>();
28         scope.Include<UInt64ResizableDirectMemoryLinks>();
29         var instance = scope.Use<ILinks<ulong>>();
30         Assert.IsType<UInt64ResizableDirectMemoryLinks>(instance);
31     }
32 }
33
34 [Fact]
35 public static void FullAutoResolutionTest()
36 {
37     using (var scope = new Scope(autoInclude: true, autoExplore: true))
38     {
39         var instance = scope.Use<UInt64Links>();
40         Assert.IsType<UInt64Links>(instance);
41     }
42 }
43 }
44 }

```

./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.Constants;
11 using Platform.Data.Doublets.Sequences;
12 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
13 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
14 using Platform.Data.Doublets.Sequences.Converters;
15 using Platform.Data.Doublets.Unicode;
16
17 namespace Platform.Data.Doublets.Tests
18 {
19     public static class SequencesTests
20     {
21         private static readonly LinksCombinedConstants<bool, ulong, int> _constants =
22             ↳ Default<LinksCombinedConstants<bool, ulong, int>>.Instance;
23
24         static SequencesTests()
25         {
26             // Trigger static constructor to not mess with performance measurements
27             _ = BitString.GetBitMaskFromIndex(1);
28         }
29
30         [Fact]
31         public static void CreateAllVariantsTest()
32         {
33             const long sequenceLength = 8;
34
35             using (var scope = new TempLinksTestScope(useSequences: true))
36             {
37                 var links = scope.Links;
38                 var sequences = scope.Sequences;
39
40                 var sequence = new ulong[sequenceLength];
41                 for (var i = 0; i < sequenceLength; i++)
42                 {
43                     sequence[i] = links.Create();
44                 }
45
46                 var sw1 = Stopwatch.StartNew();
47                 var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
48
49                 var sw2 = Stopwatch.StartNew();
50                 var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();

```



```

50
51     Assert.True(results1.Count > results2.Length);
52     Assert.True(sw1.Elapsed > sw2.Elapsed);
53
54     for (var i = 0; i < sequenceLength; i++)
55     {
56         links.Delete(sequence[i]);
57     }
58
59     Assert.True(links.Count() == 0);
60 }
61 }
62
63 //[Fact]
64 //public void CUDTest()
65 //{
66 //    var tempFilename = Path.GetTempFileName();
67 //
68 //    const long sequenceLength = 8;
69 //
70 //    const ulong itself = LinksConstants.Itself;
71 //
72 //    using (var memoryAdapter = new ResizableDirectMemoryLinks(tempFilename,
73 //        ↪ DefaultLinksSizeStep))
74 //    using (var links = new Links(memoryAdapter))
75 //    {
76 //        var sequence = new ulong[sequenceLength];
77 //        for (var i = 0; i < sequenceLength; i++)
78 //            sequence[i] = links.Create(itself, itself);
79 //
80 //        SequencesOptions o = new SequencesOptions();
81 //
82 //        TODO: Из числа в bool значения o.UseSequenceMarker = ((value & 1) != 0)
83 //        o.
84 //
85 //        var sequences = new Sequences(links);
86 //
87 //        var sw1 = Stopwatch.StartNew();
88 //        var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
89 //
90 //        var sw2 = Stopwatch.StartNew();
91 //        var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();
92 //
93 //        Assert.True(results1.Count > results2.Length);
94 //        Assert.True(sw1.Elapsed > sw2.Elapsed);
95 //
96 //        for (var i = 0; i < sequenceLength; i++)
97 //            links.Delete(sequence[i]);
98 //    }
99 //
100 //    File.Delete(tempFilename);
101 //}
102
103 [Fact]
104 public static void AllVariantsSearchTest()
105 {
106     const long sequenceLength = 8;
107
108     using (var scope = new TempLinksTestScope(useSequences: true))
109     {
110         var links = scope.Links;
111         var sequences = scope.Sequences;
112
113         var sequence = new ulong[sequenceLength];
114         for (var i = 0; i < sequenceLength; i++)
115         {
116             sequence[i] = links.Create();
117         }
118
119         var createResults = sequences.CreateAllVariants2(sequence).Distinct().ToArray();
120
121         //for (int i = 0; i < createResults.Length; i++)
122         //    sequences.Create(createResults[i]);
123
124         var sw0 = Stopwatch.StartNew();
125         var searchResults0 = sequences.GetAllMatchingSequences0(sequence); sw0.Stop();
126
127         var sw1 = Stopwatch.StartNew();

```

```

129     var searchResults1 = sequences.GetAllMatchingSequences1(sequence); sw1.Stop();
130
131     var sw2 = Stopwatch.StartNew();
132     var searchResults2 = sequences.Each1(sequence); sw2.Stop();
133
134     var sw3 = Stopwatch.StartNew();
135     var searchResults3 = sequences.Each(sequence); sw3.Stop();
136
137     var intersection0 = createResults.Intersect(searchResults0).ToList();
138     Assert.True(intersection0.Count == searchResults0.Count);
139     Assert.True(intersection0.Count == createResults.Length);
140
141     var intersection1 = createResults.Intersect(searchResults1).ToList();
142     Assert.True(intersection1.Count == searchResults1.Count);
143     Assert.True(intersection1.Count == createResults.Length);
144
145     var intersection2 = createResults.Intersect(searchResults2).ToList();
146     Assert.True(intersection2.Count == searchResults2.Count);
147     Assert.True(intersection2.Count == createResults.Length);
148
149     var intersection3 = createResults.Intersect(searchResults3).ToList();
150     Assert.True(intersection3.Count == searchResults3.Count);
151     Assert.True(intersection3.Count == createResults.Length);
152
153     for (var i = 0; i < sequenceLength; i++)
154     {
155         links.Delete(sequence[i]);
156     }
157 }
158 }
159
160 [Fact]
161 public static void BalancedVariantSearchTest()
162 {
163     const long sequenceLength = 200;
164
165     using (var scope = new TempLinksTestScope(useSequences: true))
166     {
167         var links = scope.Links;
168         var sequences = scope.Sequences;
169
170         var sequence = new ulong[sequenceLength];
171         for (var i = 0; i < sequenceLength; i++)
172         {
173             sequence[i] = links.Create();
174         }
175
176         var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
177
178         var sw1 = Stopwatch.StartNew();
179         var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();
180
181         var sw2 = Stopwatch.StartNew();
182         var searchResults2 = sequences.GetAllMatchingSequences0(sequence); sw2.Stop();
183
184         var sw3 = Stopwatch.StartNew();
185         var searchResults3 = sequences.GetAllMatchingSequences1(sequence); sw3.Stop();
186
187         // На количестве в 200 элементов это будет занимать вечность
188         //var sw4 = Stopwatch.StartNew();
189         //var searchResults4 = sequences.Each(sequence); sw4.Stop();
190
191         Assert.True(searchResults2.Count == 1 && balancedVariant == searchResults2[0]);
192
193         Assert.True(searchResults3.Count == 1 && balancedVariant ==
194             ↪ searchResults3.First());
195
196         //Assert.True(sw1.Elapsed < sw2.Elapsed);
197
198         for (var i = 0; i < sequenceLength; i++)
199         {
200             links.Delete(sequence[i]);
201         }
202     }
203 }
204
205 [Fact]
206 public static void AllPartialVariantsSearchTest()
207 {
208     const long sequenceLength = 8;

```

```

208
209 using (var scope = new TempLinksTestScope(useSequences: true))
210 {
211     var links = scope.Links;
212     var sequences = scope.Sequences;
213
214     var sequence = new ulong[sequenceLength];
215     for (var i = 0; i < sequenceLength; i++)
216     {
217         sequence[i] = links.Create();
218     }
219
220     var createResults = sequences.CreateAllVariants2(sequence);
221
222     //var createResultsStrings = createResults.Select(x => x + ": " +
223     ↪ sequences.FormatSequence(x)).ToList();
224     //Global.Trash = createResultsStrings;
225
226     var partialSequence = new ulong[sequenceLength - 2];
227
228     Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
229
230     var sw1 = Stopwatch.StartNew();
231     var searchResults1 =
232     ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
233
234     var sw2 = Stopwatch.StartNew();
235     var searchResults2 =
236     ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
237
238     //var sw3 = Stopwatch.StartNew();
239     //var searchResults3 =
240     ↪ sequences.GetAllPartiallyMatchingSequences2(partialSequence); sw3.Stop();
241
242     var sw4 = Stopwatch.StartNew();
243     var searchResults4 =
244     ↪ sequences.GetAllPartiallyMatchingSequences3(partialSequence); sw4.Stop();
245
246     //Global.Trash = searchResults3;
247
248     //var searchResults1Strings = searchResults1.Select(x => x + ": " +
249     ↪ sequences.FormatSequence(x)).ToList();
250     //Global.Trash = searchResults1Strings;
251
252     var intersection1 = createResults.Intersect(searchResults1).ToList();
253     Assert.True(intersection1.Count == createResults.Length);
254
255     var intersection2 = createResults.Intersect(searchResults2).ToList();
256     Assert.True(intersection2.Count == createResults.Length);
257
258     var intersection4 = createResults.Intersect(searchResults4).ToList();
259     Assert.True(intersection4.Count == createResults.Length);
260
261     for (var i = 0; i < sequenceLength; i++)
262     {
263         links.Delete(sequence[i]);
264     }
265 }
266
267 [Fact]
268 public static void BalancedPartialVariantsSearchTest()
269 {
270     const long sequenceLength = 200;
271
272     using (var scope = new TempLinksTestScope(useSequences: true))
273     {
274         var links = scope.Links;
275         var sequences = scope.Sequences;
276
277         var sequence = new ulong[sequenceLength];
278         for (var i = 0; i < sequenceLength; i++)
279         {
280             sequence[i] = links.Create();
281         }
282
283         var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
284
285         var balancedVariant = balancedVariantConverter.Convert(sequence);

```

```

282     var partialSequence = new ulong[sequenceLength - 2];
283
284     Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
285
286     var sw1 = Stopwatch.StartNew();
287     var searchResults1 =
288         ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
289
290     var sw2 = Stopwatch.StartNew();
291     var searchResults2 =
292         ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
293
294     Assert.True(searchResults1.Count == 1 && balancedVariant == searchResults1[0]);
295
296     Assert.True(searchResults2.Count == 1 && balancedVariant ==
297         ↪ searchResults2.First());
298
299     for (var i = 0; i < sequenceLength; i++)
300     {
301         links.Delete(sequence[i]);
302     }
303 }
304
305 [Fact(Skip = "Correct implementation is pending")]
306 public static void PatternMatchTest()
307 {
308     var zeroOrMany = Sequences.Sequences.ZeroOrMany;
309
310     using (var scope = new TempLinksTestScope(useSequences: true))
311     {
312         var links = scope.Links;
313         var sequences = scope.Sequences;
314
315         var e1 = links.Create();
316         var e2 = links.Create();
317
318         var sequence = new[]
319         {
320             e1, e2, e1, e2 // mama / papa
321         };
322
323         var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
324
325         var balancedVariant = balancedVariantConverter.Convert(sequence);
326
327         // 1: [1]
328         // 2: [2]
329         // 3: [1,2]
330         // 4: [1,2,1,2]
331
332         var doublet = links.GetSource(balancedVariant);
333
334         var matchedSequences1 = sequences.MatchPattern(e2, e1, zeroOrMany);
335
336         Assert.True(matchedSequences1.Count == 0);
337
338         var matchedSequences2 = sequences.MatchPattern(zeroOrMany, e2, e1);
339
340         Assert.True(matchedSequences2.Count == 0);
341
342         var matchedSequences3 = sequences.MatchPattern(e1, zeroOrMany, e1);
343
344         Assert.True(matchedSequences3.Count == 0);
345
346         var matchedSequences4 = sequences.MatchPattern(e1, zeroOrMany, e2);
347
348         Assert.Contains(doublet, matchedSequences4);
349         Assert.Contains(balancedVariant, matchedSequences4);
350
351         for (var i = 0; i < sequence.Length; i++)
352         {
353             links.Delete(sequence[i]);
354         }
355     }
356 }
357
358 [Fact]
359 public static void IndexTest()
360 {

```

```

359 using (var scope = new TempLinksTestScope(new SequencesOptions<ulong> { UseIndex =
    ↳ true }, useSequences: true))
360 {
361     var links = scope.Links;
362     var sequences = scope.Sequences;
363     var index = sequences.Options.Index;
364
365     var e1 = links.Create();
366     var e2 = links.Create();
367
368     var sequence = new[]
369     {
370         e1, e2, e1, e2 // mama / papa
371     };
372
373     Assert.False(index.MightContain(sequence));
374
375     index.Add(sequence);
376
377     Assert.True(index.MightContain(sequence));
378 }
379 }
380
381 /// <summary>Imported from https://raw.githubusercontent.com/wiki/Konard/LinksPlatform/%
    ↳ D0%9E-%D1%82%D0%BE%D0%BC%2C-%D0%BA%D0%B0%D0%BA-%D0%B2%D1%81%D1%91-%D0%BD%D0%B0%D1%87
    ↳ %D0%B8%D0%BD%D0%B0%D0%BB%D0%BE%D1%81%D1%8C.md</summary>
382 private static readonly string _exampleText =
383     @"([english
    ↳ 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
 ↳ (носителей света)? Или это то, что полностью отражает свет? Пустой белый лист бумаги? Там
 ↳ где есть место для нового начала? Разве пустота это не характеристика пространства?
 ↳ Пространство это то, что можно чем-то наполнить?

```

386
387 [![чёрное пространство, белое
    ↳ пространство] (https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/1.png
    ↳ "чёрное пространство, белое пространство")] (https://raw.githubusercontent.com/Konard/Links
    ↳ Platform/master/doc/Intro/1.png)
388

```

Что может быть минимальным рисунком, образом, графикой? Может быть это точка? Это ли простейшая
 ↳ форма? Но есть ли у точки размер? Цвет? Масса? Координаты? Время существования?

```

389
390
391 [![чёрное пространство, чёрная
    ↳ точка] (https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/2.png
    ↳ "чёрное пространство, чёрная
    ↳ точка")] (https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/2.png)
392

```

А что если повторить? Сделать копию? Создать дубликат? Из одного сделать два? Может это быть
 ↳ так? Инверсия? Отражение? Сумма?

```

393
394
395 [![белая точка, чёрная
    ↳ точка] (https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/3.png "белая
    ↳ точка, чёрная
    ↳ точка")] (https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/3.png)
396

```

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?

```

397
398
399 [![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)
400

```

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?

```

401
402
403 [![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)
404

```

405 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?

406

407 [![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)

408

409 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?

410

411 [![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)

412

413 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?

414

415 [![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)

416

417 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?

418

419 [![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)

420

421 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?

422

423 [![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)

424

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

426

427 [![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)

428

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

430

431 [![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)

432

433 ...

434

435 [![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)";

436

437

```

438     private static readonly string _exampleLoremIpsumText =
439         @"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor
        ↳ incididunt ut labore et dolore magna aliqua.
440     Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo
        ↳ consequat.";
441
442     [Fact]
443     public static void CompressionTest()
444     {
445         using (var scope = new TempLinksTestScope(useSequences: true))
446         {
447             var links = scope.Links;
448             var sequences = scope.Sequences;
449
450             var e1 = links.Create();
451             var e2 = links.Create();
452
453             var sequence = new[]
454             {
455                 e1, e2, e1, e2 // mama / papa / template [(m/p), a] { [1] [2] [1] [2] }
456             };
457
458             var balancedVariantConverter = new BalancedVariantConverter<ulong>(links.Unsync);
459             var totalSequenceSymbolFrequencyCounter = new
460                 ↳ TotalSequenceSymbolFrequencyCounter<ulong>(links.Unsync);
461             var doubletFrequenciesCache = new LinkFrequenciesCache<ulong>(links.Unsync,
462                 ↳ totalSequenceSymbolFrequencyCounter);
463             var compressingConverter = new CompressingConverter<ulong>(links.Unsync,
464                 ↳ balancedVariantConverter, doubletFrequenciesCache);
465
466             var compressedVariant = compressingConverter.Convert(sequence);
467
468             // 1: [1]          (1->1) point
469             // 2: [2]          (2->2) point
470             // 3: [1,2]        (1->2) doublet
471             // 4: [1,2,1,2]    (3->3) doublet
472
473             Assert.True(links.GetSource(links.GetSource(compressedVariant)) == sequence[0]);
474             Assert.True(links.GetTarget(links.GetSource(compressedVariant)) == sequence[1]);
475             Assert.True(links.GetSource(links.GetTarget(compressedVariant)) == sequence[2]);
476             Assert.True(links.GetTarget(links.GetTarget(compressedVariant)) == sequence[3]);
477
478             var source = _constants.SourcePart;
479             var target = _constants.TargetPart;
480
481             Assert.True(links.GetByKeys(compressedVariant, source, source) == sequence[0]);
482             Assert.True(links.GetByKeys(compressedVariant, source, target) == sequence[1]);
483             Assert.True(links.GetByKeys(compressedVariant, target, source) == sequence[2]);
484             Assert.True(links.GetByKeys(compressedVariant, target, target) == sequence[3]);
485
486             // 4 - length of sequence
487             Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 0)
488                 ↳ == sequence[0]);
489             Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 1)
490                 ↳ == sequence[1]);
491             Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 2)
492                 ↳ == sequence[2]);
493             Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 3)
494                 ↳ == sequence[3]);
495         }
496     }
497
498     [Fact]
499     public static void CompressionEfficiencyTest()
500     {
501         var strings = _exampleLoremIpsumText.Split(new[] { '\n', '\r' },
502             ↳ StringSplitOptions.RemoveEmptyEntries);
503         var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
504         var totalCharacters = arrays.Select(x => x.Length).Sum();
505
506         using (var scope1 = new TempLinksTestScope(useSequences: true))
507         using (var scope2 = new TempLinksTestScope(useSequences: true))
508         using (var scope3 = new TempLinksTestScope(useSequences: true))
509         {
510             scope1.Links.Unsync.UseUnicode();
511             scope2.Links.Unsync.UseUnicode();
512             scope3.Links.Unsync.UseUnicode();
513         }
514     }

```

```

506     var balancedVariantConverter1 = new
507         ↳ BalancedVariantConverter<ulong>(scope1.Links.Unsync);
508     var totalSequenceSymbolFrequencyCounter = new
509         ↳ TotalSequenceSymbolFrequencyCounter<ulong>(scope1.Links.Unsync);
510     var linkFrequenciesCache1 = new LinkFrequenciesCache<ulong>(scope1.Links.Unsync,
511         ↳ totalSequenceSymbolFrequencyCounter);
512     var compressor1 = new CompressingConverter<ulong>(scope1.Links.Unsync,
513         ↳ balancedVariantConverter1, linkFrequenciesCache1,
514         ↳ doInitialFrequenciesIncrement: false);
515
516     var compressor2 = scope2.Sequences;
517     var compressor3 = scope3.Sequences;
518
519     var constants = Default<LinksCombinedConstants<bool, ulong, int>>.Instance;
520
521     var sequences = compressor3;
522     //var meaningRoot = links.CreatePoint();
523     //var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
524     //var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
525     //var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
526         ↳ constants.Itself);
527
528     //var unaryNumberToAddressConverter = new
529         ↳ UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
530     //var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links,
531         ↳ unaryOne);
532     //var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
533         ↳ frequencyMarker, unaryOne, unaryNumberIncrementer);
534     //var frequencyPropertyOperator = new FrequencyPropertyOperator<ulong>(links,
535         ↳ frequencyPropertyMarker, frequencyMarker);
536     //var linkFrequencyIncrementer = new LinkFrequencyIncrementer<ulong>(links,
537         ↳ frequencyPropertyOperator, frequencyIncrementer);
538     //var linkToItsFrequencyNumberConverter = new
539         ↳ LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
540         ↳ unaryNumberToAddressConverter);
541
542     var linkFrequenciesCache3 = new LinkFrequenciesCache<ulong>(scope3.Links.Unsync,
543         ↳ totalSequenceSymbolFrequencyCounter);
544
545     var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<ulong>(linkFrequenciesCache3);
546
547     var sequenceToItsLocalElementLevelsConverter = new
548         ↳ SequenceToItsLocalElementLevelsConverter<ulong>(scope3.Links.Unsync,
549         ↳ linkToItsFrequencyNumberConverter);
550     var optimalVariantConverter = new
551         ↳ OptimalVariantConverter<ulong>(scope3.Links.Unsync,
552         ↳ sequenceToItsLocalElementLevelsConverter);
553
554     var compressed1 = new ulong[arrays.Length];
555     var compressed2 = new ulong[arrays.Length];
556     var compressed3 = new ulong[arrays.Length];
557
558     var START = 0;
559     var END = arrays.Length;
560
561     //for (int i = START; i < END; i++)
562     //    linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
563
564     var initialCount1 = scope2.Links.Unsync.Count();
565
566     var sw1 = Stopwatch.StartNew();
567
568     for (int i = START; i < END; i++)
569     {
570         linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
571         compressed1[i] = compressor1.Convert(arrays[i]);
572     }
573
574     var elapsed1 = sw1.Elapsed;
575
576     var balancedVariantConverter2 = new
577         ↳ BalancedVariantConverter<ulong>(scope2.Links.Unsync);
578
579     var initialCount2 = scope2.Links.Unsync.Count();
580
581     var sw2 = Stopwatch.StartNew();
582
583     for (int i = START; i < END; i++)

```



```

565     {
566         compressed2[i] = balancedVariantConverter2.Convert(arrays[i]);
567     }
568
569     var elapsed2 = sw2.Elapsed;
570
571     for (int i = START; i < END; i++)
572     {
573         linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
574     }
575
576     var initialCount3 = scope3.Links.Unsync.Count();
577
578     var sw3 = Stopwatch.StartNew();
579
580     for (int i = START; i < END; i++)
581     {
582         //linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
583         compressed3[i] = optimalVariantConverter.Convert(arrays[i]);
584     }
585
586     var elapsed3 = sw3.Elapsed;
587
588     Console.WriteLine($"Compressor: {elapsed1}, Balanced variant: {elapsed2},
589         ↳ Optimal variant: {elapsed3}");
590
591     // Assert.True(elapsed1 > elapsed2);
592
593     // Checks
594     for (int i = START; i < END; i++)
595     {
596         var sequence1 = compressed1[i];
597         var sequence2 = compressed2[i];
598         var sequence3 = compressed3[i];
599
600         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
601             ↳ scope1.Links.Unsync);
602
603         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
604             ↳ scope2.Links.Unsync);
605
606         var decompress3 = UnicodeMap.FromSequenceLinkToString(sequence3,
607             ↳ scope3.Links.Unsync);
608
609         var structure1 = scope1.Links.Unsync.FormatStructure(sequence1, link =>
610             ↳ link.IsPartialPoint());
611         var structure2 = scope2.Links.Unsync.FormatStructure(sequence2, link =>
612             ↳ link.IsPartialPoint());
613         var structure3 = scope3.Links.Unsync.FormatStructure(sequence3, link =>
614             ↳ link.IsPartialPoint());
615
616         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
617             ↳ arrays[i].Length > 3)
618         //    Assert.False(structure1 == structure2);
619         //if (sequence3 != Constants.Null && sequence2 != Constants.Null &&
620             ↳ arrays[i].Length > 3)
621         //    Assert.False(structure3 == structure2);
622
623         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
624         Assert.True(strings[i] == decompress3 && decompress3 == decompress2);
625     }
626
627     Assert.True((int)(scope1.Links.Unsync.Count() - initialCount1) <
628         ↳ totalCharacters);
629     Assert.True((int)(scope2.Links.Unsync.Count() - initialCount2) <
630         ↳ totalCharacters);
631     Assert.True((int)(scope3.Links.Unsync.Count() - initialCount3) <
632         ↳ totalCharacters);
633
634     Console.WriteLine($"{{(double)(scope1.Links.Unsync.Count() - initialCount1) /
635         ↳ totalCharacters}} | {{(double)(scope2.Links.Unsync.Count() - initialCount2) /
636         ↳ totalCharacters}} | {{(double)(scope3.Links.Unsync.Count() - initialCount3) /
637         ↳ totalCharacters}}");
638
639     Assert.True(scope1.Links.Unsync.Count() - initialCount1 <
640         ↳ scope2.Links.Unsync.Count() - initialCount2);
641     Assert.True(scope3.Links.Unsync.Count() - initialCount3 <
642         ↳ scope2.Links.Unsync.Count() - initialCount2);

```

```

626     var duplicateProvider1 = new
627         ↳ DuplicateSegmentsProvider<ulong>(scope1.Links.Unsync, scope1.Sequences);
628     var duplicateProvider2 = new
629         ↳ DuplicateSegmentsProvider<ulong>(scope2.Links.Unsync, scope2.Sequences);
630     var duplicateProvider3 = new
631         ↳ DuplicateSegmentsProvider<ulong>(scope3.Links.Unsync, scope3.Sequences);
632
633     var duplicateCounter1 = new DuplicateSegmentsCounter<ulong>(duplicateProvider1);
634     var duplicateCounter2 = new DuplicateSegmentsCounter<ulong>(duplicateProvider2);
635     var duplicateCounter3 = new DuplicateSegmentsCounter<ulong>(duplicateProvider3);
636
637     var duplicates1 = duplicateCounter1.Count();
638
639     ConsoleHelpers.Debug("-----");
640
641     var duplicates2 = duplicateCounter2.Count();
642
643     ConsoleHelpers.Debug("-----");
644
645     var duplicates3 = duplicateCounter3.Count();
646
647     Console.WriteLine($"{duplicates1} | {duplicates2} | {duplicates3}");
648
649     linkFrequenciesCache1.ValidateFrequencies();
650     linkFrequenciesCache3.ValidateFrequencies();
651 }
652
653 [Fact]
654 public static void CompressionStabilityTest()
655 {
656     // TODO: Fix bug (do a separate test)
657     //const ulong minNumbers = 0;
658     //const ulong maxNumbers = 1000;
659
660     const ulong minNumbers = 10000;
661     const ulong maxNumbers = 12500;
662
663     var strings = new List<string>();
664
665     for (ulong i = minNumbers; i < maxNumbers; i++)
666     {
667         strings.Add(i.ToString());
668     }
669
670     var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
671     var totalCharacters = arrays.Select(x => x.Length).Sum();
672
673     using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
674         ↳ SequencesOptions<ulong> { UseCompression = true,
675         ↳ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
676     using (var scope2 = new TempLinksTestScope(useSequences: true))
677     {
678         scope1.Links.UseUnicode();
679         scope2.Links.UseUnicode();
680
681         //var compressor1 = new Compressor(scope1.Links.Unsync, scope1.Sequences);
682         var compressor1 = scope1.Sequences;
683         var compressor2 = scope2.Sequences;
684
685         var compressed1 = new ulong[arrays.Length];
686         var compressed2 = new ulong[arrays.Length];
687
688         var sw1 = Stopwatch.StartNew();
689
690         var START = 0;
691         var END = arrays.Length;
692
693         // Collisions proved (cannot be solved by max doublet comparison, no stable rule)
694         // Stability issue starts at 10001 or 11000
695         //for (int i = START; i < END; i++)
696         //{
697         //    var first = compressor1.Compress(arrays[i]);
698         //    var second = compressor1.Compress(arrays[i]);
699
700         //    if (first == second)
701         //        compressed1[i] = first;
702         //    else
703         //        {

```

```

701 //      // TODO: Find a solution for this case
702 //  }
703 //}
704
705 for (int i = START; i < END; i++)
706 {
707     var first = compressor1.Create(arrays[i]);
708     var second = compressor1.Create(arrays[i]);
709
710     if (first == second)
711     {
712         compressed1[i] = first;
713     }
714     else
715     {
716         // TODO: Find a solution for this case
717     }
718 }
719
720 var elapsed1 = sw1.Elapsed;
721
722 var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
723
724 var sw2 = Stopwatch.StartNew();
725
726 for (int i = START; i < END; i++)
727 {
728     var first = balancedVariantConverter.Convert(arrays[i]);
729     var second = balancedVariantConverter.Convert(arrays[i]);
730
731     if (first == second)
732     {
733         compressed2[i] = first;
734     }
735 }
736
737 var elapsed2 = sw2.Elapsed;
738
739 Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
740 ↪ {elapsed2}");
741
742 Assert.True(elapsed1 > elapsed2);
743
744 // Checks
745 for (int i = START; i < END; i++)
746 {
747     var sequence1 = compressed1[i];
748     var sequence2 = compressed2[i];
749
750     if (sequence1 != _constants.Null && sequence2 != _constants.Null)
751     {
752         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
753             ↪ scope1.Links);
754
755         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
756             ↪ scope2.Links);
757
758         //var structure1 = scope1.Links.FormatStructure(sequence1, link =>
759             ↪ link.IsPartialPoint());
760         //var structure2 = scope2.Links.FormatStructure(sequence2, link =>
761             ↪ link.IsPartialPoint());
762
763         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
764             ↪ arrays[i].Length > 3)
765         //    Assert.False(structure1 == structure2);
766
767         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
768     }
769 }
770
771 Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
772 Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
773
774 Debug.WriteLine($"{{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
775 ↪ totalCharacters}} | {{(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
776 ↪ totalCharacters}}");
777
778 Assert.True(scope1.Links.Count() <= scope2.Links.Count());

```

```

772         //compressor1.ValidateFrequencies();
773     }
774 }
775
776 [Fact]
777 public static void RandomNumbersCompressionQualityTest()
778 {
779     const ulong N = 500;
780
781     //const ulong minNumbers = 10000;
782     //const ulong maxNumbers = 20000;
783
784     //var strings = new List<string>();
785
786     //for (ulong i = 0; i < N; i++)
787     //    strings.Add(RandomHelpers.DefaultFactory.NextUInt64(minNumbers,
788         ↪ maxNumbers).ToString());
789
789     var strings = new List<string>();
790
791     for (ulong i = 0; i < N; i++)
792     {
793         strings.Add(RandomHelpers.Default.NextUInt64().ToString());
794     }
795
796     strings = strings.Distinct().ToList();
797
798     var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
799     var totalCharacters = arrays.Select(x => x.Length).Sum();
800
801     using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
802         ↪ SequencesOptions<ulong> { UseCompression = true,
803         ↪ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
804     using (var scope2 = new TempLinksTestScope(useSequences: true))
805     {
806         scope1.Links.UseUnicode();
807         scope2.Links.UseUnicode();
808
809         var compressor1 = scope1.Sequences;
810         var compressor2 = scope2.Sequences;
811
812         var compressed1 = new ulong[arrays.Length];
813         var compressed2 = new ulong[arrays.Length];
814
815         var sw1 = Stopwatch.StartNew();
816
817         var START = 0;
818         var END = arrays.Length;
819
820         for (int i = START; i < END; i++)
821         {
822             compressed1[i] = compressor1.Create(arrays[i]);
823         }
824
825         var elapsed1 = sw1.Elapsed;
826
827         var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
828         var sw2 = Stopwatch.StartNew();
829
830         for (int i = START; i < END; i++)
831         {
832             compressed2[i] = balancedVariantConverter.Convert(arrays[i]);
833         }
834
835         var elapsed2 = sw2.Elapsed;
836
837         Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
838             ↪ {elapsed2}");
839
840         Assert.True(elapsed1 > elapsed2);
841
842         // Checks
843         for (int i = START; i < END; i++)
844         {
845             var sequence1 = compressed1[i];
846             var sequence2 = compressed2[i];
847
848             if (sequence1 != _constants.Null && sequence2 != _constants.Null)
849             {

```

```

848         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
849             ↪ scope1.Links);
850         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
851             ↪ scope2.Links);
852         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
853     }
854 }
855
856 Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
857 Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
858
859 Debug.WriteLine($"{{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
    ↪ totalCharacters}} | {{(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
    ↪ totalCharacters}}");
860
861 // Can be worse than balanced variant
862 //Assert.True(scope1.Links.Count() <= scope2.Links.Count());
863
864 //compressor1.ValidateFrequencies();
865 }
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         Global.Trash = createResults;
890
891         for (var i = 0; i < sequenceLength; i++)
892         {
893             links.Delete(sequence[i]);
894         }
895     }
896 }
897
898 [Fact]
899 public static void AllPossibleConnectionsTest()
900 {
901     const long sequenceLength = 5;
902
903     using (var scope = new TempLinksTestScope(useSequences: true))
904     {
905         var links = scope.Links;
906         var sequences = scope.Sequences;
907
908         var sequence = new ulong[sequenceLength];
909         for (var i = 0; i < sequenceLength; i++)
910         {
911             sequence[i] = links.Create();
912         }
913
914         var createResults = sequences.CreateAllVariants2(sequence);
915         var reverseResults = sequences.CreateAllVariants2(sequence.Reverse().ToArray());
916
917         for (var i = 0; i < 1; i++)
918         {
919             var sw1 = Stopwatch.StartNew();
920             var searchResults1 = sequences.GetAllConnections(sequence); sw1.Stop();
921
922

```

```

923     var sw2 = Stopwatch.StartNew();
924     var searchResults2 = sequences.GetAllConnections1(sequence); sw2.Stop();
925
926     var sw3 = Stopwatch.StartNew();
927     var searchResults3 = sequences.GetAllConnections2(sequence); sw3.Stop();
928
929     var sw4 = Stopwatch.StartNew();
930     var searchResults4 = sequences.GetAllConnections3(sequence); sw4.Stop();
931
932     Global.Trash = searchResults3;
933     Global.Trash = searchResults4; //-V3008
934
935     var intersection1 = createResults.Intersect(searchResults1).ToList();
936     Assert.True(intersection1.Count == createResults.Length);
937
938     var intersection2 = reverseResults.Intersect(searchResults1).ToList();
939     Assert.True(intersection2.Count == reverseResults.Length);
940
941     var intersection0 = searchResults1.Intersect(searchResults2).ToList();
942     Assert.True(intersection0.Count == searchResults2.Count);
943
944     var intersection3 = searchResults2.Intersect(searchResults3).ToList();
945     Assert.True(intersection3.Count == searchResults3.Count);
946
947     var intersection4 = searchResults3.Intersect(searchResults4).ToList();
948     Assert.True(intersection4.Count == searchResults4.Count);
949 }
950
951 for (var i = 0; i < sequenceLength; i++)
952 {
953     links.Delete(sequence[i]);
954 }
955 }
956 }
957
958 [Fact(Skip = "Correct implementation is pending")]
959 public static void CalculateAllUsagesTest()
960 {
961     const long sequenceLength = 3;
962
963     using (var scope = new TempLinksTestScope(useSequences: true))
964     {
965         var links = scope.Links;
966         var sequences = scope.Sequences;
967
968         var sequence = new ulong[sequenceLength];
969         for (var i = 0; i < sequenceLength; i++)
970         {
971             sequence[i] = links.Create();
972         }
973
974         var createResults = sequences.CreateAllVariants2(sequence);
975
976         //var reverseResults =
977         ↪ sequences.CreateAllVariants2(sequence.Reverse().ToArray());
978
979         for (var i = 0; i < 1; i++)
980         {
981             var linksTotalUsages1 = new ulong[links.Count() + 1];
982             sequences.CalculateAllUsages(linksTotalUsages1);
983
984             var linksTotalUsages2 = new ulong[links.Count() + 1];
985             sequences.CalculateAllUsages2(linksTotalUsages2);
986
987             var intersection1 = linksTotalUsages1.Intersect(linksTotalUsages2).ToList();
988             Assert.True(intersection1.Count == linksTotalUsages2.Length);
989         }
990
991         for (var i = 0; i < sequenceLength; i++)
992         {
993             links.Delete(sequence[i]);
994         }
995     }
996 }
997 }
998 }
999 }

```

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

```
1 using System.IO;
2 using Platform.Disposables;
3 using Platform.Data.Doublets.ResizableDirectMemory;
4 using Platform.Data.Doublets.Sequences;
5 using Platform.Data.Doublets.Decorators;
6
7 namespace Platform.Data.Doublets.Tests
8 {
9     public class TempLinksTestScope : DisposableBase
10    {
11        public readonly ILinks<ulong> MemoryAdapter;
12        public readonly SynchronizedLinks<ulong> Links;
13        public readonly Sequences.Sequences Sequences;
14        public readonly string TempFilename;
15        public readonly string TempTransactionLogFilename;
16        private readonly bool _deleteFiles;
17
18        public TempLinksTestScope(bool deleteFiles = true, bool useSequences = false, bool
19            ↪ useLog = false)
20            : this(new SequencesOptions<ulong>(), deleteFiles, useSequences, useLog)
21        {
22        }
23
24        public TempLinksTestScope(SequencesOptions<ulong> sequencesOptions, bool deleteFiles =
25            ↪ true, bool useSequences = false, bool useLog = false)
26        {
27            _deleteFiles = deleteFiles;
28            TempFilename = Path.GetTempFileName();
29            TempTransactionLogFilename = Path.GetTempFileName();
30
31            var coreMemoryAdapter = new UInt64ResizableDirectMemoryLinks(TempFilename);
32
33            MemoryAdapter = useLog ? (ILinks<ulong>)new
34                ↪ UInt64LinksTransactionsLayer(coreMemoryAdapter, TempTransactionLogFilename) :
35                ↪ coreMemoryAdapter;
36
37            Links = new SynchronizedLinks<ulong>(new UInt64Links(MemoryAdapter));
38            if (useSequences)
39            {
40                Sequences = new Sequences.Sequences(Links, sequencesOptions);
41            }
42        }
43
44        protected override void Dispose(bool manual, bool wasDisposed)
45        {
46            if (!wasDisposed)
47            {
48                Links.Unsync.DisposeIfPossible();
49                if (_deleteFiles)
50                {
51                    DeleteFiles();
52                }
53            }
54        }
55
56        public void DeleteFiles()
57        {
58            File.Delete(TempFilename);
59            File.Delete(TempTransactionLogFilename);
60        }
61    }
62 }
```

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

```
1 using Xunit;
2 using Platform.Random;
3 using Platform.Data.Doublets.UnaryNumbers;
4
5 namespace Platform.Data.Doublets.Tests
6 {
7     public static class UnaryNumberConvertersTests
8     {
9         [Fact]
10        public static void ConvertersTest()
11        {
12            using (var scope = new TempLinksTestScope())
13            {
14                const int N = 10;
15                var links = scope.Links;
```

```

16     var meaningRoot = links.CreatePoint();
17     var one = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
18     var powerOf2ToUnaryNumberConverter = new
    ↪ PowerOf2ToUnaryNumberConverter<ulong>(links, one);
19     var toUnaryNumberConverter = new AddressToUnaryNumberConverter<ulong>(links,
    ↪ powerOf2ToUnaryNumberConverter);
20     var random = new System.Random(0);
21     ulong[] numbers = new ulong[N];
22     ulong[] unaryNumbers = new ulong[N];
23     for (int i = 0; i < N; i++)
24     {
25         numbers[i] = random.NextUInt64();
26         unaryNumbers[i] = toUnaryNumberConverter.Convert(numbers[i]);
27     }
28     var fromUnaryNumberConverterUsingOrOperation = new
    ↪ UnaryNumberToAddressOrOperationConverter<ulong>(links,
    ↪ powerOf2ToUnaryNumberConverter);
29     var fromUnaryNumberConverterUsingAddOperation = new
    ↪ UnaryNumberToAddressAddOperationConverter<ulong>(links, one);
30     for (int i = 0; i < N; i++)
31     {
32         Assert.Equal(numbers[i],
    ↪ fromUnaryNumberConverterUsingOrOperation.Convert(unaryNumbers[i]));
33         Assert.Equal(numbers[i],
    ↪ fromUnaryNumberConverterUsingAddOperation.Convert(unaryNumbers[i]));
34     }
35 }
36 }
37 }
38 }

```

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

```

1  using Platform.Data.Doublets.Incrementers;
2  using Platform.Data.Doublets.PropertyOperators;
3  using Platform.Data.Doublets.Sequences.Converters;
4  using Platform.Data.Doublets.Sequences.Indexes;
5  using Platform.Data.Doublets.Sequences.Walkers;
6  using Platform.Data.Doublets.UnaryNumbers;
7  using Platform.Data.Doublets.Unicode;
8  using Xunit;
9
10 namespace Platform.Data.Doublets.Tests
11 {
12     public static class UnicodeConvertersTests
13     {
14         [Fact]
15         public static void CharAndUnicodeSymbolConvertersTest()
16         {
17             using (var scope = new TempLinksTestScope())
18             {
19                 var links = scope.Links;
20
21                 var itself = links.Constants.Itself;
22
23                 var meaningRoot = links.CreatePoint();
24                 var one = links.CreateAndUpdate(meaningRoot, itself);
25                 var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, itself);
26
27                 var powerOf2ToUnaryNumberConverter = new
    ↪ PowerOf2ToUnaryNumberConverter<ulong>(links, one);
28                 var addressToUnaryNumberConverter = new
    ↪ AddressToUnaryNumberConverter<ulong>(links, powerOf2ToUnaryNumberConverter);
29                 var charToUnicodeSymbolConverter = new
    ↪ CharToUnicodeSymbolConverter<ulong>(links, addressToUnaryNumberConverter,
    ↪ unicodeSymbolMarker);
30
31                 var originalCharacter = 'H';
32
33                 var characterLink = charToUnicodeSymbolConverter.Convert(originalCharacter);
34
35                 var unaryNumberToAddressConverter = new
    ↪ UnaryNumberToAddressOrOperationConverter<ulong>(links,
    ↪ powerOf2ToUnaryNumberConverter);
36                 var unicodeSymbolCriterionMatcher = new
    ↪ UnicodeSymbolCriterionMatcher<ulong>(links, unicodeSymbolMarker);
37                 var unicodeSymbolToCharConverter = new
    ↪ UnicodeSymbolToCharConverter<ulong>(links, unaryNumberToAddressConverter,
    ↪ unicodeSymbolCriterionMatcher);
38

```



```

39     var resultingCharacter = unicodeSymbolToCharConverter.Convert(characterLink);
40
41     Assert.Equal(originalCharacter, resultingCharacter);
42 }
43 }
44
45 [Fact]
46 public static void StringAndUnicodeSequenceConvertersTest()
47 {
48     using (var scope = new TempLinksTestScope())
49     {
50         var links = scope.Links;
51
52         var itself = links.Constants.Itself;
53
54         var meaningRoot = links.CreatePoint();
55         var unaryOne = links.CreateAndUpdate(meaningRoot, itself);
56         var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, itself);
57         var unicodeSequenceMarker = links.CreateAndUpdate(meaningRoot, itself);
58         var frequencyMarker = links.CreateAndUpdate(meaningRoot, itself);
59         var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot, itself);
60
61         var powerOf2ToUnaryNumberConverter = new
62             ↪ PowerOf2ToUnaryNumberConverter<ulong>(links, unaryOne);
63         var addressToUnaryNumberConverter = new
64             ↪ AddressToUnaryNumberConverter<ulong>(links, powerOf2ToUnaryNumberConverter);
65         var charToUnicodeSymbolConverter = new
66             ↪ CharToUnicodeSymbolConverter<ulong>(links, addressToUnaryNumberConverter,
67             ↪ unicodeSymbolMarker);
68
69         var unaryNumberToAddressConverter = new
70             ↪ UnaryNumberToAddressOrOperationConverter<ulong>(links,
71             ↪ powerOf2ToUnaryNumberConverter);
72         var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
73         var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
74             ↪ frequencyMarker, unaryOne, unaryNumberIncrementer);
75         var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
76             ↪ frequencyPropertyMarker, frequencyMarker);
77         var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
78             ↪ frequencyPropertyOperator, frequencyIncrementer);
79         var linkToItsFrequencyNumberConverter = new
80             ↪ LinkToItsFrequencyNumberConverter<ulong>(links, frequencyPropertyOperator,
81             ↪ unaryNumberToAddressConverter);
82         var sequenceToItsLocalElementLevelsConverter = new
83             ↪ SequenceToItsLocalElementLevelsConverter<ulong>(links,
84             ↪ linkToItsFrequencyNumberConverter);
85         var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
86             ↪ sequenceToItsLocalElementLevelsConverter);
87
88         var stringToUnicodeSymbolConverter = new
89             ↪ StringToUnicodeSequenceConverter<ulong>(links, charToUnicodeSymbolConverter,
90             ↪ index, optimalVariantConverter, unicodeSequenceMarker);
91
92         var originalString = "Hello";
93
94         var unicodeSequenceLink = stringToUnicodeSymbolConverter.Convert(originalString);
95
96         var unicodeSymbolCriterionMatcher = new
97             ↪ UnicodeSymbolCriterionMatcher<ulong>(links, unicodeSymbolMarker);
98         var unicodeSymbolToCharConverter = new
99             ↪ UnicodeSymbolToCharConverter<ulong>(links, unaryNumberToAddressConverter,
100             ↪ unicodeSymbolCriterionMatcher);
101
102         var unicodeSequenceCriterionMatcher = new
103             ↪ UnicodeSequenceCriterionMatcher<ulong>(links, unicodeSequenceMarker);
104
105         var sequenceWalker = new LeveledSequenceWalker<ulong>(links,
106             ↪ unicodeSymbolCriterionMatcher.IsMatched);
107
108         var unicodeSequenceToStringConverter = new
109             ↪ UnicodeSequenceToStringConverter<ulong>(links,
110             ↪ unicodeSequenceCriterionMatcher, sequenceWalker,
111             ↪ unicodeSymbolToCharConverter);
112
113         var resultingString =
114             ↪ unicodeSequenceToStringConverter.Convert(unicodeSequenceLink);
115
116         Assert.Equal(originalString, resultingString);

```

92
93
94
95

}

}

}

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