

LinksPlatform's Platform.Data.Doublets Class Library

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

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

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

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

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

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

```

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

```

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

```

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

```

```

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

```

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

```

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

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Decorators
8  {
9      public class LinksItselfConstantToSelfReferenceResolver<TLink> : LinksDecoratorBase<TLink>
10     {
11         private static readonly EqualityComparer<TLink> _equalityComparer =
12             ↳ EqualityComparer<TLink>.Default;
13     }
14 }

```

```

13 [MethodImpl(MethodImplOptions.AggressiveInlining)]
14 public LinksItselfConstantToSelfReferenceResolver(ILinks<TLink> links) : base(links) { }
15
16 [MethodImpl(MethodImplOptions.AggressiveInlining)]
17 public override TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
18 {
19     var constants = Constants;
20     var itselfConstant = constants.Itself;
21     var indexPartConstant = constants.IndexPart;
22     var sourcePartConstant = constants.SourcePart;
23     var targetPartConstant = constants.TargetPart;
24     var restrictionsCount = restrictions.Count;
25     if (!_equalityComparer.Equals(constants.Any, itselfConstant)
26         && (((restrictionsCount > indexPartConstant) &&
27             ↪ _equalityComparer.Equals(restrictions[indexPartConstant], itselfConstant))
28             || ((restrictionsCount > sourcePartConstant) &&
29                 ↪ _equalityComparer.Equals(restrictions[sourcePartConstant], itselfConstant))
30             || ((restrictionsCount > targetPartConstant) &&
31                 ↪ _equalityComparer.Equals(restrictions[targetPartConstant], itselfConstant))))
32     {
33         // Itself constant is not supported for Each method right now, skipping execution
34         return constants.Continue;
35     }
36     return Links.Each(handler, restrictions);
37 }
38
39 [MethodImpl(MethodImplOptions.AggressiveInlining)]
40 public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution) =>
41     ↪ Links.Update(restrictions, Links.ResolveConstantAsSelfReference(Constants.Itself,
42     ↪ restrictions, substitution));
43 }
44 }

```

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

```

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

```

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

```

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

```

```

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

```

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

```

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

```

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

```

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

```

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

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

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

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

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

```
1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Decorators
7 {
8     /// <summary>
9     /// Представляет объект для работы с базой данных (файлом) в формате Links (массива связей).
10     /// </summary>
11     /// <remarks>
12     /// Возможные оптимизации:
13     /// Объединение в одном поле Source и Target с уменьшением до 32 бит.
14     ///     + меньше объём БД
15     ///     - меньше производительность
16     ///     - больше ограничение на количество связей в БД)
17     /// Ленивое хранение размеров поддеревьев (расчитываемое по мере использования БД)
18     ///     + меньше объём БД
19     ///     - больше сложность
20     ///
21     /// Текущее теоретическое ограничение на индекс связи, из-за использования 5 бит в размере
22     ///     ↳ поддеревьев для AVL баланса и флагов нитей: 2 в степени(64 минус 5 равно 59 ) равно 576
23     ///     ↳ 460 752 303 423 488
24     /// Желательно реализовать поддержку переключения между деревьями и битовыми индексами
25     ///     ↳ (битовыми строками) - вариант матрицы (выстраиваемой лениво).
```

```

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

```

1.14 ./Platform.Data.Doublets/Decorators/UniLinks.cs

```

1  using System;
2  using System.Collections.Generic;
3  using System.Linq;
4  using Platform.Collections;
5  using Platform.Collections.Lists;
6  using Platform.Data.Universal;
7
8  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets.Decorators
11 {
12     /// <remarks>
13     /// What does empty pattern (for condition or substitution) mean? Nothing or Everything?
14     /// Now we go with nothing. And nothing is something one, but empty, and cannot be changed
        ↳ by itself. But can cause creation (update from nothing) or deletion (update to nothing).
15     ///
16     /// TODO: Decide to change to IDoubletLinks or not to change. (Better to create
        ↳ DefaultUniLinksBase, that contains logic itself and can be implemented using both
        ↳ IDoubletLinks and ILinks.)
17     /// </remarks>

```

```

18 internal class UniLinks<TLink> : LinksDecoratorBase<TLink>, IUniLinks<TLink>
19 {
20     private static readonly EqualityComparer<TLink> _equalityComparer =
21         ↳ EqualityComparer<TLink>.Default;
22
23     public UniLinks(ILinks<TLink> links) : base(links) { }
24
25     private struct Transition
26     {
27         public IList<TLink> Before;
28         public IList<TLink> After;
29
30         public Transition(IList<TLink> before, IList<TLink> after)
31         {
32             Before = before;
33             After = after;
34         }
35     }
36
37     //public static readonly TLink NullConstant = Use<LinksConstants<TLink>>.Single.Null;
38     //public static readonly IReadOnlyList<TLink> NullLink = new
39     ↳ ReadOnlyCollection<TLink>(new List<TLink> { NullConstant, NullConstant, NullConstant
40     ↳ });
41
42     // TODO: Подумать о том, как реализовать древовидный Restriction и Substitution
43     ↳ (Links-Expression)
44     public TLink Trigger(IList<TLink> restriction, Func<IList<TLink>, IList<TLink>, TLink>
45     ↳ matchedHandler, IList<TLink> substitution, Func<IList<TLink>, IList<TLink>, TLink>
46     ↳ substitutedHandler)
47     {
48         /////List<Transition> transitions = null;
49         /////if (!restriction.IsNullOrEmpty())
50         /////{
51         /////    // Есть причина делать проход (чтение)
52         /////    if (matchedHandler != null)
53         /////    {
54         /////        if (!substitution.IsNullOrEmpty())
55         /////        {
56         /////            // restriction => { 0, 0, 0 } | { 0 } // Create
57         /////            // substitution => { itself, 0, 0 } | { itself, itself, itself } //
58         ↳ Create / Update
59         /////            // substitution => { 0, 0, 0 } | { 0 } // Delete
60         /////            transitions = new List<Transition>();
61         /////            if (Equals(substitution[Constants.IndexPart], Constants.Null))
62         /////            {
63         /////                // If index is Null, that means we always ignore every other
64         ↳ value (they are also Null by definition)
65         /////                var matchDecision = matchedHandler(, NullLink);
66         /////                if (Equals(matchDecision, Constants.Break))
67         /////                    return false;
68         /////                if (!Equals(matchDecision, Constants.Skip))
69         /////                    transitions.Add(new Transition(matchedLink, newValue));
70         /////            }
71         /////            else
72         /////            {
73         /////                Func<T, bool> handler;
74         /////                handler = link =>
75         /////                {
76         /////                    var matchedLink = Memory.GetLinkValue(link);
77         /////                    var newValue = Memory.GetLinkValue(link);
78         /////                    newValue[Constants.IndexPart] = Constants.Itself;
79         /////                    newValue[Constants.SourcePart] =
80         ↳ Equals(substitution[Constants.SourcePart], Constants.Itself) ?
81         ↳ matchedLink[Constants.IndexPart] : substitution[Constants.SourcePart];
82         /////                    newValue[Constants.TargetPart] =
83         ↳ Equals(substitution[Constants.TargetPart], Constants.Itself) ?
84         ↳ matchedLink[Constants.IndexPart] : substitution[Constants.TargetPart];
85         /////                    var matchDecision = matchedHandler(matchedLink, newValue);
86         /////                    if (Equals(matchDecision, Constants.Break))
87         /////                        return false;
88         /////                    if (!Equals(matchDecision, Constants.Skip))
89         /////                        transitions.Add(new Transition(matchedLink, newValue));
90         /////                    return true;
91         /////                };
92         /////            if (!Memory.Each(handler, restriction))
93         /////                return Constants.Break;
94         /////        }
95     }

```



```

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

```

```

161         //         if (!Memory.Each(handler, restriction))
162             //             return Constants.Break;
163         //     }
164         //     if (!matchedLinks.IsNullOrEmpty())
165         //     {
166             //         var totalMatchedLinks = matchedLinks.Count;
167             //         for (var i = 0; i < totalMatchedLinks; i++)
168             //         {
169                 //             var matchedLink = matchedLinks[i];
170                 //             if (substitutedHandler != null)
171                 //             {
172                     //                 var newValue = new List<T>(); // TODO: Prepare value to update here
173                     //                 // TODO: Decide is it actually needed to use Before and After
174                     ↪ substitution handling.
175                     //                 var substitutedDecision = substitutedHandler(matchedLink,
176                     ↪ newValue);
177                     //                 if (Equals(substitutedDecision, Constants.Break))
178                     //                     return Constants.Break;
179                     //                 if (Equals(substitutedDecision, Constants.Continue))
180                     //                 {
181                         //                     // Actual update here
182                         //                     Memory.SetLinkValue(newValue);
183                     //                 }
184                     //                 if (Equals(substitutedDecision, Constants.Skip))
185                     //                 {
186                         //                     // Cancel the update. TODO: decide use separate Cancel
187                         ↪ constant or Skip is enough?
188                     //                 }
189                     //             }
190             //         }
191         //     }
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999     // }
1000    // }

```

```

231     {
232         return substitutionHandler(before, after);
233     }
234     return Constants.Continue;
235 }
236 else if (!patternOrCondition.IsNullOrEmpty()) // Deletion
237 {
238     if (patternOrCondition.Count == 1)
239     {
240         var linkToDelete = patternOrCondition[0];
241         var before = Links.GetLink(linkToDelete);
242         if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
243             ↪ Constants.Break))
244         {
245             return Constants.Break;
246         }
247         var after = Array.Empty<TLink>();
248         Links.Update(linkToDelete, Constants.Null, Constants.Null);
249         Links.Delete(linkToDelete);
250         if (matchHandler != null)
251         {
252             return substitutionHandler(before, after);
253         }
254         return Constants.Continue;
255     }
256     else
257     {
258         throw new NotSupportedException();
259     }
260 }
261 else // Replace / Update
262 {
263     if (patternOrCondition.Count == 1) //-V3125
264     {
265         var linkToUpdate = patternOrCondition[0];
266         var before = Links.GetLink(linkToUpdate);
267         if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
268             ↪ Constants.Break))
269         {
270             return Constants.Break;
271         }
272         var after = (IList<TLink>)substitution.ToArray(); //-V3125
273         if (_equalityComparer.Equals(after[0], default))
274         {
275             after[0] = linkToUpdate;
276         }
277         if (substitution.Count == 1)
278         {
279             if (!_equalityComparer.Equals(substitution[0], linkToUpdate))
280             {
281                 after = Links.GetLink(substitution[0]);
282                 Links.Update(linkToUpdate, Constants.Null, Constants.Null);
283                 Links.Delete(linkToUpdate);
284             }
285         }
286         else if (substitution.Count == 3)
287         {
288             //Links.Update(after);
289         }
290         else
291         {
292             throw new NotSupportedException();
293         }
294         if (matchHandler != null)
295         {
296             return substitutionHandler(before, after);
297         }
298         return Constants.Continue;
299     }
300     else
301     {
302         throw new NotSupportedException();
303     }
304 }
305 }
306
307 /// <remarks>
308 /// IList[IList[IList[T]]]

```

```

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

```

1.15 ./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 =
11             ↳ EqualityComparer<T>.Default;
12
13         public T Source { get; set; }
14         public T Target { get; set; }
15
16         public Doublet(T source, T target)
17         {
18             Source = source;
19             Target = target;
20         }
21
22         public override string ToString() => $"{Source}->{Target}";
23
24         public bool Equals(Doublet<T> other) => _equalityComparer.Equals(Source, other.Source)
25             ↳ && _equalityComparer.Equals(Target, other.Target);
26
27         public override bool Equals(object obj) => obj is Doublet<T> doublet ?
28             ↳ base.Equals(doublet) : false;
29
30         public override int GetHashCode() => (Source, Target).GetHashCode();
31     }
32 }

```

1.16 ./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 }

```

1.17 ./Platform.Data.Doublets/Hybrid.cs

```

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

```

```

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

```

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

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

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

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

```

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

```



```

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

```

```

201
202 /// <summary>
203 /// Возвращает индекс конечной (Target) связи для указанной связи.
204 /// </summary>
205 /// <param name="links">Хранилище связей.</param>
206 /// <param name="link">Индекс связи.</param>
207 /// <returns>Индекс конечной связи для указанной связи.</returns>
208 [MethodImpl(MethodImplOptions.AggressiveInlining)]
209 public static TLink GetTarget<TLink>(this ILinks<TLink> links, TLink link) =>
210     ↪ links.GetLink(link)[links.Constants.TargetPart];
211
212 /// <summary>
213 /// Возвращает индекс конечной (Target) связи для указанной связи.
214 /// </summary>
215 /// <param name="links">Хранилище связей.</param>
216 /// <param name="link">Связь представленная списком, состоящим из её адреса и
217     ↪ содержимого.</param>
218 /// <returns>Индекс конечной связи для указанной связи.</returns>
219 [MethodImpl(MethodImplOptions.AggressiveInlining)]
220 public static TLink GetTarget<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
221     ↪ link[links.Constants.TargetPart];
222
223 /// <summary>
224 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
225     ↪ (handler) для каждой подходящей связи.
226 /// </summary>
227 /// <param name="links">Хранилище связей.</param>
228 /// <param name="handler">Обработчик каждой подходящей связи.</param>
229 /// <param name="restrictions">Ограничения на содержимое связей. Каждое ограничение
230     ↪ может иметь значения: Constants.Null - 0-я связь, обозначающая ссылку на пустоту,
231     ↪ Any - отсутствие ограничения, 1..∞ конкретный адрес связи.</param>
232 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
233     ↪ случае.</returns>
234 [MethodImpl(MethodImplOptions.AggressiveInlining)]
235 public static bool Each<TLink>(this ILinks<TLink> links, Func<IList<TLink>, TLink>
236     ↪ handler, params TLink[] restrictions)
237     => EqualityComparer<TLink>.Default.Equals(links.Each(handler, restrictions),
238     ↪ links.Constants.Continue);
239
240 /// <summary>
241 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
242     ↪ (handler) для каждой подходящей связи.
243 /// </summary>
244 /// <param name="links">Хранилище связей.</param>
245 /// <param name="source">Значение, определяющее соответствующие шаблону связи.
246     ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве начала,
247     ↪ Constants.Any - любое начало, 1..∞ конкретное начало)</param>
248 /// <param name="target">Значение, определяющее соответствующие шаблону связи.
249     ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве конца,
250     ↪ Constants.Any - любой конец, 1..∞ конкретный конец)</param>
251 /// <param name="handler">Обработчик каждой подходящей связи.</param>
252 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
253     ↪ случае.</returns>
254 [MethodImpl(MethodImplOptions.AggressiveInlining)]
255 public static bool Each<TLink>(this ILinks<TLink> links, TLink source, TLink target,
256     ↪ Func<TLink, bool> handler)
257 {
258     var constants = links.Constants;
259     return links.Each(link => handler(link[constants.IndexPart]) ? constants.Continue :
260     ↪ constants.Break, constants.Any, source, target);
261 }
262
263 /// <summary>
264 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
265     ↪ (handler) для каждой подходящей связи.
266 /// </summary>
267 /// <param name="links">Хранилище связей.</param>
268 /// <param name="source">Значение, определяющее соответствующие шаблону связи.
269     ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве начала,
270     ↪ Constants.Any - любое начало, 1..∞ конкретное начало)</param>
271 /// <param name="target">Значение, определяющее соответствующие шаблону связи.
272     ↪ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве конца,
273     ↪ Constants.Any - любой конец, 1..∞ конкретный конец)</param>
274 /// <param name="handler">Обработчик каждой подходящей связи.</param>
275 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
276     ↪ случае.</returns>

```

```

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

```

```

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

```

```

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

```

```

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

```

```

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

```

```

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

```



```

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

```

```

732     }
733
734     public static ILinks<TLink>
735     ↪ DecorateWithAutomaticUniquenessAndUsagesResolution<TLink>(this ILinks<TLink> links)
736     {
737         links = new LinksCascadeUsagesResolver<TLink>(links);
738         links = new NonNullContentsLinkDeletionResolver<TLink>(links);
739         links = new LinksCascadeUniquenessAndUsagesResolver<TLink>(links);
740         return links;
741     }
742 }

```

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

```

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

```

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

```

1  using System.Collections.Generic;
2  using Platform.Incrementers;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Incrementers
7  {
8      public class FrequencyIncrementer<TLink> : LinksOperatorBase<TLink>, IIncrementer<TLink>
9      {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11         ↪ EqualityComparer<TLink>.Default;
12
13         private readonly TLink _frequencyMarker;
14         private readonly TLink _unaryOne;
15         private readonly IIncrementer<TLink> _unaryNumberIncrementer;
16
17         public FrequencyIncrementer(ILinks<TLink> links, TLink frequencyMarker, TLink unaryOne,
18         ↪ IIncrementer<TLink> unaryNumberIncrementer)
19         : base(links)
20         {
21             _frequencyMarker = frequencyMarker;
22             _unaryOne = unaryOne;
23             _unaryNumberIncrementer = unaryNumberIncrementer;
24         }
25
26         public TLink Increment(TLink frequency)
27         {
28             if (_equalityComparer.Equals(frequency, default))
29             {
30                 return Links.GetOrCreate(_unaryOne, _frequencyMarker);
31             }
32             var source = Links.GetSource(frequency);
33             var incrementedSource = _unaryNumberIncrementer.Increment(source);
34             return Links.GetOrCreate(incrementedSource, _frequencyMarker);
35         }
36     }
37 }

```

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

```

1  using System.Collections.Generic;
2  using Platform.Incrementers;
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 }

```

```

15
16 public TLink Increment(TLink unaryNumber)
17 {
18     if (_equalityComparer.Equals(unaryNumber, _unaryOne))
19     {
20         return Links.GetOrCreate(_unaryOne, _unaryOne);
21     }
22     var source = Links.GetSource(unaryNumber);
23     var target = Links.GetTarget(unaryNumber);
24     if (_equalityComparer.Equals(source, target))
25     {
26         return Links.GetOrCreate(unaryNumber, _unaryOne);
27     }
28     else
29     {
30         return Links.GetOrCreate(source, Increment(target));
31     }
32 }
33 }
34 }

```

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

```

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

```

```

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

```

```

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

```

```

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

```

1.24 ./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 }

```

1.25 ./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 }

```

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

```

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

```

```

26         {
27             target = _equalityComparer.Equals(target, nullConstant)
28                 ? _powerOf2ToUnaryNumberConverter.Convert(i)
29                 : Links.GetOrCreate(_powerOf2ToUnaryNumberConverter.Convert(i), target);
30         }
31         number = Bit.ShiftRight(number, 1);
32     }
33     return target;
34 }
35 }
36 }

```

1.27 ./Platform.Data.Doublets/Numbers/Unary/LinkToItsFrequencyNumberConverter.cs

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Interfaces;
4  using Platform.Converters;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Numbers.Unary
9  {
10     public class LinkToItsFrequencyNumberConverter<TLink> : LinksOperatorBase<TLink>,
11         ↪ IConverter<Doublet<TLink>, TLink>
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
14             ↪ EqualityComparer<TLink>.Default;
15
16         private readonly IProperty<TLink, TLink> _frequencyPropertyOperator;
17         private readonly IConverter<TLink> _unaryNumberToAddressConverter;
18
19         public LinkToItsFrequencyNumberConverter(
20             ILinks<TLink> links,
21             IProperty<TLink, TLink> frequencyPropertyOperator,
22             IConverter<TLink> unaryNumberToAddressConverter)
23             : base(links)
24         {
25             _frequencyPropertyOperator = frequencyPropertyOperator;
26             _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
27         }
28
29         public TLink Convert(Doublet<TLink> doublet)
30         {
31             var link = Links.SearchOrDefault(doublet.Source, doublet.Target);
32             if (_equalityComparer.Equals(link, default))
33             {
34                 throw new ArgumentException($"Link ({doublet}) not found.", nameof(doublet));
35             }
36             var frequency = _frequencyPropertyOperator.Get(link);
37             if (_equalityComparer.Equals(frequency, default))
38             {
39                 return default;
40             }
41             var frequencyNumber = Links.GetSource(frequency);
42             return _unaryNumberToAddressConverter.Convert(frequencyNumber);
43         }
44     }
45 }

```

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

```

1  using System.Collections.Generic;
2  using Platform.Exceptions;
3  using Platform.Ranges;
4  using Platform.Converters;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Numbers.Unary
9  {
10     public class PowerOf2ToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
11         ↪ IConverter<int, TLink>
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
14             ↪ EqualityComparer<TLink>.Default;
15
16         private readonly TLink[] _unaryNumberPowersOf2;
17
18         public PowerOf2ToUnaryNumberConverter(ILinks<TLink> links, TLink one) : base(links)
19         {
20             _unaryNumberPowersOf2 = new TLink[64];
21         }
22     }
23 }

```

```

19     _unaryNumberPowersOf2[0] = one;
20 }
21
22 public TLink Convert(int power)
23 {
24     Ensure.Always.ArgumentInRange(power, new Range<int>(0, _unaryNumberPowersOf2.Length
25     ↪ - 1), nameof(power));
26     if (!_equalityComparer.Equals(_unaryNumberPowersOf2[power], default))
27     {
28         return _unaryNumberPowersOf2[power];
29     }
30     var previousPowerOf2 = Convert(power - 1);
31     var powerOf2 = Links.GetOrCreate(previousPowerOf2, previousPowerOf2);
32     _unaryNumberPowersOf2[power] = powerOf2;
33     return powerOf2;
34 }
35 }

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3 using Platform.Converters;
4 using Platform.Numbers;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Numbers.Unary
9 {
10     public class UnaryNumberToAddressAddOperationConverter<TLink> : LinksOperatorBase<TLink>,
11     ↪ IConverter<TLink>
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
14         ↪ EqualityComparer<TLink>.Default;
15
16         private Dictionary<TLink, TLink> _unaryToUInt64;
17         private readonly TLink _unaryOne;
18
19         public UnaryNumberToAddressAddOperationConverter(ILinks<TLink> links, TLink unaryOne)
20             : base(links)
21         {
22             _unaryOne = unaryOne;
23             InitUnaryToUInt64();
24         }
25
26         private void InitUnaryToUInt64()
27         {
28             var one = Integer<TLink>.One;
29             _unaryToUInt64 = new Dictionary<TLink, TLink>
30             {
31                 { _unaryOne, one }
32             };
33             var unary = _unaryOne;
34             var number = one;
35             for (var i = 1; i < 64; i++)
36             {
37                 unary = Links.GetOrCreate(unary, unary);
38                 number = Double(number);
39                 _unaryToUInt64.Add(unary, number);
40             }
41         }
42
43         public TLink Convert(TLink unaryNumber)
44         {
45             if (_equalityComparer.Equals(unaryNumber, default))
46             {
47                 return default;
48             }
49             if (_equalityComparer.Equals(unaryNumber, _unaryOne))
50             {
51                 return Integer<TLink>.One;
52             }
53             var source = Links.GetSource(unaryNumber);
54             var target = Links.GetTarget(unaryNumber);
55             if (_equalityComparer.Equals(source, target))
56             {
57                 return _unaryToUInt64[unaryNumber];
58             }
59             else
60             {

```



```

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 *
    ↪ 2UL);
74 }
75 }

```

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

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Reflection;
4  using Platform.Converters;
5  using Platform.Numbers;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets.Numbers.Unary
10 {
11     public class UnaryNumberToAddressOrOperationConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<TLink>
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
    ↪ EqualityComparer<TLink>.Default;
14
15         private readonly IDictionary<TLink, int> _unaryNumberPowerOf2Indicies;
16
17         public UnaryNumberToAddressOrOperationConverter(ILinks<TLink> links, IConverter<int,
    ↪ TLink> powerOf2ToUnaryNumberConverter)
    : base(links)
18         {
19             _unaryNumberPowerOf2Indicies = new Dictionary<TLink, int>();
20             for (int i = 0; i < NumericType<TLink>.BitsSize; i++)
21             {
22                 _unaryNumberPowerOf2Indicies.Add(powerOf2ToUnaryNumberConverter.Convert(i), i);
23             }
24         }
25
26         public TLink Convert(TLink sourceNumber)
27         {
28             var nullConstant = Links.Constants.Null;
29             var source = sourceNumber;
30             var target = nullConstant;
31             if (!_equalityComparer.Equals(source, nullConstant))
32             {
33                 while (true)
34                 {
35                     if (_unaryNumberPowerOf2Indicies.TryGetValue(source, out int powerOf2Index))
36                     {
37                         SetBit(ref target, powerOf2Index);
38                         break;
39                     }
40                     else
41                     {
42                         powerOf2Index = _unaryNumberPowerOf2Indicies[Links.GetSource(source)];
43                         SetBit(ref target, powerOf2Index);
44                         source = Links.GetTarget(source);
45                     }
46                 }
47             }
48             return target;
49         }
50
51         [MethodImpl(MethodImplOptions.AggressiveInlining)]
52         private static void SetBit(ref TLink target, int powerOf2Index) => target =
    ↪ Bit.Or(target, Bit.ShiftLeft(Integer<TLink>.One, powerOf2Index));
53
54     }
55 }

```

1.31 ./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>, IProperties<TLink, TLink,
10         ↪ 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  }

```

1.32 ./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>, IProperty<TLink, TLink>
9      {
10          private static readonly EqualityComparer<TLink> _equalityComparer =
11             ↪ EqualityComparer<TLink>.Default;
12
13          private readonly TLink _propertyMarker;
14          private readonly TLink _propertyValueMarker;
15
16          public PropertyOperator(ILinks<TLink> links, TLink propertyMarker, TLink
17             ↪ propertyValueMarker) : base(links)
18          {
19              _propertyMarker = propertyMarker;
20              _propertyValueMarker = propertyValueMarker;
21          }
22
23          public TLink Get(TLink link)
24          {
25              var property = Links.SearchOrDefault(link, _propertyMarker);
26              var container = GetContainer(property);
27              var value = GetValue(container);
28              return value;
29          }
30
31          private TLink GetContainer(TLink property)
32          {
33              var valueContainer = default(TLink);
34              if (_equalityComparer.Equals(property, default))
35              {
36                  return valueContainer;
37              }
38              var constants = Links.Constants;

```

```

37     var continueConstant = constants.Continue;
38     var breakConstant = constants.Break;
39     var anyConstant = constants.Any;
40     var query = new Link<TLink>(anyConstant, property, anyConstant);
41     Links.Each(candidate =>
42     {
43         var candidateTarget = Links.GetTarget(candidate);
44         var valueTarget = Links.GetTarget(candidateTarget);
45         if (_equalityComparer.Equals(valueTarget, _propertyValueMarker))
46         {
47             valueContainer = Links.GetIndex(candidate);
48             return breakConstant;
49         }
50         return continueConstant;
51     }, query);
52     return valueContainer;
53 }
54
55 private TLink GetValue(TLink container) => _equalityComparer.Equals(container, default)
56     ? default : Links.GetTarget(container);
57
58 public void Set(TLink link, TLink value)
59 {
60     var property = Links.GetOrCreate(link, _propertyMarker);
61     var container = GetContainer(property);
62     if (_equalityComparer.Equals(container, default))
63     {
64         Links.GetOrCreate(property, value);
65     }
66     else
67     {
68         Links.Update(container, property, value);
69     }
70 }
71 }

```

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

```

1  using System;
2  using System.Text;
3  using System.Collections.Generic;
4  using System.Runtime.CompilerServices;
5  using Platform.Collections.Methods.Trees;
6  using Platform.Numbers;
7  using static System.Runtime.CompilerServices.Unsafe;
8
9  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
10
11 namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
12 {
13     public unsafe abstract class LinksAvlBalancedTreeMethodsBase<TLink> :
14         ↳ SizedAndThreadedAVLBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
15     {
16         protected readonly TLink Break;
17         protected readonly TLink Continue;
18         protected readonly byte* Links;
19         protected readonly byte* Header;
20
21         public LinksAvlBalancedTreeMethodsBase(LinksConstants<TLink> constants, byte* links,
22             ↳ byte* header)
23         {
24             Links = links;
25             Header = header;
26             Break = constants.Break;
27             Continue = constants.Continue;
28
29             [MethodImpl(MethodImplOptions.AggressiveInlining)]
30             protected abstract TLink GetTreeRoot();
31
32             [MethodImpl(MethodImplOptions.AggressiveInlining)]
33             protected abstract TLink GetBasePartValue(TLink link);
34
35             [MethodImpl(MethodImplOptions.AggressiveInlining)]
36             protected abstract bool FirstIsToTheRightOfSecond(TLink source, TLink target, TLink
37                 ↳ rootSource, TLink rootTarget);
38
39             [MethodImpl(MethodImplOptions.AggressiveInlining)]
40             protected abstract bool FirstIsToTheLeftOfSecond(TLink source, TLink target, TLink
41                 ↳ rootSource, TLink rootTarget);

```

```

39 [MethodImpl(MethodImplOptions.AggressiveInlining)]
40 protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
41     ↳ AsRef<LinksHeader<TLink>>(Header);
42
43 [MethodImpl(MethodImplOptions.AggressiveInlining)]
44 protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
45     ↳ AsRef<RawLink<TLink>>(Links + (RawLink<TLink>.SizeInBytes * (Integer<TLink>)link));
46
47 [MethodImpl(MethodImplOptions.AggressiveInlining)]
48 protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
49 {
50     ref var link = ref GetLinkReference(linkIndex);
51     return new Link<TLink>(linkIndex, link.Source, link.Target);
52 }
53
54 [MethodImpl(MethodImplOptions.AggressiveInlining)]
55 protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
56 {
57     ref var firstLink = ref GetLinkReference(first);
58     ref var secondLink = ref GetLinkReference(second);
59     return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
60     ↳ secondLink.Source, secondLink.Target);
61 }
62
63 [MethodImpl(MethodImplOptions.AggressiveInlining)]
64 protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
65 {
66     ref var firstLink = ref GetLinkReference(first);
67     ref var secondLink = ref GetLinkReference(second);
68     return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
69     ↳ secondLink.Source, secondLink.Target);
70 }
71
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 protected virtual TLink GetSizeValue(TLink value) => Bit<TLink>.PartialRead(value, 5,
74     ↳ -5);
75
76 [MethodImpl(MethodImplOptions.AggressiveInlining)]
77 protected virtual void SetSizeValue(ref TLink storedValue, TLink size) => storedValue =
78     ↳ Bit<TLink>.PartialWrite(storedValue, size, 5, -5);
79
80 [MethodImpl(MethodImplOptions.AggressiveInlining)]
81 protected virtual bool GetLeftIsChildValue(TLink value)
82 {
83     unchecked
84     {
85         //return (Integer<TLink>)Bit<TLink>.PartialRead(previousValue, 4, 1);
86         return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 4, 1), default);
87     }
88 }
89
90 [MethodImpl(MethodImplOptions.AggressiveInlining)]
91 protected virtual void SetLeftIsChildValue(ref TLink storedValue, bool value)
92 {
93     unchecked
94     {
95         var previousValue = storedValue;
96         var modified = Bit<TLink>.PartialWrite(previousValue, (Integer<TLink>)value, 4,
97         ↳ 1);
98         storedValue = modified;
99     }
100 }
101
102 [MethodImpl(MethodImplOptions.AggressiveInlining)]
103 protected virtual bool GetRightIsChildValue(TLink value)
104 {
105     unchecked
106     {
107         //return (Integer<TLink>)Bit<TLink>.PartialRead(previousValue, 3, 1);
108         return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 3, 1), default);
109     }
110 }
111
112 [MethodImpl(MethodImplOptions.AggressiveInlining)]
113 protected virtual void SetRightIsChildValue(ref TLink storedValue, bool value)
114 {
115     unchecked

```

```

110     {
111         var previousValue = storedValue;
112         var modified = Bit<TLink>.PartialWrite(previousValue, (Integer<TLink>)value, 3,
            ↪ 1);
113         storedValue = modified;
114     }
115 }
116
117 [MethodImpl(MethodImplOptions.AggressiveInlining)]
118 protected bool IsChild(TLink parent, TLink possibleChild)
119 {
120     var parentSize = GetSize(parent);
121     var childSize = GetSizeOrZero(possibleChild);
122     return GreaterThanZero(childSize) && LessOrEqualThan(childSize, parentSize);
123 }
124
125 [MethodImpl(MethodImplOptions.AggressiveInlining)]
126 protected virtual sbyte GetBalanceValue(TLink storedValue)
127 {
128     unchecked
129     {
130         var value = (int)(Integer<TLink>)Bit<TLink>.PartialRead(storedValue, 0, 3);
131         value |= 0xF8 * ((value & 4) >> 2); // if negative, then continue ones to the
            ↪ end of sbyte
132         return (sbyte)value;
133     }
134 }
135
136 [MethodImpl(MethodImplOptions.AggressiveInlining)]
137 protected virtual void SetBalanceValue(ref TLink storedValue, sbyte value)
138 {
139     unchecked
140     {
141         var packagedValue = (TLink)(Integer<TLink>)((byte)value >> 5 & 4 | value & 3);
142         var modified = Bit<TLink>.PartialWrite(storedValue, packagedValue, 0, 3);
143         storedValue = modified;
144     }
145 }
146
147 public TLink this[TLink index]
148 {
149     get
150     {
151         var root = GetTreeRoot();
152         if (GreaterOrEqualThan(index, GetSize(root)))
153         {
154             return Zero;
155         }
156         while (!EqualToZero(root))
157         {
158             var left = GetLeftOrDefault(root);
159             var leftSize = GetSizeOrZero(left);
160             if (LessThan(index, leftSize))
161             {
162                 root = left;
163                 continue;
164             }
165             if (AreEqual(index, leftSize))
166             {
167                 return root;
168             }
169             root = GetRightOrDefault(root);
170             index = Subtract(index, Increment(leftSize));
171         }
172         return Zero; // TODO: Impossible situation exception (only if tree structure
            ↪ broken)
173     }
174 }
175
176 /// <summary>
177 /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
178 ↪ (концом).
179 /// </summary>
180 /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
181 /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
182 /// <returns>Индекс искомой связи.</returns>
183 public TLink Search(TLink source, TLink target)
184 {
185     var root = GetTreeRoot();

```

```

185 while (!EqualToZero(root))
186 {
187     ref var rootLink = ref GetLinkReference(root);
188     var rootSource = rootLink.Source;
189     var rootTarget = rootLink.Target;
190     if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
191         ↪ node.Key < root.Key
192     {
193         root = GetLeftOrDefault(root);
194     }
195     else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget)) //
196         ↪ node.Key > root.Key
197     {
198         root = GetRightOrDefault(root);
199     }
200     else // node.Key == root.Key
201     {
202         return root;
203     }
204 }
205 return Zero;
206 }
207 // TODO: Return indices range instead of references count
208 public TLink CountUsages(TLink link)
209 {
210     var root = GetTreeRoot();
211     var total = GetSize(root);
212     var totalRightIgnore = Zero;
213     while (!EqualToZero(root))
214     {
215         var @base = GetBasePartValue(root);
216         if (LessOrEqualThan(@base, link))
217         {
218             root = GetRightOrDefault(root);
219         }
220         else
221         {
222             totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
223             root = GetLeftOrDefault(root);
224         }
225     }
226     root = GetTreeRoot();
227     var totalLeftIgnore = Zero;
228     while (!EqualToZero(root))
229     {
230         var @base = GetBasePartValue(root);
231         if (GreaterOrEqualThan(@base, link))
232         {
233             root = GetLeftOrDefault(root);
234         }
235         else
236         {
237             totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
238             root = GetRightOrDefault(root);
239         }
240     }
241     return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
242 }
243
244 public TLink EachUsage(TLink link, Func<IList<TLink>, TLink> handler)
245 {
246     var root = GetTreeRoot();
247     if (EqualToZero(root))
248     {
249         return Continue;
250     }
251     TLink first = Zero, current = root;
252     while (!EqualToZero(current))
253     {
254         var @base = GetBasePartValue(current);
255         if (GreaterOrEqualThan(@base, link))
256         {
257             if (AreEqual(@base, link))
258             {
259                 first = current;
260             }
261             current = GetLeftOrDefault(current);

```

```

262     }
263     else
264     {
265         current = GetRightOrDefault(current);
266     }
267 }
268 if (!EqualToZero(first))
269 {
270     current = first;
271     while (true)
272     {
273         if (AreEqual(handler(GetLinkValues(current)), Break))
274         {
275             return Break;
276         }
277         current = GetNext(current);
278         if (EqualToZero(current) || !AreEqual(GetBasePartValue(current), link))
279         {
280             break;
281         }
282     }
283 }
284 return Continue;
285 }
286
287 protected override void PrintNodeValue(TLink node, StringBuilder sb)
288 {
289     ref var link = ref GetLinkReference(node);
290     sb.Append(' ');
291     sb.Append(link.Source);
292     sb.Append('-');
293     sb.Append('>');
294     sb.Append(link.Target);
295 }
296 }
297 }

```

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

```

1  using System;
2  using System.Text;
3  using System.Collections.Generic;
4  using System.Runtime.CompilerServices;
5  using Platform.Collections.Methods.Trees;
6  using Platform.Numbers;
7  using static System.Runtime.CompilerServices.Unsafe;
8
9  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
10
11 namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
12 {
13     public unsafe abstract class LinksSizeBalancedTreeMethodsBase<TLink> :
14         ↳ SizeBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
15     {
16         protected readonly TLink Break;
17         protected readonly TLink Continue;
18         protected readonly byte* Links;
19         protected readonly byte* Header;
20
21         public LinksSizeBalancedTreeMethodsBase(LinksConstants<TLink> constants, byte* links,
22             ↳ byte* header)
23         {
24             Links = links;
25             Header = header;
26             Break = constants.Break;
27             Continue = constants.Continue;
28         }
29
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]
31         protected abstract TLink GetTreeRoot();
32
33         [MethodImpl(MethodImplOptions.AggressiveInlining)]
34         protected abstract TLink GetBasePartValue(TLink link);
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected abstract bool FirstIsToTheRightOfSecond(TLink source, TLink target, TLink
38             ↳ rootSource, TLink rootTarget);
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         protected abstract bool FirstIsToTheLeftOfSecond(TLink source, TLink target, TLink
42             ↳ rootSource, TLink rootTarget);
43     }
44 }

```

```

39 [MethodImpl(MethodImplOptions.AggressiveInlining)]
40 protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
41     ↳ AsRef<LinksHeader<TLink>>(Header);
42
43 [MethodImpl(MethodImplOptions.AggressiveInlining)]
44 protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
45     ↳ AsRef<RawLink<TLink>>(Links + (RawLink<TLink>.SizeInBytes * (Integer<TLink>)link));
46
47 [MethodImpl(MethodImplOptions.AggressiveInlining)]
48 protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
49 {
50     ref var link = ref GetLinkReference(linkIndex);
51     return new Link<TLink>(linkIndex, link.Source, link.Target);
52 }
53
54 [MethodImpl(MethodImplOptions.AggressiveInlining)]
55 protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
56 {
57     ref var firstLink = ref GetLinkReference(first);
58     ref var secondLink = ref GetLinkReference(second);
59     return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
60     ↳ secondLink.Source, secondLink.Target);
61 }
62
63 [MethodImpl(MethodImplOptions.AggressiveInlining)]
64 protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
65 {
66     ref var firstLink = ref GetLinkReference(first);
67     ref var secondLink = ref GetLinkReference(second);
68     return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
69     ↳ secondLink.Source, secondLink.Target);
70 }
71
72 public TLink this[TLink index]
73 {
74     get
75     {
76         var root = GetTreeRoot();
77         if (GreaterOrEqualThan(index, GetSize(root)))
78         {
79             return Zero;
80         }
81         while (!EqualToZero(root))
82         {
83             var left = GetLeftOrDefault(root);
84             var leftSize = GetSizeOrZero(left);
85             if (LessThan(index, leftSize))
86             {
87                 root = left;
88                 continue;
89             }
90             if (AreEqual(index, leftSize))
91             {
92                 return root;
93             }
94             root = GetRightOrDefault(root);
95             index = Subtract(index, Increment(leftSize));
96         }
97         return Zero; // TODO: Impossible situation exception (only if tree structure
98     ↳ broken)
99     }
100 }
101
102 /// <summary>
103 /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
104 ↳ (концом).
105 /// </summary>
106 /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
107 /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
108 /// <returns>Индекс искомой связи.</returns>
109 public TLink Search(TLink source, TLink target)
110 {
111     var root = GetTreeRoot();
112     while (!EqualToZero(root))
113     {
114         ref var rootLink = ref GetLinkReference(root);
115         var rootSource = rootLink.Source;

```



```

111     var rootTarget = rootLink.Target;
112     if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
113         ↪ node.Key < root.Key
114     {
115         root = GetLeftOrDefault(root);
116     }
117     else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget)) //
118         ↪ node.Key > root.Key
119     {
120         root = GetRightOrDefault(root);
121     }
122     else // node.Key == root.Key
123     {
124         return root;
125     }
126 }
127 return Zero;
128 }
129 // TODO: Return indices range instead of references count
130 public TLink CountUsages(TLink link)
131 {
132     var root = GetTreeRoot();
133     var total = GetSize(root);
134     var totalRightIgnore = Zero;
135     while (!EqualToZero(root))
136     {
137         var @base = GetBasePartValue(root);
138         if (LessOrEqualThan(@base, link))
139         {
140             root = GetRightOrDefault(root);
141         }
142         else
143         {
144             totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
145             root = GetLeftOrDefault(root);
146         }
147     }
148     root = GetTreeRoot();
149     var totalLeftIgnore = Zero;
150     while (!EqualToZero(root))
151     {
152         var @base = GetBasePartValue(root);
153         if (GreaterOrEqualThan(@base, link))
154         {
155             root = GetLeftOrDefault(root);
156         }
157         else
158         {
159             totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
160             root = GetRightOrDefault(root);
161         }
162     }
163     return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
164 }
165
166 [MethodImpl(MethodImplOptions.AggressiveInlining)]
167 public TLink EachUsage(TLink @base, Func<IList<TLink>, TLink> handler) =>
168     ↪ EachUsageCore(@base, GetTreeRoot(), handler);
169
170 // TODO: 1. Move target, handler to separate object. 2. Use stack or walker 3. Use
171     ↪ low-level MSIL stack.
172 private TLink EachUsageCore(TLink @base, TLink link, Func<IList<TLink>, TLink> handler)
173 {
174     var @continue = Continue;
175     if (EqualToZero(link))
176     {
177         return @continue;
178     }
179     var linkBasePart = GetBasePartValue(link);
180     var @break = Break;
181     if (GreaterThan(linkBasePart, @base))
182     {
183         if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
184         {
185             return @break;
186         }
187     }
188 }

```

```

186     else if (LessThan(linkBasePart, @base))
187     {
188         if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
189         {
190             return @break;
191         }
192     }
193     else //if (linkBasePart == @base)
194     {
195         if (AreEqual(handler(GetLinkValues(link)), @break))
196         {
197             return @break;
198         }
199         if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
200         {
201             return @break;
202         }
203         if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
204         {
205             return @break;
206         }
207     }
208     return @continue;
209 }
210
211 protected override void PrintNodeValue(TLink node, StringBuilder sb)
212 {
213     ref var link = ref GetLinkReference(node);
214     sb.Append(' ');
215     sb.Append(link.Source);
216     sb.Append('-');
217     sb.Append('>');
218     sb.Append(link.Target);
219 }
220 }
221 }

```

1.35 ./Platform.Data.Doublets/ResizableDirectMemory/Generic/LinksSourcesAvlBalancedTreeMethods.cs

```

1 using System.Runtime.CompilerServices;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
6 {
7     public unsafe class LinksSourcesAvlBalancedTreeMethods<TLink> :
8     ↪ LinksAvlBalancedTreeMethodsBase<TLink>
9     {
10         public LinksSourcesAvlBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
11         ↪ byte* header) : base(constants, links, header) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         protected unsafe override ref TLink GetLeftReference(TLink node) => ref
15         ↪ GetLinkReference(node).LeftAsSource;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         protected unsafe override ref TLink GetRightReference(TLink node) => ref
19         ↪ GetLinkReference(node).RightAsSource;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsSource;
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsSource;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected override void SetLeft(TLink node, TLink left) =>
29         ↪ GetLinkReference(node).LeftAsSource = left;
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected override void SetRight(TLink node, TLink right) =>
33         ↪ GetLinkReference(node).RightAsSource = right;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override TLink GetSize(TLink node) =>
37         ↪ GetSizeValue(GetLinkReference(node).SizeAsSource);
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override void SetSize(TLink node, TLink size) => SetSizeValue(ref
41         ↪ GetLinkReference(node).SizeAsSource, size);
42     }
43 }

```

```

34 [MethodImpl(MethodImplOptions.AggressiveInlining)]
35 protected override bool GetLeftIsChild(TLink node) =>
36     ↳ GetLeftIsChildValue(GetLinkReference(node).SizeAsSource);
37
38 [MethodImpl(MethodImplOptions.AggressiveInlining)]
39 protected override void SetLeftIsChild(TLink node, bool value) =>
40     ↳ SetLeftIsChildValue(ref GetLinkReference(node).SizeAsSource, value);
41
42 [MethodImpl(MethodImplOptions.AggressiveInlining)]
43 protected override bool GetRightIsChild(TLink node) =>
44     ↳ GetRightIsChildValue(GetLinkReference(node).SizeAsSource);
45
46 [MethodImpl(MethodImplOptions.AggressiveInlining)]
47 protected override void SetRightIsChild(TLink node, bool value) =>
48     ↳ SetRightIsChildValue(ref GetLinkReference(node).SizeAsSource, value);
49
50 [MethodImpl(MethodImplOptions.AggressiveInlining)]
51 protected override sbyte GetBalance(TLink node) =>
52     ↳ GetBalanceValue(GetLinkReference(node).SizeAsSource);
53
54 [MethodImpl(MethodImplOptions.AggressiveInlining)]
55 protected override void SetBalance(TLink node, sbyte value) => SetBalanceValue(ref
56     ↳ GetLinkReference(node).SizeAsSource, value);
57
58 [MethodImpl(MethodImplOptions.AggressiveInlining)]
59 protected override TLink GetTreeRoot() => GetHeaderReference().FirstAsSource;
60
61 [MethodImpl(MethodImplOptions.AggressiveInlining)]
62 protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Source;
63
64 [MethodImpl(MethodImplOptions.AggressiveInlining)]
65 protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
66     ↳ TLink secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) ||
67     ↳ (AreEqual(firstSource, secondSource) && LessThan(firstTarget, secondTarget));
68
69 [MethodImpl(MethodImplOptions.AggressiveInlining)]
70 protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
71     ↳ TLink secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) ||
72     ↳ (AreEqual(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget));
73
74 [MethodImpl(MethodImplOptions.AggressiveInlining)]
75 protected override void ClearNode(TLink node)
76 {
77     ref var link = ref GetLinkReference(node);
78     link.LeftAsSource = Zero;
79     link.RightAsSource = Zero;
80     link.SizeAsSource = Zero;
81 }
82 }
83 }

```

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

```

1 using System.Runtime.CompilerServices;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
6 {
7     public unsafe class LinksSourcesSizeBalancedTreeMethods<TLink> :
8         ↳ LinksSizeBalancedTreeMethodsBase<TLink>
9     {
10         public LinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
11             ↳ byte* header) : base(constants, links, header) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         protected unsafe override ref TLink GetLeftReference(TLink node) => ref
15             ↳ GetLinkReference(node).LeftAsSource;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         protected unsafe override ref TLink GetRightReference(TLink node) => ref
19             ↳ GetLinkReference(node).RightAsSource;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsSource;
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsSource;
26

```

```

22     [MethodImpl(MethodImplOptions.AggressiveInlining)]
23     protected override void SetLeft(TLink node, TLink left) =>
24         ↳ GetLinkReference(node).LeftAsSource = left;
25
26     [MethodImpl(MethodImplOptions.AggressiveInlining)]
27     protected override void SetRight(TLink node, TLink right) =>
28         ↳ GetLinkReference(node).RightAsSource = right;
29
30     [MethodImpl(MethodImplOptions.AggressiveInlining)]
31     protected override TLink GetSize(TLink node) => GetLinkReference(node).SizeAsSource;
32
33     [MethodImpl(MethodImplOptions.AggressiveInlining)]
34     protected override void SetSize(TLink node, TLink size) =>
35         ↳ GetLinkReference(node).SizeAsSource = size;
36
37     [MethodImpl(MethodImplOptions.AggressiveInlining)]
38     protected override TLink GetTreeRoot() => GetHeaderReference().FirstAsSource;
39
40     [MethodImpl(MethodImplOptions.AggressiveInlining)]
41     protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Source;
42
43     [MethodImpl(MethodImplOptions.AggressiveInlining)]
44     protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
45         ↳ TLink secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) ||
46         ↳ (AreEqual(firstSource, secondSource) && LessThan(firstTarget, secondTarget));
47
48     [MethodImpl(MethodImplOptions.AggressiveInlining)]
49     protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
50         ↳ TLink secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) ||
51         ↳ (AreEqual(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget));
52
53     [MethodImpl(MethodImplOptions.AggressiveInlining)]
54     protected override void ClearNode(TLink node)
55     {
56         ref var link = ref GetLinkReference(node);
57         link.LeftAsSource = Zero;
58         link.RightAsSource = Zero;
59         link.SizeAsSource = Zero;
60     }
61 }
62 }

```

1.37 ./Platform.Data.Doublets/ResizableDirectMemory/Generic/LinksTargetsAvlBalancedTreeMethods.cs

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
6  {
7      public unsafe class LinksTargetsAvlBalancedTreeMethods<TLink> :
8          ↳ LinksAvlBalancedTreeMethodsBase<TLink>
9      {
10         public LinksTargetsAvlBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
11             ↳ byte* header) : base(constants, links, header) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         protected unsafe override ref TLink GetLeftReference(TLink node) => ref
15             ↳ GetLinkReference(node).LeftAsTarget;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         protected unsafe override ref TLink GetRightReference(TLink node) => ref
19             ↳ GetLinkReference(node).RightAsTarget;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsTarget;
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsTarget;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected override void SetLeft(TLink node, TLink left) =>
29             ↳ GetLinkReference(node).LeftAsTarget = left;
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected override void SetRight(TLink node, TLink right) =>
33             ↳ GetLinkReference(node).RightAsTarget = right;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

30     protected override TLink GetSize(TLink node) =>
31         ↪ GetSizeValue(GetLinkReference(node).SizeAsTarget);
32
33     [MethodImpl(MethodImplOptions.AggressiveInlining)]
34     protected override void SetSize(TLink node, TLink size) => SetSizeValue(ref
35         ↪ GetLinkReference(node).SizeAsTarget, size);
36
37     [MethodImpl(MethodImplOptions.AggressiveInlining)]
38     protected override bool GetLeftIsChild(TLink node) =>
39         ↪ GetLeftIsChildValue(GetLinkReference(node).SizeAsTarget);
40
41     [MethodImpl(MethodImplOptions.AggressiveInlining)]
42     protected override void SetLeftIsChild(TLink node, bool value) =>
43         ↪ SetLeftIsChildValue(ref GetLinkReference(node).SizeAsTarget, value);
44
45     [MethodImpl(MethodImplOptions.AggressiveInlining)]
46     protected override bool GetRightIsChild(TLink node) =>
47         ↪ GetRightIsChildValue(GetLinkReference(node).SizeAsTarget);
48
49     [MethodImpl(MethodImplOptions.AggressiveInlining)]
50     protected override void SetRightIsChild(TLink node, bool value) =>
51         ↪ SetRightIsChildValue(ref GetLinkReference(node).SizeAsTarget, value);
52
53     [MethodImpl(MethodImplOptions.AggressiveInlining)]
54     protected override sbyte GetBalance(TLink node) =>
55         ↪ GetBalanceValue(GetLinkReference(node).SizeAsTarget);
56
57     [MethodImpl(MethodImplOptions.AggressiveInlining)]
58     protected override void SetBalance(TLink node, sbyte value) => SetBalanceValue(ref
59         ↪ GetLinkReference(node).SizeAsTarget, value);
60
61     [MethodImpl(MethodImplOptions.AggressiveInlining)]
62     protected override TLink GetTreeRoot() => GetHeaderReference().FirstAsTarget;
63
64     [MethodImpl(MethodImplOptions.AggressiveInlining)]
65     protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Target;
66
67     [MethodImpl(MethodImplOptions.AggressiveInlining)]
68     protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
69         ↪ TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
70         ↪ (AreEqual(firstTarget, secondTarget) && LessThan(firstSource, secondSource));
71
72     [MethodImpl(MethodImplOptions.AggressiveInlining)]
73     protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
74         ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
75         ↪ (AreEqual(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource));
76
77     [MethodImpl(MethodImplOptions.AggressiveInlining)]
78     protected override void ClearNode(TLink node)
79     {
80         ref var link = ref GetLinkReference(node);
81         link.LeftAsTarget = Zero;
82         link.RightAsTarget = Zero;
83         link.SizeAsTarget = Zero;
84     }
85 }

```

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

```

1     using System.Runtime.CompilerServices;
2
3     #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5     namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
6     {
7         public unsafe class LinksTargetsSizeBalancedTreeMethods<TLink> :
8             ↪ LinksSizeBalancedTreeMethodsBase<TLink>
9         {
10             public LinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
11                 ↪ byte* header) : base(constants, links, header) { }
12
13             [MethodImpl(MethodImplOptions.AggressiveInlining)]
14             protected unsafe override ref TLink GetLeftReference(TLink node) => ref
15                 ↪ GetLinkReference(node).LeftAsTarget;
16
17             [MethodImpl(MethodImplOptions.AggressiveInlining)]
18             protected unsafe override ref TLink GetRightReference(TLink node) => ref
19                 ↪ GetLinkReference(node).RightAsTarget;
20
21             [MethodImpl(MethodImplOptions.AggressiveInlining)]
22             protected unsafe override void SetLeftReference(TLink node, ref TLink value) =>
23                 ↪ SetLeftReferenceValue(ref GetLinkReference(node).LeftAsTarget, value);
24
25             [MethodImpl(MethodImplOptions.AggressiveInlining)]
26             protected unsafe override void SetRightReference(TLink node, ref TLink value) =>
27                 ↪ SetRightReferenceValue(ref GetLinkReference(node).RightAsTarget, value);
28
29             [MethodImpl(MethodImplOptions.AggressiveInlining)]
30             protected unsafe override void ClearNode(TLink node)
31             {
32                 ref var link = ref GetLinkReference(node);
33                 link.LeftAsTarget = Zero;
34                 link.RightAsTarget = Zero;
35                 link.SizeAsTarget = Zero;
36             }
37         }
38     }

```

```

16
17     [MethodImpl(MethodImplOptions.AggressiveInlining)]
18     protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsTarget;
19
20     [MethodImpl(MethodImplOptions.AggressiveInlining)]
21     protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsTarget;
22
23     [MethodImpl(MethodImplOptions.AggressiveInlining)]
24     protected override void SetLeft(TLink node, TLink left) =>
25         ↪ GetLinkReference(node).LeftAsTarget = left;
26
27     [MethodImpl(MethodImplOptions.AggressiveInlining)]
28     protected override void SetRight(TLink node, TLink right) =>
29         ↪ GetLinkReference(node).RightAsTarget = right;
30
31     [MethodImpl(MethodImplOptions.AggressiveInlining)]
32     protected override TLink GetSize(TLink node) => GetLinkReference(node).SizeAsTarget;
33
34     [MethodImpl(MethodImplOptions.AggressiveInlining)]
35     protected override void SetSize(TLink node, TLink size) =>
36         ↪ GetLinkReference(node).SizeAsTarget = size;
37
38     [MethodImpl(MethodImplOptions.AggressiveInlining)]
39     protected override TLink GetTreeRoot() => GetHeaderReference().FirstAsTarget;
40
41     [MethodImpl(MethodImplOptions.AggressiveInlining)]
42     protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
43         ↪ TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
44         ↪ (AreEqual(firstTarget, secondTarget) && LessThan(firstSource, secondSource));
45
46     [MethodImpl(MethodImplOptions.AggressiveInlining)]
47     protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
48         ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
49         ↪ (AreEqual(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource));
50
51     [MethodImpl(MethodImplOptions.AggressiveInlining)]
52     protected override void ClearNode(TLink node)
53     {
54         ref var link = ref GetLinkReference(node);
55         link.LeftAsTarget = Zero;
56         link.RightAsTarget = Zero;
57         link.SizeAsTarget = Zero;
58     }
59 }

```

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

```

1  using System;
2  using System.Runtime.CompilerServices;
3  using Platform.Singletons;
4  using Platform.Numbers;
5  using Platform.Memory;
6  using static System.Runtime.CompilerServices.Unsafe;
7
8  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
11 {
12     public unsafe partial class ResizableDirectMemoryLinks<TLink> :
13         ↪ ResizableDirectMemoryLinksBase<TLink>
14     {
15         private readonly Func<ILinksTreeMethods<TLink>> _createSourceTreeMethods;
16         private readonly Func<ILinksTreeMethods<TLink>> _createTargetTreeMethods;
17         private byte* _header;
18         private byte* _links;
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         public ResizableDirectMemoryLinks(string address) : this(address, DefaultLinksSizeStep)
22             ↪ { }
23
24         /// <summary>
25         /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
26         ↪ минимальным шагом расширения базы данных.
27         /// </summary>
28         /// <param name="address">Полный путь к файлу базы данных.</param>
29         /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
30         ↪ байтах.</param>

```

```

27 [MethodImpl(MethodImplOptions.AggressiveInlining)]
28 public ResizableDirectMemoryLinks(string address, long memoryReservationStep) : this(new
    ↳ FileMappedResizableDirectMemory(address, memoryReservationStep),
    ↳ memoryReservationStep) { }
29
30 [MethodImpl(MethodImplOptions.AggressiveInlining)]
31 public ResizableDirectMemoryLinks(IResizableDirectMemory memory) : this(memory,
    ↳ DefaultLinksSizeStep) { }
32
33 [MethodImpl(MethodImplOptions.AggressiveInlining)]
34 public ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
    ↳ memoryReservationStep) : this(memory, memoryReservationStep,
    ↳ Default<LinksConstants<TLink>>.Instance, true) { }
35
36 [MethodImpl(MethodImplOptions.AggressiveInlining)]
37 public ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
    ↳ memoryReservationStep, LinksConstants<TLink> constants, bool useAvlBasedIndex) :
    ↳ base(memory, memoryReservationStep, constants)
38 {
39     if (useAvlBasedIndex)
40     {
41         _createSourceTreeMethods = () => new
            ↳ LinksSourcesAvlBalancedTreeMethods<TLink>(Constants, _links, _header);
42         _createTargetTreeMethods = () => new
            ↳ LinksTargetsAvlBalancedTreeMethods<TLink>(Constants, _links, _header);
43     }
44     else
45     {
46         _createSourceTreeMethods = () => new
            ↳ LinksSourcesSizeBalancedTreeMethods<TLink>(Constants, _links, _header);
47         _createTargetTreeMethods = () => new
            ↳ LinksTargetsSizeBalancedTreeMethods<TLink>(Constants, _links, _header);
48     }
49     Init(memory, memoryReservationStep);
50 }
51
52 [MethodImpl(MethodImplOptions.AggressiveInlining)]
53 protected override void SetPointers(IResizableDirectMemory memory)
54 {
55     _links = (byte*)memory.Pointer;
56     _header = _links;
57     SourcesTreeMethods = _createSourceTreeMethods();
58     TargetsTreeMethods = _createTargetTreeMethods();
59     UnusedLinksListMethods = new UnusedLinksListMethods<TLink>(_links, _header);
60 }
61
62 [MethodImpl(MethodImplOptions.AggressiveInlining)]
63 protected override void ResetPointers()
64 {
65     base.ResetPointers();
66     _links = null;
67     _header = null;
68 }
69
70 [MethodImpl(MethodImplOptions.AggressiveInlining)]
71 protected override ref LinksHeader<TLink> GetHeaderReference() => ref
    ↳ AsRef<LinksHeader<TLink>>(_header);
72
73 [MethodImpl(MethodImplOptions.AggressiveInlining)]
74 protected override ref RawLink<TLink> GetLinkReference(TLink linkIndex) => ref
    ↳ AsRef<RawLink<TLink>>(_links + (LinkSizeInBytes * (Integer<TLink>)linkIndex));
75 }
76 }

```

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

```

1 using System;
2 using System.Collections.Generic;
3 using System.Runtime.CompilerServices;
4 using Platform.Disposables;
5 using Platform.Singletons;
6 using Platform.Numbers;
7 using Platform.Memory;
8 using Platform.Data.Exceptions;
9
10 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
11 namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
12 {
13

```

```

14 public abstract class ResizableDirectMemoryLinksBase<TLink> : DisposableBase, ILinks<TLink>
15 {
16     protected static readonly EqualityComparer<TLink> EqualityComparer =
17         ↳ EqualityComparer<TLink>.Default;
18     protected static readonly Comparer<TLink> Comparer = Comparer<TLink>.Default;
19
20     /// <summary>Возвращает размер одной связи в байтах.</summary>
21     /// <remarks>
22     ///     Используется только во вне класса, не рекомендуется использовать внутри.
23     ///     Так как во вне не обязательно будет доступен unsafe C#.
24     /// </remarks>
25     public static readonly long LinkSizeInBytes = RawLink<TLink>.SizeInBytes;
26
27     public static readonly long LinkHeaderSizeInBytes = LinksHeader<TLink>.SizeInBytes;
28
29     public static readonly long DefaultLinksSizeStep = LinkSizeInBytes * 1024 * 1024;
30
31     protected readonly IResizableDirectMemory _memory;
32     protected readonly long _memoryReservationStep;
33
34     protected ILinksTreeMethods<TLink> TargetsTreeMethods;
35     protected ILinksTreeMethods<TLink> SourcesTreeMethods;
36     // TODO: Возможно чтобы гарантированно проверять на то, является ли связь удалённой,
37     // ↳ нужно использовать не список а дерево, так как так можно быстрее проверить на
38     // ↳ наличие связи внутри
39     protected ILinksListMethods<TLink> UnusedLinksListMethods;
40
41     /// <summary>
42     ///     Возвращает общее число связей находящихся в хранилище.
43     /// </summary>
44     protected virtual TLink Total
45     {
46         get
47         {
48             ref var header = ref GetHeaderReference();
49             return Subtract(header.AllocatedLinks, header.FreeLinks);
50         }
51     }
52
53     public virtual LinksConstants<TLink> Constants { get; }
54
55     [MethodImpl(MethodImplOptions.AggressiveInlining)]
56     public ResizableDirectMemoryLinksBase(IResizableDirectMemory memory, long
57         ↳ memoryReservationStep, LinksConstants<TLink> constants)
58     {
59         _memory = memory;
60         _memoryReservationStep = memoryReservationStep;
61         Constants = constants;
62     }
63
64     [MethodImpl(MethodImplOptions.AggressiveInlining)]
65     public ResizableDirectMemoryLinksBase(IResizableDirectMemory memory, long
66         ↳ memoryReservationStep) : this(memory, memoryReservationStep,
67         ↳ Default<LinksConstants<TLink>>.Instance) { }
68
69     protected virtual void Init(IResizableDirectMemory memory, long memoryReservationStep)
70     {
71         if (memory.ReservedCapacity < memoryReservationStep)
72         {
73             memory.ReservedCapacity = memoryReservationStep;
74         }
75         SetPointers(_memory);
76         ref var header = ref GetHeaderReference();
77         // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
78         _memory.UsedCapacity = (ConvertToUInt64(header.AllocatedLinks) * LinkSizeInBytes) +
79         ↳ LinkHeaderSizeInBytes;
80         // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
81         header.ReservedLinks = ConvertToAddress((_memory.ReservedCapacity -
82         ↳ LinkHeaderSizeInBytes) / LinkSizeInBytes);
83     }
84
85     [MethodImpl(MethodImplOptions.AggressiveInlining)]
86     public virtual TLink Count(IList<TLink> restrictions)
87     {
88         // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
89         if (restrictions.Count == 0)
90         {
91             return Total;
92         }
93         var constants = Constants;
94     }
95

```



```

86 var any = constants.Any;
87 var index = restrictions[constants.IndexPart];
88 if (restrictions.Count == 1)
89 {
90     if (AreEqual(index, any))
91     {
92         return Total;
93     }
94     return Exists(index) ? GetOne() : GetZero();
95 }
96 if (restrictions.Count == 2)
97 {
98     var value = restrictions[1];
99     if (AreEqual(index, any))
100     {
101         if (AreEqual(value, any))
102         {
103             return Total; // Any - как отсутствие ограничения
104         }
105         return Add(SourcesTreeMethods.CountUsages(value),
106             ↪ TargetsTreeMethods.CountUsages(value));
107     }
108     else
109     {
110         if (!Exists(index))
111         {
112             return GetZero();
113         }
114         if (AreEqual(value, any))
115         {
116             return GetOne();
117         }
118         ref var storedLinkValue = ref GetLinkReference(index);
119         if (AreEqual(storedLinkValue.Source, value) ||
120             ↪ AreEqual(storedLinkValue.Target, value))
121         {
122             return GetOne();
123         }
124         return GetZero();
125     }
126 }
127 if (restrictions.Count == 3)
128 {
129     var source = restrictions[constants.SourcePart];
130     var target = restrictions[constants.TargetPart];
131     if (AreEqual(index, any))
132     {
133         if (AreEqual(source, any) && AreEqual(target, any))
134         {
135             return Total;
136         }
137         else if (AreEqual(source, any))
138         {
139             return TargetsTreeMethods.CountUsages(target);
140         }
141         else if (AreEqual(target, any))
142         {
143             return SourcesTreeMethods.CountUsages(source);
144         }
145         else //if(source != Any && target != Any)
146         {
147             // Эквивалент Exists(source, target) => Count(Any, source, target) > 0
148             var link = SourcesTreeMethods.Search(source, target);
149             return AreEqual(link, constants.Null) ? GetZero() : GetOne();
150         }
151     }
152     else
153     {
154         if (!Exists(index))
155         {
156             return GetZero();
157         }
158         if (AreEqual(source, any) && AreEqual(target, any))
159         {
160             return GetOne();
161         }
162         ref var storedLinkValue = ref GetLinkReference(index);
163         if (!AreEqual(source, any) && !AreEqual(target, any))

```

```

162         {
163             if (AreEqual(storedLinkValue.Source, source) &&
164                 ↪ AreEqual(storedLinkValue.Target, target))
165             {
166                 return GetOne();
167             }
168             return GetZero();
169         }
170         var value = default(TLink);
171         if (AreEqual(source, any))
172         {
173             value = target;
174         }
175         if (AreEqual(target, any))
176         {
177             value = source;
178         }
179         if (AreEqual(storedLinkValue.Source, value) ||
180             ↪ AreEqual(storedLinkValue.Target, value))
181         {
182             return GetOne();
183         }
184         return GetZero();
185     }
186 }
187
188 [MethodImpl(MethodImplOptions.AggressiveInlining)]
189 public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
190 {
191     var constants = Constants;
192     var @break = constants.Break;
193     if (restrictions.Count == 0)
194     {
195         for (var link = GetOne(); LessOrEqualThan(link,
196             ↪ GetHeaderReference().AllocatedLinks); link = Increment(link))
197         {
198             if (Exists(link) && AreEqual(handler(GetLinkStruct(link)), @break))
199             {
200                 return @break;
201             }
202         }
203         return @break;
204     }
205     var @continue = constants.Continue;
206     var any = constants.Any;
207     var index = restrictions[constants.IndexPart];
208     if (restrictions.Count == 1)
209     {
210         if (AreEqual(index, any))
211         {
212             return Each(handler, GetEmptyList());
213         }
214         if (!Exists(index))
215         {
216             return @continue;
217         }
218         return handler(GetLinkStruct(index));
219     }
220     if (restrictions.Count == 2)
221     {
222         var value = restrictions[1];
223         if (AreEqual(index, any))
224         {
225             if (AreEqual(value, any))
226             {
227                 return Each(handler, GetEmptyList());
228             }
229             if (AreEqual(Each(handler, new Link<TLink>(index, value, any)), @break))
230             {
231                 return @break;
232             }
233             return Each(handler, new Link<TLink>(index, any, value));
234         }
235         else
236         {

```

```

236         if (!Exists(index))
237         {
238             return @continue;
239         }
240         if (AreEqual(value, any))
241         {
242             return handler(GetLinkStruct(index));
243         }
244         ref var storedLinkValue = ref GetLinkReference(index);
245         if (AreEqual(storedLinkValue.Source, value) ||
246             AreEqual(storedLinkValue.Target, value))
247         {
248             return handler(GetLinkStruct(index));
249         }
250         return @continue;
251     }
252 }
253 if (restrictions.Count == 3)
254 {
255     var source = restrictions[constants.SourcePart];
256     var target = restrictions[constants.TargetPart];
257     if (AreEqual(index, any))
258     {
259         if (AreEqual(source, any) && AreEqual(target, any))
260         {
261             return Each(handler, GetEmptyList());
262         }
263         else if (AreEqual(source, any))
264         {
265             return TargetsTreeMethods.EachUsage(target, handler);
266         }
267         else if (AreEqual(target, any))
268         {
269             return SourcesTreeMethods.EachUsage(source, handler);
270         }
271         else //if(source != Any && target != Any)
272         {
273             var link = SourcesTreeMethods.Search(source, target);
274             return AreEqual(link, constants.Null) ? @continue :
275                 ↪ handler(GetLinkStruct(link));
276         }
277     }
278     else
279     {
280         if (!Exists(index))
281         {
282             return @continue;
283         }
284         if (AreEqual(source, any) && AreEqual(target, any))
285         {
286             return handler(GetLinkStruct(index));
287         }
288         ref var storedLinkValue = ref GetLinkReference(index);
289         if (!AreEqual(source, any) && !AreEqual(target, any))
290         {
291             if (AreEqual(storedLinkValue.Source, source) &&
292                 AreEqual(storedLinkValue.Target, target))
293             {
294                 return handler(GetLinkStruct(index));
295             }
296             return @continue;
297         }
298         var value = default(TLink);
299         if (AreEqual(source, any))
300         {
301             value = target;
302         }
303         if (AreEqual(target, any))
304         {
305             value = source;
306         }
307         if (AreEqual(storedLinkValue.Source, value) ||
308             AreEqual(storedLinkValue.Target, value))
309         {
310             return handler(GetLinkStruct(index));
311         }
312         return @continue;
313     }
314 }

```

```

313     }
314     throw new NotSupportedException("Другие размеры и способы ограничений не
    ↳ поддерживаются.");
315 }
316
317 /// <remarks>
318 /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
    ↳ в другом месте (но не в менеджере памяти, а в логике Links)
319 /// </remarks>
320 [MethodImpl(MethodImplOptions.AggressiveInlining)]
321 public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
322 {
323     var constants = Constants;
324     var @null = constants.Null;
325     var linkIndex = restrictions[constants.IndexPart];
326     ref var link = ref GetLinkReference(linkIndex);
327     ref var header = ref GetHeaderReference();
328     ref var firstAsSource = ref header.FirstAsSource;
329     ref var firstAsTarget = ref header.FirstAsTarget;
330     // Будет корректно работать только в том случае, если пространство выделенной связи
    ↳ предварительно заполнено нулями
331     if (!AreEqual(link.Source, @null))
332     {
333         SourcesTreeMethods.Detach(ref firstAsSource, linkIndex);
334     }
335     if (!AreEqual(link.Target, @null))
336     {
337         TargetsTreeMethods.Detach(ref firstAsTarget, linkIndex);
338     }
339     link.Source = substitution[constants.SourcePart];
340     link.Target = substitution[constants.TargetPart];
341     if (!AreEqual(link.Source, @null))
342     {
343         SourcesTreeMethods.Attach(ref firstAsSource, linkIndex);
344     }
345     if (!AreEqual(link.Target, @null))
346     {
347         TargetsTreeMethods.Attach(ref firstAsTarget, linkIndex);
348     }
349     return linkIndex;
350 }
351
352 /// <remarks>
353 /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
    ↳ пространство
354 /// </remarks>
355 public virtual TLink Create(IList<TLink> restrictions)
356 {
357     ref var header = ref GetHeaderReference();
358     var freeLink = header.FirstFreeLink;
359     if (!AreEqual(freeLink, Constants.Null))
360     {
361         UnusedLinksListMethods.Detach(freeLink);
362     }
363     else
364     {
365         var maximumPossibleInnerReference = Constants.InternalReferencesRange.Maximum;
366         if (GreaterThan(header.AllocatedLinks, maximumPossibleInnerReference))
367         {
368             throw new LinksLimitReachedException<TLink>(maximumPossibleInnerReference);
369         }
370         if (GreaterOrEqualThan(header.AllocatedLinks, Decrement(header.ReservedLinks)))
371         {
372             _memory.ReservedCapacity += _memory.ReservationStep;
373             SetPointers(_memory);
374             header.ReservedLinks = ConvertToAddress(_memory.ReservedCapacity /
    ↳ LinkSizeInBytes);
375         }
376         header.AllocatedLinks = Increment(header.AllocatedLinks);
377         _memory.UsedCapacity += LinkSizeInBytes;
378         freeLink = header.AllocatedLinks;
379     }
380     return freeLink;
381 }
382
383 [MethodImpl(MethodImplOptions.AggressiveInlining)]
384 public virtual void Delete(IList<TLink> restrictions)
385 {
386     ref var header = ref GetHeaderReference();

```

```

387     var link = restrictions[Constants.IndexPart];
388     if (LessThan(link, header.AllocatedLinks))
389     {
390         UnusedLinksListMethods.AttachAsFirst(link);
391     }
392     else if (AreEqual(link, header.AllocatedLinks))
393     {
394         header.AllocatedLinks = Decrement(header.AllocatedLinks);
395         _memory.UsedCapacity -= LinkSizeInBytes;
396         // Убираем все связи, находящиеся в списке свободных в конце файла, до тех пор,
397         // ↳ пока не дойдём до первой существующей связи
398         // Позволяет оптимизировать количество выделенных связей (AllocatedLinks)
399         while (GreaterThan(header.AllocatedLinks, GetZero()) &&
400             ↳ IsUnusedLink(header.AllocatedLinks))
401         {
402             UnusedLinksListMethods.Detach(header.AllocatedLinks);
403             header.AllocatedLinks = Decrement(header.AllocatedLinks);
404             _memory.UsedCapacity -= LinkSizeInBytes;
405         }
406     }
407 }
408
409 [MethodImpl(MethodImplOptions.AggressiveInlining)]
410 public IList<TLink> GetLinkStruct(TLink linkIndex)
411 {
412     ref var link = ref GetLinkReference(linkIndex);
413     return new Link<TLink>(linkIndex, link.Source, link.Target);
414 }
415
416 /// <remarks>
417 /// TODO: Возможно это должно быть событием, вызываемым из IMemory, в том случае, если
418 /// ↳ адрес реально поменялся
419 ///
420 /// Указатель this.links может быть в том же месте,
421 /// так как 0-я связь не используется и имеет такой же размер как Header,
422 /// поэтому header размещается в том же месте, что и 0-я связь
423 /// </remarks>
424 [MethodImpl(MethodImplOptions.AggressiveInlining)]
425 protected abstract void SetPointers(IResizableDirectMemory memory);
426
427 [MethodImpl(MethodImplOptions.AggressiveInlining)]
428 protected virtual void ResetPointers()
429 {
430     SourcesTreeMethods = null;
431     TargetsTreeMethods = null;
432     UnusedLinksListMethods = null;
433 }
434
435 [MethodImpl(MethodImplOptions.AggressiveInlining)]
436 protected abstract ref LinksHeader<TLink> GetHeaderReference();
437
438 [MethodImpl(MethodImplOptions.AggressiveInlining)]
439 protected abstract ref RawLink<TLink> GetLinkReference(TLink linkIndex);
440
441 [MethodImpl(MethodImplOptions.AggressiveInlining)]
442 protected virtual bool Exists(TLink link)
443 => GreaterOrEqualThan(link, Constants.InternalReferencesRange.Minimum)
444     && LessOrEqualThan(link, GetHeaderReference().AllocatedLinks)
445     && !IsUnusedLink(link);
446
447 [MethodImpl(MethodImplOptions.AggressiveInlining)]
448 protected virtual bool IsUnusedLink(TLink linkIndex)
449 {
450     if (!AreEqual(GetHeaderReference().FirstFreeLink, linkIndex)) // May be this check
451     ↳ is not needed
452     {
453         ref var link = ref GetLinkReference(linkIndex);
454         return AreEqual(link.SizeAsSource, default) && !AreEqual(link.Source, default);
455     }
456     else
457     {
458         return true;
459     }
460 }
461
462 [MethodImpl(MethodImplOptions.AggressiveInlining)]
463 protected virtual TLink GetOne() => Integer<TLink>.One;
464
465 [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

462     protected virtual TLink GetZero() => Integer<TLink>.Zero;
463
464     [MethodImpl(MethodImplOptions.AggressiveInlining)]
465     protected virtual bool AreEqual(TLink first, TLink second) =>
466         ↪ EqualityComparer.Equals(first, second);
467
468     [MethodImpl(MethodImplOptions.AggressiveInlining)]
469     protected virtual bool LessThan(TLink first, TLink second) => Comparer.Compare(first,
470         ↪ second) < 0;
471
472     [MethodImpl(MethodImplOptions.AggressiveInlining)]
473     protected virtual bool LessOrEqualThan(TLink first, TLink second) =>
474         ↪ Comparer.Compare(first, second) <= 0;
475
476     [MethodImpl(MethodImplOptions.AggressiveInlining)]
477     protected virtual bool GreaterThan(TLink first, TLink second) => Comparer.Compare(first,
478         ↪ second) > 0;
479
480     [MethodImpl(MethodImplOptions.AggressiveInlining)]
481     protected virtual long ConvertToInt64(TLink value) => (Integer<TLink>)value;
482
483     [MethodImpl(MethodImplOptions.AggressiveInlining)]
484     protected virtual TLink ConvertToAddress(long value) => (Integer<TLink>)value;
485
486     [MethodImpl(MethodImplOptions.AggressiveInlining)]
487     protected virtual TLink Add(TLink first, TLink second) => Arithmetic<TLink>.Add(first,
488         ↪ second);
489
490     [MethodImpl(MethodImplOptions.AggressiveInlining)]
491     protected virtual TLink Subtract(TLink first, TLink second) =>
492         ↪ Arithmetic<TLink>.Subtract(first, second);
493
494     [MethodImpl(MethodImplOptions.AggressiveInlining)]
495     protected virtual TLink Increment(TLink link) => Arithmetic<TLink>.Increment(link);
496
497     [MethodImpl(MethodImplOptions.AggressiveInlining)]
498     protected virtual TLink Decrement(TLink link) => Arithmetic<TLink>.Decrement(link);
499
500     [MethodImpl(MethodImplOptions.AggressiveInlining)]
501     protected virtual IList<TLink> GetEmptyList() => Array.Empty<TLink>();
502
503     #region Disposable
504
505     protected override bool AllowMultipleDisposeCalls => true;
506
507     protected override void Dispose(bool manual, bool wasDisposed)
508     {
509         if (!wasDisposed)
510         {
511             ResetPointers();
512             _memory.DisposeIfPossible();
513         }
514     }
515
516     #endregion
517 }

```

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

```

1  using System.Runtime.CompilerServices;
2  using Platform.Collections.Methods.Lists;
3  using Platform.Numbers;
4  using static System.Runtime.CompilerServices.Unsafe;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.ResizableDirectMemory.Generic
9  {
10     public unsafe class UnusedLinksListMethods<TLink> : CircularDoublyLinkedListMethods<TLink>,
11         ↪ ILinksListMethods<TLink>
12     {
13         private readonly byte* _links;
14         private readonly byte* _header;
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         public UnusedLinksListMethods(byte* links, byte* header)

```

```

17     {
18         _links = links;
19         _header = header;
20     }
21
22     [MethodImpl(MethodImplOptions.AggressiveInlining)]
23     protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
24         ↳ AsRef<LinksHeader<TLink>>(_header);
25
26     [MethodImpl(MethodImplOptions.AggressiveInlining)]
27     protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
28         ↳ AsRef<RawLink<TLink>>(_links + (RawLink<TLink>.SizeInBytes * (Integer<TLink>)link));
29
30     [MethodImpl(MethodImplOptions.AggressiveInlining)]
31     protected override TLink GetFirst() => GetHeaderReference().FirstFreeLink;
32
33     [MethodImpl(MethodImplOptions.AggressiveInlining)]
34     protected override TLink GetLast() => GetHeaderReference().LastFreeLink;
35
36     [MethodImpl(MethodImplOptions.AggressiveInlining)]
37     protected override TLink GetPrevious(TLink element) => GetLinkReference(element).Source;
38
39     [MethodImpl(MethodImplOptions.AggressiveInlining)]
40     protected override TLink GetNext(TLink element) => GetLinkReference(element).Target;
41
42     [MethodImpl(MethodImplOptions.AggressiveInlining)]
43     protected override TLink GetSize() => GetHeaderReference().FreeLinks;
44
45     [MethodImpl(MethodImplOptions.AggressiveInlining)]
46     protected override void SetFirst(TLink element) => GetHeaderReference().FirstFreeLink =
47         ↳ element;
48
49     [MethodImpl(MethodImplOptions.AggressiveInlining)]
50     protected override void SetLast(TLink element) => GetHeaderReference().LastFreeLink =
51         ↳ element;
52
53     [MethodImpl(MethodImplOptions.AggressiveInlining)]
54     protected override void SetPrevious(TLink element, TLink previous) =>
55         ↳ GetLinkReference(element).Source = previous;
56
57     [MethodImpl(MethodImplOptions.AggressiveInlining)]
58     protected override void SetNext(TLink element, TLink next) =>
59         ↳ GetLinkReference(element).Target = next;
60
61     [MethodImpl(MethodImplOptions.AggressiveInlining)]
62     protected override void SetSize(TLink size) => GetHeaderReference().FreeLinks = size;
63 }

```

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

```

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

```

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

```

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

```

```

1 using Platform.Unsafe;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.ResizableDirectMemory
6 {
7     public struct LinksHeader<TLink>
8     {
9         public static readonly long SizeInBytes = Structure<LinksHeader<TLink>>.Size;
10
11         public TLink AllocatedLinks;
12         public TLink ReservedLinks;
13         public TLink FreeLinks;
14         public TLink FirstFreeLink;
15         public TLink FirstAsSource;
16         public TLink FirstAsTarget;
17         public TLink LastFreeLink;
18         public TLink Reserved8;
19     }
20 }

```

```

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

```

```

1 using System.Runtime.CompilerServices;
2 using Platform.Data.Doublets.ResizableDirectMemory.Generic;
3 using static System.Runtime.CompilerServices.Unsafe;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Data.Doublets.ResizableDirectMemory.Specific
8 {
9     public unsafe abstract class UInt64LinksAvlBalancedTreeMethodsBase :
10         ↳ LinksAvlBalancedTreeMethodsBase<ulong>
11     {
12         protected new readonly RawLink<ulong>* Links;
13         protected new readonly LinksHeader<ulong>* Header;
14
15         public UInt64LinksAvlBalancedTreeMethodsBase(LinksConstants<ulong> constants,
16             ↳ RawLink<ulong>* links, LinksHeader<ulong>* header)
17             : base(constants, (byte*)links, (byte*)header)
18         {
19             Links = links;
20             Header = header;
21         }
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected override ulong GetZero() => OUL;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         protected override bool EqualToZero(ulong value) => value == OUL;
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         protected override bool AreEqual(ulong first, ulong second) => first == second;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override bool GreaterThanZero(ulong value) => value > OUL;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override bool GreaterThan(ulong first, ulong second) => first > second;
37     }
38 }

```



```

35 [MethodImpl(MethodImplOptions.AggressiveInlining)]
36 protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
37
38 [MethodImpl(MethodImplOptions.AggressiveInlining)]
39 protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
40 ↪ always true for ulong
41
42 [MethodImpl(MethodImplOptions.AggressiveInlining)]
43 protected override bool LessOrEqualThanZero(ulong value) => value == 0UL; // value is
44 ↪ always >= 0 for ulong
45
46 [MethodImpl(MethodImplOptions.AggressiveInlining)]
47 protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
48
49 [MethodImpl(MethodImplOptions.AggressiveInlining)]
50 protected override bool LessThanZero(ulong value) => false; // value < 0 is always false
51 ↪ for ulong
52
53 [MethodImpl(MethodImplOptions.AggressiveInlining)]
54 protected override bool LessThan(ulong first, ulong second) => first < second;
55
56 [MethodImpl(MethodImplOptions.AggressiveInlining)]
57 protected override ulong Increment(ulong value) => ++value;
58
59 [MethodImpl(MethodImplOptions.AggressiveInlining)]
60 protected override ulong Decrement(ulong value) => --value;
61
62 [MethodImpl(MethodImplOptions.AggressiveInlining)]
63 protected override ulong Add(ulong first, ulong second) => first + second;
64
65 [MethodImpl(MethodImplOptions.AggressiveInlining)]
66 protected override ulong Subtract(ulong first, ulong second) => first - second;
67
68 [MethodImpl(MethodImplOptions.AggressiveInlining)]
69 protected override bool FirstIsToTheLeftOfSecond(ulong first, ulong second)
70 {
71     ref var firstLink = ref Links[first];
72     ref var secondLink = ref Links[second];
73     return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
74 ↪ secondLink.Source, secondLink.Target);
75 }
76
77 [MethodImpl(MethodImplOptions.AggressiveInlining)]
78 protected override bool FirstIsToTheRightOfSecond(ulong first, ulong second)
79 {
80     ref var firstLink = ref Links[first];
81     ref var secondLink = ref Links[second];
82     return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
83 ↪ secondLink.Source, secondLink.Target);
84 }
85
86 [MethodImpl(MethodImplOptions.AggressiveInlining)]
87 protected override ulong GetSizeValue(ulong value) => unchecked((value & 4294967264UL)
88 ↪ >> 5);
89
90 [MethodImpl(MethodImplOptions.AggressiveInlining)]
91 protected override void SetSizeValue(ref ulong storedValue, ulong size) => storedValue =
92 ↪ unchecked(storedValue & 31UL | (size & 134217727UL) << 5);
93
94 [MethodImpl(MethodImplOptions.AggressiveInlining)]
95 protected override bool GetLeftIsChildValue(ulong value) => unchecked((value & 16UL) >>
96 ↪ 4 == 1UL);
97
98 [MethodImpl(MethodImplOptions.AggressiveInlining)]
99 protected override void SetLeftIsChildValue(ref ulong storedValue, bool value) =>
100 ↪ storedValue = unchecked(storedValue & 4294967279UL | (As<bool, byte>(ref value) &
101 ↪ 1UL) << 4);
102
103 [MethodImpl(MethodImplOptions.AggressiveInlining)]
104 protected override bool GetRightIsChildValue(ulong value) => unchecked((value & 8UL) >>
105 ↪ 3 == 1UL);
106
107 [MethodImpl(MethodImplOptions.AggressiveInlining)]
108 protected override void SetRightIsChildValue(ref ulong storedValue, bool value) =>
109 ↪ storedValue = unchecked(storedValue & 4294967287UL | (As<bool, byte>(ref value) &
110 ↪ 1UL) << 3);

```

```

100 [MethodImpl(MethodImplOptions.AggressiveInlining)]
101 protected override sbyte GetBalanceValue(ulong value) => unchecked((sbyte)(value & 7UL |
    ↳ 0xF8UL * ((value & 4UL) >> 2))); // if negative, then continue ones to the end of
    ↳ sbyte
102
103 [MethodImpl(MethodImplOptions.AggressiveInlining)]
104 protected override void SetBalanceValue(ref ulong storedValue, sbyte value) =>
    ↳ storedValue = unchecked(storedValue & 4294967288UL | (ulong)((byte)value >> 5 & 4 |
    ↳ value & 3) & 7UL);
105
106 [MethodImpl(MethodImplOptions.AggressiveInlining)]
107 protected override ref LinksHeader<ulong> GetHeaderReference() => ref *Header;
108
109 [MethodImpl(MethodImplOptions.AggressiveInlining)]
110 protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref Links[link];
111 }
112 }

```

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

```

1 using System.Runtime.CompilerServices;
2 using Platform.Data.Doublets.ResizableDirectMemory.Generic;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.ResizableDirectMemory.Specific
7 {
8     public unsafe abstract class UInt64LinksSizeBalancedTreeMethodsBase :
9         ↳ LinksSizeBalancedTreeMethodsBase<ulong>
10     {
11         protected new readonly RawLink<ulong>* Links;
12         protected new readonly LinksHeader<ulong>* Header;
13
14         public UInt64LinksSizeBalancedTreeMethodsBase(LinksConstants<ulong> constants,
15             ↳ RawLink<ulong>* links, LinksHeader<ulong>* header)
16             : base(constants, (byte*)links, (byte*)header)
17         {
18             Links = links;
19             Header = header;
20
21             [MethodImpl(MethodImplOptions.AggressiveInlining)]
22             protected override ulong GetZero() => 0UL;
23
24             [MethodImpl(MethodImplOptions.AggressiveInlining)]
25             protected override bool EqualToZero(ulong value) => value == 0UL;
26
27             [MethodImpl(MethodImplOptions.AggressiveInlining)]
28             protected override bool AreEqual(ulong first, ulong second) => first == second;
29
30             [MethodImpl(MethodImplOptions.AggressiveInlining)]
31             protected override bool GreaterThanZero(ulong value) => value > 0UL;
32
33             [MethodImpl(MethodImplOptions.AggressiveInlining)]
34             protected override bool GreaterThan(ulong first, ulong second) => first > second;
35
36             [MethodImpl(MethodImplOptions.AggressiveInlining)]
37             protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
38
39             [MethodImpl(MethodImplOptions.AggressiveInlining)]
40             protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
41             ↳ always true for ulong
42
43             [MethodImpl(MethodImplOptions.AggressiveInlining)]
44             protected override bool LessOrEqualThanZero(ulong value) => value == 0UL; // value is
45             ↳ always >= 0 for ulong
46
47             [MethodImpl(MethodImplOptions.AggressiveInlining)]
48             protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
49
50             [MethodImpl(MethodImplOptions.AggressiveInlining)]
51             protected override bool LessThanZero(ulong value) => false; // value < 0 is always false
52             ↳ for ulong
53
54             [MethodImpl(MethodImplOptions.AggressiveInlining)]
55             protected override bool LessThan(ulong first, ulong second) => first < second;
56
57             [MethodImpl(MethodImplOptions.AggressiveInlining)]
58             protected override ulong Increment(ulong value) => ++value;
59
60             [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

57     protected override ulong Decrement(ulong value) => --value;
58
59     [MethodImpl(MethodImplOptions.AggressiveInlining)]
60     protected override ulong Add(ulong first, ulong second) => first + second;
61
62     [MethodImpl(MethodImplOptions.AggressiveInlining)]
63     protected override ulong Subtract(ulong first, ulong second) => first - second;
64
65     [MethodImpl(MethodImplOptions.AggressiveInlining)]
66     protected override bool FirstIsToTheLeftOfSecond(ulong first, ulong second)
67     {
68         ref var firstLink = ref Links[first];
69         ref var secondLink = ref Links[second];
70         return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
71             ↪ secondLink.Source, secondLink.Target);
72     }
73
74     [MethodImpl(MethodImplOptions.AggressiveInlining)]
75     protected override bool FirstIsToTheRightOfSecond(ulong first, ulong second)
76     {
77         ref var firstLink = ref Links[first];
78         ref var secondLink = ref Links[second];
79         return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
80             ↪ secondLink.Source, secondLink.Target);
81     }
82
83     [MethodImpl(MethodImplOptions.AggressiveInlining)]
84     protected override ref LinksHeader<ulong> GetHeaderReference() => ref *Header;
85
86     [MethodImpl(MethodImplOptions.AggressiveInlining)]
87     protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref Links[link];
88 }

```

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

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.ResizableDirectMemory.Specific
6  {
7      public unsafe class UInt64LinksSourcesAvlBalancedTreeMethods :
8          ↪ UInt64LinksAvlBalancedTreeMethodsBase
9      {
10         public UInt64LinksSourcesAvlBalancedTreeMethods(LinksConstants<ulong> constants,
11             ↪ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
12             ↪ { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected override ref ulong GetLeftReference(ulong node) => ref
16             ↪ Links[node].LeftAsSource;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override ref ulong GetRightReference(ulong node) => ref
20             ↪ Links[node].RightAsSource;
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected override ulong GetLeft(ulong node) => Links[node].LeftAsSource;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected override ulong GetRight(ulong node) => Links[node].RightAsSource;
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsSource =
30             ↪ left;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override void SetRight(ulong node, ulong right) => Links[node].RightAsSource =
34             ↪ right;
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected override ulong GetSize(ulong node) => GetSizeValue(Links[node].SizeAsSource);
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override void SetSize(ulong node, ulong size) => SetSizeValue(ref
41             ↪ Links[node].SizeAsSource, size);
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

36     protected override bool GetLeftIsChild(ulong node) =>
37         ↳ GetLeftIsChildValue(Links[node].SizeAsSource);
38
39     //[MethodImpl(MethodImplOptions.AggressiveInlining)]
40     //protected override bool GetLeftIsChild(ulong node) => IsChild(node, GetLeft(node));
41
42     [MethodImpl(MethodImplOptions.AggressiveInlining)]
43     protected override void SetLeftIsChild(ulong node, bool value) =>
44         ↳ SetLeftIsChildValue(ref Links[node].SizeAsSource, value);
45
46     [MethodImpl(MethodImplOptions.AggressiveInlining)]
47     protected override bool GetRightIsChild(ulong node) =>
48         ↳ GetRightIsChildValue(Links[node].SizeAsSource);
49
50     //[MethodImpl(MethodImplOptions.AggressiveInlining)]
51     //protected override bool GetRightIsChild(ulong node) => IsChild(node, GetRight(node));
52
53     [MethodImpl(MethodImplOptions.AggressiveInlining)]
54     protected override void SetRightIsChild(ulong node, bool value) =>
55         ↳ SetRightIsChildValue(ref Links[node].SizeAsSource, value);
56
57     [MethodImpl(MethodImplOptions.AggressiveInlining)]
58     protected override sbyte GetBalance(ulong node) =>
59         ↳ GetBalanceValue(Links[node].SizeAsSource);
60
61     [MethodImpl(MethodImplOptions.AggressiveInlining)]
62     protected override void SetBalance(ulong node, sbyte value) => SetBalanceValue(ref
63         ↳ Links[node].SizeAsSource, value);
64
65     [MethodImpl(MethodImplOptions.AggressiveInlining)]
66     protected override ulong GetTreeRoot() => Header->FirstAsSource;
67
68     [MethodImpl(MethodImplOptions.AggressiveInlining)]
69     protected override ulong GetBasePartValue(ulong link) => Links[link].Source;
70
71     [MethodImpl(MethodImplOptions.AggressiveInlining)]
72     protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
73         ↳ ulong secondSource, ulong secondTarget)
74         => firstSource < secondSource || (firstSource == secondSource && firstTarget <
75         ↳ secondTarget);
76
77     [MethodImpl(MethodImplOptions.AggressiveInlining)]
78     protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
79         ↳ ulong secondSource, ulong secondTarget)
80         => firstSource > secondSource || (firstSource == secondSource && firstTarget >
81         ↳ secondTarget);
82
83     [MethodImpl(MethodImplOptions.AggressiveInlining)]
84     protected override void ClearNode(ulong node)
85     {
86         ref var link = ref Links[node];
87         link.LeftAsSource = OUL;
88         link.RightAsSource = OUL;
89         link.SizeAsSource = OUL;
90     }
91 }

```

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

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.ResizableDirectMemory.Specific
6  {
7      public unsafe class UInt64LinksSourcesSizeBalancedTreeMethods :
8          ↳ UInt64LinksSizeBalancedTreeMethodsBase
9      {
10         public UInt64LinksSourcesSizeBalancedTreeMethods(LinksConstants<ulong> constants,
11             ↳ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
12             ↳ { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected override ref ulong GetLeftReference(ulong node) => ref
16             ↳ Links[node].LeftAsSource;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override ref ulong GetRightReference(ulong node) => ref
20             ↳ Links[node].RightAsSource;

```

```

16 [MethodImpl(MethodImplOptions.AggressiveInlining)]
17 protected override ulong GetLeft(ulong node) => Links[node].LeftAsSource;
18
19 [MethodImpl(MethodImplOptions.AggressiveInlining)]
20 protected override ulong GetRight(ulong node) => Links[node].RightAsSource;
21
22 [MethodImpl(MethodImplOptions.AggressiveInlining)]
23 protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsSource =
24     ↳ left;
25
26 [MethodImpl(MethodImplOptions.AggressiveInlining)]
27 protected override void SetRight(ulong node, ulong right) => Links[node].RightAsSource =
28     ↳ right;
29
30 [MethodImpl(MethodImplOptions.AggressiveInlining)]
31 protected override ulong GetSize(ulong node) => Links[node].SizeAsSource;
32
33 [MethodImpl(MethodImplOptions.AggressiveInlining)]
34 protected override void SetSize(ulong node, ulong size) => Links[node].SizeAsSource =
35     ↳ size;
36
37 [MethodImpl(MethodImplOptions.AggressiveInlining)]
38 protected override ulong GetTreeRoot() => Header->FirstAsSource;
39
40 [MethodImpl(MethodImplOptions.AggressiveInlining)]
41 protected override ulong GetBasePartValue(ulong link) => Links[link].Source;
42
43 [MethodImpl(MethodImplOptions.AggressiveInlining)]
44 protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
45     ↳ ulong secondSource, ulong secondTarget)
46     => firstSource < secondSource || (firstSource == secondSource && firstTarget <
47     ↳ secondTarget);
48
49 [MethodImpl(MethodImplOptions.AggressiveInlining)]
50 protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
51     ↳ ulong secondSource, ulong secondTarget)
52     => firstSource > secondSource || (firstSource == secondSource && firstTarget >
53     ↳ secondTarget);
54
55 [MethodImpl(MethodImplOptions.AggressiveInlining)]
56 protected override void ClearNode(ulong node)
57 {
58     ref var link = ref Links[node];
59     link.LeftAsSource = OUL;
60     link.RightAsSource = OUL;
61     link.SizeAsSource = OUL;
62 }
63 }
64 }

```

1.50 ./Platform.Data.Doublets/ResizableDirectMemory/Specific/UInt64LinksTargetsAvlBalancedTreeMethods.cs

```

1 using System.Runtime.CompilerServices;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.ResizableDirectMemory.Specific
6 {
7     public unsafe class UInt64LinksTargetsAvlBalancedTreeMethods :
8     ↳ UInt64LinksAvlBalancedTreeMethodsBase
9     {
10         public UInt64LinksTargetsAvlBalancedTreeMethods(LinksConstants<ulong> constants,
11     ↳ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
12     ↳ { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected override ref ulong GetLeftReference(ulong node) => ref
16     ↳ Links[node].LeftAsTarget;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override ref ulong GetRightReference(ulong node) => ref
20     ↳ Links[node].RightAsTarget;
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected override ulong GetLeft(ulong node) => Links[node].LeftAsTarget;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected override ulong GetRight(ulong node) => Links[node].RightAsTarget;
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected override void SetLeft(ulong node, ref ulong left) => Links[node].LeftAsTarget =
30     ↳ ref left;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override void SetRight(ulong node, ref ulong right) => Links[node].RightAsTarget =
34     ↳ ref right;
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected override void SetSize(ulong node, ulong size) => Links[node].SizeAsTarget =
38     ↳ size;
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         protected override void SetTreeRoot(ulong root) => Header->FirstAsTarget =
42     ↳ ref root;
43
44         [MethodImpl(MethodImplOptions.AggressiveInlining)]
45         protected override void SetBasePartValue(ulong link, ulong value) => Links[link].Source =
46     ↳ value;
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         protected override void ClearNode(ulong node)
50         {
51             ref var link = ref Links[node];
52             link.LeftAsSource = OUL;
53             link.RightAsSource = OUL;
54             link.SizeAsSource = OUL;
55         }
56     }
57 }
58 }

```

```

23     [MethodImpl(MethodImplOptions.AggressiveInlining)]
24     protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsTarget =
    ↪ left;
25
26     [MethodImpl(MethodImplOptions.AggressiveInlining)]
27     protected override void SetRight(ulong node, ulong right) => Links[node].RightAsTarget =
    ↪ right;
28
29     [MethodImpl(MethodImplOptions.AggressiveInlining)]
30     protected override ulong GetSize(ulong node) => GetSizeValue(Links[node].SizeAsTarget);
31
32     [MethodImpl(MethodImplOptions.AggressiveInlining)]
33     protected override void SetSize(ulong node, ulong size) => SetSizeValue(ref
    ↪ Links[node].SizeAsTarget, size);
34
35     [MethodImpl(MethodImplOptions.AggressiveInlining)]
36     protected override bool GetLeftIsChild(ulong node) =>
    ↪ GetLeftIsChildValue(Links[node].SizeAsTarget);
37
38     [MethodImpl(MethodImplOptions.AggressiveInlining)]
39     protected override void SetLeftIsChild(ulong node, bool value) =>
    ↪ SetLeftIsChildValue(ref Links[node].SizeAsTarget, value);
40
41     [MethodImpl(MethodImplOptions.AggressiveInlining)]
42     protected override bool GetRightIsChild(ulong node) =>
    ↪ GetRightIsChildValue(Links[node].SizeAsTarget);
43
44     [MethodImpl(MethodImplOptions.AggressiveInlining)]
45     protected override void SetRightIsChild(ulong node, bool value) =>
    ↪ SetRightIsChildValue(ref Links[node].SizeAsTarget, value);
46
47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     protected override sbyte GetBalance(ulong node) =>
    ↪ GetBalanceValue(Links[node].SizeAsTarget);
49
50     [MethodImpl(MethodImplOptions.AggressiveInlining)]
51     protected override void SetBalance(ulong node, sbyte value) => SetBalanceValue(ref
    ↪ Links[node].SizeAsTarget, value);
52
53     [MethodImpl(MethodImplOptions.AggressiveInlining)]
54     protected override ulong GetTreeRoot() => Header->FirstAsTarget;
55
56     [MethodImpl(MethodImplOptions.AggressiveInlining)]
57     protected override ulong GetBasePartValue(ulong link) => Links[link].Target;
58
59     [MethodImpl(MethodImplOptions.AggressiveInlining)]
60     protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
    ↪ ulong secondSource, ulong secondTarget)
61     => firstTarget < secondTarget || (firstTarget == secondTarget && firstSource <
    ↪ secondSource);
62
63     [MethodImpl(MethodImplOptions.AggressiveInlining)]
64     protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
    ↪ ulong secondSource, ulong secondTarget)
65     => firstTarget > secondTarget || (firstTarget == secondTarget && firstSource >
    ↪ secondSource);
66
67     [MethodImpl(MethodImplOptions.AggressiveInlining)]
68     protected override void ClearNode(ulong node)
69     {
70         ref var link = ref Links[node];
71         link.LeftAsTarget = OUL;
72         link.RightAsTarget = OUL;
73         link.SizeAsTarget = OUL;
74     }
75 }
76 }

```

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

```

1 using System.Runtime.CompilerServices;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.ResizableDirectMemory.Specific
6 {
7     public unsafe class UInt64LinksTargetsSizeBalancedTreeMethods :
    ↪ UInt64LinksSizeBalancedTreeMethodsBase
8     {

```

```

9      public UInt64LinksTargetsSizeBalancedTreeMethods(LinksConstants<ulong> constants,
10         ↳ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
11         ↳ { }
12
13     [MethodImpl(MethodImplOptions.AggressiveInlining)]
14     protected override ref ulong GetLeftReference(ulong node) => ref
15         ↳ Links[node].LeftAsTarget;
16
17     [MethodImpl(MethodImplOptions.AggressiveInlining)]
18     protected override ref ulong GetRightReference(ulong node) => ref
19         ↳ Links[node].RightAsTarget;
20
21     [MethodImpl(MethodImplOptions.AggressiveInlining)]
22     protected override ulong GetLeft(ulong node) => Links[node].LeftAsTarget;
23
24     [MethodImpl(MethodImplOptions.AggressiveInlining)]
25     protected override ulong GetRight(ulong node) => Links[node].RightAsTarget;
26
27     [MethodImpl(MethodImplOptions.AggressiveInlining)]
28     protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsTarget =
29         ↳ left;
30
31     [MethodImpl(MethodImplOptions.AggressiveInlining)]
32     protected override void SetRight(ulong node, ulong right) => Links[node].RightAsTarget =
33         ↳ right;
34
35     [MethodImpl(MethodImplOptions.AggressiveInlining)]
36     protected override ulong GetSize(ulong node) => Links[node].SizeAsTarget;
37
38     [MethodImpl(MethodImplOptions.AggressiveInlining)]
39     protected override void SetSize(ulong node, ulong size) => Links[node].SizeAsTarget =
40         ↳ size;
41
42     [MethodImpl(MethodImplOptions.AggressiveInlining)]
43     protected override ulong GetTreeRoot() => Header->FirstAsTarget;
44
45     [MethodImpl(MethodImplOptions.AggressiveInlining)]
46     protected override ulong GetBasePartValue(ulong link) => Links[link].Target;
47
48     [MethodImpl(MethodImplOptions.AggressiveInlining)]
49     protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
50         ↳ ulong secondSource, ulong secondTarget)
51         ↳ => firstTarget < secondTarget || (firstTarget == secondTarget && firstSource <
52         ↳ secondSource);
53
54     [MethodImpl(MethodImplOptions.AggressiveInlining)]
55     protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
56         ↳ ulong secondSource, ulong secondTarget)
57         ↳ => firstTarget > secondTarget || (firstTarget == secondTarget && firstSource >
58         ↳ secondSource);
59
60     [MethodImpl(MethodImplOptions.AggressiveInlining)]
61     protected override void ClearNode(ulong node)
62     {
63         ref var link = ref Links[node];
64         link.LeftAsTarget = OUL;
65         link.RightAsTarget = OUL;
66         link.SizeAsTarget = OUL;
67     }
68 }

```

1.52 ./Platform.Data.Doublents/ResizableDirectMemory/Specific/UInt64ResizableDirectMemoryLinks.cs

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Memory;
5  using Platform.Data.Doublents.ResizableDirectMemory.Generic;
6  using Platform.Singletons;
7
8  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublents.ResizableDirectMemory.Specific
11 {
12     public unsafe class UInt64ResizableDirectMemoryLinks : ResizableDirectMemoryLinksBase<ulong>
13     {
14         private readonly Func<ILinksTreeMethods<ulong>> _createSourceTreeMethods;
15         private readonly Func<ILinksTreeMethods<ulong>> _createTargetTreeMethods;
16         private LinksHeader<ulong>* _header;

```

```

17 private RawLink<ulong>* _links;
18
19 [MethodImpl(MethodImplOptions.AggressiveInlining)]
20 public UInt64ResizableDirectMemoryLinks(string address) : this(address,
    ↳ DefaultLinksSizeStep) { }
21
22 /// <summary>
23 /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
    ↳ минимальным шагом расширения базы данных.
24 /// </summary>
25 /// <param name="address">Полный путь к файлу базы данных.</param>
26 /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
    ↳ байтах.</param>
27 [MethodImpl(MethodImplOptions.AggressiveInlining)]
28 public UInt64ResizableDirectMemoryLinks(string address, long memoryReservationStep) :
    ↳ this(new FileMappedResizableDirectMemory(address, memoryReservationStep),
    ↳ memoryReservationStep) { }
29
30 [MethodImpl(MethodImplOptions.AggressiveInlining)]
31 public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory) : this(memory,
    ↳ DefaultLinksSizeStep) { }
32
33 [MethodImpl(MethodImplOptions.AggressiveInlining)]
34 public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
    ↳ memoryReservationStep) : this(memory, memoryReservationStep,
    ↳ Default<LinksConstants<ulong>>.Instance, true) { }
35
36 [MethodImpl(MethodImplOptions.AggressiveInlining)]
37 public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
    ↳ memoryReservationStep, LinksConstants<ulong> constants, bool useAvlBasedIndex) :
    ↳ base(memory, memoryReservationStep, constants)
38 {
39     if (useAvlBasedIndex)
40     {
41         _createSourceTreeMethods = () => new
            ↳ UInt64LinksSourcesAvlBalancedTreeMethods(Constants, _links, _header);
42         _createTargetTreeMethods = () => new
            ↳ UInt64LinksTargetsAvlBalancedTreeMethods(Constants, _links, _header);
43     }
44     else
45     {
46         _createSourceTreeMethods = () => new
            ↳ UInt64LinksSourcesSizeBalancedTreeMethods(Constants, _links, _header);
47         _createTargetTreeMethods = () => new
            ↳ UInt64LinksTargetsSizeBalancedTreeMethods(Constants, _links, _header);
48     }
49     Init(memory, memoryReservationStep);
50 }
51
52 [MethodImpl(MethodImplOptions.AggressiveInlining)]
53 protected override void SetPointers(IResizableDirectMemory memory)
54 {
55     _header = (LinksHeader<ulong>*)memory.Pointer;
56     _links = (RawLink<ulong>*)memory.Pointer;
57     SourcesTreeMethods = _createSourceTreeMethods();
58     TargetsTreeMethods = _createTargetTreeMethods();
59     UnusedLinksListMethods = new UInt64UnusedLinksListMethods(_links, _header);
60 }
61
62 [MethodImpl(MethodImplOptions.AggressiveInlining)]
63 protected override void ResetPointers()
64 {
65     base.ResetPointers();
66     _links = null;
67     _header = null;
68 }
69
70 [MethodImpl(MethodImplOptions.AggressiveInlining)]
71 protected override ref LinksHeader<ulong> GetHeaderReference() => ref *_header;
72
73 [MethodImpl(MethodImplOptions.AggressiveInlining)]
74 protected override ref RawLink<ulong> GetLinkReference(ulong linkIndex) => ref
    ↳ _links[linkIndex];
75
76 [MethodImpl(MethodImplOptions.AggressiveInlining)]
77 protected override bool AreEqual(ulong first, ulong second) => first == second;
78
79 [MethodImpl(MethodImplOptions.AggressiveInlining)]

```



```

80     protected override bool LessThan(ulong first, ulong second) => first < second;
81
82     [MethodImpl(MethodImplOptions.AggressiveInlining)]
83     protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
84
85     [MethodImpl(MethodImplOptions.AggressiveInlining)]
86     protected override bool GreaterThan(ulong first, ulong second) => first > second;
87
88     [MethodImpl(MethodImplOptions.AggressiveInlining)]
89     protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
90
91     [MethodImpl(MethodImplOptions.AggressiveInlining)]
92     protected override ulong GetZero() => 0UL;
93
94     [MethodImpl(MethodImplOptions.AggressiveInlining)]
95     protected override ulong GetOne() => 1UL;
96
97     [MethodImpl(MethodImplOptions.AggressiveInlining)]
98     protected override long ConvertToUInt64(ulong value) => (long)value;
99
100    [MethodImpl(MethodImplOptions.AggressiveInlining)]
101    protected override ulong ConvertToAddress(long value) => (ulong)value;
102
103    [MethodImpl(MethodImplOptions.AggressiveInlining)]
104    protected override ulong Add(ulong first, ulong second) => first + second;
105
106    [MethodImpl(MethodImplOptions.AggressiveInlining)]
107    protected override ulong Subtract(ulong first, ulong second) => first - second;
108
109    [MethodImpl(MethodImplOptions.AggressiveInlining)]
110    protected override ulong Increment(ulong link) => ++link;
111
112    [MethodImpl(MethodImplOptions.AggressiveInlining)]
113    protected override ulong Decrement(ulong link) => --link;
114
115    [MethodImpl(MethodImplOptions.AggressiveInlining)]
116    protected override IList<ulong> GetEmptyList() => new ulong[0];
117 }
118 }

```

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

```

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

```

1.54 ./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 private void HalveSequence(ICollection<TLink> destination, ICollection<TLink> source, int length)
41 {
42     var loopedLength = length - (length % 2);
43     for (var i = 0; i < loopedLength; i += 2)
44     {
45         destination[i / 2] = Links.GetOrCreate(source[i], source[i + 1]);
46     }
47     if (length > loopedLength)
48     {
49         destination[length / 2] = source[length - 1];
50     }
51 }
52 }
53 }

```

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

```

1 using System;
2 using System.Collections.Generic;
3 using System.Runtime.CompilerServices;
4 using Platform.Collections;
5 using Platform.Converters;
6 using Platform.Singletons;
7 using Platform.Numbers;
8 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
9
10 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
11
12 namespace Platform.Data.Doublets.Sequences.Converters
13 {
14     /// <remarks>
15     /// TODO: Возможно будет лучше если алгоритм будет выполняться полностью изолированно от
16     /// ↪ Links на этапе сжатия.
17     /// A именно будет создаваться временный список пар необходимых для выполнения сжатия, в
18     /// ↪ таком случае тип значения элемента массива может быть любым, как char так и ulong.
19     /// Как только список/словарь пар был выявлен можно разом выполнить создание всех этих
20     /// ↪ пар, а так же разом выполнить замену.
21     /// </remarks>
22     public class CompressingConverter<TLink> : LinksListToSequenceConverterBase<TLink>
23     {
24         private static readonly LinksConstants<TLink> _constants =
25             ↪ Default<LinksConstants<TLink>>.Instance;
26         private static readonly EqualityComparer<TLink> _equalityComparer =
27             ↪ EqualityComparer<TLink>.Default;
28         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
29
30         private readonly IConverter<ICollection<TLink>, TLink> _baseConverter;
31         private readonly LinkFrequenciesCache<TLink> _doubletFrequenciesCache;
32         private readonly TLink _minFrequencyToCompress;
33         private readonly bool _doInitialFrequenciesIncrement;
34         private Doublet<TLink> _maxDoublet;

```

```

30 private LinkFrequency<TLink> _maxDoubletData;
31
32 private struct HalfDoublet
33 {
34     public TLink Element;
35     public LinkFrequency<TLink> DoubletData;
36
37     public HalfDoublet(TLink element, LinkFrequency<TLink> doubletData)
38     {
39         Element = element;
40         DoubletData = doubletData;
41     }
42
43     public override string ToString() => $"{Element}: ({DoubletData})";
44 }
45
46 public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
47     ↪ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache)
48     : this(links, baseConverter, doubletFrequenciesCache, Integer<TLink>.One, true)
49 {
50 }
51
52 public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
53     ↪ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, bool
54     ↪ doInitialFrequenciesIncrement)
55     : this(links, baseConverter, doubletFrequenciesCache, Integer<TLink>.One,
56         ↪ doInitialFrequenciesIncrement)
57 {
58 }
59
60 public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
61     ↪ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, TLink
62     ↪ minFrequencyToCompress, bool doInitialFrequenciesIncrement)
63     : base(links)
64 {
65     _baseConverter = baseConverter;
66     _doubletFrequenciesCache = doubletFrequenciesCache;
67     if (_comparer.Compare(minFrequencyToCompress, Integer<TLink>.One) < 0)
68     {
69         minFrequencyToCompress = Integer<TLink>.One;
70     }
71     _minFrequencyToCompress = minFrequencyToCompress;
72     _doInitialFrequenciesIncrement = doInitialFrequenciesIncrement;
73     ResetMaxDoublet();
74 }
75
76 public override TLink Convert(IList<TLink> source) =>
77     ↪ _baseConverter.Convert(Compress(source));
78
79 /// <remarks>
80 /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte\_pair\_encoding .
81 /// Faster version (doublets' frequencies dictionary is not recreated).
82 /// </remarks>
83 private IList<TLink> Compress(IList<TLink> sequence)
84 {
85     if (sequence.IsNullOrEmpty())
86     {
87         return null;
88     }
89     if (sequence.Count == 1)
90     {
91         return sequence;
92     }
93     if (sequence.Count == 2)
94     {
95         return new[] { Links.GetOrCreate(sequence[0], sequence[1]) };
96     }
97     // TODO: arraypool with min size (to improve cache locality) or stackalloc with Sigil
98     var copy = new HalfDoublet[sequence.Count];
99     Doublet<TLink> doublet = default;
100     for (var i = 1; i < sequence.Count; i++)
101     {
102         doublet.Source = sequence[i - 1];
103         doublet.Target = sequence[i];
104         LinkFrequency<TLink> data;
105         if (_doInitialFrequenciesIncrement)
106         {
107             data = _doubletFrequenciesCache.IncrementFrequency(ref doublet);
108         }

```

```

102     else
103     {
104         data = _doubletFrequenciesCache.GetFrequency(ref doublet);
105         if (data == null)
106         {
107             throw new NotSupportedException("If you ask not to increment
108                 ↪ frequencies, it is expected that all frequencies for the sequence
109                 ↪ are prepared.");
110         }
111     }
112     copy[i - 1].Element = sequence[i - 1];
113     copy[i - 1].DoubletData = data;
114     UpdateMaxDoublet(ref doublet, data);
115 }
116 copy[sequence.Count - 1].Element = sequence[sequence.Count - 1];
117 copy[sequence.Count - 1].DoubletData = new LinkFrequency<TLink>();
118 if (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
119 {
120     var newLength = ReplaceDoublets(copy);
121     sequence = new TLink[newLength];
122     for (int i = 0; i < newLength; i++)
123     {
124         sequence[i] = copy[i].Element;
125     }
126 }
127 return sequence;
128 }
129
130 /// <remarks>
131 /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte\_pair\_encoding
132 /// </remarks>
133 private int ReplaceDoublets(HalfDoublet[] copy)
134 {
135     var oldLength = copy.Length;
136     var newLength = copy.Length;
137     while (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
138     {
139         var maxDoubletSource = _maxDoublet.Source;
140         var maxDoubletTarget = _maxDoublet.Target;
141         if (_equalityComparer.Equals(_maxDoubletData.Link, _constants.Null))
142         {
143             _maxDoubletData.Link = Links.GetOrCreate(maxDoubletSource, maxDoubletTarget);
144         }
145         var maxDoubletReplacementLink = _maxDoubletData.Link;
146         oldLength--;
147         var oldLengthMinusTwo = oldLength - 1;
148         // Substitute all usages
149         int w = 0, r = 0; // (r == read, w == write)
150         for (; r < oldLength; r++)
151         {
152             if (_equalityComparer.Equals(copy[r].Element, maxDoubletSource) &&
153                 ↪ _equalityComparer.Equals(copy[r + 1].Element, maxDoubletTarget))
154             {
155                 if (r > 0)
156                 {
157                     var previous = copy[w - 1].Element;
158                     copy[w - 1].DoubletData.DecrementFrequency();
159                     copy[w - 1].DoubletData =
160                         ↪ _doubletFrequenciesCache.IncrementFrequency(previous,
161                         ↪ maxDoubletReplacementLink);
162                 }
163                 if (r < oldLengthMinusTwo)
164                 {
165                     var next = copy[r + 2].Element;
166                     copy[r + 1].DoubletData.DecrementFrequency();
167                     copy[w].DoubletData = _doubletFrequenciesCache.IncrementFrequency(max
168                         ↪ xDoubletReplacementLink,
169                         ↪ next);
170                 }
171                 copy[w++].Element = maxDoubletReplacementLink;
172                 r++;
173                 newLength--;
174             }
175             else
176             {
177                 copy[w++] = copy[r];
178             }
179         }
180     }
181 }

```

```

173         if (w < newLength)
174         {
175             copy[w] = copy[r];
176         }
177         oldLength = newLength;
178         ResetMaxDoublet();
179         UpdateMaxDoublet(copy, newLength);
180     }
181     return newLength;
182 }
183
184 [MethodImpl(MethodImplOptions.AggressiveInlining)]
185 private void ResetMaxDoublet()
186 {
187     _maxDoublet = new Doublet<TLink>();
188     _maxDoubletData = new LinkFrequency<TLink>();
189 }
190
191 [MethodImpl(MethodImplOptions.AggressiveInlining)]
192 private void UpdateMaxDoublet(HalfDoublet[] copy, int length)
193 {
194     Doublet<TLink> doublet = default;
195     for (var i = 1; i < length; i++)
196     {
197         doublet.Source = copy[i - 1].Element;
198         doublet.Target = copy[i].Element;
199         UpdateMaxDoublet(ref doublet, copy[i - 1].DoubletData);
200     }
201 }
202
203 [MethodImpl(MethodImplOptions.AggressiveInlining)]
204 private void UpdateMaxDoublet(ref Doublet<TLink> doublet, LinkFrequency<TLink> data)
205 {
206     var frequency = data.Frequency;
207     var maxFrequency = _maxDoubletData.Frequency;
208     //if (frequency > _minFrequencyToCompress && (maxFrequency < frequency ||
209     ↪ (maxFrequency == frequency && doublet.Source + doublet.Target < /* gives better
210     ↪ compression string data (and gives collisions quickly) */ _maxDoublet.Source +
211     ↪ _maxDoublet.Target)))
212     if (_comparer.Compare(frequency, _minFrequencyToCompress) > 0 &&
213     ↪ (_comparer.Compare(maxFrequency, frequency) < 0 ||
214     ↪ (_equalityComparer.Equals(maxFrequency, frequency) &&
215     ↪ _comparer.Compare(Arithmetic.Add(doublet.Source, doublet.Target),
216     ↪ Arithmetic.Add(_maxDoublet.Source, _maxDoublet.Target)) > 0))) /* gives
217     ↪ better stability and better compression on sequent data and even on random
218     ↪ numbers data (but gives collisions anyway) */
219     {
220         _maxDoublet = doublet;
221         _maxDoubletData = data;
222     }
223 }
224 }
225 }
226 }
227 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Converters;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences.Converters
7 {
8     public abstract class LinksListToSequenceConverterBase<TLink> : IConverter<IList<TLink>,
9     ↪ TLink>
10     {
11         protected readonly ILinks<TLink> Links;
12         public LinksListToSequenceConverterBase(ILinks<TLink> links) => Links = links;
13         public abstract TLink Convert(IList<TLink> source);
14     }
15 }

```

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

```

1 using System.Collections.Generic;
2 using System.Linq;
3 using Platform.Converters;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Data.Doublets.Sequences.Converters

```

```

8 {
9 public class OptimalVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
10 {
11     private static readonly EqualityComparer<TLink> _equalityComparer =
12         ↳ EqualityComparer<TLink>.Default;
13     private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
14     private readonly IConverter<IList<TLink>> _sequenceToItsLocalElementLevelsConverter;
15
16     public OptimalVariantConverter(ILinks<TLink> links, IConverter<IList<TLink>>
17         ↳ sequenceToItsLocalElementLevelsConverter) : base(links)
18         => _sequenceToItsLocalElementLevelsConverter =
19             ↳ sequenceToItsLocalElementLevelsConverter;
20
21     public override TLink Convert(IList<TLink> sequence)
22     {
23         var length = sequence.Count;
24         if (length == 1)
25         {
26             return sequence[0];
27         }
28         var links = Links;
29         if (length == 2)
30         {
31             return links.GetOrCreate(sequence[0], sequence[1]);
32         }
33         sequence = sequence.ToArray();
34         var levels = _sequenceToItsLocalElementLevelsConverter.Convert(sequence);
35         while (length > 2)
36         {
37             var levelRepeat = 1;
38             var currentLevel = levels[0];
39             var previousLevel = levels[0];
40             var skipOnce = false;
41             var w = 0;
42             for (var i = 1; i < length; i++)
43             {
44                 if (_equalityComparer.Equals(currentLevel, levels[i]))
45                 {
46                     levelRepeat++;
47                     skipOnce = false;
48                     if (levelRepeat == 2)
49                     {
50                         sequence[w] = links.GetOrCreate(sequence[i - 1], sequence[i]);
51                         var newLevel = i >= length - 1 ?
52                             GetPreviousLowerThanCurrentOrCurrent(previousLevel,
53                                 ↳ currentLevel) :
54                             i < 2 ?
55                                 GetNextLowerThanCurrentOrCurrent(currentLevel, levels[i + 1]) :
56                                 GetGreatestNeighbourLowerThanCurrentOrCurrent(previousLevel,
57                                     ↳ currentLevel, levels[i + 1]);
58                         levels[w] = newLevel;
59                         previousLevel = currentLevel;
60                         w++;
61                         levelRepeat = 0;
62                         skipOnce = true;
63                     }
64                     else if (i == length - 1)
65                     {
66                         sequence[w] = sequence[i];
67                         levels[w] = levels[i];
68                         w++;
69                     }
70                 }
71                 else
72                 {
73                     currentLevel = levels[i];
74                     levelRepeat = 1;
75                     if (skipOnce)
76                     {
77                         skipOnce = false;
78                     }
79                     else
80                     {
81                         sequence[w] = sequence[i - 1];
82                         levels[w] = levels[i - 1];
83                         previousLevel = levels[w];
84                         w++;
85                     }
86                 }
87                 if (i == length - 1)

```

```

83         {
84             sequence[w] = sequence[i];
85             levels[w] = levels[i];
86             w++;
87         }
88     }
89     }
90     length = w;
91 }
92 return links.GetOrCreate(sequence[0], sequence[1]);
93 }
94
95 private static TLink GetGreatestNeighbourLowerThanCurrentOrCurrent(TLink previous, TLink
    ↪ current, TLink next)
96 {
97     return _comparer.Compare(previous, next) > 0
98         ? _comparer.Compare(previous, current) < 0 ? previous : current
99         : _comparer.Compare(next, current) < 0 ? next : current;
100 }
101
102 private static TLink GetNextLowerThanCurrentOrCurrent(TLink current, TLink next) =>
    ↪ _comparer.Compare(next, current) < 0 ? next : current;
103
104 private static TLink GetPreviousLowerThanCurrentOrCurrent(TLink previous, TLink current)
    ↪ => _comparer.Compare(previous, current) < 0 ? previous : current;
105 }
106 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Converters;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences.Converters
7 {
8     public class SequenceToItsLocalElementLevelsConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<IList<TLink>>
9     {
10         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
11
12         private readonly IConverter<Doublet<TLink>, TLink> _linkToItsFrequencyToNumberConveter;
13
14         public SequenceToItsLocalElementLevelsConverter(ILinks<TLink> links,
    ↪ IConverter<Doublet<TLink>, TLink> linkToItsFrequencyToNumberConveter) : base(links)
    ↪ => _linkToItsFrequencyToNumberConveter = linkToItsFrequencyToNumberConveter;
15
16         public IList<TLink> Convert(IList<TLink> sequence)
17         {
18             var levels = new TLink[sequence.Count];
19             levels[0] = GetFrequencyNumber(sequence[0], sequence[1]);
20             for (var i = 1; i < sequence.Count - 1; i++)
21             {
22                 var previous = GetFrequencyNumber(sequence[i - 1], sequence[i]);
23                 var next = GetFrequencyNumber(sequence[i], sequence[i + 1]);
24                 levels[i] = _comparer.Compare(previous, next) > 0 ? previous : next;
25             }
26             levels[levels.Length - 1] = GetFrequencyNumber(sequence[sequence.Count - 2],
    ↪ sequence[sequence.Count - 1]);
27             return levels;
28         }
29
30         public TLink GetFrequencyNumber(TLink source, TLink target) =>
    ↪ _linkToItsFrequencyToNumberConveter.Convert(new Doublet<TLink>(source, target));
31     }
32 }

```

1.59 ./Platform.Data.Doublets/Sequences/CriterionMatchers/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.CriterionMatchers
6 {
7     public class DefaultSequenceElementCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
    ↪ ICriterionMatcher<TLink>
8     {
9         public DefaultSequenceElementCriterionMatcher(ILinks<TLink> links) : base(links) { }
10         public bool IsMatched(TLink argument) => Links.IsPartialPoint(argument);

```

```

11     }
12 }

```

1.60 ./Platform.Data.Doublets/Sequences/CriterionMatchers/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.CriterionMatchers
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 }

```

1.61 ./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))

```



```

44         {
45             right = Links.GetOrCreate(left, right);
46             left = cursor;
47         }
48         return Links.GetOrCreate(left, right);
49     }
50 }
51 }

```

1.62 ./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 }

```

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

```

1  using System;
2  using System.Linq;
3  using System.Collections.Generic;
4  using Platform.Interfaces;
5  using Platform.Collections;
6  using Platform.Collections.Lists;
7  using Platform.Collections.Segments;
8  using Platform.Collections.Segments.Walkers;
9  using Platform.Singletons;
10 using Platform.Numbers;
11 using Platform.Data.Doublets.Unicode;
12
13 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
14
15 namespace Platform.Data.Doublets.Sequences
16 {
17     public class DuplicateSegmentsProvider<TLink> :
18         ↪ DictionaryBasedDuplicateSegmentsWalkerBase<TLink>,
19         ↪ IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
20     {
21         private readonly ILinks<TLink> _links;
22         private readonly ILinks<TLink> _sequences;
23         private HashSet<KeyValuePair<IList<TLink>, IList<TLink>>> _groups;
24         private BitString _visited;
25
26         private class ItemEquilityComparer : IEqualityComparer<KeyValuePair<IList<TLink>,
27             ↪ IList<TLink>>>
28         {
29             private readonly IListEqualityComparer<TLink> _listComparer;
30             public ItemEquilityComparer() => _listComparer =
31                 ↪ Default<IListEqualityComparer<TLink>>.Instance;
32             public bool Equals(KeyValuePair<IList<TLink>, IList<TLink>> left,
33                 ↪ KeyValuePair<IList<TLink>, IList<TLink>> right) =>
34                 ↪ _listComparer.Equals(left.Key, right.Key) && _listComparer.Equals(left.Value,
35                 ↪ right.Value);
36             public int GetHashCode(KeyValuePair<IList<TLink>, IList<TLink>> pair) =>
37                 ↪ (_listComparer.GetHashCode(pair.Key),
38                 ↪ _listComparer.GetHashCode(pair.Value)).GetHashCode();
39         }
40
41         private class ItemComparer : IComparer<KeyValuePair<IList<TLink>, IList<TLink>>>
42         {
43             private readonly IListComparer<TLink> _listComparer;
44             public ItemComparer() => _listComparer = Default<IListComparer<TLink>>.Instance;
45             public int Compare(KeyValuePair<IList<TLink>, IList<TLink>> left,
46                 ↪ KeyValuePair<IList<TLink>, IList<TLink>> right)
47             {
48                 var intermediateResult = _listComparer.Compare(left.Key, right.Key);

```

```

41         if (intermediateResult == 0)
42         {
43             intermediateResult = _listComparer.Compare(left.Value, right.Value);
44         }
45         return intermediateResult;
46     }
47 }
48
49 public DuplicateSegmentsProvider(ILinks<TLink> links, ILinks<TLink> sequences)
50     : base(minimumStringSegmentLength: 2)
51 {
52     _links = links;
53     _sequences = sequences;
54 }
55
56 public IList<KeyValuePair<IList<TLink>, IList<TLink>>> Get()
57 {
58     _groups = new HashSet<KeyValuePair<IList<TLink>,
59         ↪ IList<TLink>>>(Default<ItemEqualityComparer>.Instance);
60     var count = _links.Count();
61     _visited = new BitString((long)(Integer<TLink>)count + 1);
62     _links.Each(link =>
63     {
64         var linkIndex = _links.GetIndex(link);
65         var linkBitIndex = (long)(Integer<TLink>)linkIndex;
66         if (!_visited.Get(linkBitIndex))
67         {
68             var sequenceElements = new List<TLink>();
69             var filler = new ListFiller<TLink, TLink>(sequenceElements,
70                 ↪ _sequences.Constants.Break);
71             _sequences.Each(filler.AddSkipFirstAndReturnConstant, new
72                 ↪ LinkAddress<TLink>(linkIndex));
73             if (sequenceElements.Count > 2)
74             {
75                 WalkAll(sequenceElements);
76             }
77             return _links.Constants.Continue;
78         }
79     });
80     var resultList = _groups.ToList();
81     var comparer = Default<ItemComparer>.Instance;
82     resultList.Sort(comparer);
83
84     #if DEBUG
85     foreach (var item in resultList)
86     {
87         PrintDuplicates(item);
88     }
89     #endif
90     return resultList;
91 }
92
93 protected override Segment<TLink> CreateSegment(IList<TLink> elements, int offset, int
94     ↪ length) => new Segment<TLink>(elements, offset, length);
95
96 protected override void OnDuplicateFound(Segment<TLink> segment)
97 {
98     var duplicates = CollectDuplicatesForSegment(segment);
99     if (duplicates.Count > 1)
100     {
101         _groups.Add(new KeyValuePair<IList<TLink>, IList<TLink>>(segment.ToArray(),
102             ↪ duplicates));
103     }
104 }
105
106 private List<TLink> CollectDuplicatesForSegment(Segment<TLink> segment)
107 {
108     var duplicates = new List<TLink>();
109     var readAsElement = new HashSet<TLink>();
110     var restrictions = segment.ShiftRight();
111     restrictions[0] = _sequences.Constants.Any;
112     _sequences.Each(sequence =>
113     {
114         var sequenceIndex = sequence[_sequences.Constants.IndexPart];
115         duplicates.Add(sequenceIndex);
116         readAsElement.Add(sequenceIndex);
117         return _sequences.Constants.Continue;
118     }, restrictions);
119     if (duplicates.Any(x => _visited.Get((Integer<TLink>)x)))

```

```

114     {
115         return new List<TLink>();
116     }
117     foreach (var duplicate in duplicates)
118     {
119         var duplicateBitIndex = (long)(Integer<TLink>)duplicate;
120         _visited.Set(duplicateBitIndex);
121     }
122     if (_sequences is Sequences sequencesExperiments)
123     {
124         var partiallyMatched = sequencesExperiments.GetAllPartiallyMatchingSequences4((H
            ↪ ashSet<ulong>)(object)readAsElement,
            ↪ (IList<ulong>)segment);
125         foreach (var partiallyMatchedSequence in partiallyMatched)
126         {
127             TLink sequenceIndex = (Integer<TLink>)partiallyMatchedSequence;
128             duplicates.Add(sequenceIndex);
129         }
130     }
131     duplicates.Sort();
132     return duplicates;
133 }
134
135 private void PrintDuplicates(KeyValuePair<IList<TLink>, IList<TLink>> duplicatesItem)
136 {
137     if (!(_links is ILinks<ulong> ulongLinks))
138     {
139         return;
140     }
141     var duplicatesKey = duplicatesItem.Key;
142     var keyString = UnicodeMap.FromLinksToString((IList<ulong>)duplicatesKey);
143     Console.WriteLine($"> {keyString} ({string.Join(", ", duplicatesKey)}");
144     var duplicatesList = duplicatesItem.Value;
145     for (int i = 0; i < duplicatesList.Count; i++)
146     {
147         ulong sequenceIndex = (Integer<TLink>)duplicatesList[i];
148         var formattedSequenceStructure = ulongLinks.FormatStructure(sequenceIndex, x =>
            ↪ Point<ulong>.IsPartialPoint(x), (sb, link) => _ =
            ↪ UnicodeMap.IsCharLink(link.Index) ?
            ↪ sb.Append(UnicodeMap.FromLinkToChar(link.Index)) : sb.Append(link.Index));
149         Console.WriteLine(formattedSequenceStructure);
150         var sequenceString = UnicodeMap.FromSequenceLinkToString(sequenceIndex,
            ↪ ulongLinks);
151         Console.WriteLine(sequenceString);
152     }
153     Console.WriteLine();
154 }
155 }
156 }

```

1.64 ./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         {

```

```

26     _doubletsCache = new Dictionary<Doublet<TLink>, LinkFrequency<TLink>>(4096,
27         ↪ DoubletComparer<TLink>.Default);
28     _frequencyCounter = frequencyCounter;
29 }
30 [MethodImpl(MethodImplOptions.AggressiveInlining)]
31 public LinkFrequency<TLink> GetFrequency(TLink source, TLink target)
32 {
33     var doublet = new Doublet<TLink>(source, target);
34     return GetFrequency(ref doublet);
35 }
36 [MethodImpl(MethodImplOptions.AggressiveInlining)]
37 public LinkFrequency<TLink> GetFrequency(ref Doublet<TLink> doublet)
38 {
39     _doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data);
40     return data;
41 }
42 }
43 public void IncrementFrequencies(IList<TLink> sequence)
44 {
45     for (var i = 1; i < sequence.Count; i++)
46     {
47         IncrementFrequency(sequence[i - 1], sequence[i]);
48     }
49 }
50 }
51 [MethodImpl(MethodImplOptions.AggressiveInlining)]
52 public LinkFrequency<TLink> IncrementFrequency(TLink source, TLink target)
53 {
54     var doublet = new Doublet<TLink>(source, target);
55     return IncrementFrequency(ref doublet);
56 }
57 }
58 public void PrintFrequencies(IList<TLink> sequence)
59 {
60     for (var i = 1; i < sequence.Count; i++)
61     {
62         PrintFrequency(sequence[i - 1], sequence[i]);
63     }
64 }
65 }
66 public void PrintFrequency(TLink source, TLink target)
67 {
68     var number = GetFrequency(source, target).Frequency;
69     Console.WriteLine("{0},{1}) - {2}", source, target, number);
70 }
71 }
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 public LinkFrequency<TLink> IncrementFrequency(ref Doublet<TLink> doublet)
74 {
75     if (_doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data))
76     {
77         data.IncrementFrequency();
78     }
79     else
80     {
81         var link = Links.SearchOrDefault(doublet.Source, doublet.Target);
82         data = new LinkFrequency<TLink>(Integer<TLink>.One, link);
83         if (!_equalityComparer.Equals(link, default))
84         {
85             data.Frequency = Arithmetic.Add(data.Frequency,
86                 ↪ _frequencyCounter.Count(link));
87         }
88         _doubletsCache.Add(doublet, data);
89     }
90     return data;
91 }
92 }
93 public void ValidateFrequencies()
94 {
95     foreach (var entry in _doubletsCache)
96     {
97         var value = entry.Value;
98         var linkIndex = value.Link;
99         if (!_equalityComparer.Equals(linkIndex, default))
100         {
101             var frequency = value.Frequency;
102             var count = _frequencyCounter.Count(linkIndex);

```

```

103         // TODO: Why `frequency` always greater than `count` by 1?
104         if (((_comparer.Compare(frequency, count) > 0) &&
            ↪ (_comparer.Compare(Arithmetic.Subtract(frequency, count),
            ↪ Integer<TLink>.One) > 0))
105         || ((_comparer.Compare(count, frequency) > 0) &&
            ↪ (_comparer.Compare(Arithmetic.Subtract(count, frequency),
            ↪ Integer<TLink>.One) > 0)))
106         {
107             throw new InvalidOperationException("Frequencies validation failed.");
108         }
109     }
110     //else
111     //{
112     //    if (value.Frequency > 0)
113     //    {
114     //        var frequency = value.Frequency;
115     //        linkIndex = _createLink(entry.Key.Source, entry.Key.Target);
116     //        var count = _countLinkFrequency(linkIndex);
117     //
118     //        if ((frequency > count && frequency - count > 1) || (count > frequency
            ↪ && count - frequency > 1))
119     //            throw new Exception("Frequencies validation failed.");
120     //    }
121     //}
122 }
123 }
124 }
125 }

```

1.65 ./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 }

```

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

```

1 using Platform.Converters;
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> :
            ↪ IConverter<Doublet<TLink>, TLink>
8     {
9         private readonly LinkFrequenciesCache<TLink> _cache;
10        public
            ↪ FrequenciesCacheBasedLinkToItsFrequencyNumberConverter(LinkFrequenciesCache<TLink>
            ↪ cache) => _cache = cache;
11        public TLink Convert(Doublet<TLink> source) => _cache.GetFrequency(ref source).Frequency;
12    }
13 }

```

```

1.67 ./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 }

```

```

1.68 ./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             StoppableSequenceWalker.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 }

```

```

47     }
48 }
49 }

```

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

```

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 }

```

1.70 ./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 }

```

1.71 ./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 }

```

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

```

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            else
46            {
47                _links.Each(EachElementHandler, any, link);
48            }
49        }
50
51        protected virtual void CountSequenceSymbolFrequency(TLink link)
52        {
53            var symbolFrequencyCounter = new SequenceSymbolFrequencyOneOffCounter<TLink>(_links,
54                ↪ link, _symbol);
55            _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
56        }
57
58        private TLink EachElementHandler(IList<TLink> doublet)
59        {
60            var constants = _links.Constants;
61            var doubletIndex = doublet[constants.IndexPart];
62            if (_visits.Add(doubletIndex))
63            {
64                CountCore(doubletIndex);
65            }
66            return constants.Continue;
67        }
68    }
69 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3 using Platform.Converters;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Data.Doublets.Sequences.HeightProviders
8 {
9     public class CachedSequenceHeightProvider<TLink> : LinksOperatorBase<TLink>,
10        ↪ ISequenceHeightProvider<TLink>
11    {
12        private static readonly EqualityComparer<TLink> _equalityComparer =
13            ↪ EqualityComparer<TLink>.Default;
14    }
15 }

```



```

13 private readonly TLink _heightPropertyMarker;
14 private readonly ISequenceHeightProvider<TLink> _baseHeightProvider;
15 private readonly IConverter<TLink> _addressToUnaryNumberConverter;
16 private readonly IConverter<TLink> _unaryNumberToAddressConverter;
17 private readonly IProperties<TLink, TLink, TLink> _propertyOperator;
18
19 public CachedSequenceHeightProvider(
20     ILinks<TLink> links,
21     ISequenceHeightProvider<TLink> baseHeightProvider,
22     IConverter<TLink> addressToUnaryNumberConverter,
23     IConverter<TLink> unaryNumberToAddressConverter,
24     TLink heightPropertyMarker,
25     IProperties<TLink, TLink, TLink> propertyOperator)
26     : base(links)
27 {
28     _heightPropertyMarker = heightPropertyMarker;
29     _baseHeightProvider = baseHeightProvider;
30     _addressToUnaryNumberConverter = addressToUnaryNumberConverter;
31     _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
32     _propertyOperator = propertyOperator;
33 }
34
35 public TLink Get(TLink sequence)
36 {
37     TLink height;
38     var heightValue = _propertyOperator.GetValue(sequence, _heightPropertyMarker);
39     if (_equalityComparer.Equals(heightValue, default))
40     {
41         height = _baseHeightProvider.Get(sequence);
42         heightValue = _addressToUnaryNumberConverter.Convert(height);
43         _propertyOperator.SetValue(sequence, _heightPropertyMarker, heightValue);
44     }
45     else
46     {
47         height = _unaryNumberToAddressConverter.Convert(heightValue);
48     }
49     return height;
50 }
51 }
52 }

```

1.74 ./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 }

```

1.75 ./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 }

```

1.76 ./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             for (; i >= 1; i--)
25             {
26                 _cache.IncrementFrequency(sequence[i - 1], sequence[i]);
27             }
28             return indexed;
29         }
30
31         private bool IsIndexedWithIncrement(TLink source, TLink target)
32         {
33             var frequency = _cache.GetFrequency(source, target);
34             if (frequency == null)
35             {
36                 return false;
37             }
38             var indexed = !_equalityComparer.Equals(frequency.Frequency, default);
39             if (indexed)
40             {
41                 _cache.IncrementFrequency(source, target);
42             }
43             return indexed;
44         }
45
46         public bool MightContain(ICollection<TLink> sequence)
47         {
48             var indexed = true;
49             var i = sequence.Count;
50             while (--i >= 1 && (indexed = IsIndexed(sequence[i - 1], sequence[i]))) { }
51             return indexed;
52         }
53
54         private bool IsIndexed(TLink source, TLink target)
55         {
56             var frequency = _cache.GetFrequency(source, target);
57             if (frequency == null)
58             {
59                 return false;
60             }
61             return !_equalityComparer.Equals(frequency.Frequency, default);
62         }
63     }
64 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3 using Platform.Incrementers;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Data.Doublets.Sequences.Indexes
8 {
9     public class FrequencyIncrementingSequenceIndex<TLink> : SequenceIndex<TLink>,
10         ⇨ ISequenceIndex<TLink>

```

```

10 {
11     private static readonly EqualityComparer<TLink> _equalityComparer =
12         ↪ EqualityComparer<TLink>.Default;
13
14     private readonly IProperty<TLink, TLink> _frequencyPropertyOperator;
15     private readonly IIncrementer<TLink> _frequencyIncrementer;
16
17     public FrequencyIncrementingSequenceIndex(ILinks<TLink> links, IProperty<TLink, TLink>
18         ↪ frequencyPropertyOperator, IIncrementer<TLink> frequencyIncrementer)
19         : base(links)
20     {
21         _frequencyPropertyOperator = frequencyPropertyOperator;
22         _frequencyIncrementer = frequencyIncrementer;
23     }
24
25     public override bool Add(IList<TLink> sequence)
26     {
27         var indexed = true;
28         var i = sequence.Count;
29         while (--i >= 1 && (indexed = IsIndexedWithIncrement(sequence[i - 1], sequence[i])))
30             ↪ { }
31         for (; i >= 1; i--)
32         {
33             Increment(Links.GetOrCreate(sequence[i - 1], sequence[i]));
34         }
35         return indexed;
36     }
37
38     private bool IsIndexedWithIncrement(TLink source, TLink target)
39     {
40         var link = Links.SearchOrCreate(source, target);
41         var indexed = !_equalityComparer.Equals(link, default);
42         if (indexed)
43         {
44             Increment(link);
45         }
46         return indexed;
47     }
48
49     private void Increment(TLink link)
50     {
51         var previousFrequency = _frequencyPropertyOperator.Get(link);
52         var frequency = _frequencyIncrementer.Increment(previousFrequency);
53         _frequencyPropertyOperator.Set(link, frequency);
54     }
55 }

```

1.78 ./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 }

```

1.79 ./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;

```

```

10
11     public SequenceIndex(ILinks<TLink> links) : base(links) { }
12
13     public virtual bool Add(IList<TLink> sequence)
14     {
15         var indexed = true;
16         var i = sequence.Count;
17         while (--i >= 1 && (indexed =
18             ↪ !_equalityComparer.Equals(Links.SearchOrDefault(sequence[i - 1], sequence[i]),
19             ↪ default))) { }
20         for (; i >= 1; i--)
21         {
22             Links.GetOrCreate(sequence[i - 1], sequence[i]);
23         }
24         return indexed;
25     }
26
27     public virtual bool MightContain(IList<TLink> sequence)
28     {
29         var indexed = true;
30         var i = sequence.Count;
31         while (--i >= 1 && (indexed =
32             ↪ !_equalityComparer.Equals(Links.SearchOrDefault(sequence[i - 1], sequence[i]),
33             ↪ default))) { }
34         return indexed;
35     }
36 }

```

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

```

1  using System.Collections.Generic;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Sequences.Indexes
6  {
7      public class SynchronizedSequenceIndex<TLink> : ISequenceIndex<TLink>
8      {
9          private static readonly EqualityComparer<TLink> _equalityComparer =
10             ↪ EqualityComparer<TLink>.Default;
11
12          private readonly ISynchronizedLinks<TLink> _links;
13
14          public SynchronizedSequenceIndex(ISynchronizedLinks<TLink> links) => _links = links;
15
16          public bool Add(IList<TLink> sequence)
17          {
18              var indexed = true;
19              var i = sequence.Count;
20              var links = _links.Unsync;
21              _links.SyncRoot.ExecuteReadOperation(() =>
22              {
23                  while (--i >= 1 && (indexed =
24                      ↪ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
25                      ↪ sequence[i]), default))) { }
26              });
27              if (!indexed)
28              {
29                  _links.SyncRoot.ExecuteWriteOperation(() =>
30                  {
31                      for (; i >= 1; i--)
32                      {
33                          links.GetOrCreate(sequence[i - 1], sequence[i]);
34                      }
35                  });
36              }
37              return indexed;
38          }
39
40          public bool MightContain(IList<TLink> sequence)
41          {
42              var links = _links.Unsync;
43              return _links.SyncRoot.ExecuteReadOperation(() =>
44              {
45                  var indexed = true;
46                  var i = sequence.Count;
47                  while (--i >= 1 && (indexed =
48                      ↪ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
49                      ↪ sequence[i]), default))) { }
50              });
51          }
52      }
53  }

```

```

45         return indexed;
46     });
47 }
48 }
49 }

```

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

```

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

```

1.82 ./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.Collections.Sets;
9 using Platform.Collections.Stacks;
10 using Platform.Data.Exceptions;
11 using Platform.Data.Sequences;
12 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
13 using Platform.Data.Doublets.Sequences.Walkers;
14
15 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
16
17 namespace Platform.Data.Doublets.Sequences
18 {
19     partial class Sequences
20     {
21         #region Create All Variants (Not Practical)
22
23         /// <remarks>
24         /// Number of links that is needed to generate all variants for
25         /// sequence of length N corresponds to https://oeis.org/A014143/list sequence.
26         /// </remarks>
27         public ulong[] CreateAllVariants2(ulong[] sequence)
28         {
29             return _sync.ExecuteWriteOperation(() =>
30             {
31                 if (sequence.IsNullOrEmpty())
32                 {
33                     return new ulong[0];
34                 }
35                 Links.EnsureLinkExists(sequence);
36                 if (sequence.Length == 1)
37                 {
38                     return sequence;
39                 }
40                 return CreateAllVariants2Core(sequence, 0, sequence.Length - 1);
41             });
42         }
43
44         private ulong[] CreateAllVariants2Core(ulong[] sequence, long startAt, long stopAt)
45         {
46             #if DEBUG
47                 if ((stopAt - startAt) < 0)
48                 {
49                     throw new ArgumentOutOfRangeException(nameof(startAt), "startAt должен быть
50                     ↪ меньше или равен stopAt");
51                 }
52             #endif
53
54             if ((stopAt - startAt) == 0)
55             {
56                 return new[] { sequence[startAt] };
57             }
58             if ((stopAt - startAt) == 1)
59             {
60
61             }
62         }
63     }
64 }

```

```

58         return new[] { Links.Unsync.GetOrCreate(sequence[startAt], sequence[stopAt]) };
59     }
60     var variants = new ulong[(ulong)Platform.Numbers.Math.Catalan(stopAt - startAt)];
61     var last = 0;
62     for (var splitter = startAt; splitter < stopAt; splitter++)
63     {
64         var left = CreateAllVariants2Core(sequence, startAt, splitter);
65         var right = CreateAllVariants2Core(sequence, splitter + 1, stopAt);
66         for (var i = 0; i < left.Length; i++)
67         {
68             for (var j = 0; j < right.Length; j++)
69             {
70                 var variant = Links.Unsync.GetOrCreate(left[i], right[j]);
71                 if (variant == Constants.Null)
72                 {
73                     throw new NotImplementedException("Creation cancellation is not
74                                     ↳ implemented.");
75                 }
76                 variants[last++] = variant;
77             }
78         }
79     }
80     return variants;
81 }
82 public List<ulong> CreateAllVariants1(params ulong[] sequence)
83 {
84     return _sync.ExecuteWriteOperation(() =>
85     {
86         if (sequence.IsNullOrEmpty())
87         {
88             return new List<ulong>();
89         }
90         Links.Unsync.EnsureLinkExists(sequence);
91         if (sequence.Length == 1)
92         {
93             return new List<ulong> { sequence[0] };
94         }
95         var results = new
96             ↳ List<ulong>((int)Platform.Numbers.Math.Catalan(sequence.Length));
97         return CreateAllVariants1Core(sequence, results);
98     });
99 }
100 private List<ulong> CreateAllVariants1Core(ulong[] sequence, List<ulong> results)
101 {
102     if (sequence.Length == 2)
103     {
104         var link = Links.Unsync.GetOrCreate(sequence[0], sequence[1]);
105         if (link == Constants.Null)
106         {
107             throw new NotImplementedException("Creation cancellation is not
108                                     ↳ implemented.");
109         }
110         results.Add(link);
111         return results;
112     }
113     var innerSequenceLength = sequence.Length - 1;
114     var innerSequence = new ulong[innerSequenceLength];
115     for (var li = 0; li < innerSequenceLength; li++)
116     {
117         var link = Links.Unsync.GetOrCreate(sequence[li], sequence[li + 1]);
118         if (link == Constants.Null)
119         {
120             throw new NotImplementedException("Creation cancellation is not
121                                     ↳ implemented.");
122         }
123         for (var isi = 0; isi < li; isi++)
124         {
125             innerSequence[isi] = sequence[isi];
126         }
127         innerSequence[li] = link;
128         for (var isi = li + 1; isi < innerSequenceLength; isi++)
129         {
130             innerSequence[isi] = sequence[isi + 1];
131         }
132         CreateAllVariants1Core(innerSequence, results);
133     }

```

```

132     return results;
133 }
134
135 #endregion
136
137 public HashSet<ulong> Each1(params ulong[] sequence)
138 {
139     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
140     Each1(link =>
141     {
142         if (!visitedLinks.Contains(link))
143         {
144             visitedLinks.Add(link); // изучить почему случаются повторы
145         }
146         return true;
147     }, sequence);
148     return visitedLinks;
149 }
150
151 private void Each1(Func<ulong, bool> handler, params ulong[] sequence)
152 {
153     if (sequence.Length == 2)
154     {
155         Links.Unsync.Each(sequence[0], sequence[1], handler);
156     }
157     else
158     {
159         var innerSequenceLength = sequence.Length - 1;
160         for (var li = 0; li < innerSequenceLength; li++)
161         {
162             var left = sequence[li];
163             var right = sequence[li + 1];
164             if (left == 0 && right == 0)
165             {
166                 continue;
167             }
168             var linkIndex = li;
169             ulong[] innerSequence = null;
170             Links.Unsync.Each(doublet =>
171             {
172                 if (innerSequence == null)
173                 {
174                     innerSequence = new ulong[innerSequenceLength];
175                     for (var isi = 0; isi < linkIndex; isi++)
176                     {
177                         innerSequence[isi] = sequence[isi];
178                     }
179                     for (var isi = linkIndex + 1; isi < innerSequenceLength; isi++)
180                     {
181                         innerSequence[isi] = sequence[isi + 1];
182                     }
183                 }
184                 innerSequence[linkIndex] = doublet[Constants.IndexPart];
185                 Each1(handler, innerSequence);
186                 return Constants.Continue;
187             }, Constants.Any, left, right);
188         }
189     }
190 }
191
192 public HashSet<ulong> EachPart(params ulong[] sequence)
193 {
194     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
195     EachPartCore(link =>
196     {
197         var linkIndex = link[Constants.IndexPart];
198         if (!visitedLinks.Contains(linkIndex))
199         {
200             visitedLinks.Add(linkIndex); // изучить почему случаются повторы
201         }
202         return Constants.Continue;
203     }, sequence);
204     return visitedLinks;
205 }
206
207 public void EachPart(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[] sequence)
208 {
209     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
210     EachPartCore(link =>

```

```

211     {
212         var linkIndex = link[Constants.IndexPart];
213         if (!visitedLinks.Contains(linkIndex))
214         {
215             visitedLinks.Add(linkIndex); // изучить почему случаются повторы
216             return handler(new LinkAddress<LinkIndex>(linkIndex));
217         }
218         return Constants.Continue;
219     }, sequence);
220 }
221
222 private void EachPartCore(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[]
↪ sequence)
223 {
224     if (sequence.IsNullOrEmpty())
225     {
226         return;
227     }
228     Links.EnsureLinkIsAnyOrExists(sequence);
229     if (sequence.Length == 1)
230     {
231         var link = sequence[0];
232         if (link > 0)
233         {
234             handler(new LinkAddress<LinkIndex>(link));
235         }
236         else
237         {
238             Links.Each(Constants.Any, Constants.Any, handler);
239         }
240     }
241     else if (sequence.Length == 2)
242     {
243         //_links.Each(sequence[0], sequence[1], handler);
244         //  o_|      x_o ...
245         //  x_|      |___|
246         Links.Each(sequence[1], Constants.Any, doublet =>
247         {
248             var match = Links.SearchOrDefault(sequence[0], doublet);
249             if (match != Constants.Null)
250             {
251                 handler(new LinkAddress<LinkIndex>(match));
252             }
253             return true;
254         });
255         //_x      ... x_o
256         //  |_o      |___|
257         Links.Each(Constants.Any, sequence[0], doublet =>
258         {
259             var match = Links.SearchOrDefault(doublet, sequence[1]);
260             if (match != 0)
261             {
262                 handler(new LinkAddress<LinkIndex>(match));
263             }
264             return true;
265         });
266         //      .x o_
267         //      |___|
268         PartialStepRight(x => handler(x), sequence[0], sequence[1]);
269     }
270     else
271     {
272         throw new NotImplementedException();
273     }
274 }
275
276 private void PartialStepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
277 {
278     Links.Unsync.Each(Constants.Any, left, doublet =>
279     {
280         StepRight(handler, doublet, right);
281         if (left != doublet)
282         {
283             PartialStepRight(handler, doublet, right);
284         }
285         return true;
286     });
287 }

```



```

288
289 private void StepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
290 {
291     Links.Unsync.Each(left, Constants.Any, rightStep =>
292     {
293         TryStepRightUp(handler, right, rightStep);
294         return true;
295     });
296 }
297
298 private void TryStepRightUp(Action<IList<LinkIndex>> handler, ulong right, ulong
299 ↪ stepFrom)
300 {
301     var upStep = stepFrom;
302     var firstSource = Links.Unsync.GetTarget(upStep);
303     while (firstSource != right && firstSource != upStep)
304     {
305         upStep = firstSource;
306         firstSource = Links.Unsync.GetSource(upStep);
307     }
308     if (firstSource == right)
309     {
310         handler(new LinkAddress<LinkIndex>(stepFrom));
311     }
312 }
313
314 // TODO: Test
315 private void PartialStepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
316 {
317     Links.Unsync.Each(right, Constants.Any, doublet =>
318     {
319         StepLeft(handler, left, doublet);
320         if (right != doublet)
321         {
322             PartialStepLeft(handler, left, doublet);
323         }
324         return true;
325     });
326 }
327
328 private void StepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
329 {
330     Links.Unsync.Each(Constants.Any, right, leftStep =>
331     {
332         TryStepLeftUp(handler, left, leftStep);
333         return true;
334     });
335 }
336
337 private void TryStepLeftUp(Action<IList<LinkIndex>> handler, ulong left, ulong stepFrom)
338 {
339     var upStep = stepFrom;
340     var firstTarget = Links.Unsync.GetSource(upStep);
341     while (firstTarget != left && firstTarget != upStep)
342     {
343         upStep = firstTarget;
344         firstTarget = Links.Unsync.GetTarget(upStep);
345     }
346     if (firstTarget == left)
347     {
348         handler(new LinkAddress<LinkIndex>(stepFrom));
349     }
350 }
351
352 private bool StartsWith(ulong sequence, ulong link)
353 {
354     var upStep = sequence;
355     var firstSource = Links.Unsync.GetSource(upStep);
356     while (firstSource != link && firstSource != upStep)
357     {
358         upStep = firstSource;
359         firstSource = Links.Unsync.GetSource(upStep);
360     }
361     return firstSource == link;
362 }
363
364 private bool EndsWith(ulong sequence, ulong link)
365 {
366     var upStep = sequence;

```

```

366     var lastTarget = Links.Unsync.GetTarget(upStep);
367     while (lastTarget != link && lastTarget != upStep)
368     {
369         upStep = lastTarget;
370         lastTarget = Links.Unsync.GetTarget(upStep);
371     }
372     return lastTarget == link;
373 }
374
375 public List<ulong> GetAllMatchingSequences0(params ulong[] sequence)
376 {
377     return _sync.ExecuteReadOperation(() =>
378     {
379         var results = new List<ulong>();
380         if (sequence.Length > 0)
381         {
382             Links.EnsureLinkExists(sequence);
383             var firstElement = sequence[0];
384             if (sequence.Length == 1)
385             {
386                 results.Add(firstElement);
387                 return results;
388             }
389             if (sequence.Length == 2)
390             {
391                 var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
392                 if (doublet != Constants.Null)
393                 {
394                     results.Add(doublet);
395                 }
396                 return results;
397             }
398             var linksInSequence = new HashSet<ulong>(sequence);
399             void handler(ICollection<LinkIndex> result)
400             {
401                 var resultIndex = result[Links.Constants.IndexPart];
402                 var filterPosition = 0;
403                 StoppableSequenceWalker.WalkRight(resultIndex, Links.Unsync.GetSource,
404                     ↪ Links.Unsync.GetTarget,
405                     x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
406                     ↪ x =>
407                     {
408                         if (filterPosition == sequence.Length)
409                         {
410                             filterPosition = -2; // Длиннее чем нужно
411                             return false;
412                         }
413                         if (x != sequence[filterPosition])
414                         {
415                             filterPosition = -1;
416                             return false; // Начинается иначе
417                         }
418                         filterPosition++;
419                     }
420                     return true;
421                 });
422                 if (filterPosition == sequence.Length)
423                 {
424                     results.Add(resultIndex);
425                 }
426             }
427             if (sequence.Length >= 2)
428             {
429                 StepRight(handler, sequence[0], sequence[1]);
430             }
431             var last = sequence.Length - 2;
432             for (var i = 1; i < last; i++)
433             {
434                 PartialStepRight(handler, sequence[i], sequence[i + 1]);
435             }
436             if (sequence.Length >= 3)
437             {
438                 StepLeft(handler, sequence[sequence.Length - 2],
439                     ↪ sequence[sequence.Length - 1]);
440             }
441         }
442         return results;
443     });
444 }

```

```

442 public HashSet<ulong> GetAllMatchingSequences1(params ulong[] sequence)
443 {
444     return _sync.ExecuteReadOperation(() =>
445     {
446         var results = new HashSet<ulong>();
447         if (sequence.Length > 0)
448         {
449             Links.EnsureLinkExists(sequence);
450             var firstElement = sequence[0];
451             if (sequence.Length == 1)
452             {
453                 results.Add(firstElement);
454                 return results;
455             }
456             if (sequence.Length == 2)
457             {
458                 var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
459                 if (doublet != Constants.Null)
460                 {
461                     results.Add(doublet);
462                 }
463                 return results;
464             }
465             var matcher = new Matcher(this, sequence, results, null);
466             if (sequence.Length >= 2)
467             {
468                 StepRight(matcher.AddFullMatchedToResults, sequence[0], sequence[1]);
469             }
470             var last = sequence.Length - 2;
471             for (var i = 1; i < last; i++)
472             {
473                 PartialStepRight(matcher.AddFullMatchedToResults, sequence[i],
474                     ↪ sequence[i + 1]);
475             }
476             if (sequence.Length >= 3)
477             {
478                 StepLeft(matcher.AddFullMatchedToResults, sequence[sequence.Length - 2],
479                     ↪ sequence[sequence.Length - 1]);
480             }
481             return results;
482         });
483     }
484
485     public const int MaxSequenceFormatSize = 200;
486
487     public string FormatSequence(LinkIndex sequenceLink, params LinkIndex[] knownElements)
488     ↪ => FormatSequence(sequenceLink, (sb, x) => sb.Append(x), true, knownElements);
489
490     public string FormatSequence(LinkIndex sequenceLink, Action<StringBuilder, LinkIndex>
491     ↪ elementToString, bool insertComma, params LinkIndex[] knownElements) =>
492     ↪ Links.SyncRoot.ExecuteReadOperation(() => FormatSequence(Links.Unsync, sequenceLink,
493     ↪ elementToString, insertComma, knownElements));
494
495     private string FormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
496     ↪ Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
497     ↪ LinkIndex[] knownElements)
498     {
499         var linksInSequence = new HashSet<ulong>(knownElements);
500         //var entered = new HashSet<ulong>();
501         var sb = new StringBuilder();
502         sb.Append('{');
503         if (links.Exists(sequenceLink))
504         {
505             StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
506                 x => linksInSequence.Contains(x) || links.IsPartialPoint(x), element => //
507                 ↪ entered.AddAndReturnVoid, x => { }, entered.DoNotContains
508             {
509                 if (insertComma && sb.Length > 1)
510                 {
511                     sb.Append(',');
512                 }
513                 //if (entered.Contains(element))
514                 //{
515                 //    sb.Append('{');
516                 //    elementToString(sb, element);
517                 //    sb.Append('}');
518             }
519         }
520     }

```

```

511         //}
512         //else
513         elementToString(sb, element);
514         if (sb.Length < MaxSequenceFormatSize)
515         {
516             return true;
517         }
518         sb.Append(insertComma ? ", ..." : "...");
519         return false;
520     });
521 }
522 sb.Append('}');
523 return sb.ToString();
524 }
525
526 public string SafeFormatSequence(LinkIndex sequenceLink, params LinkIndex[]
    ↪ knownElements) => SafeFormatSequence(sequenceLink, (sb, x) => sb.Append(x), true,
    ↪ knownElements);
527
528 public string SafeFormatSequence(LinkIndex sequenceLink, Action<StringBuilder,
    ↪ LinkIndex> elementToString, bool insertComma, params LinkIndex[] knownElements) =>
    ↪ Links.SyncRoot.ExecuteReadOperation(() => SafeFormatSequence(Links.Unsync,
    ↪ sequenceLink, elementToString, insertComma, knownElements));
529
530 private string SafeFormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
    ↪ Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
    ↪ LinkIndex[] knownElements)
531 {
532     var linksInSequence = new HashSet<ulong>(knownElements);
533     var entered = new HashSet<ulong>();
534     var sb = new StringBuilder();
535     sb.Append('{');
536     if (links.Exists(sequenceLink))
537     {
538         StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
539             x => linksInSequence.Contains(x) || links.IsFullPoint(x),
540             ↪ entered.AddAndReturnVoid, x => { }, entered.DoNotContains, element =>
541             {
542                 if (insertComma && sb.Length > 1)
543                 {
544                     sb.Append(',');
545                 }
546                 if (entered.Contains(element))
547                 {
548                     sb.Append('{');
549                     elementToString(sb, element);
550                     sb.Append('}');
551                 }
552                 else
553                 {
554                     elementToString(sb, element);
555                 }
556                 if (sb.Length < MaxSequenceFormatSize)
557                 {
558                     return true;
559                 }
560                 sb.Append(insertComma ? ", ..." : "...");
561                 return false;
562             });
563     }
564     sb.Append('}');
565     return sb.ToString();
566 }
567
568 public List<ulong> GetAllPartiallyMatchingSequences0(params ulong[] sequence)
569 {
570     return _sync.ExecuteReadOperation(() =>
571     {
572         if (sequence.Length > 0)
573         {
574             Links.EnsureLinkExists(sequence);
575             var results = new HashSet<ulong>();
576             for (var i = 0; i < sequence.Length; i++)
577             {
578                 AllUsagesCore(sequence[i], results);
579             }
580             var filteredResults = new List<ulong>();
581             var linksInSequence = new HashSet<ulong>(sequence);

```

```

581         foreach (var result in results)
582         {
583             var filterPosition = -1;
584             StopableSequenceWalker.WalkRight(result, Links.Unsync.GetSource,
585                 ↪ Links.Unsync.GetTarget,
586                 x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
587                 ↪ x =>
588                 {
589                     if (filterPosition == (sequence.Length - 1))
590                     {
591                         return false;
592                     }
593                     if (filterPosition >= 0)
594                     {
595                         if (x == sequence[filterPosition + 1])
596                         {
597                             filterPosition++;
598                         }
599                         else
600                         {
601                             return false;
602                         }
603                     }
604                     if (filterPosition < 0)
605                     {
606                         if (x == sequence[0])
607                         {
608                             filterPosition = 0;
609                         }
610                     }
611                     return true;
612                 });
613             if (filterPosition == (sequence.Length - 1))
614             {
615                 filteredResults.Add(result);
616             }
617         }
618         return filteredResults;
619     }
620     return new List<ulong>();
621 });
622
623 public HashSet<ulong> GetAllPartiallyMatchingSequences1(params ulong[] sequence)
624 {
625     return _sync.ExecuteReadOperation(() =>
626     {
627         if (sequence.Length > 0)
628         {
629             Links.EnsureLinkExists(sequence);
630             var results = new HashSet<ulong>();
631             for (var i = 0; i < sequence.Length; i++)
632             {
633                 AllUsagesCore(sequence[i], results);
634             }
635             var filteredResults = new HashSet<ulong>();
636             var matcher = new Matcher(this, sequence, filteredResults, null);
637             matcher.AddAllPartialMatchedToResults(results);
638             return filteredResults;
639         }
640         return new HashSet<ulong>();
641     });
642 }
643
644 public bool GetAllPartiallyMatchingSequences2(Func<IList<LinkIndex>, LinkIndex> handler,
645 ↪ params ulong[] sequence)
646 {
647     return _sync.ExecuteReadOperation(() =>
648     {
649         if (sequence.Length > 0)
650         {
651             Links.EnsureLinkExists(sequence);
652
653             var results = new HashSet<ulong>();
654             var filteredResults = new HashSet<ulong>();
655             var matcher = new Matcher(this, sequence, filteredResults, handler);
656             for (var i = 0; i < sequence.Length; i++)
657             {
658                 if (!AllUsagesCore1(sequence[i], results, matcher.HandlePartialMatched))

```

```

657         {
658             return false;
659         }
660     }
661     return true;
662 }
663 return true;
664 });
665 }
666
667 //public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
668 //{
669 //    return Sync.ExecuteReadOperation(() =>
670 //    {
671 //        if (sequence.Length > 0)
672 //        {
673 //            _links.EnsureEachLinkIsAnyOrExists(sequence);
674 //
675 //            var firstResults = new HashSet<ulong>();
676 //            var lastResults = new HashSet<ulong>();
677 //
678 //            var first = sequence.First(x => x != LinksConstants.Any);
679 //            var last = sequence.Last(x => x != LinksConstants.Any);
680 //
681 //            AllUsagesCore(first, firstResults);
682 //            AllUsagesCore(last, lastResults);
683 //
684 //            firstResults.IntersectWith(lastResults);
685 //
686 //            //for (var i = 0; i < sequence.Length; i++)
687 //            //    AllUsagesCore(sequence[i], results);
688 //
689 //            var filteredResults = new HashSet<ulong>();
690 //            var matcher = new Matcher(this, sequence, filteredResults, null);
691 //            matcher.AddAllPartialMatchedToResults(firstResults);
692 //            return filteredResults;
693 //        }
694 //
695 //        return new HashSet<ulong>();
696 //    });
697 //}
698
699 public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
700 {
701     return _sync.ExecuteReadOperation((Func<HashSet<ulong>>)(() =>
702     {
703         if (sequence.Length > 0)
704         {
705             ILinksExtensions.EnsureLinkIsAnyOrExists<ulong>(Links,
706                 ↪ (IList<ulong>)sequence);
707             var firstResults = new HashSet<ulong>();
708             var lastResults = new HashSet<ulong>();
709             var first = sequence.First(x => x != Constants.Any);
710             var last = sequence.Last(x => x != Constants.Any);
711             AllUsagesCore(first, firstResults);
712             AllUsagesCore(last, lastResults);
713             firstResults.IntersectWith(lastResults);
714             //for (var i = 0; i < sequence.Length; i++)
715             //    AllUsagesCore(sequence[i], results);
716             var filteredResults = new HashSet<ulong>();
717             var matcher = new Matcher(this, sequence, filteredResults, null);
718             matcher.AddAllPartialMatchedToResults(firstResults);
719             return filteredResults;
720         }
721         return new HashSet<ulong>();
722     }));
723 }
724
725 public HashSet<ulong> GetAllPartiallyMatchingSequences4(HashSet<ulong> readAsElements,
726     ↪ IList<ulong> sequence)
727 {
728     return _sync.ExecuteReadOperation(() =>
729     {
730         if (sequence.Count > 0)
731         {
732             Links.EnsureLinkExists(sequence);
733             var results = new HashSet<LinkIndex>();
734             //var nextResults = new HashSet<ulong>();
735             //for (var i = 0; i < sequence.Length; i++)

```

```

734         //{
735         //     AllUsagesCore(sequence[i], nextResults);
736         //     if (results.IsNullOrEmpty())
737         //     {
738         //         results = nextResults;
739         //         nextResults = new HashSet<ulong>();
740         //     }
741         //     else
742         //     {
743         //         results.IntersectWith(nextResults);
744         //         nextResults.Clear();
745         //     }
746         //}
747         var collector1 = new AllUsagesCollector1(Links.Unsync, results);
748         collector1.Collect(Links.Unsync.GetLink(sequence[0]));
749         var next = new HashSet<ulong>();
750         for (var i = 1; i < sequence.Count; i++)
751         {
752             var collector = new AllUsagesCollector1(Links.Unsync, next);
753             collector.Collect(Links.Unsync.GetLink(sequence[i]));
754
755             results.IntersectWith(next);
756             next.Clear();
757         }
758         var filteredResults = new HashSet<ulong>();
759         var matcher = new Matcher(this, sequence, filteredResults, null,
760             ↪ readAsElements);
761         matcher.AddAllPartialMatchedToResultsAndReadAsElements(results.OrderBy(x =>
762             ↪ x)); // OrderBy is a Hack
763         return filteredResults;
764     }
765     return new HashSet<ulong>();
766 }
767
768 // Does not work
769 //public HashSet<ulong> GetAllPartiallyMatchingSequences5(HashSet<ulong> readAsElements,
770 //    ↪ params ulong[] sequence)
771 //{
772 //    var visited = new HashSet<ulong>();
773 //    var results = new HashSet<ulong>();
774 //    var matcher = new Matcher(this, sequence, visited, x => { results.Add(x); return
775 //    ↪ true; }, readAsElements);
776 //    var last = sequence.Length - 1;
777 //    for (var i = 0; i < last; i++)
778 //    {
779 //        PartialStepRight(matcher.PartialMatch, sequence[i], sequence[i + 1]);
780 //    }
781 //    return results;
782 //}
783
784 public List<ulong> GetAllPartiallyMatchingSequences(params ulong[] sequence)
785 {
786     return _sync.ExecuteReadOperation(() =>
787     {
788         if (sequence.Length > 0)
789         {
790             Links.EnsureLinkExists(sequence);
791             //var firstElement = sequence[0];
792             //if (sequence.Length == 1)
793             //{
794             //    //results.Add(firstElement);
795             //    return results;
796             //}
797             //if (sequence.Length == 2)
798             //{
799             //    //var doublet = _links.SearchCore(firstElement, sequence[1]);
800             //    //if (doublet != Doublets.Links.Null)
801             //    //    results.Add(doublet);
802             //    return results;
803             //}
804             //var lastElement = sequence[sequence.Length - 1];
805             //Func<ulong, bool> handler = x =>
806             //{
807                 if (StartsWith(x, firstElement) && EndsWith(x, lastElement))
808                     ↪ results.Add(x);
809                 ↪ 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?
818     //if (sequence.Length == 2)
819     //    {
820     //        var results = new List<ulong>();
821     //        PartialStepRight(results.Add, sequence[0], sequence[1]);
822     //        return results;
823     //    }
824     //var matches = new List<List<ulong>>();
825     //var last = sequence.Length - 1;
826     //for (var i = 0; i < last; i++)
827     //    {
828     //        var results = new List<ulong>();
829     //        //StepRight(results.Add, sequence[i], sequence[i + 1]);
830     //        PartialStepRight(results.Add, sequence[i], sequence[i + 1]);
831     //        if (results.Count > 0)
832     //            matches.Add(results);
833     //        else
834     //            return results;
835     //        if (matches.Count == 2)
836     //            {
837     //                var merged = new List<ulong>();
838     //                for (var j = 0; j < matches[0].Count; j++)
839     //                    for (var k = 0; k < matches[1].Count; k++)
840     //                        CloseInnerConnections(merged.Add, matches[0][j],
841     //                            ↪ matches[1][k]);
842     //                if (merged.Count > 0)
843     //                    matches = new List<List<ulong>> { merged };
844     //                else
845     //                    return new List<ulong>();
846     //            }
847     //        if (matches.Count > 0)
848     //            {
849     //                var usages = new HashSet<ulong>();
850     //                for (int i = 0; i < sequence.Length; i++)
851     //                    {
852     //                        AllUsagesCore(sequence[i], usages);
853     //                    }
854     //                //for (int i = 0; i < matches[0].Count; i++)
855     //                //    AllUsagesCore(matches[0][i], usages);
856     //                //usages.UnionWith(matches[0]);
857     //                return usages.ToList();
858     //            }
859     //var firstLinkUsages = new HashSet<ulong>();
860     //AllUsagesCore(sequence[0], firstLinkUsages);
861     //firstLinkUsages.Add(sequence[0]);
862     //var previousMatchings = firstLinkUsages.ToList(); //new List<ulong>() {
863     //    ↪ sequence[0] }; // or all sequences, containing this element?
864     //return GetAllPartiallyMatchingSequencesCore(sequence, firstLinkUsages,
865     //    ↪ 1).ToList();
866     var results = new HashSet<ulong>();
867     foreach (var match in GetAllPartiallyMatchingSequencesCore(sequence,
868     ↪ firstLinkUsages, 1))
869     {
870         AllUsagesCore(match, results);
871     }
872     return results.ToList();
873 }
874 }
875 }
876 }

```

/// <remarks>
 /// TODO: Может потребоваться ограничение на уровень глубины рекурсии


```

877 /// </remarks>
878 public HashSet<ulong> AllUsages(ulong link)
879 {
880     return _sync.ExecuteReadOperation(() =>
881     {
882         var usages = new HashSet<ulong>();
883         AllUsagesCore(link, usages);
884         return usages;
885     });
886 }
887
888 // При сборе всех использований (последовательностей) можно сохранять обратный путь к
889 // той связи с которой начинался поиск (STTTSSSTT),
890 // причём достаточно одного бита для хранения перехода влево или вправо
891 private void AllUsagesCore(ulong link, HashSet<ulong> usages)
892 {
893     bool handler(ulong doublet)
894     {
895         if (usages.Add(doublet))
896         {
897             AllUsagesCore(doublet, usages);
898         }
899         return true;
900     }
901     Links.Unsync.Each(link, Constants.Any, handler);
902     Links.Unsync.Each(Constants.Any, link, handler);
903 }
904
905 public HashSet<ulong> AllBottomUsages(ulong link)
906 {
907     return _sync.ExecuteReadOperation(() =>
908     {
909         var visits = new HashSet<ulong>();
910         var usages = new HashSet<ulong>();
911         AllBottomUsagesCore(link, visits, usages);
912         return usages;
913     });
914 }
915
916 private void AllBottomUsagesCore(ulong link, HashSet<ulong> visits, HashSet<ulong>
917     ↳ usages)
918 {
919     bool handler(ulong doublet)
920     {
921         if (visits.Add(doublet))
922         {
923             AllBottomUsagesCore(doublet, visits, usages);
924         }
925         return true;
926     }
927     if (Links.Unsync.Count(Constants.Any, link) == 0)
928     {
929         usages.Add(link);
930     }
931     else
932     {
933         Links.Unsync.Each(link, Constants.Any, handler);
934         Links.Unsync.Each(Constants.Any, link, handler);
935     }
936 }
937
938 public ulong CalculateTotalSymbolFrequencyCore(ulong symbol)
939 {
940     if (Options.UseSequenceMarker)
941     {
942         var counter = new TotalMarkedSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
943     ↳ Options.MarkedSequenceMatcher, symbol);
944         return counter.Count();
945     }
946     else
947     {
948         var counter = new TotalSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
949     ↳ symbol);
950         return counter.Count();
951     }
952 }

```

```

950 private bool AllUsagesCore1(ulong link, HashSet<ulong> usages, Func<IList<LinkIndex>,
    ↳ LinkIndex> outerHandler)
951 {
952     bool handler(ulong doublet)
953     {
954         if (usages.Add(doublet))
955         {
956             if (outerHandler(new LinkAddress<LinkIndex>(doublet)) != Constants.Continue)
957             {
958                 return false;
959             }
960             if (!AllUsagesCore1(doublet, usages, outerHandler))
961             {
962                 return false;
963             }
964         }
965         return true;
966     }
967     return Links.Unsync.Each(link, Constants.Any, handler)
968         && Links.Unsync.Each(Constants.Any, link, handler);
969 }
970
971 public void CalculateAllUsages(ulong[] totals)
972 {
973     var calculator = new AllUsagesCalculator(Links, totals);
974     calculator.Calculate();
975 }
976
977 public void CalculateAllUsages2(ulong[] totals)
978 {
979     var calculator = new AllUsagesCalculator2(Links, totals);
980     calculator.Calculate();
981 }
982
983 private class AllUsagesCalculator
984 {
985     private readonly SynchronizedLinks<ulong> _links;
986     private readonly ulong[] _totals;
987
988     public AllUsagesCalculator(SynchronizedLinks<ulong> links, ulong[] totals)
989     {
990         _links = links;
991         _totals = totals;
992     }
993
994     public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
    ↳ CalculateCore);
995
996     private bool CalculateCore(ulong link)
997     {
998         if (_totals[link] == 0)
999         {
1000             var total = 1UL;
1001             _totals[link] = total;
1002             var visitedChildren = new HashSet<ulong>();
1003             bool linkCalculator(ulong child)
1004             {
1005                 if (link != child && visitedChildren.Add(child))
1006                 {
1007                     total += _totals[child] == 0 ? 1 : _totals[child];
1008                 }
1009                 return true;
1010             }
1011             _links.Unsync.Each(link, _links.Constants.Any, linkCalculator);
1012             _links.Unsync.Each(_links.Constants.Any, link, linkCalculator);
1013             _totals[link] = total;
1014         }
1015         return true;
1016     }
1017 }
1018
1019 private class AllUsagesCalculator2
1020 {
1021     private readonly SynchronizedLinks<ulong> _links;
1022     private readonly ulong[] _totals;
1023
1024     public AllUsagesCalculator2(SynchronizedLinks<ulong> links, ulong[] totals)
1025     {
1026         _links = links;

```

```

1027     _totals = totals;
1028 }
1029
1030 public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
    ↪ CalculateCore);
1031
1032 private bool IsElement(ulong link)
1033 {
1034     // _linksInSequence.Contains(link) ||
1035     return _links.Unsync.GetTarget(link) == link || _links.Unsync.GetSource(link) ==
    ↪ link;
1036 }
1037
1038 private bool CalculateCore(ulong link)
1039 {
1040     // TODO: Проработать защиту от заикливания
1041     // Основано на SequenceWalker.WalkLeft
1042     Func<ulong, ulong> getSource = _links.Unsync.GetSource;
1043     Func<ulong, ulong> getTarget = _links.Unsync.GetTarget;
1044     Func<ulong, bool> isElement = IsElement;
1045     void visitLeaf(ulong parent)
1046     {
1047         if (link != parent)
1048         {
1049             _totals[parent]++;
1050         }
1051     }
1052     void visitNode(ulong parent)
1053     {
1054         if (link != parent)
1055         {
1056             _totals[parent]++;
1057         }
1058     }
1059     var stack = new Stack();
1060     var element = link;
1061     if (isElement(element))
1062     {
1063         visitLeaf(element);
1064     }
1065     else
1066     {
1067         while (true)
1068         {
1069             if (isElement(element))
1070             {
1071                 if (stack.Count == 0)
1072                 {
1073                     break;
1074                 }
1075                 element = stack.Pop();
1076                 var source = getSource(element);
1077                 var target = getTarget(element);
1078                 // Обработка элемента
1079                 if (isElement(target))
1080                 {
1081                     visitLeaf(target);
1082                 }
1083                 if (isElement(source))
1084                 {
1085                     visitLeaf(source);
1086                 }
1087                 element = source;
1088             }
1089             else
1090             {
1091                 stack.Push(element);
1092                 visitNode(element);
1093                 element = getTarget(element);
1094             }
1095         }
1096     }
1097     _totals[link]++;
1098     return true;
1099 }
1100
1101 private class AllUsagesCollector
1102 {
1103

```

```

1104     private readonly ILinks<ulong> _links;
1105     private readonly HashSet<ulong> _usages;
1106
1107     public AllUsagesCollector(ILinks<ulong> links, HashSet<ulong> usages)
1108     {
1109         _links = links;
1110         _usages = usages;
1111     }
1112
1113     public bool Collect(ulong link)
1114     {
1115         if (_usages.Add(link))
1116         {
1117             _links.Each(link, _links.Constants.Any, Collect);
1118             _links.Each(_links.Constants.Any, link, Collect);
1119         }
1120         return true;
1121     }
1122 }
1123
1124 private class AllUsagesCollector1
1125 {
1126     private readonly ILinks<ulong> _links;
1127     private readonly HashSet<ulong> _usages;
1128     private readonly ulong _continue;
1129
1130     public AllUsagesCollector1(ILinks<ulong> links, HashSet<ulong> usages)
1131     {
1132         _links = links;
1133         _usages = usages;
1134         _continue = _links.Constants.Continue;
1135     }
1136
1137     public ulong Collect(IList<ulong> link)
1138     {
1139         var linkIndex = _links.GetIndex(link);
1140         if (_usages.Add(linkIndex))
1141         {
1142             _links.Each(Collect, _links.Constants.Any, linkIndex);
1143         }
1144         return _continue;
1145     }
1146 }
1147
1148 private class AllUsagesCollector2
1149 {
1150     private readonly ILinks<ulong> _links;
1151     private readonly BitString _usages;
1152
1153     public AllUsagesCollector2(ILinks<ulong> links, BitString usages)
1154     {
1155         _links = links;
1156         _usages = usages;
1157     }
1158
1159     public bool Collect(ulong link)
1160     {
1161         if (_usages.Add((long)link))
1162         {
1163             _links.Each(link, _links.Constants.Any, Collect);
1164             _links.Each(_links.Constants.Any, link, Collect);
1165         }
1166         return true;
1167     }
1168 }
1169
1170 private class AllUsagesIntersectingCollector
1171 {
1172     private readonly SynchronizedLinks<ulong> _links;
1173     private readonly HashSet<ulong> _intersectWith;
1174     private readonly HashSet<ulong> _usages;
1175     private readonly HashSet<ulong> _enter;
1176
1177     public AllUsagesIntersectingCollector(SynchronizedLinks<ulong> links, HashSet<ulong>
↵ intersectWith, HashSet<ulong> usages)
1178     {
1179         _links = links;
1180         _intersectWith = intersectWith;
1181         _usages = usages;
1182         _enter = new HashSet<ulong>(); // защита от зацикливания
1183     }

```

```

1184 public bool Collect(ulong link)
1185 {
1186     if (_enter.Add(link))
1187     {
1188         if (_intersectWith.Contains(link))
1189         {
1190             _usages.Add(link);
1191         }
1192         _links.Unsync.Each(link, _links.Constants.Any, Collect);
1193         _links.Unsync.Each(_links.Constants.Any, link, Collect);
1194     }
1195     return true;
1196 }
1197 }
1198 }
1199
1200 private void CloseInnerConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
↪ right)
1201 {
1202     TryStepLeftUp(handler, left, right);
1203     TryStepRightUp(handler, right, left);
1204 }
1205
1206 private void AllCloseConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
↪ right)
1207 {
1208     // Direct
1209     if (left == right)
1210     {
1211         handler(new LinkAddress<LinkIndex>(left));
1212     }
1213     var doublet = Links.Unsync.SearchOrDefault(left, right);
1214     if (doublet != Constants.Null)
1215     {
1216         handler(new LinkAddress<LinkIndex>(doublet));
1217     }
1218     // Inner
1219     CloseInnerConnections(handler, left, right);
1220     // Outer
1221     StepLeft(handler, left, right);
1222     StepRight(handler, left, right);
1223     PartialStepRight(handler, left, right);
1224     PartialStepLeft(handler, left, right);
1225 }
1226
1227 private HashSet<ulong> GetAllPartiallyMatchingSequencesCore(ulong[] sequence,
↪ HashSet<ulong> previousMatchings, long startAt)
1228 {
1229     if (startAt >= sequence.Length) // ?
1230     {
1231         return previousMatchings;
1232     }
1233     var secondLinkUsages = new HashSet<ulong>();
1234     AllUsagesCore(sequence[startAt], secondLinkUsages);
1235     secondLinkUsages.Add(sequence[startAt]);
1236     var matchings = new HashSet<ulong>();
1237     var filler = new SetFiller<LinkIndex, LinkIndex>(matchings, Constants.Continue);
1238     //for (var i = 0; i < previousMatchings.Count; i++)
1239     foreach (var secondLinkUsage in secondLinkUsages)
1240     {
1241         foreach (var previousMatching in previousMatchings)
1242         {
1243             //AllCloseConnections(matchings.AddAndReturnVoid, previousMatching,
↪ secondLinkUsage);
1244             StepRight(filler.AddFirstAndReturnConstant, previousMatching,
↪ secondLinkUsage);
1245             TryStepRightUp(filler.AddFirstAndReturnConstant, secondLinkUsage,
↪ previousMatching);
1246             //PartialStepRight(matchings.AddAndReturnVoid, secondLinkUsage,
↪ sequence[startAt]); // почему-то эта ошибочная запись приводит к
↪ желаемым результатам.
1247             PartialStepRight(filler.AddFirstAndReturnConstant, previousMatching,
↪ secondLinkUsage);
1248         }
1249     }
1250     if (matchings.Count == 0)
1251     {

```

```

1252         return matchings;
1253     }
1254     return GetAllPartiallyMatchingSequencesCore(sequence, matchings, startAt + 1); // ??
1255 }
1256
1257 private static void EnsureEachLinkIsAnyOrZeroOrManyOrExists(SynchronizedLinks<ulong>
↪ links, params ulong[] sequence)
1258 {
1259     if (sequence == null)
1260     {
1261         return;
1262     }
1263     for (var i = 0; i < sequence.Length; i++)
1264     {
1265         if (sequence[i] != links.Constants.Any && sequence[i] != ZeroOrMany &&
↪ !links.Exists(sequence[i]))
1266         {
1267             throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
↪ $"patternSequence[{i}]");
1268         }
1269     }
1270 }
1271
1272 // Pattern Matching -> Key To Triggers
1273 public HashSet<ulong> MatchPattern(params ulong[] patternSequence)
1274 {
1275     return _sync.ExecuteReadOperation(() =>
1276     {
1277         patternSequence = Simplify(patternSequence);
1278         if (patternSequence.Length > 0)
1279         {
1280             EnsureEachLinkIsAnyOrZeroOrManyOrExists(links, patternSequence);
1281             var uniqueSequenceElements = new HashSet<ulong>();
1282             for (var i = 0; i < patternSequence.Length; i++)
1283             {
1284                 if (patternSequence[i] != Constants.Any && patternSequence[i] !=
↪ ZeroOrMany)
1285                 {
1286                     uniqueSequenceElements.Add(patternSequence[i]);
1287                 }
1288             }
1289             var results = new HashSet<ulong>();
1290             foreach (var uniqueSequenceElement in uniqueSequenceElements)
1291             {
1292                 AllUsagesCore(uniqueSequenceElement, results);
1293             }
1294             var filteredResults = new HashSet<ulong>();
1295             var matcher = new PatternMatcher(this, patternSequence, filteredResults);
1296             matcher.AddAllPatternMatchedToResults(results);
1297             return filteredResults;
1298         }
1299         return new HashSet<ulong>();
1300     });
1301 }
1302
1303 // Найти все возможные связи между указанным списком связей.
1304 // Находит связи между всеми указанными связями в любом порядке.
1305 // TODO: решить что делать с повторами (когда одни и те же элементы встречаются
↪ несколько раз в последовательности)
1306 public HashSet<ulong> GetAllConnections(params ulong[] linksToConnect)
1307 {
1308     return _sync.ExecuteReadOperation(() =>
1309     {
1310         var results = new HashSet<ulong>();
1311         if (linksToConnect.Length > 0)
1312         {
1313             links.EnsureLinkExists(linksToConnect);
1314             AllUsagesCore(linksToConnect[0], results);
1315             for (var i = 1; i < linksToConnect.Length; i++)
1316             {
1317                 var next = new HashSet<ulong>();
1318                 AllUsagesCore(linksToConnect[i], next);
1319                 results.IntersectWith(next);
1320             }
1321             return results;
1322         }
1323     });
1324 }

```

```

1325
1326 public HashSet<ulong> GetAllConnections1(params ulong[] linksToConnect)
1327 {
1328     return _sync.ExecuteReadOperation(() =>
1329     {
1330         var results = new HashSet<ulong>();
1331         if (linksToConnect.Length > 0)
1332         {
1333             Links.EnsureLinkExists(linksToConnect);
1334             var collector1 = new AllUsagesCollector(Links.Unsync, results);
1335             collector1.Collect(linksToConnect[0]);
1336             var next = new HashSet<ulong>();
1337             for (var i = 1; i < linksToConnect.Length; i++)
1338             {
1339                 var collector = new AllUsagesCollector(Links.Unsync, next);
1340                 collector.Collect(linksToConnect[i]);
1341                 results.IntersectWith(next);
1342                 next.Clear();
1343             }
1344         }
1345         return results;
1346     });
1347 }
1348
1349 public HashSet<ulong> GetAllConnections2(params ulong[] linksToConnect)
1350 {
1351     return _sync.ExecuteReadOperation(() =>
1352     {
1353         var results = new HashSet<ulong>();
1354         if (linksToConnect.Length > 0)
1355         {
1356             Links.EnsureLinkExists(linksToConnect);
1357             var collector1 = new AllUsagesCollector(Links, results);
1358             collector1.Collect(linksToConnect[0]);
1359             //AllUsagesCore(linksToConnect[0], results);
1360             for (var i = 1; i < linksToConnect.Length; i++)
1361             {
1362                 var next = new HashSet<ulong>();
1363                 var collector = new AllUsagesIntersectingCollector(Links, results, next);
1364                 collector.Collect(linksToConnect[i]);
1365                 //AllUsagesCore(linksToConnect[i], next);
1366                 //results.IntersectWith(next);
1367                 results = next;
1368             }
1369         }
1370         return results;
1371     });
1372 }
1373
1374 public List<ulong> GetAllConnections3(params ulong[] linksToConnect)
1375 {
1376     return _sync.ExecuteReadOperation(() =>
1377     {
1378         var results = new BitString((long)Links.Unsync.Count() + 1); // new
1379         ⇨ BitArray((int)_links.Total + 1);
1380         if (linksToConnect.Length > 0)
1381         {
1382             Links.EnsureLinkExists(linksToConnect);
1383             var collector1 = new AllUsagesCollector2(Links.Unsync, results);
1384             collector1.Collect(linksToConnect[0]);
1385             for (var i = 1; i < linksToConnect.Length; i++)
1386             {
1387                 var next = new BitString((long)Links.Unsync.Count() + 1); //new
1388                 ⇨ BitArray((int)_links.Total + 1);
1389                 var collector = new AllUsagesCollector2(Links.Unsync, next);
1390                 collector.Collect(linksToConnect[i]);
1391                 results = results.And(next);
1392             }
1393         }
1394         return results.GetSetUInt64Indices();
1395     });
1396 }
1397
1398 private static ulong[] Simplify(ulong[] sequence)
1399 {
1400     // Считаем новый размер последовательности
1401     long newLength = 0;
1402     var zeroOrManyStepped = false;

```

```

1401     for (var i = 0; i < sequence.Length; i++)
1402     {
1403         if (sequence[i] == ZeroOrMany)
1404         {
1405             if (zeroOrManyStepped)
1406             {
1407                 continue;
1408             }
1409             zeroOrManyStepped = true;
1410         }
1411         else
1412         {
1413             //if (zeroOrManyStepped) Is it efficient?
1414             zeroOrManyStepped = false;
1415         }
1416         newLength++;
1417     }
1418     // Строим новую последовательность
1419     zeroOrManyStepped = false;
1420     var newSequence = new ulong[newLength];
1421     long j = 0;
1422     for (var i = 0; i < sequence.Length; i++)
1423     {
1424         //var current = zeroOrManyStepped;
1425         //zeroOrManyStepped = patternSequence[i] == zeroOrMany;
1426         //if (current && zeroOrManyStepped)
1427         //    continue;
1428         //var newZeroOrManyStepped = patternSequence[i] == zeroOrMany;
1429         //if (zeroOrManyStepped && newZeroOrManyStepped)
1430         //    continue;
1431         //zeroOrManyStepped = newZeroOrManyStepped;
1432         if (sequence[i] == ZeroOrMany)
1433         {
1434             if (zeroOrManyStepped)
1435             {
1436                 continue;
1437             }
1438             zeroOrManyStepped = true;
1439         }
1440         else
1441         {
1442             //if (zeroOrManyStepped) Is it efficient?
1443             zeroOrManyStepped = false;
1444         }
1445         newSequence[j++] = sequence[i];
1446     }
1447     return newSequence;
1448 }
1449
1450 public static void TestSimplify()
1451 {
1452     var sequence = new ulong[] { ZeroOrMany, ZeroOrMany, 2, 3, 4, ZeroOrMany,
1453     ↪ ZeroOrMany, ZeroOrMany, 4, ZeroOrMany, ZeroOrMany, ZeroOrMany };
1454     var simplifiedSequence = Simplify(sequence);
1455 }
1456
1457 public List<ulong> GetSimilarSequences() => new List<ulong>();
1458
1459 public void Prediction()
1460 {
1461     //_links
1462     //_sequences
1463 }
1464
1465 #region From Triplets
1466
1467 //public static void DeleteSequence(Link sequence)
1468 //{
1469 //}
1470
1471 public List<ulong> CollectMatchingSequences(ulong[] links)
1472 {
1473     if (links.Length == 1)
1474     {
1475         throw new Exception("Подпоследовательности с одним элементом не
1476         ↪ поддерживаются.");
1477     }
1478     var leftBound = 0;
1479     var rightBound = links.Length - 1;

```



```

1478     var left = links[leftBound++];
1479     var right = links[rightBound--];
1480     var results = new List<ulong>();
1481     CollectMatchingSequences(left, leftBound, links, right, rightBound, ref results);
1482     return results;
1483 }
1484
1485 private void CollectMatchingSequences(ulong leftLink, int leftBound, ulong[]
→ middleLinks, ulong rightLink, int rightBound, ref List<ulong> results)
1486 {
1487     var leftLinkTotalReferers = Links.Unsync.Count(leftLink);
1488     var rightLinkTotalReferers = Links.Unsync.Count(rightLink);
1489     if (leftLinkTotalReferers <= rightLinkTotalReferers)
1490     {
1491         var nextLeftLink = middleLinks[leftBound];
1492         var elements = GetRightElements(leftLink, nextLeftLink);
1493         if (leftBound <= rightBound)
1494         {
1495             for (var i = elements.Length - 1; i >= 0; i--)
1496             {
1497                 var element = elements[i];
1498                 if (element != 0)
1499                 {
1500                     CollectMatchingSequences(element, leftBound + 1, middleLinks,
→ rightLink, rightBound, ref results);
1501                 }
1502             }
1503         }
1504         else
1505         {
1506             for (var i = elements.Length - 1; i >= 0; i--)
1507             {
1508                 var element = elements[i];
1509                 if (element != 0)
1510                 {
1511                     results.Add(element);
1512                 }
1513             }
1514         }
1515     }
1516     else
1517     {
1518         var nextRightLink = middleLinks[rightBound];
1519         var elements = GetLeftElements(rightLink, nextRightLink);
1520         if (leftBound <= rightBound)
1521         {
1522             for (var i = elements.Length - 1; i >= 0; i--)
1523             {
1524                 var element = elements[i];
1525                 if (element != 0)
1526                 {
1527                     CollectMatchingSequences(leftLink, leftBound, middleLinks,
→ elements[i], rightBound - 1, ref results);
1528                 }
1529             }
1530         }
1531         else
1532         {
1533             for (var i = elements.Length - 1; i >= 0; i--)
1534             {
1535                 var element = elements[i];
1536                 if (element != 0)
1537                 {
1538                     results.Add(element);
1539                 }
1540             }
1541         }
1542     }
1543 }
1544
1545 public ulong[] GetRightElements(ulong startLink, ulong rightLink)
1546 {
1547     var result = new ulong[5];
1548     TryStepRight(startLink, rightLink, result, 0);
1549     Links.Each(Constants.Any, startLink, couple =>
1550     {
1551         if (couple != startLink)
1552         {

```

```

1553         if (TryStepRight(couple, rightLink, result, 2))
1554         {
1555             return false;
1556         }
1557     }
1558     return true;
1559 });
1560 if (Links.GetTarget(Links.GetTarget(startLink)) == rightLink)
1561 {
1562     result[4] = startLink;
1563 }
1564 return result;
1565 }
1566
1567 public bool TryStepRight(ulong startLink, ulong rightLink, ulong[] result, int offset)
1568 {
1569     var added = 0;
1570     Links.Each(startLink, Constants.Any, couple =>
1571     {
1572         if (couple != startLink)
1573         {
1574             var coupleTarget = Links.GetTarget(couple);
1575             if (coupleTarget == rightLink)
1576             {
1577                 result[offset] = couple;
1578                 if (++added == 2)
1579                 {
1580                     return false;
1581                 }
1582             }
1583             else if (Links.GetSource(coupleTarget) == rightLink) // coupleTarget.Linker
1584                 ↪ == Net.And &&
1585             {
1586                 result[offset + 1] = couple;
1587                 if (++added == 2)
1588                 {
1589                     return false;
1590                 }
1591             }
1592         }
1593     });
1594     return added > 0;
1595 }
1596
1597 public ulong[] GetLeftElements(ulong startLink, ulong leftLink)
1598 {
1599     var result = new ulong[5];
1600     TryStepLeft(startLink, leftLink, result, 0);
1601     Links.Each(startLink, Constants.Any, couple =>
1602     {
1603         if (couple != startLink)
1604         {
1605             if (TryStepLeft(couple, leftLink, result, 2))
1606             {
1607                 return false;
1608             }
1609         }
1610     });
1611     return result;
1612 }
1613 if (Links.GetSource(Links.GetSource(leftLink)) == startLink)
1614 {
1615     result[4] = leftLink;
1616 }
1617 return result;
1618 }
1619
1620 public bool TryStepLeft(ulong startLink, ulong leftLink, ulong[] result, int offset)
1621 {
1622     var added = 0;
1623     Links.Each(Constants.Any, startLink, couple =>
1624     {
1625         if (couple != startLink)
1626         {
1627             var coupleSource = Links.GetSource(couple);
1628             if (coupleSource == leftLink)
1629             {
1630                 result[offset] = couple;
1631                 if (++added == 2)

```

```

1631         {
1632             return false;
1633         }
1634     }
1635     else if (Links.GetTarget(coupleSource) == leftLink) // coupleSource.Linker
1636         ↪ == Net.And &&
1637     {
1638         result[offset + 1] = couple;
1639         if (++added == 2)
1640         {
1641             return false;
1642         }
1643     }
1644     return true;
1645 });
1646 return added > 0;
1647 }
1648
1649 #endregion
1650
1651 #region Walkers
1652
1653 public class PatternMatcher : RightSequenceWalker<ulong>
1654 {
1655     private readonly Sequences _sequences;
1656     private readonly ulong[] _patternSequence;
1657     private readonly HashSet<LinkIndex> _linksInSequence;
1658     private readonly HashSet<LinkIndex> _results;
1659
1660     #region Pattern Match
1661
1662     enum PatternBlockType
1663     {
1664         Undefined,
1665         Gap,
1666         Elements
1667     }
1668
1669     struct PatternBlock
1670     {
1671         public PatternBlockType Type;
1672         public long Start;
1673         public long Stop;
1674     }
1675
1676     private readonly List<PatternBlock> _pattern;
1677     private int _patternPosition;
1678     private long _sequencePosition;
1679
1680     #endregion
1681
1682     public PatternMatcher(Sequences sequences, LinkIndex[] patternSequence,
1683         ↪ HashSet<LinkIndex> results)
1684         : base(sequences.Links.Unsync, new DefaultStack<ulong>())
1685     {
1686         _sequences = sequences;
1687         _patternSequence = patternSequence;
1688         _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
1689             ↪ _sequences.Constants.Any && x != ZeroOrMany));
1690         _results = results;
1691         _pattern = CreateDetailedPattern();
1692     }
1693
1694     protected override bool IsElement(ulong link) => _linksInSequence.Contains(link) ||
1695         ↪ base.IsElement(link);
1696
1697     public bool PatternMatch(LinkIndex sequenceToMatch)
1698     {
1699         _patternPosition = 0;
1700         _sequencePosition = 0;
1701         foreach (var part in Walk(sequenceToMatch))
1702         {
1703             if (!PatternMatchCore(part))
1704             {
1705                 break;
1706             }
1707         }
1708         return _patternPosition == _pattern.Count || (_patternPosition == _pattern.Count
1709             ↪ - 1 && _pattern[_patternPosition].Start == 0);
1710     }

```

```

1707 private List<PatternBlock> CreateDetailedPattern()
1708 {
1709     var pattern = new List<PatternBlock>();
1710     var patternBlock = new PatternBlock();
1711     for (var i = 0; i < _patternSequence.Length; i++)
1712     {
1713         if (patternBlock.Type == PatternBlockType.Undefined)
1714         {
1715             if (_patternSequence[i] == _sequences.Constants.Any)
1716             {
1717                 patternBlock.Type = PatternBlockType.Gap;
1718                 patternBlock.Start = 1;
1719                 patternBlock.Stop = 1;
1720             }
1721             else if (_patternSequence[i] == ZeroOrMany)
1722             {
1723                 patternBlock.Type = PatternBlockType.Gap;
1724                 patternBlock.Start = 0;
1725                 patternBlock.Stop = long.MaxValue;
1726             }
1727             else
1728             {
1729                 patternBlock.Type = PatternBlockType.Elements;
1730                 patternBlock.Start = i;
1731                 patternBlock.Stop = i;
1732             }
1733         }
1734         else if (patternBlock.Type == PatternBlockType.Elements)
1735         {
1736             if (_patternSequence[i] == _sequences.Constants.Any)
1737             {
1738                 pattern.Add(patternBlock);
1739                 patternBlock = new PatternBlock
1740                 {
1741                     Type = PatternBlockType.Gap,
1742                     Start = 1,
1743                     Stop = 1
1744                 };
1745             }
1746             else if (_patternSequence[i] == ZeroOrMany)
1747             {
1748                 pattern.Add(patternBlock);
1749                 patternBlock = new PatternBlock
1750                 {
1751                     Type = PatternBlockType.Gap,
1752                     Start = 0,
1753                     Stop = long.MaxValue
1754                 };
1755             }
1756             else
1757             {
1758                 patternBlock.Stop = i;
1759             }
1760         }
1761         else // patternBlock.Type == PatternBlockType.Gap
1762         {
1763             if (_patternSequence[i] == _sequences.Constants.Any)
1764             {
1765                 patternBlock.Start++;
1766                 if (patternBlock.Stop < patternBlock.Start)
1767                 {
1768                     patternBlock.Stop = patternBlock.Start;
1769                 }
1770             }
1771             else if (_patternSequence[i] == ZeroOrMany)
1772             {
1773                 patternBlock.Stop = long.MaxValue;
1774             }
1775             else
1776             {
1777                 pattern.Add(patternBlock);
1778                 patternBlock = new PatternBlock
1779                 {
1780                     Type = PatternBlockType.Elements,
1781                     Start = i,
1782                     Stop = i
1783                 };
1784             }
1785         }
1786     }

```

```

1787     }
1788     if (patternBlock.Type != PatternBlockType.Undefined)
1789     {
1790         pattern.Add(patternBlock);
1791     }
1792     return pattern;
1793 }
1794
1795 // match: search for regexp anywhere in text
1796 //int match(char* regexp, char* text)
1797 //{
1798 //    do
1799 //    {
1800 //        } while (*text++ != '\0');
1801 //    return 0;
1802 //}
1803
1804 // matchhere: search for regexp at beginning of text
1805 //int matchhere(char* regexp, char* text)
1806 //{
1807 //    if (regexp[0] == '\0')
1808 //        return 1;
1809 //    if (regexp[1] == '*')
1810 //        return matchstar(regexp[0], regexp + 2, text);
1811 //    if (regexp[0] == '$' && regexp[1] == '\0')
1812 //        return *text == '\0';
1813 //    if (*text != '\0' && (regexp[0] == '.' || regexp[0] == *text))
1814 //        return matchhere(regexp + 1, text + 1);
1815 //    return 0;
1816 //}
1817
1818 // matchstar: search for c*regexp at beginning of text
1819 //int matchstar(int c, char* regexp, char* text)
1820 //{
1821 //    do
1822 //    {
1823 //        /* a * matches zero or more instances */
1824 //        if (matchhere(regexp, text))
1825 //            return 1;
1826 //    } while (*text != '\0' && (*text++ == c || c == '.'));
1827 //    return 0;
1828 //}
1829
1830 //private void GetNextPatternElement(out LinkIndex element, out long mininumGap, out
1831 //    long maximumGap)
1832 //{
1833 //    mininumGap = 0;
1834 //    maximumGap = 0;
1835 //    element = 0;
1836 //    for (; _patternPosition < _patternSequence.Length; _patternPosition++)
1837 //    {
1838 //        if (_patternSequence[_patternPosition] == Doublets.Links.Null)
1839 //            mininumGap++;
1840 //        else if (_patternSequence[_patternPosition] == ZeroOrMany)
1841 //            maximumGap = long.MaxValue;
1842 //        else
1843 //            break;
1844 //    }
1845 //    if (maximumGap < mininumGap)
1846 //        maximumGap = mininumGap;
1847 //}
1848 private bool PatternMatchCore(LinkIndex element)
1849 {
1850     if (_patternPosition >= _pattern.Count)
1851     {
1852         _patternPosition = -2;
1853         return false;
1854     }
1855     var currentPatternBlock = _pattern[_patternPosition];
1856     if (currentPatternBlock.Type == PatternBlockType.Gap)
1857     {
1858         //var currentMatchingBlockLength = (_sequencePosition -
1859 //    ↪ _lastMatchedBlockPosition);
1860         if (_sequencePosition < currentPatternBlock.Start)
1861         {
1862             _sequencePosition++;
1863             return true; // Двигаемся дальше

```

```

1863     }
1864     // Это последний блок
1865     if (_pattern.Count == _patternPosition + 1)
1866     {
1867         _patternPosition++;
1868         _sequencePosition = 0;
1869         return false; // Полное соответствие
1870     }
1871     else
1872     {
1873         if (_sequencePosition > currentPatternBlock.Stop)
1874         {
1875             return false; // Соответствие невозможно
1876         }
1877         var nextPatternBlock = _pattern[_patternPosition + 1];
1878         if (_patternSequence[nextPatternBlock.Start] == element)
1879         {
1880             if (nextPatternBlock.Start < nextPatternBlock.Stop)
1881             {
1882                 _patternPosition++;
1883                 _sequencePosition = 1;
1884             }
1885             else
1886             {
1887                 _patternPosition += 2;
1888                 _sequencePosition = 0;
1889             }
1890         }
1891     }
1892 }
1893 else // currentPatternBlock.Type == PatternBlockType.Elements
1894 {
1895     var patternElementPosition = currentPatternBlock.Start + _sequencePosition;
1896     if (_patternSequence[patternElementPosition] != element)
1897     {
1898         return false; // Соответствие невозможно
1899     }
1900     if (patternElementPosition == currentPatternBlock.Stop)
1901     {
1902         _patternPosition++;
1903         _sequencePosition = 0;
1904     }
1905     else
1906     {
1907         _sequencePosition++;
1908     }
1909 }
1910 return true;
1911 //if (_patternSequence[_patternPosition] != element)
1912 //    return false;
1913 //else
1914 //{
1915 //    _sequencePosition++;
1916 //    _patternPosition++;
1917 //    return true;
1918 //}
1919 ///////
1920 //if (_filterPosition == _patternSequence.Length)
1921 //{
1922 //    _filterPosition = -2; // Длиннее чем нужно
1923 //    return false;
1924 //}
1925 //if (element != _patternSequence[_filterPosition])
1926 //{
1927 //    _filterPosition = -1;
1928 //    return false; // Начинается иначе
1929 //}
1930 //_filterPosition++;
1931 //if (_filterPosition == (_patternSequence.Length - 1))
1932 //    return false;
1933 //if (_filterPosition >= 0)
1934 //{
1935 //    if (element == _patternSequence[_filterPosition + 1])
1936 //        _filterPosition++;
1937 //    else
1938 //        return false;
1939 //}
1940 //if (_filterPosition < 0)
1941 //{

```

```

1942         //      if (element == _patternSequence[0])
1943         //          _filterPosition = 0;
1944         //}
1945     }
1946
1947     public void AddAllPatternMatchedToResults(IEnumerable<ulong> sequencesToMatch)
1948     {
1949         foreach (var sequenceToMatch in sequencesToMatch)
1950         {
1951             if (PatternMatch(sequenceToMatch))
1952             {
1953                 _results.Add(sequenceToMatch);
1954             }
1955         }
1956     }
1957 }
1958
1959 #endregion
1960 }
1961 }

```

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

```

```

52  /// <summary>Возвращает значение LinkIndex, обозначающее любое количество
    ↳ связей.</summary>
53  public const LinkIndex ZeroOrMany = LinkIndex.MaxValue;
54
55  public SequencesOptions<LinkIndex> Options { get; }
56  public SynchronizedLinks<LinkIndex> Links { get; }
57  private readonly ISynchronization _sync;
58
59  public LinksConstants<LinkIndex> Constants { get; }
60
61  public Sequences(SynchronizedLinks<LinkIndex> links, SequencesOptions<LinkIndex> options)
62  {
63      Links = links;
64      _sync = links.SyncRoot;
65      Options = options;
66      Options.ValidateOptions();
67      Options.InitOptions(Links);
68      Constants = links.Constants;
69  }
70
71  public Sequences(SynchronizedLinks<LinkIndex> links)
72      : this(links, new SequencesOptions<LinkIndex>())
73  {
74  }
75
76  public bool IsSequence(LinkIndex sequence)
77  {
78      return _sync.ExecuteReadOperation(() =>
79      {
80          if (Options.UseSequenceMarker)
81          {
82              return Options.MarkedSequenceMatcher.IsMatched(sequence);
83          }
84          return !Links.Unsync.IsPartialPoint(sequence);
85      });
86  }
87
88  [MethodImpl(MethodImplOptions.AggressiveInlining)]
89  private LinkIndex GetSequenceByElements(LinkIndex sequence)
90  {
91      if (Options.UseSequenceMarker)
92      {
93          return Links.SearchOrDefault(Options.SequenceMarkerLink, sequence);
94      }
95      return sequence;
96  }
97
98  private LinkIndex GetSequenceElements(LinkIndex sequence)
99  {
100     if (Options.UseSequenceMarker)
101     {
102         var linkContents = new Link<ulong>(Links.GetLink(sequence));
103         if (linkContents.Source == Options.SequenceMarkerLink)
104         {
105             return linkContents.Target;
106         }
107         if (linkContents.Target == Options.SequenceMarkerLink)
108         {
109             return linkContents.Source;
110         }
111     }
112     return sequence;
113 }
114
115 #region Count
116
117 public LinkIndex Count(IList<LinkIndex> restrictions)
118 {
119     if (restrictions.IsNullOrEmpty())
120     {
121         return Links.Count(Constants.Any, Options.SequenceMarkerLink, Constants.Any);
122     }
123     if (restrictions.Count == 1) // Первая связь это адрес
124     {
125         var sequenceIndex = restrictions[0];
126         if (sequenceIndex == Constants.Null)
127         {
128             return 0;
129         }
130     }
131 }

```



```

130         if (sequenceIndex == Constants.Any)
131         {
132             return Count(null);
133         }
134         if (Options.UseSequenceMarker)
135         {
136             return Links.Count(Constants.Any, Options.SequenceMarkerLink, sequenceIndex);
137         }
138         return Links.Exists(sequenceIndex) ? 1UL : 0;
139     }
140     throw new NotImplementedException();
141 }
142
143 private LinkIndex CountUsages(params LinkIndex[] restrictions)
144 {
145     if (restrictions.Length == 0)
146     {
147         return 0;
148     }
149     if (restrictions.Length == 1) // Первая связь это адрес
150     {
151         if (restrictions[0] == Constants.Null)
152         {
153             return 0;
154         }
155         var any = Constants.Any;
156         if (Options.UseSequenceMarker)
157         {
158             var elementsLink = GetSequenceElements(restrictions[0]);
159             var sequenceLink = GetSequenceByElements(elementsLink);
160             if (sequenceLink != Constants.Null)
161             {
162                 return Links.Count(any, sequenceLink) + Links.Count(any, elementsLink) -
163                     ↪ 1;
164             }
165             return Links.Count(any, elementsLink);
166         }
167         return Links.Count(any, restrictions[0]);
168     }
169     throw new NotImplementedException();
170 }
171 #endregion
172
173 #region Create
174
175 public LinkIndex Create(IList<LinkIndex> restrictions)
176 {
177     return _sync.ExecuteWriteOperation(() =>
178     {
179         if (restrictions.IsNullOrEmpty())
180         {
181             return Constants.Null;
182         }
183         Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
184         return CreateCore(restrictions);
185     });
186 }
187
188 private LinkIndex CreateCore(IList<LinkIndex> restrictions)
189 {
190     LinkIndex[] sequence = restrictions.SkipFirst();
191     if (Options.UseIndex)
192     {
193         Options.Index.Add(sequence);
194     }
195     var sequenceRoot = default(LinkIndex);
196     if (Options.EnforceSingleSequenceVersionOnWriteBasedOnExisting)
197     {
198         var matches = Each(restrictions);
199         if (matches.Count > 0)
200         {
201             sequenceRoot = matches[0];
202         }
203     }
204     else if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew)
205     {
206         return CompactCore(sequence);
207     }
208 }

```

```

207     }
208     if (sequenceRoot == default)
209     {
210         sequenceRoot = Options.LinksToSequenceConverter.Convert(sequence);
211     }
212     if (Options.UseSequenceMarker)
213     {
214         return Links.Unsync.GetOrCreate(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<LinkIndex> Each(IList<LinkIndex> sequence)
224 {
225     var results = new List<LinkIndex>();
226     var filler = new ListFiller<LinkIndex, LinkIndex>(results, Constants.Continue);
227     Each(filler.AddFirstAndReturnConstant, sequence);
228     return results;
229 }
230
231 public LinkIndex Each(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
↪ restrictions)
232 {
233     return _sync.ExecuteReadOperation(() =>
234     {
235         if (restrictions.IsNullOrEmpty())
236         {
237             return Constants.Continue;
238         }
239         Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
240         if (restrictions.Count == 1)
241         {
242             var link = restrictions[0];
243             var any = Constants.Any;
244             if (link == any)
245             {
246                 if (Options.UseSequenceMarker)
247                 {
248                     return Links.Unsync.Each(handler, new Link<LinkIndex>(any,
↪ Options.SequenceMarkerLink, any));
249                 }
250                 else
251                 {
252                     return Links.Unsync.Each(handler, new Link<LinkIndex>(any, any,
↪ any));
253                 }
254             }
255             if (Options.UseSequenceMarker)
256             {
257                 var sequenceLinkValues = Links.Unsync.GetLink(link);
258                 if (sequenceLinkValues[Constants.SourcePart] ==
↪ Options.SequenceMarkerLink)
259                 {
260                     link = sequenceLinkValues[Constants.TargetPart];
261                 }
262             }
263             var sequence = Options.Walker.Walk(link).ToArray().ShiftRight();
264             sequence[0] = link;
265             return handler(sequence);
266         }
267         else if (restrictions.Count == 2)
268         {
269             throw new NotImplementedException();
270         }
271         else if (restrictions.Count == 3)
272         {
273             return Links.Unsync.Each(handler, restrictions);
274         }
275         else
276         {
277             var sequence = restrictions.SkipFirst();
278             if (Options.UseIndex && !Options.Index.MightContain(sequence))
279             {
280                 return Constants.Break;

```

```

281     }
282     return EachCore(handler, sequence);
283 }
284 });
285 }
286
287 private LinkIndex EachCore(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
    ↪ values)
288 {
289     var matcher = new Matcher(this, values, new HashSet<LinkIndex>(), handler);
290     // TODO: Find out why matcher.HandleFullMatched executed twice for the same sequence
    ↪ Id.
291     Func<IList<LinkIndex>, LinkIndex> innerHandler = Options.UseSequenceMarker ?
    ↪ (Func<IList<LinkIndex>, LinkIndex>)matcher.HandleFullMatchedSequence :
    ↪ matcher.HandleFullMatched;
292     //if (sequence.Length >= 2)
293     if (StepRight(innerHandler, values[0], values[1]) != Constants.Continue)
294     {
295         return Constants.Break;
296     }
297     var last = values.Count - 2;
298     for (var i = 1; i < last; i++)
299     {
300         if (PartialStepRight(innerHandler, values[i], values[i + 1]) !=
    ↪ Constants.Continue)
301         {
302             return Constants.Break;
303         }
304     }
305     if (values.Count >= 3)
306     {
307         if (StepLeft(innerHandler, values[values.Count - 2], values[values.Count - 1])
    ↪ != Constants.Continue)
308         {
309             return Constants.Break;
310         }
311     }
312     return Constants.Continue;
313 }
314
315 private LinkIndex PartialStepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
    ↪ left, LinkIndex right)
316 {
317     return Links.Unsync.Each(doublet =>
318     {
319         var doubletIndex = doublet[Constants.IndexPart];
320         if (StepRight(handler, doubletIndex, right) != Constants.Continue)
321         {
322             return Constants.Break;
323         }
324         if (left != doubletIndex)
325         {
326             return PartialStepRight(handler, doubletIndex, right);
327         }
328         return Constants.Continue;
329     }, new Link<LinkIndex>(Constants.Any, Constants.Any, left));
330 }
331
332 private LinkIndex StepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex left,
    ↪ LinkIndex right) => Links.Unsync.Each(rightStep => TryStepRightUp(handler, right,
    ↪ rightStep[Constants.IndexPart]), new Link<LinkIndex>(Constants.Any, left,
    ↪ Constants.Any));
333
334 private LinkIndex TryStepRightUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
    ↪ right, LinkIndex stepFrom)
335 {
336     var upStep = stepFrom;
337     var firstSource = Links.Unsync.GetTarget(upStep);
338     while (firstSource != right && firstSource != upStep)
339     {
340         upStep = firstSource;
341         firstSource = Links.Unsync.GetSource(upStep);
342     }
343     if (firstSource == right)
344     {
345         return handler(new LinkAddress<LinkIndex>(stepFrom));
346     }
347     return Constants.Continue;

```

```

348 }
349
350 private LinkIndex StepLeft(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex left,
    ↳ LinkIndex right) => Links.Unsync.Each(leftStep => TryStepLeftUp(handler, left,
    ↳ leftStep[Constants.IndexPart]), new Link<LinkIndex>(Constants.Any, Constants.Any,
    ↳ right));
351
352 private LinkIndex TryStepLeftUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
    ↳ left, LinkIndex stepFrom)
353 {
354     var upStep = stepFrom;
355     var firstTarget = Links.Unsync.GetSource(upStep);
356     while (firstTarget != left && firstTarget != upStep)
357     {
358         upStep = firstTarget;
359         firstTarget = Links.Unsync.GetTarget(upStep);
360     }
361     if (firstTarget == left)
362     {
363         return handler(new LinkAddress<LinkIndex>(stepFrom));
364     }
365     return Constants.Continue;
366 }
367
368 #endregion
369
370 #region Update
371
372 public LinkIndex Update(IList<LinkIndex> restrictions, IList<LinkIndex> substitution)
373 {
374     var sequence = restrictions.SkipFirst();
375     var newSequence = substitution.SkipFirst();
376
377     if (sequence.IsNullOrEmpty() && newSequence.IsNullOrEmpty())
378     {
379         return Constants.Null;
380     }
381     if (sequence.IsNullOrEmpty())
382     {
383         return Create(substitution);
384     }
385     if (newSequence.IsNullOrEmpty())
386     {
387         Delete(restrictions);
388         return Constants.Null;
389     }
390     return _sync.ExecuteWriteOperation((Func<ulong>)(() =>
391     {
392         ILinksExtensions.EnsureLinkIsAnyOrExists<ulong>(Links, (IList<ulong>)sequence);
393         Links.EnsureLinkExists(newSequence);
394         return UpdateCore(sequence, newSequence);
395     }));
396 }
397
398 private LinkIndex UpdateCore(IList<LinkIndex> sequence, IList<LinkIndex> newSequence)
399 {
400     LinkIndex bestVariant;
401     if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew &&
402         ↳ !sequence.EqualTo(newSequence))
403     {
404         bestVariant = CompactCore(newSequence);
405     }
406     else
407     {
408         bestVariant = CreateCore(newSequence);
409     }
410     // TODO: Check all options only ones before loop execution
411     // Возможно нужно две версии Each, возвращающий фактические последовательности и с
412     ↳ маркером,
413     // или возможно даже возвращать и тот и тот вариант. С другой стороны все варианты
414     ↳ можно получить имея только фактические последовательности.
415     foreach (var variant in Each(sequence))
416     {
417         if (variant != bestVariant)
418         {
419             UpdateOneCore(variant, bestVariant);
420         }
421     }
422     return bestVariant;
423 }

```

```

420 }
421
422 private void UpdateOneCore(LinkIndex sequence, LinkIndex newSequence)
423 {
424     if (Options.UseGarbageCollection)
425     {
426         var sequenceElements = GetSequenceElements(sequence);
427         var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
428         var sequenceLink = GetSequenceByElements(sequenceElements);
429         var newSequenceElements = GetSequenceElements(newSequence);
430         var newSequenceLink = GetSequenceByElements(newSequenceElements);
431         if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
432         {
433             if (sequenceLink != Constants.Null)
434             {
435                 Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
436             }
437             Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
438         }
439         ClearGarbage(sequenceElementsContents.Source);
440         ClearGarbage(sequenceElementsContents.Target);
441     }
442     else
443     {
444         if (Options.UseSequenceMarker)
445         {
446             var sequenceElements = GetSequenceElements(sequence);
447             var sequenceLink = GetSequenceByElements(sequenceElements);
448             var newSequenceElements = GetSequenceElements(newSequence);
449             var newSequenceLink = GetSequenceByElements(newSequenceElements);
450             if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
451             {
452                 if (sequenceLink != Constants.Null)
453                 {
454                     Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
455                 }
456                 Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
457             }
458         }
459         else
460         {
461             if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
462             {
463                 Links.Unsync.MergeAndDelete(sequence, newSequence);
464             }
465         }
466     }
467 }
468
469 #endregion
470
471 #region Delete
472
473 public void Delete(IList<LinkIndex> restrictions)
474 {
475     _sync.ExecuteWriteOperation(() =>
476     {
477         var sequence = restrictions.SkipFirst();
478         // TODO: Check all options only ones before loop execution
479         foreach (var linkToDelete in Each(sequence))
480         {
481             DeleteOneCore(linkToDelete);
482         }
483     });
484 }
485
486 private void DeleteOneCore(LinkIndex link)
487 {
488     if (Options.UseGarbageCollection)
489     {
490         var sequenceElements = GetSequenceElements(link);
491         var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
492         var sequenceLink = GetSequenceByElements(sequenceElements);
493         if (Options.UseCascadeDelete || CountUsages(link) == 0)
494         {
495             if (sequenceLink != Constants.Null)
496             {
497                 Links.Unsync.Delete(sequenceLink);

```

```

498         }
499         Links.Unsync.Delete(link);
500     }
501     ClearGarbage(sequenceElementsContents.Source);
502     ClearGarbage(sequenceElementsContents.Target);
503 }
504 else
505 {
506     if (Options.UseSequenceMarker)
507     {
508         var sequenceElements = GetSequenceElements(link);
509         var sequenceLink = GetSequenceByElements(sequenceElements);
510         if (Options.UseCascadeDelete || CountUsages(link) == 0)
511         {
512             if (sequenceLink != Constants.Null)
513             {
514                 Links.Unsync.Delete(sequenceLink);
515             }
516             Links.Unsync.Delete(link);
517         }
518     }
519     else
520     {
521         if (Options.UseCascadeDelete || CountUsages(link) == 0)
522         {
523             Links.Unsync.Delete(link);
524         }
525     }
526 }
527 }
528
529 #endregion
530
531 #region Compactification
532
533 public void CompactAll()
534 {
535     _sync.ExecuteWriteOperation(() =>
536     {
537         var sequences = Each((LinkAddress<LinkIndex>)Constants.Any);
538         for (int i = 0; i < sequences.Count; i++)
539         {
540             var sequence = this.ToList(sequences[i]);
541             Compact(sequence.ShiftRight());
542         }
543     });
544 }
545
546 /// <remarks>
547 /// bestVariant можно выбирать по максимальному числу использований,
548 /// но балансированный позволяет гарантировать уникальность (если есть возможность,
549 /// гарантировать его использование в других местах).
550 ///
551 /// Получается этот метод должен игнорировать Options.EnforceSingleSequenceVersionOnWrite
552 /// </remarks>
553 public LinkIndex Compact(IList<LinkIndex> sequence)
554 {
555     return _sync.ExecuteWriteOperation(() =>
556     {
557         if (sequence.IsNullOrEmpty())
558         {
559             return Constants.Null;
560         }
561         Links.EnsureInnerReferenceExists(sequence, nameof(sequence));
562         return CompactCore(sequence);
563     });
564 }
565
566 [MethodImpl(MethodImplOptions.AggressiveInlining)]
567 private LinkIndex CompactCore(IList<LinkIndex> sequence) => UpdateCore(sequence,
568     ↪ sequence);
569
570 #endregion
571
572 #region Garbage Collection
573
574 /// <remarks>
575 /// TODO: Добавить дополнительный обработчик / событие CanBeDeleted которое можно
576     ↪ определить извне или в унаследованном классе

```

```

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

```

```

649     {
650         _filterPosition = -2; // Длиннее чем нужно
651         return false;
652     }
653     if (_patternSequence[_filterPosition] != Links.Constants.Any
654         && element != _patternSequence[_filterPosition])
655     {
656         _filterPosition = -1;
657         return false; // Начинается/Продолжается иначе
658     }
659     _filterPosition++;
660     return true;
661 }
662
663 public void AddFullMatchedToResults(IList<LinkIndex> restrictions)
664 {
665     var sequenceToMatch = restrictions[Links.Constants.IndexPart];
666     if (FullMatch(sequenceToMatch))
667     {
668         _results.Add(sequenceToMatch);
669     }
670 }
671
672 public LinkIndex HandleFullMatched(IList<LinkIndex> restrictions)
673 {
674     var sequenceToMatch = restrictions[Links.Constants.IndexPart];
675     if (FullMatch(sequenceToMatch) && _results.Add(sequenceToMatch))
676     {
677         return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
678     }
679     return Links.Constants.Continue;
680 }
681
682 public LinkIndex HandleFullMatchedSequence(IList<LinkIndex> restrictions)
683 {
684     var sequenceToMatch = restrictions[Links.Constants.IndexPart];
685     var sequence = _sequences.GetSequenceByElements(sequenceToMatch);
686     if (sequence != Links.Constants.Null && FullMatch(sequenceToMatch) &&
687         ↪ _results.Add(sequenceToMatch))
688     {
689         return _stopableHandler(new LinkAddress<LinkIndex>(sequence));
690     }
691     return Links.Constants.Continue;
692 }
693
694 /// <remarks>
695 /// TODO: Add support for LinksConstants.Any
696 /// </remarks>
697 public bool PartialMatch(LinkIndex sequenceToMatch)
698 {
699     _filterPosition = -1;
700     foreach (var part in Walk(sequenceToMatch))
701     {
702         if (!PartialMatchCore(part))
703         {
704             break;
705         }
706     }
707     return _filterPosition == _patternSequence.Count - 1;
708 }
709
710 private bool PartialMatchCore(LinkIndex element)
711 {
712     if (_filterPosition == (_patternSequence.Count - 1))
713     {
714         return false; // Нашлось
715     }
716     if (_filterPosition >= 0)
717     {
718         if (element == _patternSequence[_filterPosition + 1])
719         {
720             _filterPosition++;
721         }
722         else
723         {
724             _filterPosition = -1;
725         }
726     }
727     if (_filterPosition < 0)

```



```

727     {
728         if (element == _patternSequence[0])
729         {
730             _filterPosition = 0;
731         }
732     }
733     return true; // Ищем дальше
734 }
735
736 public void AddPartialMatchedToResults(LinkIndex sequenceToMatch)
737 {
738     if (PartialMatch(sequenceToMatch))
739     {
740         _results.Add(sequenceToMatch);
741     }
742 }
743
744 public LinkIndex HandlePartialMatched(IList<LinkIndex> restrictions)
745 {
746     var sequenceToMatch = restrictions[Links.Constants.IndexPart];
747     if (PartialMatch(sequenceToMatch))
748     {
749         return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
750     }
751     return Links.Constants.Continue;
752 }
753
754 public void AddAllPartialMatchedToResults(IEnumerable<LinkIndex> sequencesToMatch)
755 {
756     foreach (var sequenceToMatch in sequencesToMatch)
757     {
758         if (PartialMatch(sequenceToMatch))
759         {
760             _results.Add(sequenceToMatch);
761         }
762     }
763 }
764
765 public void AddAllPartialMatchedToResultsAndReadAsElements(IEnumerable<LinkIndex>
766 ↪ sequencesToMatch)
767 {
768     foreach (var sequenceToMatch in sequencesToMatch)
769     {
770         if (PartialMatch(sequenceToMatch))
771         {
772             _readAsElements.Add(sequenceToMatch);
773             _results.Add(sequenceToMatch);
774         }
775     }
776 }
777
778 #endregion
779 }
780 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Collections.Lists;
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 ILinks<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] :
19 ↪ sequences.Create(part.ShiftRight());
20             }
21             return sequences.Create(finalSequence.ShiftRight());
22         }
23     }
24 }

```

```

21
22     public static IList<TLink> ToList<TLink>(this ILinks<TLink> sequences, TLink sequence)
23     {
24         var list = new List<TLink>();
25         var filler = new ListFiller<TLink, TLink>(list, sequences.Constants.Break);
26         sequences.Each(filler.AddSkipFirstAndReturnConstant, new
27             ↪ LinkAddress<TLink>(sequence));
28         return list;
29     }
30 }

```

1.85 ./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.Converters;
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.Sequences.Walkers;
10 using Platform.Data.Doublets.Sequences.Indexes;
11 using Platform.Data.Doublets.Sequences.CriterionMatchers;
12
13 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
14
15 namespace Platform.Data.Doublets.Sequences
16 {
17     public class SequencesOptions<TLink> // TODO: To use type parameter <TLink> the
18         ↪ ILinks<TLink> must contain GetConstants function.
19     {
20         private static readonly EqualityComparer<TLink> _equalityComparer =
21             ↪ EqualityComparer<TLink>.Default;
22
23         public TLink SequenceMarkerLink { get; set; }
24         public bool UseCascadeUpdate { get; set; }
25         public bool UseCascadeDelete { get; set; }
26         public bool UseIndex { get; set; } // TODO: Update Index on sequence update/delete.
27         public bool UseSequenceMarker { get; set; }
28         public bool UseCompression { get; set; }
29         public bool UseGarbageCollection { get; set; }
30         public bool EnforceSingleSequenceVersionOnWriteBasedOnExisting { get; set; }
31         public bool EnforceSingleSequenceVersionOnWriteBasedOnNew { get; set; }
32
33         public MarkedSequenceCriterionMatcher<TLink> MarkedSequenceMatcher { get; set; }
34         public IConverter<IList<TLink>, TLink> LinksToSequenceConverter { get; set; }
35         public ISequenceIndex<TLink> Index { get; set; }
36         public ISequenceWalker<TLink> Walker { get; set; }
37         public bool ReadFullSequence { get; set; }
38
39         // TODO: Реализовать компактификацию при чтении
40         //public bool EnforceSingleSequenceVersionOnRead { get; set; }
41         //public bool UseRequestMarker { get; set; }
42         //public bool StoreRequestResults { get; set; }
43
44         public void InitOptions(ISynchronizedLinks<TLink> links)
45         {
46             if (UseSequenceMarker)
47             {
48                 if (_equalityComparer.Equals(SequenceMarkerLink, links.Constants.Null))
49                 {
50                     SequenceMarkerLink = links.CreatePoint();
51                 }
52             }
53             else
54             {
55                 if (!links.Exists(SequenceMarkerLink))
56                 {
57                     var link = links.CreatePoint();
58                     if (!_equalityComparer.Equals(link, SequenceMarkerLink))
59                     {
60                         throw new InvalidOperationException("Cannot recreate sequence marker
61                             ↪ link.");
62                     }
63                 }
64             }
65
66             if (MarkedSequenceMatcher == null)
67             {
68                 MarkedSequenceMatcher = new MarkedSequenceCriterionMatcher<TLink>(links,
69                     ↪ SequenceMarkerLink);
70             }
71         }
72     }
73 }

```

```

64     }
65 }
66 var balancedVariantConverter = new BalancedVariantConverter<TLink>(links);
67 if (UseCompression)
68 {
69     if (LinksToSequenceConverter == null)
70     {
71         ICounter<TLink, TLink> totalSequenceSymbolFrequencyCounter;
72         if (UseSequenceMarker)
73         {
74             totalSequenceSymbolFrequencyCounter = new
75                 ↪ TotalMarkedSequenceSymbolFrequencyCounter<TLink>(links,
76                 ↪ MarkedSequenceMatcher);
77         }
78         else
79         {
80             totalSequenceSymbolFrequencyCounter = new
81                 ↪ TotalSequenceSymbolFrequencyCounter<TLink>(links);
82         }
83         var doubletFrequenciesCache = new LinkFrequenciesCache<TLink>(links,
84             ↪ totalSequenceSymbolFrequencyCounter);
85         var compressingConverter = new CompressingConverter<TLink>(links,
86             ↪ balancedVariantConverter, doubletFrequenciesCache);
87         LinksToSequenceConverter = compressingConverter;
88     }
89 }
90 else
91 {
92     if (LinksToSequenceConverter == null)
93     {
94         LinksToSequenceConverter = balancedVariantConverter;
95     }
96 }
97 if (UseIndex && Index == null)
98 {
99     Index = new SequenceIndex<TLink>(links);
100 }
101 if (Walker == null)
102 {
103     Walker = new RightSequenceWalker<TLink>(links, new DefaultStack<TLink>());
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 }
116 }

```

1.86 ./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 }

```

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

```

1 using System;
2 using System.Collections.Generic;
3 using System.Runtime.CompilerServices;
4 using Platform.Collections.Stacks;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Sequences.Walkers
9 {
10     public class LeftSequenceWalker<TLink> : SequenceWalkerBase<TLink>
11     {

```

```

12     public LeftSequenceWalker(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
13         ↪ isElement) : base(links, stack, isElement) { }
14
15     public LeftSequenceWalker(ILinks<TLink> links, IStack<TLink> stack) : base(links, stack,
16         ↪ links.IsPartialPoint) { }
17
18     [MethodImpl(MethodImplOptions.AggressiveInlining)]
19     protected override TLink GetNextElementAfterPop(TLink element) =>
20         ↪ Links.GetSource(element);
21
22     [MethodImpl(MethodImplOptions.AggressiveInlining)]
23     protected override TLink GetNextElementAfterPush(TLink element) =>
24         ↪ Links.GetTarget(element);
25
26     [MethodImpl(MethodImplOptions.AggressiveInlining)]
27     protected override IEnumerable<TLink> WalkContents(TLink element)
28     {
29         var parts = Links.GetLink(element);
30         var start = Links.Constants.IndexPart + 1;
31         for (var i = parts.Count - 1; i >= start; i--)
32         {
33             var part = parts[i];
34             if (IsElement(part))
35             {
36                 yield return part;
37             }
38         }
39     }
40 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  //#define USEARRAYPOOL
8  #if USEARRAYPOOL
9  using Platform.Collections;
10 #endif
11
12 namespace Platform.Data.Doublets.Sequences.Walkers
13 {
14     public class LeveledSequenceWalker<TLink> : LinksOperatorBase<TLink>, ISequenceWalker<TLink>
15     {
16         private static readonly EqualityComparer<TLink> _equalityComparer =
17             ↪ EqualityComparer<TLink>.Default;
18
19         private readonly Func<TLink, bool> _isElement;
20
21         public LeveledSequenceWalker(ILinks<TLink> links, Func<TLink, bool> isElement) :
22             ↪ base(links) => _isElement = isElement;
23
24         public LeveledSequenceWalker(ILinks<TLink> links) : base(links) => _isElement =
25             ↪ Links.IsPartialPoint;
26
27         public IEnumerable<TLink> Walk(TLink sequence) => ToArray(sequence);
28
29         public TLink[] ToArray(TLink sequence)
30         {
31             var length = 1;
32             var array = new TLink[length];
33             array[0] = sequence;
34             if (_isElement(sequence))
35             {
36                 return array;
37             }
38             bool hasElements;
39             do
40             {
41                 length *= 2;
42 #if USEARRAYPOOL
43                 var nextArray = ArrayPool.Allocate<ulong>(length);
44 #else
45                 var nextArray = new TLink[length];
46 #endif
47                 hasElements = false;
48                 for (var i = 0; i < array.Length; i++)

```

```

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 }

```

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

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

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

```
1 using System;
2 using System.Collections.Generic;
3 using System.Runtime.CompilerServices;
4 using Platform.Collections.Stacks;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Sequences.Walkers
9 {
10     public abstract class SequenceWalkerBase<TLink> : LinksOperatorBase<TLink>,
11         ↪ ISequenceWalker<TLink>
12     {
13         private readonly IStack<TLink> _stack;
14         private readonly Func<TLink, bool> _isElement;
15
16         protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
17             ↪ isElement) : base(links)
18         {
19             _stack = stack;
20             _isElement = isElement;
21         }
22
23         protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack) : this(links,
24             ↪ stack, links.IsPartialPoint)
25         {
26         }
27
28         public IEnumerable<TLink> Walk(TLink sequence)
29         {
30             _stack.Clear();
31             var element = sequence;
32             if (IsElement(element))
33             {
34                 yield return element;
35             }
36             else
37             {
38             }
```

```

35         while (true)
36         {
37             if (IsElement(element))
38             {
39                 if (_stack.IsEmpty)
40                 {
41                     break;
42                 }
43                 element = _stack.Pop();
44                 foreach (var output in WalkContents(element))
45                 {
46                     yield return output;
47                 }
48                 element = GetNextElementAfterPop(element);
49             }
50             else
51             {
52                 _stack.Push(element);
53                 element = GetNextElementAfterPush(element);
54             }
55         }
56     }
57 }
58
59 [MethodImpl(MethodImplOptions.AggressiveInlining)]
60 protected virtual bool IsElement(TLink elementLink) => _isElement(elementLink);
61
62 [MethodImpl(MethodImplOptions.AggressiveInlining)]
63 protected abstract TLink GetNextElementAfterPop(TLink element);
64
65 [MethodImpl(MethodImplOptions.AggressiveInlining)]
66 protected abstract TLink GetNextElementAfterPush(TLink element);
67
68 [MethodImpl(MethodImplOptions.AggressiveInlining)]
69 protected abstract IEnumerable<TLink> WalkContents(TLink element);
70 }
71 }

```

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

```

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

```

```

41     public void Push(TLink element) => _links.Update(_stack, GetStackMarker(),
42         ↳ _links.GetOrCreate(GetTop(), element));
43 }
44 }

```

1.92 ./Platform.Data.Doublents/Stacks/StackExtensions.cs

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  namespace Platform.Data.Doublents.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 }

```

1.93 ./Platform.Data.Doublents/SynchronizedLinks.cs

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Data.Doublents;
4  using Platform.Threading.Synchronization;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublents
9  {
10     /// <remarks>
11     /// TODO: Autogeneration of synchronized wrapper (decorator).
12     /// TODO: Try to unfold code of each method using IL generation for performance improvements.
13     /// TODO: Or even to unfold multiple layers of implementations.
14     /// </remarks>
15     public class SynchronizedLinks<TLinkAddress> : ISynchronizedLinks<TLinkAddress>
16     {
17         public LinksConstants<TLinkAddress> Constants { get; }
18         public ISynchronization SyncRoot { get; }
19         public ILinks<TLinkAddress> Sync { get; }
20         public ILinks<TLinkAddress> Unsync { get; }
21
22         public SynchronizedLinks(ILinks<TLinkAddress> links) : this(new
23             ↳ ReaderWriterLockSynchronization(), links) { }
24
25         public SynchronizedLinks(ISynchronization synchronization, ILinks<TLinkAddress> links)
26         {
27             SyncRoot = synchronization;
28             Sync = this;
29             Unsync = links;
30             Constants = links.Constants;
31         }
32
33         public TLinkAddress Count(IList<TLinkAddress> restriction) =>
34             ↳ SyncRoot.ExecuteReadOperation(restriction, Unsync.Count);
35         public TLinkAddress Each(Func<IList<TLinkAddress>, TLinkAddress> handler,
36             ↳ IList<TLinkAddress> restrictions) => SyncRoot.ExecuteReadOperation(handler,
37             ↳ restrictions, (handler1, restrictions1) => Unsync.Each(handler1, restrictions1));
38         public TLinkAddress Create(IList<TLinkAddress> restrictions) =>
39             ↳ SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Create);
40         public TLinkAddress Update(IList<TLinkAddress> restrictions, IList<TLinkAddress>
41             ↳ substitution) => SyncRoot.ExecuteWriteOperation(restrictions, substitution,
42             ↳ Unsync.Update);
43         public void Delete(IList<TLinkAddress> restrictions) =>
44             ↳ SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Delete);
45
46         //public T Trigger(IList<T> restriction, Func<IList<T>, IList<T>, T> matchedHandler,
47         //    ↳ IList<T> substitution, Func<IList<T>, IList<T>, T> substitutedHandler)
48         //{
49         //    if (restriction != null && substitution != null &&
50         //        ↳ !substitution.EqualTo(restriction))
51         //        return SyncRoot.ExecuteWriteOperation(restriction, matchedHandler,
52         //            ↳ substitution, substitutedHandler, Unsync.Trigger);
53         //
54         //    return SyncRoot.ExecuteReadOperation(restriction, matchedHandler, substitution,
55         //        ↳ substitutedHandler, Unsync.Trigger);
56     }
57 }

```



```

44     //}
45 }
46 }

```

1.94 ./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.Doublets.Unicode;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets
10 {
11     public static class UInt64LinksExtensions
12     {
13         public static readonly LinksConstants<ulong> Constants =
14             ↳ Default<LinksConstants<ulong>>.Instance;
15
16         public static void UseUnicode(this ILinks<ulong> links) => UnicodeMap.InitNew(links);
17
18         public static bool AnyLinkIsAny(this ILinks<ulong> links, params ulong[] sequence)
19         {
20             if (sequence == null)
21             {
22                 return false;
23             }
24             var constants = links.Constants;
25             for (var i = 0; i < sequence.Length; i++)
26             {
27                 if (sequence[i] == constants.Any)
28                 {
29                     return true;
30                 }
31             }
32             return false;
33         }
34
35         public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
36             ↳ Func<Link<ulong>, bool> isElement, bool renderIndex = false, bool renderDebug =
37             ↳ false)
38         {
39             var sb = new StringBuilder();
40             var visited = new HashSet<ulong>();
41             links.AppendStructure(sb, visited, linkIndex, isElement, (innerSb, link) =>
42                 ↳ innerSb.Append(link.Index), renderIndex, renderDebug);
43             return sb.ToString();
44         }
45
46         public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
47             ↳ Func<Link<ulong>, bool> isElement, Action<StringBuilder, Link<ulong>> appendElement,
48             ↳ bool renderIndex = false, bool renderDebug = false)
49         {
50             var sb = new StringBuilder();
51             var visited = new HashSet<ulong>();
52             links.AppendStructure(sb, visited, linkIndex, isElement, appendElement, renderIndex,
53                 ↳ renderDebug);
54             return sb.ToString();
55         }
56
57         public static void AppendStructure(this ILinks<ulong> links, StringBuilder sb,
58             ↳ HashSet<ulong> visited, ulong linkIndex, Func<Link<ulong>, bool> isElement,
59             ↳ Action<StringBuilder, Link<ulong>> appendElement, bool renderIndex = false, bool
60             ↳ renderDebug = false)
61         {
62             if (sb == null)
63             {
64                 throw new ArgumentNullException(nameof(sb));
65             }
66             if (linkIndex == Constants.Null || linkIndex == Constants.Any || linkIndex ==
67                 ↳ Constants.Itself)
68             {
69                 return;
70             }
71             if (links.Exists(linkIndex))
72             {
73                 if (visited.Add(linkIndex))
74                 {
75

```

```

64         sb.Append('(');
65         var link = new Link<ulong>(links.GetLink(linkIndex));
66         if (renderIndex)
67         {
68             sb.Append(link.Index);
69             sb.Append(':');
70         }
71         if (link.Source == link.Index)
72         {
73             sb.Append(link.Index);
74         }
75         else
76         {
77             var source = new Link<ulong>(links.GetLink(link.Source));
78             if (isElement(source))
79             {
80                 appendElement(sb, source);
81             }
82             else
83             {
84                 links.AppendStructure(sb, visited, source.Index, isElement,
85                                     ↪ appendElement, renderIndex);
86             }
87         }
88         sb.Append(' ');
89         if (link.Target == link.Index)
90         {
91             sb.Append(link.Index);
92         }
93         else
94         {
95             var target = new Link<ulong>(links.GetLink(link.Target));
96             if (isElement(target))
97             {
98                 appendElement(sb, target);
99             }
100            else
101            {
102                links.AppendStructure(sb, visited, target.Index, isElement,
103                                    ↪ appendElement, renderIndex);
104            }
105        }
106        sb.Append(')');
107    }
108    else
109    {
110        if (renderDebug)
111        {
112            sb.Append('*');
113        }
114        sb.Append(linkIndex);
115    }
116 }
117 }
118 }
119 }
120 }
121 }
122 }
123 }
124 }
125 }

```

1.95 ./Platform.Data.Doublets/UInt64LinksTransactionsLayer.cs

```

1  using System;
2  using System.Linq;
3  using System.Collections.Generic;
4  using System.IO;
5  using System.Runtime.CompilerServices;
6  using System.Threading;
7  using System.Threading.Tasks;
8  using Platform.Disposables;
9  using Platform.Timestamps;
10 using Platform.Unsafe;
11 using Platform.IO;
12 using Platform.Data.Doublets.Decorators;
13 using Platform.Exceptions;

```

```

14
15 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
16
17 namespace Platform.Data.Doublets
18 {
19     public class UInt64LinksTransactionsLayer : LinksDisposableDecoratorBase<ulong> //-V3073
20     {
21         /// <remarks>
22         /// Альтернативные варианты хранения трансформации (элемента транзакции):
23         ///
24         /// private enum TransitionType
25         /// {
26         ///     Creation,
27         ///     UpdateOf,
28         ///     UpdateTo,
29         ///     Deletion
30         /// }
31         ///
32         /// private struct Transition
33         /// {
34         ///     public ulong TransactionId;
35         ///     public UniqueTimestamp Timestamp;
36         ///     public TransactionItemType Type;
37         ///     public Link Source;
38         ///     public Link Linker;
39         ///     public Link Target;
40         /// }
41         ///
42         /// Или
43         ///
44         /// public struct TransitionHeader
45         /// {
46         ///     public ulong TransactionIdCombined;
47         ///     public ulong TimestampCombined;
48         ///
49         ///     public ulong TransactionId
50         ///     {
51         ///         get
52         ///         {
53         ///             return (ulong) mask & TransactionIdCombined;
54         ///         }
55         ///     }
56         ///
57         ///     public UniqueTimestamp Timestamp
58         ///     {
59         ///         get
60         ///         {
61         ///             return (UniqueTimestamp)mask & TransactionIdCombined;
62         ///         }
63         ///     }
64         ///
65         ///     public TransactionItemType Type
66         ///     {
67         ///         get
68         ///         {
69         ///             // Использовать по одному биту из TransactionId и Timestamp,
70         ///             // для значения в 2 бита, которое представляет тип операции
71         ///             throw new NotImplementedException();
72         ///         }
73         ///     }
74         /// }
75         ///
76         /// private struct Transition
77         /// {
78         ///     public TransitionHeader Header;
79         ///     public Link Source;
80         ///     public Link Linker;
81         ///     public Link Target;
82         /// }
83         ///
84         /// </remarks>
85         public struct Transition
86         {
87             public static readonly long Size = Structure<Transition>.Size;
88
89             public readonly ulong TransactionId;
90             public readonly Link<ulong> Before;
91             public readonly Link<ulong> After;

```

```

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

```

```

161         SetCurrentTransaction(layer, this);
162     }
163
164     public void Commit()
165     {
166         EnsureTransactionAllowsWriteOperations(this);
167         while (_transitions.Count > 0)
168         {
169             var transition = _transitions.Dequeue();
170             _layer._transitions.Enqueue(transition);
171         }
172         _layer._lastCommittedTransactionId = _layer._currentTransactionId;
173         IsCommitted = true;
174     }
175
176     private void Revert()
177     {
178         EnsureTransactionAllowsWriteOperations(this);
179         var transitionsToRevert = new Transition[_transitions.Count];
180         _transitions.CopyTo(transitionsToRevert, 0);
181         for (var i = transitionsToRevert.Length - 1; i >= 0; i--)
182         {
183             _layer.RevertTransition(transitionsToRevert[i]);
184         }
185         IsReverted = true;
186     }
187
188     public static void SetCurrentTransaction(UInt64LinksTransactionsLayer layer,
189     ↪ Transaction transaction)
190     {
191         layer._currentTransactionId = layer._lastCommittedTransactionId + 1;
192         layer._currentTransactionTransitions = transaction._transitions;
193         layer._currentTransaction = transaction;
194     }
195
196     public static void EnsureTransactionAllowsWriteOperations(Transaction transaction)
197     {
198         if (transaction.IsReverted)
199         {
200             throw new InvalidOperationException("Transation is reverted.");
201         }
202         if (transaction.IsCommitted)
203         {
204             throw new InvalidOperationException("Transation is committed.");
205         }
206     }
207
208     protected override void Dispose(bool manual, bool wasDisposed)
209     {
210         if (!wasDisposed && _layer != null && !_layer.IsDisposed)
211         {
212             if (!IsCommitted && !IsReverted)
213             {
214                 Revert();
215             }
216             _layer.ResetCurrentTransation();
217         }
218     }
219
220     public static readonly TimeSpan DefaultPushDelay = TimeSpan.FromSeconds(0.1);
221
222     private readonly string _logAddress;
223     private readonly FileStream _log;
224     private readonly Queue<Transition> _transitions;
225     private readonly UniqueTimestampFactory _uniqueTimestampFactory;
226     private Task _transitionsPusher;
227     private Transition _lastCommittedTransition;
228     private ulong _currentTransactionId;
229     private Queue<Transition> _currentTransactionTransitions;
230     private Transaction _currentTransaction;
231     private ulong _lastCommittedTransactionId;
232
233     public UInt64LinksTransactionsLayer(ILinks<ulong> links, string logAddress)
234     : base(links)
235     {
236         if (string.IsNullOrEmpty(logAddress))
237         {
238             throw new ArgumentNullException(nameof(logAddress));
239         }

```

```

240 // В первой строке файла хранится последняя закоммиченную транзакцию.
241 // При запуске это используется для проверки удачного закрытия файла лога.
242 // In the first line of the file the last committed transaction is stored.
243 // On startup, this is used to check that the log file is successfully closed.
244 var lastCommittedTransition = FileHelpers.ReadFirstOrDefault<Transition>(logAddress);
245 var lastWrittenTransition = FileHelpers.ReadLastOrDefault<Transition>(logAddress);
246 if (!lastCommittedTransition.Equals(lastWrittenTransition))
247 {
248     Dispose();
249     throw new NotSupportedException("Database is damaged, autorecovery is not
        ↳ supported yet.");
250 }
251 if (lastCommittedTransition.Equals(default(Transition)))
252 {
253     FileHelpers.WriteFirst(logAddress, lastCommittedTransition);
254 }
255 _lastCommittedTransition = lastCommittedTransition;
256 // TODO: Think about a better way to calculate or store this value
257 var allTransitions = FileHelpers.ReadAll<Transition>(logAddress);
258 _lastCommittedTransactionId = allTransitions.Length > 0 ? allTransitions.Max(x =>
    ↳ x.TransactionId) : 0;
259 _uniqueTimestampFactory = new UniqueTimestampFactory();
260 _logAddress = logAddress;
261 _log = FileHelpers.Append(logAddress);
262 _transitions = new Queue<Transition>();
263 _transitionsPusher = new Task(TransitionsPusher);
264 _transitionsPusher.Start();
265 }
266
267 public IList<ulong> GetLinkValue(ulong link) => Links.GetLink(link);
268
269 public override ulong Create(IList<ulong> restrictions)
270 {
271     var createdLinkIndex = Links.Create();
272     var createdLink = new Link<ulong>(Links.GetLink(createdLinkIndex));
273     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↳ default, createdLink));
274     return createdLinkIndex;
275 }
276
277 public override ulong Update(IList<ulong> restrictions, IList<ulong> substitution)
278 {
279     var linkIndex = restrictions[Constants.IndexPart];
280     var beforeLink = new Link<ulong>(Links.GetLink(linkIndex));
281     linkIndex = Links.Update(restrictions, substitution);
282     var afterLink = new Link<ulong>(Links.GetLink(linkIndex));
283     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↳ beforeLink, afterLink));
284     return linkIndex;
285 }
286
287 public override void Delete(IList<ulong> restrictions)
288 {
289     var link = restrictions[Constants.IndexPart];
290     var deletedLink = new Link<ulong>(Links.GetLink(link));
291     Links.Delete(link);
292     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↳ deletedLink, default));
293 }
294
295 [MethodImpl(MethodImplOptions.AggressiveInlining)]
296 private Queue<Transition> GetCurrentTransitions() => _currentTransactionTransitions ??
    ↳ _transitions;
297
298 private void CommitTransition(Transition transition)
299 {
300     if (_currentTransaction != null)
301     {
302         Transaction.EnsureTransactionAllowsWriteOperations(_currentTransaction);
303     }
304     var transitions = GetCurrentTransitions();
305     transitions.Enqueue(transition);
306 }
307
308 private void RevertTransition(Transition transition)
309 {
310     if (transition.After.IsNull()) // Revert Deletion with Creation
311     {

```

```

312         Links.Create();
313     }
314     else if (transition.Before.IsNull()) // Revert Creation with Deletion
315     {
316         Links.Delete(transition.After.Index);
317     }
318     else // Revert Update
319     {
320         Links.Update(new[] { transition.After.Index, transition.Before.Source,
            ↪ transition.Before.Target });
321     }
322 }
323
324 private void ResetCurrentTransation()
325 {
326     _currentTransactionId = 0;
327     _currentTransactionTransitions = null;
328     _currentTransaction = null;
329 }
330
331 private void PushTransitions()
332 {
333     if (_log == null || _transitions == null)
334     {
335         return;
336     }
337     for (var i = 0; i < _transitions.Count; i++)
338     {
339         var transition = _transitions.Dequeue();
340
341         _log.Write(transition);
342         _lastCommittedTransition = transition;
343     }
344 }
345
346 private void TransitionsPusher()
347 {
348     while (!IsDisposed && _transitionsPusher != null)
349     {
350         Thread.Sleep(DefaultPushDelay);
351         PushTransitions();
352     }
353 }
354
355 public Transaction BeginTransaction() => new Transaction(this);
356
357 private void DisposeTransitions()
358 {
359     try
360     {
361         var pusher = _transitionsPusher;
362         if (pusher != null)
363         {
364             _transitionsPusher = null;
365             pusher.Wait();
366         }
367         if (_transitions != null)
368         {
369             PushTransitions();
370         }
371         _log.DisposeIfPossible();
372         FileHelpers.WriteFirst(_logAddress, _lastCommittedTransition);
373     }
374     catch (Exception ex)
375     {
376         ex.Ignore();
377     }
378 }
379
380 #region DisposalBase
381
382 protected override void Dispose(bool manual, bool wasDisposed)
383 {
384     if (!wasDisposed)
385     {
386         DisposeTransitions();
387     }
388     base.Dispose(manual, wasDisposed);
389 }

```

```

390
391     #endregion
392 }
393 }

```

1.96 ./Platform.Data.Doublents/Unicode/CharToUnicodeSymbolConverter.cs

```

1 using Platform.Converters;
2 using Platform.Numbers;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublents.Unicode
7 {
8     public class CharToUnicodeSymbolConverter<TLink> : LinksOperatorBase<TLink>,
9         ⇨ IConverter<char, TLink>
10    {
11        private readonly IConverter<TLink> _addressToNumberConverter;
12        private readonly TLink _unicodeSymbolMarker;
13
14        public CharToUnicodeSymbolConverter(ILinks<TLink> links, IConverter<TLink>
15            ⇨ addressToNumberConverter, TLink unicodeSymbolMarker) : base(links)
16        {
17            _addressToNumberConverter = addressToNumberConverter;
18            _unicodeSymbolMarker = unicodeSymbolMarker;
19        }
20
21        public TLink Convert(char source)
22        {
23            var unaryNumber = _addressToNumberConverter.Convert((Integer<TLink>)source);
24            return Links.GetOrCreate(unaryNumber, _unicodeSymbolMarker);
25        }
26    }
27 }

```

1.97 ./Platform.Data.Doublents/Unicode/StringToUnicodeSequenceConverter.cs

```

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

```

1.98 ./Platform.Data.Doublents/Unicode/UnicodeMap.cs

```

1 using System;
2 using System.Collections.Generic;
3 using System.Globalization;
4 using System.Runtime.CompilerServices;

```



```

5 using System.Text;
6 using Platform.Data.Sequences;
7
8 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets.Unicode
11 {
12     public class UnicodeMap
13     {
14         public static readonly ulong FirstCharLink = 1;
15         public static readonly ulong LastCharLink = FirstCharLink + char.MaxValue;
16         public static readonly ulong MapSize = 1 + char.MaxValue;
17
18         private readonly ILinks<ulong> _links;
19         private bool _initialized;
20
21         public UnicodeMap(ILinks<ulong> links) => _links = links;
22
23         public static UnicodeMap InitNew(ILinks<ulong> links)
24         {
25             var map = new UnicodeMap(links);
26             map.Init();
27             return map;
28         }
29
30         public void Init()
31         {
32             if (_initialized)
33             {
34                 return;
35             }
36             _initialized = true;
37             var firstLink = _links.CreatePoint();
38             if (firstLink != FirstCharLink)
39             {
40                 _links.Delete(firstLink);
41             }
42             else
43             {
44                 for (var i = FirstCharLink + 1; i <= LastCharLink; i++)
45                 {
46                     // From NIL to It (NIL -> Character) transformation meaning, (or infinite
47                     // ↪ amount of NIL characters before actual Character)
48                     var createdLink = _links.CreatePoint();
49                     _links.Update(createdLink, firstLink, createdLink);
50                     if (createdLink != i)
51                     {
52                         throw new InvalidOperationException("Unable to initialize UTF 16
53                         ↪ table.");
54                     }
55                 }
56             }
57         }
58
59         // 0 - null link
60         // 1 - nil character (0 character)
61         // ...
62         // 65536 (0(1) + 65535 = 65536 possible values)
63
64         [MethodImpl(MethodImplOptions.AggressiveInlining)]
65         public static ulong FromCharToLink(char character) => (ulong)character + 1;
66
67         [MethodImpl(MethodImplOptions.AggressiveInlining)]
68         public static char FromLinkToChar(ulong link) => (char)(link - 1);
69
70         [MethodImpl(MethodImplOptions.AggressiveInlining)]
71         public static bool IsCharLink(ulong link) => link <= MapSize;
72
73         public static string FromLinksToString(IList<ulong> linksList)
74         {
75             var sb = new StringBuilder();
76             for (int i = 0; i < linksList.Count; i++)
77             {
78                 sb.Append(FromLinkToChar(linksList[i]));
79             }
80             return sb.ToString();
81         }
82
83         public static string FromSequenceLinkToString(ulong link, ILinks<ulong> links)

```

```

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 public static ulong[] FromCharsToLinkArray(char[] chars) => FromCharsToLinkArray(chars,
97     ↪ chars.Length);
98 public static ulong[] FromCharsToLinkArray(char[] chars, int count)
99 {
100     // char array to ulong array
101     var linksSequence = new ulong[count];
102     for (var i = 0; i < count; i++)
103     {
104         linksSequence[i] = FromCharToLink(chars[i]);
105     }
106     return linksSequence;
107 }
108 public static ulong[] FromStringToLinkArray(string sequence)
109 {
110     // char array to ulong array
111     var linksSequence = new ulong[sequence.Length];
112     for (var i = 0; i < sequence.Length; i++)
113     {
114         linksSequence[i] = FromCharToLink(sequence[i]);
115     }
116     return linksSequence;
117 }
118 public static List<ulong[]> FromStringToLinkArrayGroups(string sequence)
119 {
120     var result = new List<ulong[]>();
121     var offset = 0;
122     while (offset < sequence.Length)
123     {
124         var currentCategory = CharUnicodeInfo.GetUnicodeCategory(sequence[offset]);
125         var relativeLength = 1;
126         var absoluteLength = offset + relativeLength;
127         while (absoluteLength < sequence.Length &&
128             ↪ currentCategory == CharUnicodeInfo.GetUnicodeCategory(sequence[absoluteLength]))
129         {
130             relativeLength++;
131             absoluteLength++;
132         }
133         // char array to ulong array
134         var innerSequence = new ulong[relativeLength];
135         var maxLength = offset + relativeLength;
136         for (var i = offset; i < maxLength; i++)
137         {
138             innerSequence[i - offset] = FromCharToLink(sequence[i]);
139         }
140         result.Add(innerSequence);
141         offset += relativeLength;
142     }
143     return result;
144 }
145 public static List<ulong[]> FromLinkArrayToLinkArrayGroups(ulong[] array)
146 {
147     var result = new List<ulong[]>();
148     var offset = 0;
149     while (offset < array.Length)
150     {
151         var relativeLength = 1;
152         if (array[offset] <= LastCharLink)
153         {
154

```

```

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     return result;
188 }
189 }

```

1.99 ./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 }

```

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

```

1 using System;
2 using System.Linq;
3 using Platform.Interfaces;
4 using Platform.Converters;
5 using Platform.Data.Doublets.Sequences.Walkers;
6
7 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9 namespace Platform.Data.Doublets.Unicode
10 {
11     public class UnicodeSequenceToStringConverter<TLink> : LinksOperatorBase<TLink>,
12         ↳ IConverter<TLink, string>
13     {
14         private readonly ICriterionMatcher<TLink> _unicodeSequenceCriterionMatcher;
15         private readonly ISequenceWalker<TLink> _sequenceWalker;
16         private readonly IConverter<TLink, char> _unicodeSymbolToCharConverter;
17
18         public UnicodeSequenceToStringConverter(ILinks<TLink> links, ICriterionMatcher<TLink>
19             ↳ unicodeSequenceCriterionMatcher, ISequenceWalker<TLink> sequenceWalker,
20             ↳ IConverter<TLink, char> unicodeSymbolToCharConverter) : base(links)
21         {
22             _unicodeSequenceCriterionMatcher = unicodeSequenceCriterionMatcher;
23         }
24     }
25 }

```

```

20     _sequenceWalker = sequenceWalker;
21     _unicodeSymbolToCharConverter = unicodeSymbolToCharConverter;
22 }
23
24 public string Convert(TLink source)
25 {
26     if(!_unicodeSequenceCriterionMatcher.IsMatched(source))
27     {
28         throw new ArgumentOutOfRangeException(nameof(source), source, "Specified link is
↳ not a unicode sequence.");
29     }
30     var sequence = Links.GetSource(source);
31     var charArray = _sequenceWalker.Walk(sequence).Select(_unicodeSymbolToCharConverter.
↳ Convert).ToArray();
32     return new string(charArray);
33 }
34 }
35 }

```

1.101 ./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>,
↳ ICriterionMatcher<TLink>
9     {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
↳ EqualityComparer<TLink>.Default;
11         private readonly TLink _unicodeSymbolMarker;
12         public UnicodeSymbolCriterionMatcher(ILinks<TLink> links, TLink unicodeSymbolMarker) :
↳ base(links) => _unicodeSymbolMarker = unicodeSymbolMarker;
13         public bool IsMatched(TLink link) => _equalityComparer.Equals(Links.GetTarget(link),
↳ _unicodeSymbolMarker);
14     }
15 }

```

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

```

1 using System;
2 using Platform.Interfaces;
3 using Platform.Converters;
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.Unicode
9 {
10     public class UnicodeSymbolToCharConverter<TLink> : LinksOperatorBase<TLink>,
↳ IConverter<TLink, char>
11     {
12         private readonly IConverter<TLink> _numberToAddressConverter;
13         private readonly ICriterionMatcher<TLink> _unicodeSymbolCriterionMatcher;
14
15         public UnicodeSymbolToCharConverter(ILinks<TLink> links, IConverter<TLink>
↳ numberToAddressConverter, ICriterionMatcher<TLink> unicodeSymbolCriterionMatcher) :
↳ base(links)
16         {
17             _numberToAddressConverter = numberToAddressConverter;
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>)_numberToAddressConverter.Convert(Links.GetSour
↳ ce(source));
28         }
29     }
30 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Xunit;
4  using Platform.Diagnostics;
5
6  namespace Platform.Data.Doublets.Tests
7  {
8      public static class ComparisonTests
9      {
10         private class UInt64Comparer : IComparer

```

1.104 ./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
77     Func<ulong, ulong, bool> equalityComparer3 = equalityComparer2.Equals;
78
79     var ts6 = Performance.Measure(() =>
80     {
81         for (int i = 0; i < N; i++)
82         {
83             result = equalityComparer3(x, y);
84         }
85     });
86
87     var comparer = Comparer<ulong>.Default;
88
89     var ts7 = Performance.Measure(() =>

```

```

90     {
91         for (int i = 0; i < N; i++)
92         {
93             result = comparer.Compare(x, y) == 0;
94         }
95     });
96
97     Assert.True(ts2 < ts1);
98     Assert.True(ts3 < ts2);
99     Assert.True(ts5 < ts4);
100    Assert.True(ts5 < ts6);
101
102    Console.WriteLine($"{ts1} {ts2} {ts3} {ts4} {ts5} {ts6} {ts7} {result}");
103 }
104 }
105 }

```

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

```

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

```

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

```

1  using Xunit;
2
3  namespace Platform.Data.Doublets.Tests
4  {
5      public static class LinksConstantsTests

```

```

6 {
7     [Fact]
8     public static void ExternalReferencesTest()
9     {
10         LinksConstants<ulong> constants = new LinksConstants<ulong>((1, long.MaxValue),
11             ↳ (long.MaxValue + 1UL, ulong.MaxValue));
12
13         //var minimum = new Hybrid<ulong>(0, isExternal: true);
14         var minimum = new Hybrid<ulong>(1, isExternal: true);
15         var maximum = new Hybrid<ulong>(long.MaxValue, isExternal: true);
16
17         Assert.True(constants.IsExternalReference(minimum));
18         Assert.True(constants.IsExternalReference(maximum));
19     }
20 }

```

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

```

1 using System;
2 using System.Linq;
3 using Xunit;
4 using Platform.Collections.Stacks;
5 using Platform.Collections.Arrays;
6 using Platform.Memory;
7 using Platform.Data.Numbers.Raw;
8 using Platform.Data.Doublets.Sequences;
9 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
10 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
11 using Platform.Data.Doublets.Sequences.Converters;
12 using Platform.Data.Doublets.PropertyOperators;
13 using Platform.Data.Doublets.Incrementers;
14 using Platform.Data.Doublets.Sequences.Walkers;
15 using Platform.Data.Doublets.Sequences.Indexes;
16 using Platform.Data.Doublets.Unicode;
17 using Platform.Data.Doublets.Numbers.Unary;
18 using Platform.Data.Doublets.Decorators;
19 using Platform.Data.Doublets.ResizableDirectMemory.Specific;
20
21 namespace Platform.Data.Doublets.Tests
22 {
23     public static class OptimalVariantSequenceTests
24     {
25         private static readonly string _sequenceExample = "зеленела зелёная зелень";
26         private static readonly string _loremIpsumExample = @"Lorem ipsum dolor sit amet,
27             ↳ consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore
28             ↳ magna aliqua.
29             Facilisi nullam vehicula ipsum a arcu cursus vitae congue mauris.
30             Et malesuada fames ac turpis egestas sed.
31             Eget velit aliquet sagittis id consectetur purus.
32             Dignissim cras tincidunt lobortis feugiat vivamus.
33             Vitae aliquet nec ullamcorper sit.
34             Lectus quam id leo in vitae.
35             Tortor dignissim convallis aenean et tortor at risus viverra adipiscing.
36             Sed risus ultricies tristique nulla aliquet enim tortor at auctor.
37             Integer eget aliquet nibh praesent tristique.
38             Vitae congue eu consequat ac felis donec et odio.
39             Tristique et egestas quis ipsum suspendisse.
40             Suspendisse potenti nullam ac tortor vitae purus faucibus ornare.
41             Nulla facilisi etiam dignissim diam quis enim lobortis scelerisque.
42             Imperdiet proin fermentum leo vel orci.
43             In ante metus dictum at tempor commodo.
44             Nisi lacus sed viverra tellus in.
45             Quam vulputate dignissim suspendisse in.
46             Elit scelerisque mauris pellentesque pulvinar pellentesque habitant morbi tristique senectus.
47             Gravida cum sociis natoque penatibus et magnis dis parturient.
48             Risus quis varius quam quisque id diam.
49             Congue nisi vitae suscipit tellus mauris a diam maecenas.
50             Eget nunc scelerisque viverra mauris in aliquam sem fringilla.
51             Pharetra vel turpis nunc eget lorem dolor sed viverra.
52             Mattis pellentesque id nibh tortor id aliquet.
53             Purus non enim praesent elementum facilisis leo vel.
54             Etiam sit amet nisl purus in mollis nunc sed.
55             Tortor at auctor urna nunc id cursus metus aliquam.
56             Volutpat odio facilisis mauris sit amet.
57             Turpis egestas pretium aenean pharetra magna ac placerat.
58             Fermentum dui faucibus in ornare quam viverra orci sagittis eu.
59             Porttitor leo a diam sollicitudin tempor id eu.
60             Volutpat sed cras ornare arcu dui.
61             Ut aliquam purus sit amet luctus venenatis lectus magna.
62             Aliquet risus feugiat in ante metus dictum at.
63             Mattis nunc sed blandit libero.
64             Elit pellentesque habitant morbi tristique senectus et netus.
65             Nibh sit amet commodo nulla facilisi nullam vehicula ipsum a.

```



```

64 Enim sit amet venenatis urna cursus eget nunc scelerisque viverra.
65 Amet venenatis urna cursus eget nunc scelerisque viverra mauris in.
66 Diam donec adipiscing tristique risus nec feugiat.
67 Pulvinar mattis nunc sed blandit libero volutpat.
68 Cras fermentum odio eu feugiat pretium nibh ipsum.
69 In nulla posuere sollicitudin aliquam ultrices sagittis orci a.
70 Mauris pellentesque pulvinar pellentesque habitant morbi tristique senectus et.
71 A iaculis at erat pellentesque.
72 Morbi blandit cursus risus at ultrices mi tempus imperdiet nulla.
73 Eget lorem dolor sed viverra ipsum nunc.
74 Leo a diam sollicitudin tempor id eu.
75 Interdum consectetur libero id faucibus nisl tincidunt eget nullam non.";
76
77 [Fact]
78 public static void LinksBasedFrequencyStoredOptimalVariantSequenceTest()
79 {
80     using (var scope = new TempLinksTestScope(useSequences: false))
81     {
82         var links = scope.Links;
83         var constants = links.Constants;
84
85         links.UseUnicode();
86
87         var sequence = UnicodeMap.FromStringToLinkArray(_sequenceExample);
88
89         var meaningRoot = links.CreatePoint();
90         var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
91         var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
92         var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
93             ↳ constants.Itself);
94
95         var unaryNumberToAddressConverter = new
96             ↳ UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
97         var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
98         var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
99             ↳ frequencyMarker, unaryOne, unaryNumberIncrementer);
100         var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
101             ↳ frequencyPropertyMarker, frequencyMarker);
102         var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
103             ↳ frequencyPropertyOperator, frequencyIncrementer);
104         var linkToItsFrequencyNumberConverter = new
105             ↳ LinkToItsFrequencyNumberConverter<ulong>(links, frequencyPropertyOperator,
106             ↳ unaryNumberToAddressConverter);
107         var sequenceToItsLocalElementLevelsConverter = new
108             ↳ SequenceToItsLocalElementLevelsConverter<ulong>(links,
109             ↳ linkToItsFrequencyNumberConverter);
110         var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
111             ↳ sequenceToItsLocalElementLevelsConverter);
112
113         var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
114             ↳ Walker = new LeveledSequenceWalker<ulong>(links) });
115
116         ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
117             ↳ index, optimalVariantConverter);
118     }
119 }
120
121 [Fact]
122 public static void DictionaryBasedFrequencyStoredOptimalVariantSequenceTest()
123 {
124     using (var scope = new TempLinksTestScope(useSequences: false))
125     {
126         var links = scope.Links;
127
128         links.UseUnicode();
129
130         var sequence = UnicodeMap.FromStringToLinkArray(_sequenceExample);
131
132         var totalSequenceSymbolFrequencyCounter = new
133             ↳ TotalSequenceSymbolFrequencyCounter<ulong>(links);
134
135         var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
136             ↳ totalSequenceSymbolFrequencyCounter);
137
138         var index = new
139             ↳ CachedFrequencyIncrementingSequenceIndex<ulong>(linkFrequenciesCache);
140         var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<ulong>(linkFrequenciesCache);

```

```

127     var sequenceToItsLocalElementLevelsConverter = new
128         ↪ SequenceToItsLocalElementLevelsConverter<ulong>(links,
129         ↪ linkToItsFrequencyNumberConverter);
130     var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
131         ↪ sequenceToItsLocalElementLevelsConverter);
132
133     var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
134         ↪ Walker = new LeveledSequenceWalker<ulong>(links) });
135
136     ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
137         ↪ index, optimalVariantConverter);
138 }
139
140 private static void ExecuteTest(Sequences.Sequences sequences, ulong[] sequence,
141     ↪ SequenceToItsLocalElementLevelsConverter<ulong>
142     ↪ sequenceToItsLocalElementLevelsConverter, ISequenceIndex<ulong> index,
143     ↪ OptimalVariantConverter<ulong> optimalVariantConverter)
144 {
145     index.Add(sequence);
146
147     var optimalVariant = optimalVariantConverter.Convert(sequence);
148
149     var readSequence1 = sequences.ToList(optimalVariant);
150
151     Assert.True(sequence.SequenceEqual(readSequence1));
152 }
153
154 [Fact]
155 public static void SavedSequencesOptimizationTest()
156 {
157     LinksConstants<ulong> constants = new LinksConstants<ulong>((1, long.MaxValue),
158         ↪ (long.MaxValue + 1UL, ulong.MaxValue));
159
160     using (var memory = new HeapResizableDirectMemory())
161     using (var disposableLinks = new UInt64ResizableDirectMemoryLinks(memory,
162         ↪ UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep, constants,
163         ↪ useAvlBasedIndex: false))
164     {
165         var links = new UInt64Links(disposableLinks);
166
167         var root = links.CreatePoint();
168
169         //var numberToAddressConverter = new RawNumberToAddressConverter<ulong>();
170         var addressToNumberConverter = new AddressToRawNumberConverter<ulong>();
171
172         var unicodeSymbolMarker = links.GetOrCreate(root,
173             ↪ addressToNumberConverter.Convert(1));
174         var unicodeSequenceMarker = links.GetOrCreate(root,
175             ↪ addressToNumberConverter.Convert(2));
176
177         var totalSequenceSymbolFrequencyCounter = new
178             ↪ TotalSequenceSymbolFrequencyCounter<ulong>(links);
179         var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
180             ↪ totalSequenceSymbolFrequencyCounter);
181         var index = new
182             ↪ CachedFrequencyIncrementingSequenceIndex<ulong>(linkFrequenciesCache);
183         var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<ulong>(linkFrequenciesCache);
184         var sequenceToItsLocalElementLevelsConverter = new
185             ↪ SequenceToItsLocalElementLevelsConverter<ulong>(links,
186             ↪ linkToItsFrequencyNumberConverter);
187         var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
188             ↪ sequenceToItsLocalElementLevelsConverter);
189
190         var walker = new RightSequenceWalker<ulong>(links, new DefaultStack<ulong>(),
191             ↪ (link) => constants.IsExternalReference(link) || links.IsPartialPoint(link));
192
193         var unicodeSequencesOptions = new SequencesOptions<ulong>()
194         {
195             UseSequenceMarker = true,
196             SequenceMarkerLink = unicodeSequenceMarker,
197             UseIndex = true,
198             Index = index,
199             LinksToSequenceConverter = optimalVariantConverter,
200             Walker = walker,
201             UseGarbageCollection = true
202         };
203     }
204 }

```

```

184
185     var unicodeSequences = new Sequences.Sequences(new
    ↪ SynchronizedLinks<ulong>(links), unicodeSequencesOptions);
186
187     // Create some sequences
188     var strings = _loremIpsumExample.Split(new[] { '\n', '\r' },
    ↪ StringSplitOptions.RemoveEmptyEntries);
189     var arrays = strings.Select(x => x.Select(y =>
    ↪ addressToNumberConverter.Convert(y)).ToArray()).ToArray();
190     for (int i = 0; i < arrays.Length; i++)
191     {
192         unicodeSequences.Create(arrays[i].ShiftRight());
193     }
194
195     var linksCountAfterCreation = links.Count();
196
197     // get list of sequences links
198     // for each sequence link
199     //     create new sequence version
200     //     if new sequence is not the same as sequence link
201     //         delete sequence link
202     //         collect garbadge
203     unicodeSequences.CompactAll();
204
205     var linksCountAfterCompactification = links.Count();
206
207     Assert.True(linksCountAfterCompactification < linksCountAfterCreation);
208 }
209 }
210 }
211 }

```

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

```

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

```



```

55     memoryAdapter.Each(foundLink =>
56     {
57         resultLink = foundLink[_constants.IndexPart];
58         return _constants.Break;
59     }, _constants.Any, ulong.MaxValue, ulong.MaxValue);
60     Assert.True(resultLink == link);
61     Assert.True(memoryAdapter.Count(ulong.MaxValue) == 0);
62     memoryAdapter.Delete(link);
63 }
64 }
65 }

```

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

```

1  using Xunit;
2  using Platform.Scopes;
3  using Platform.Memory;
4  using Platform.Data.Doublets.Decorators;
5  using Platform.Reflection;
6  using Platform.Data.Doublets.ResizableDirectMemory.Generic;
7  using Platform.Data.Doublets.ResizableDirectMemory.Specific;
8
9  namespace Platform.Data.Doublets.Tests
10 {
11     public static class ScopeTests
12     {
13         [Fact]
14         public static void SingleDependencyTest()
15         {
16             using (var scope = new Scope())
17             {
18                 scope.IncludeAssemblyOf<IMemory>();
19                 var instance = scope.Use<IDirectMemory>();
20                 Assert.IsType<HeapResizableDirectMemory>(instance);
21             }
22         }
23
24         [Fact]
25         public static void CascadeDependencyTest()
26         {
27             using (var scope = new Scope())
28             {
29                 scope.Include<TemporaryFileMappedResizableDirectMemory>();
30                 scope.Include<UInt64ResizableDirectMemoryLinks>();
31                 var instance = scope.Use<ILinks<ulong>>();
32                 Assert.IsType<UInt64ResizableDirectMemoryLinks>(instance);
33             }
34         }
35
36         [Fact]
37         public static void FullAutoResolutionTest()
38         {
39             using (var scope = new Scope(autoInclude: true, autoExplore: true))
40             {
41                 var instance = scope.Use<UInt64Links>();
42                 Assert.IsType<UInt64Links>(instance);
43             }
44         }
45
46         [Fact]
47         public static void TypeParametersTest()
48         {
49             using (var scope = new Scope<Types<HeapResizableDirectMemory,
50 ↵ ResizableDirectMemoryLinks<ulong>>>())
51             {
52                 var links = scope.Use<ILinks<ulong>>();
53                 Assert.IsType<ResizableDirectMemoryLinks<ulong>>(links);
54             }
55         }
56     }
57 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Diagnostics;
4  using System.Linq;
5  using Xunit;
6  using Platform.Collections;
7  using Platform.Collections.Arrays;

```

```

8 using Platform.Random;
9 using Platform.IO;
10 using Platform.Singletons;
11 using Platform.Data.Doublets.Sequences;
12 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
13 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
14 using Platform.Data.Doublets.Sequences.Converters;
15 using Platform.Data.Doublets.Unicode;
16
17 namespace Platform.Data.Doublets.Tests
18 {
19     public static class SequencesTests
20     {
21         private static readonly LinksConstants<ulong> _constants =
22             ↳ Default<LinksConstants<ulong>>.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();
51
52                 Assert.True(results1.Count > results2.Length);
53                 Assert.True(sw1.Elapsed > sw2.Elapsed);
54
55                 for (var i = 0; i < sequenceLength; i++)
56                 {
57                     links.Delete(sequence[i]);
58                 }
59
60                 Assert.True(links.Count() == 0);
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             //    {
75             //        using (var links = new Links(memoryAdapter))
76             //        {
77             //            var sequence = new ulong[sequenceLength];
78             //            for (var i = 0; i < sequenceLength; i++)
79             //            {
80             //                sequence[i] = links.Create(itself, itself);
81
82             //                SequencesOptions o = new SequencesOptions();
83
84             //                // TODO: Из числа в bool значения o.UseSequenceMarker = ((value & 1) != 0)
85             //                o.

```

```

86 //         var sw1 = Stopwatch.StartNew();
87 //         var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
88
89 //         var sw2 = Stopwatch.StartNew();
90 //         var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();
91
92 //         Assert.True(results1.Count > results2.Length);
93 //         Assert.True(sw1.Elapsed > sw2.Elapsed);
94
95 //         for (var i = 0; i < sequenceLength; i++)
96 //             links.Delete(sequence[i]);
97 //     }
98
99 //     File.Delete(tempFilename);
100 // }
101
102 [Fact]
103 public static void AllVariantsSearchTest()
104 {
105     const long sequenceLength = 8;
106
107     using (var scope = new TempLinksTestScope(useSequences: true))
108     {
109         var links = scope.Links;
110         var sequences = scope.Sequences;
111
112         var sequence = new ulong[sequenceLength];
113         for (var i = 0; i < sequenceLength; i++)
114         {
115             sequence[i] = links.Create();
116         }
117
118         var createResults = sequences.CreateAllVariants2(sequence).Distinct().ToArray();
119
120         //for (int i = 0; i < createResults.Length; i++)
121         //    sequences.Create(createResults[i]);
122
123         var sw0 = Stopwatch.StartNew();
124         var searchResults0 = sequences.GetAllMatchingSequences0(sequence); sw0.Stop();
125
126         var sw1 = Stopwatch.StartNew();
127         var searchResults1 = sequences.GetAllMatchingSequences1(sequence); sw1.Stop();
128
129         var sw2 = Stopwatch.StartNew();
130         var searchResults2 = sequences.Each1(sequence); sw2.Stop();
131
132         var sw3 = Stopwatch.StartNew();
133         var searchResults3 = sequences.Each(sequence.ShiftRight()); sw3.Stop();
134
135         var intersection0 = createResults.Intersect(searchResults0).ToList();
136         Assert.True(intersection0.Count == searchResults0.Count);
137         Assert.True(intersection0.Count == createResults.Length);
138
139         var intersection1 = createResults.Intersect(searchResults1).ToList();
140         Assert.True(intersection1.Count == searchResults1.Count);
141         Assert.True(intersection1.Count == createResults.Length);
142
143         var intersection2 = createResults.Intersect(searchResults2).ToList();
144         Assert.True(intersection2.Count == searchResults2.Count);
145         Assert.True(intersection2.Count == createResults.Length);
146
147         var intersection3 = createResults.Intersect(searchResults3).ToList();
148         Assert.True(intersection3.Count == searchResults3.Count);
149         Assert.True(intersection3.Count == createResults.Length);
150
151         for (var i = 0; i < sequenceLength; i++)
152         {
153             links.Delete(sequence[i]);
154         }
155     }
156 }
157
158 [Fact]
159 public static void BalancedVariantSearchTest()
160 {
161     const long sequenceLength = 200;
162
163     using (var scope = new TempLinksTestScope(useSequences: true))
164     {
165         var links = scope.Links;

```

```

166     var sequences = scope.Sequences;
167
168     var sequence = new ulong[sequenceLength];
169     for (var i = 0; i < sequenceLength; i++)
170     {
171         sequence[i] = links.Create();
172     }
173
174     var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
175
176     var sw1 = Stopwatch.StartNew();
177     var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();
178
179     var sw2 = Stopwatch.StartNew();
180     var searchResults2 = sequences.GetAllMatchingSequences0(sequence); sw2.Stop();
181
182     var sw3 = Stopwatch.StartNew();
183     var searchResults3 = sequences.GetAllMatchingSequences1(sequence); sw3.Stop();
184
185     // На количестве в 200 элементов это будет занимать вечность
186     //var sw4 = Stopwatch.StartNew();
187     //var searchResults4 = sequences.Each(sequence); sw4.Stop();
188
189     Assert.True(searchResults2.Count == 1 && balancedVariant == searchResults2[0]);
190
191     Assert.True(searchResults3.Count == 1 && balancedVariant ==
192         ↪ searchResults3.First());
193
194     //Assert.True(sw1.Elapsed < sw2.Elapsed);
195
196     for (var i = 0; i < sequenceLength; i++)
197     {
198         links.Delete(sequence[i]);
199     }
200 }
201
202 [Fact]
203 public static void AllPartialVariantsSearchTest()
204 {
205     const long sequenceLength = 8;
206
207     using (var scope = new TempLinksTestScope(useSequences: true))
208     {
209         var links = scope.Links;
210         var sequences = scope.Sequences;
211
212         var sequence = new ulong[sequenceLength];
213         for (var i = 0; i < sequenceLength; i++)
214         {
215             sequence[i] = links.Create();
216         }
217
218         var createResults = sequences.CreateAllVariants2(sequence);
219
220         //var createResultsStrings = createResults.Select(x => x + ": " +
221             ↪ sequences.FormatSequence(x)).ToList();
222         //Global.Trash = createResultsStrings;
223
224         var partialSequence = new ulong[sequenceLength - 2];
225
226         Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
227
228         var sw1 = Stopwatch.StartNew();
229         var searchResults1 =
230             ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
231
232         var sw2 = Stopwatch.StartNew();
233         var searchResults2 =
234             ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
235
236         //var sw3 = Stopwatch.StartNew();
237         //var searchResults3 =
238             ↪ sequences.GetAllPartiallyMatchingSequences2(partialSequence); sw3.Stop();
239
240         var sw4 = Stopwatch.StartNew();
241         var searchResults4 =
242             ↪ sequences.GetAllPartiallyMatchingSequences3(partialSequence); sw4.Stop();

```



```

239 //Global.Trash = searchResults3;
240
241 //var searchResults1Strings = searchResults1.Select(x => x + ": " +
    ↳ sequences.FormatSequence(x)).ToList();
242 //Global.Trash = searchResults1Strings;
243
244 var intersection1 = createResults.Intersect(searchResults1).ToList();
245 Assert.True(intersection1.Count == createResults.Length);
246
247 var intersection2 = createResults.Intersect(searchResults2).ToList();
248 Assert.True(intersection2.Count == createResults.Length);
249
250 var intersection4 = createResults.Intersect(searchResults4).ToList();
251 Assert.True(intersection4.Count == createResults.Length);
252
253 for (var i = 0; i < sequenceLength; i++)
254 {
255     links.Delete(sequence[i]);
256 }
257 }
258 }
259
260 [Fact]
261 public static void BalancedPartialVariantsSearchTest()
262 {
263     const long sequenceLength = 200;
264
265     using (var scope = new TempLinksTestScope(useSequences: true))
266     {
267         var links = scope.Links;
268         var sequences = scope.Sequences;
269
270         var sequence = new ulong[sequenceLength];
271         for (var i = 0; i < sequenceLength; i++)
272         {
273             sequence[i] = links.Create();
274         }
275
276         var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
277
278         var balancedVariant = balancedVariantConverter.Convert(sequence);
279
280         var partialSequence = new ulong[sequenceLength - 2];
281
282         Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
283
284         var sw1 = Stopwatch.StartNew();
285         var searchResults1 =
286             ↳ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
287
288         var sw2 = Stopwatch.StartNew();
289         var searchResults2 =
290             ↳ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
291
292         Assert.True(searchResults1.Count == 1 && balancedVariant == searchResults1[0]);
293
294         Assert.True(searchResults2.Count == 1 && balancedVariant ==
295             ↳ searchResults2.First());
296
297         for (var i = 0; i < sequenceLength; i++)
298         {
299             links.Delete(sequence[i]);
300         }
301     }
302 }
303
304 [Fact(Skip = "Correct implementation is pending")]
305 public static void PatternMatchTest()
306 {
307     var zeroOrMany = Sequences.Sequences.ZeroOrMany;
308
309     using (var scope = new TempLinksTestScope(useSequences: true))
310     {
311         var links = scope.Links;
312         var sequences = scope.Sequences;
313
314         var e1 = links.Create();
315         var e2 = links.Create();
316
317         var sequence = new[]

```

```

315     {
316         e1, e2, e1, e2 // mama / papa
317     };
318
319     var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
320
321     var balancedVariant = balancedVariantConverter.Convert(sequence);
322
323     // 1: [1]
324     // 2: [2]
325     // 3: [1,2]
326     // 4: [1,2,1,2]
327
328     var doublet = links.GetSource(balancedVariant);
329
330     var matchedSequences1 = sequences.MatchPattern(e2, e1, zeroOrMany);
331
332     Assert.True(matchedSequences1.Count == 0);
333
334     var matchedSequences2 = sequences.MatchPattern(zeroOrMany, e2, e1);
335
336     Assert.True(matchedSequences2.Count == 0);
337
338     var matchedSequences3 = sequences.MatchPattern(e1, zeroOrMany, e1);
339
340     Assert.True(matchedSequences3.Count == 0);
341
342     var matchedSequences4 = sequences.MatchPattern(e1, zeroOrMany, e2);
343
344     Assert.Contains(doublet, matchedSequences4);
345     Assert.Contains(balancedVariant, matchedSequences4);
346
347     for (var i = 0; i < sequence.Length; i++)
348     {
349         links.Delete(sequence[i]);
350     }
351 }
352
353 [Fact]
354 public static void IndexTest()
355 {
356     using (var scope = new TempLinksTestScope(new SequencesOptions<ulong> { UseIndex =
357         ↪ true }, useSequences: true))
358     {
359         var links = scope.Links;
360         var sequences = scope.Sequences;
361         var index = sequences.Options.Index;
362
363         var e1 = links.Create();
364         var e2 = links.Create();
365
366         var sequence = new[]
367         {
368             e1, e2, e1, e2 // mama / papa
369         };
370
371         Assert.False(index.MightContain(sequence));
372
373         index.Add(sequence);
374
375         Assert.True(index.MightContain(sequence));
376     }
377 }
378
379 /// <summary>Imported from https://raw.githubusercontent.com/Konard/LinksPlatform/%
380 ↪ 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
381 ↪ %D0%B8%D0%BD%D0%B0%D0%BB%D0%BE%D1%81%D1%8C.md</summary>
382 private static readonly string _exampleText =
383     @"([english
384     ↪ version] (https://github.com/Konard/LinksPlatform/wiki/About-the-beginning))

```

Обозначение пустоты, какое оно? Темнота ли это? Там где отсутствие света, отсутствие фотонов
 ↪ (носителей света)? Или это то, что полностью отражает свет? Пустой белый лист бумаги? Там
 ↪ где есть место для нового начала? Разве пустота это не характеристика пространства?
 ↪ Пространство это то, что можно чем-то наполнить?

385 [![чёрное пространство, белое
→ пространство](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/1.png
→ "чёрное пространство, белое пространство")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/1.png)

386

387 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?

388

389 [![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)

390

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

392

393 [![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)

394

395 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?
→ Грань? Разделителем? Единицей?

396

397 [![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)

398

399 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?

400

401 [![белая вертикальная линия, чёрный
→ круг](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/5.png "белая
→ вертикальная линия, чёрный
→ круг")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/5.png)

402

403 Как ещё можно использовать грань, черту, линию? А что если она может что-то соединять, может
→ тогда её нужно повернуть? Почему то, что перпендикулярно вертикальному горизонтально?
→ Горизонт? Инвертирует ли это смысл? Что такое смысл? Из чего состоит смысл? Существует ли
→ элементарная единица смысла?

404

405 [![белый круг, чёрная горизонтальная
→ линия](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/6.png "белый
→ круг, чёрная горизонтальная
→ линия")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/6.png)

406

407 Соединять, допустим, а какой смысл в этом есть ещё? Что если помимо смысла "соединить",
→ связать"", есть ещё и смысл направления ""от начала к концу""? От предка к потомку? От
→ родителя к ребёнку? От общего к частному?

408

409 [![белая горизонтальная линия, чёрная горизонтальная
→ стрелка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/7.png
→ "белая горизонтальная линия, чёрная горизонтальная
→ стрелка")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/7.png)

410

411 Шаг назад. Возьмём опять отделённую область, которая лишь та же замкнутая линия, что ещё она
→ может представлять собой? Объект? Но в чём его суть? Разве не в том, что у него есть
→ граница, разделяющая внутреннее и внешнее? Допустим связь, стрелка, линия соединяет два
→ объекта, как бы это выглядело?

412

413 [![белая связь, чёрная направленная
→ связь](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/8.png "белая
→ связь, чёрная направленная
→ связь")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/8.png)

414

415 Допустим у нас есть смысл "связать" и смысл "направления", много ли это нам даёт? Много ли
→ вариантов интерпретации? А что если уточнить, каким именно образом выполнена связь? Что если
→ можно задать ей чёткий, конкретный смысл? Что это будет? Тип? Глагол? Связка? Действие?
→ Трансформация? Переход из состояния в состояние? Или всё это и есть объект, суть которого в
→ его конечном состоянии, если конечно конец определён направлением?

```

417  [![белая обычная и направленная связи, чёрная типизированная
    ↳  связь](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/9.png "белая
    ↳  обычная и направленная связи, чёрная типизированная
    ↳  связь")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/9.png)
418
419  А что если всё это время, мы смотрели на суть как бы снаружи? Можно ли взглянуть на это изнутри?
    ↳  Что будет внутри объектов? Объекты ли это? Или это связи? Может ли эта структура описать
    ↳  сама себя? Но что тогда получится, разве это не рекурсия? Может это фрактал?
420
421  [![белая обычная и направленная связи с рекурсивной внутренней структурой, чёрная типизированная
    ↳  связь с рекурсивной внутренней
    ↳  структурой](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/10.png
    ↳  "белая обычная и направленная связи с рекурсивной внутренней структурой, чёрная
    ↳  типизированная связь с рекурсивной внутренней структурой")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/10.png)
422
423  На один уровень внутрь (вниз)? Или на один уровень во вне (вверх)? Или это можно назвать шагом
    ↳  рекурсии или фрактала?
424
425  [![белая обычная и направленная связи с двойной рекурсивной внутренней структурой, чёрная
    ↳  типизированная связь с двойной рекурсивной внутренней
    ↳  структурой](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/11.png
    ↳  "белая обычная и направленная связи с двойной рекурсивной внутренней структурой, чёрная
    ↳  типизированная связь с двойной рекурсивной внутренней структурой")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/11.png)
426
427  Последовательность? Массив? Список? Множество? Объект? Таблица? Элементы? Цвета? Символы? Буквы?
    ↳  Слово? Цифры? Число? Алфавит? Дерево? Сеть? Граф? Гиперграф?
428
429  [![белая обычная и направленная связи со структурой из 8 цветных элементов последовательности,
    ↳  чёрная типизированная связь со структурой из 8 цветных элементов последовательности](https://
    ↳  raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/12.png "белая обычная и
    ↳  направленная связи со структурой из 8 цветных элементов последовательности, чёрная
    ↳  типизированная связь со структурой из 8 цветных элементов последовательности")](https://raw
    ↳  .githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/12.png)
430
431  ...
432
433  [![анимация](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro-animat
    ↳  ion-500.gif
    ↳  "анимация")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro
    ↳  -animation-500.gif)";
434
435      private static readonly string _exampleLoremIpsumText =
436          @"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor
    ↳  incididunt ut labore et dolore magna aliqua.
437  Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo
    ↳  consequat.";
438
439      [Fact]
440      public static void CompressionTest()
441      {
442          using (var scope = new TempLinksTestScope(useSequences: true))
443          {
444              var links = scope.Links;
445              var sequences = scope.Sequences;
446
447              var e1 = links.Create();
448              var e2 = links.Create();
449
450              var sequence = new[]
451              {
452                  e1, e2, e1, e2 // mama / papa / template [(m/p), a] { [1] [2] [1] [2] }
453              };
454
455              var balancedVariantConverter = new BalancedVariantConverter<ulong>(links.Unsync);
456              var totalSequenceSymbolFrequencyCounter = new
    ↳  TotalSequenceSymbolFrequencyCounter<ulong>(links.Unsync);
457              var doubletFrequenciesCache = new LinkFrequenciesCache<ulong>(links.Unsync,
    ↳  totalSequenceSymbolFrequencyCounter);
458              var compressingConverter = new CompressingConverter<ulong>(links.Unsync,
    ↳  balancedVariantConverter, doubletFrequenciesCache);
459
460              var compressedVariant = compressingConverter.Convert(sequence);
461
462              // 1: [1]          (1->1) point
463              // 2: [2]          (2->2) point
464              // 3: [1,2]        (1->2) doublet
465              // 4: [1,2,1,2]    (3->3) doublet

```

```

466 Assert.True(links.GetSource(links.GetSource(compressedVariant)) == sequence[0]);
467 Assert.True(links.GetTarget(links.GetSource(compressedVariant)) == sequence[1]);
468 Assert.True(links.GetSource(links.GetTarget(compressedVariant)) == sequence[2]);
469 Assert.True(links.GetTarget(links.GetTarget(compressedVariant)) == sequence[3]);
470
471
472 var source = _constants.SourcePart;
473 var target = _constants.TargetPart;
474
475 Assert.True(links.GetByKeys(compressedVariant, source, source) == sequence[0]);
476 Assert.True(links.GetByKeys(compressedVariant, source, target) == sequence[1]);
477 Assert.True(links.GetByKeys(compressedVariant, target, source) == sequence[2]);
478 Assert.True(links.GetByKeys(compressedVariant, target, target) == sequence[3]);
479
480 // 4 - length of sequence
481 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 0)
482     ↳ == sequence[0]);
483 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 1)
484     ↳ == sequence[1]);
485 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 2)
486     ↳ == sequence[2]);
487 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 3)
488     ↳ == sequence[3]);
489
490 }
491
492 [Fact]
493 public static void CompressionEfficiencyTest()
494 {
495     var strings = _exampleLoremIpsumText.Split(new[] { '\n', '\r' },
496         ↳ StringSplitOptions.RemoveEmptyEntries);
497     var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
498     var totalCharacters = arrays.Select(x => x.Length).Sum();
499
500     using (var scope1 = new TempLinksTestScope(useSequences: true))
501     using (var scope2 = new TempLinksTestScope(useSequences: true))
502     using (var scope3 = new TempLinksTestScope(useSequences: true))
503     {
504         scope1.Links.Unsync.UseUnicode();
505         scope2.Links.Unsync.UseUnicode();
506         scope3.Links.Unsync.UseUnicode();
507
508         var balancedVariantConverter1 = new
509             ↳ BalancedVariantConverter<ulong>(scope1.Links.Unsync);
510         var totalSequenceSymbolFrequencyCounter = new
511             ↳ TotalSequenceSymbolFrequencyCounter<ulong>(scope1.Links.Unsync);
512         var linkFrequenciesCache1 = new LinkFrequenciesCache<ulong>(scope1.Links.Unsync,
513             ↳ totalSequenceSymbolFrequencyCounter);
514         var compressor1 = new CompressingConverter<ulong>(scope1.Links.Unsync,
515             ↳ balancedVariantConverter1, linkFrequenciesCache1,
516             ↳ doInitialFrequenciesIncrement: false);
517
518         //var compressor2 = scope2.Sequences;
519         var compressor3 = scope3.Sequences;
520
521         var constants = Default<LinksConstants<ulong>>.Instance;
522
523         var sequences = compressor3;
524         //var meaningRoot = links.CreatePoint();
525         //var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
526         //var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
527         //var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
528             ↳ constants.Itself);
529
530         //var unaryNumberToAddressConverter = new
531             ↳ UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
532         //var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links,
533             ↳ unaryOne);
534         //var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
535             ↳ frequencyMarker, unaryOne, unaryNumberIncrementer);
536         //var frequencyPropertyOperator = new FrequencyPropertyOperator<ulong>(links,
537             ↳ frequencyPropertyMarker, frequencyMarker);
538         //var linkFrequencyIncrementer = new LinkFrequencyIncrementer<ulong>(links,
539             ↳ frequencyPropertyOperator, frequencyIncrementer);
540         //var linkToItsFrequencyNumberConverter = new
541             ↳ LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
542             ↳ unaryNumberToAddressConverter);

```

```

526 var linkFrequenciesCache3 = new LinkFrequenciesCache<ulong>(scope3.Links.Unsync,
527 ↪ totalSequenceSymbolFrequencyCounter);
528
529 var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<ulong>(linkFrequenciesCache3);
530
531 var sequenceToItsLocalElementLevelsConverter = new
532 ↪ SequenceToItsLocalElementLevelsConverter<ulong>(scope3.Links.Unsync,
533 ↪ linkToItsFrequencyNumberConverter);
534
535 var optimalVariantConverter = new
536 ↪ OptimalVariantConverter<ulong>(scope3.Links.Unsync,
537 ↪ sequenceToItsLocalElementLevelsConverter);
538
539 var compressed1 = new ulong[arrays.Length];
540 var compressed2 = new ulong[arrays.Length];
541 var compressed3 = new ulong[arrays.Length];
542
543 var START = 0;
544 var END = arrays.Length;
545
546 //for (int i = START; i < END; i++)
547 //    linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
548
549 var initialCount1 = scope2.Links.Unsync.Count();
550
551 var sw1 = Stopwatch.StartNew();
552
553 for (int i = START; i < END; i++)
554 {
555     linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
556     compressed1[i] = compressor1.Convert(arrays[i]);
557 }
558
559 var elapsed1 = sw1.Elapsed;
560
561 var balancedVariantConverter2 = new
562 ↪ BalancedVariantConverter<ulong>(scope2.Links.Unsync);
563
564 var initialCount2 = scope2.Links.Unsync.Count();
565
566 var sw2 = Stopwatch.StartNew();
567
568 for (int i = START; i < END; i++)
569 {
570     compressed2[i] = balancedVariantConverter2.Convert(arrays[i]);
571 }
572
573 var elapsed2 = sw2.Elapsed;
574
575 for (int i = START; i < END; i++)
576 {
577     linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
578 }
579
580 var initialCount3 = scope3.Links.Unsync.Count();
581
582 var sw3 = Stopwatch.StartNew();
583
584 for (int i = START; i < END; i++)
585 {
586     //linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
587     compressed3[i] = optimalVariantConverter.Convert(arrays[i]);
588 }
589
590 var elapsed3 = sw3.Elapsed;
591
592 Console.WriteLine($"Compressor: {elapsed1}, Balanced variant: {elapsed2},
593 ↪ Optimal variant: {elapsed3}");
594
595 // Assert.True(elapsed1 > elapsed2);
596
597 // Checks
598 for (int i = START; i < END; i++)
599 {
600     var sequence1 = compressed1[i];
601     var sequence2 = compressed2[i];
602     var sequence3 = compressed3[i];
603
604     var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
605     ↪ scope1.Links.Unsync);

```

```

597         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
598             ↳ scope2.Links.Unsync);
599
600         var decompress3 = UnicodeMap.FromSequenceLinkToString(sequence3,
601             ↳ scope3.Links.Unsync);
602
603         var structure1 = scope1.Links.Unsync.FormatStructure(sequence1, link =>
604             ↳ link.IsPartialPoint());
605         var structure2 = scope2.Links.Unsync.FormatStructure(sequence2, link =>
606             ↳ link.IsPartialPoint());
607         var structure3 = scope3.Links.Unsync.FormatStructure(sequence3, link =>
608             ↳ link.IsPartialPoint());
609
610         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
611             ↳ arrays[i].Length > 3)
612             // Assert.False(structure1 == structure2);
613         //if (sequence3 != Constants.Null && sequence2 != Constants.Null &&
614             ↳ arrays[i].Length > 3)
615             // Assert.False(structure3 == structure2);
616
617         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
618         Assert.True(strings[i] == decompress3 && decompress3 == decompress2);
619     }
620
621     Assert.True((int)(scope1.Links.Unsync.Count() - initialCount1) <
622         ↳ totalCharacters);
623     Assert.True((int)(scope2.Links.Unsync.Count() - initialCount2) <
624         ↳ totalCharacters);
625     Assert.True((int)(scope3.Links.Unsync.Count() - initialCount3) <
626         ↳ totalCharacters);
627
628     Console.WriteLine($"{(double)(scope1.Links.Unsync.Count() - initialCount1) /
629         ↳ totalCharacters} | {(double)(scope2.Links.Unsync.Count() - initialCount2) /
630         ↳ totalCharacters} | {(double)(scope3.Links.Unsync.Count() - initialCount3) /
631         ↳ totalCharacters}");
632
633     Assert.True(scope1.Links.Unsync.Count() - initialCount1 <
634         ↳ scope2.Links.Unsync.Count() - initialCount2);
635     Assert.True(scope3.Links.Unsync.Count() - initialCount3 <
636         ↳ scope2.Links.Unsync.Count() - initialCount2);
637
638     var duplicateProvider1 = new
639         ↳ DuplicateSegmentsProvider<ulong>(scope1.Links.Unsync, scope1.Sequences);
640     var duplicateProvider2 = new
641         ↳ DuplicateSegmentsProvider<ulong>(scope2.Links.Unsync, scope2.Sequences);
642     var duplicateProvider3 = new
643         ↳ DuplicateSegmentsProvider<ulong>(scope3.Links.Unsync, scope3.Sequences);
644
645     var duplicateCounter1 = new DuplicateSegmentsCounter<ulong>(duplicateProvider1);
646     var duplicateCounter2 = new DuplicateSegmentsCounter<ulong>(duplicateProvider2);
647     var duplicateCounter3 = new DuplicateSegmentsCounter<ulong>(duplicateProvider3);
648
649     var duplicates1 = duplicateCounter1.Count();
650
651     ConsoleHelpers.Debug("-----");
652
653     var duplicates2 = duplicateCounter2.Count();
654
655     ConsoleHelpers.Debug("-----");
656
657     var duplicates3 = duplicateCounter3.Count();
658
659     Console.WriteLine($"{duplicates1} | {duplicates2} | {duplicates3}");
660
661     linkFrequenciesCache1.ValidateFrequencies();
662     linkFrequenciesCache3.ValidateFrequencies();
663 }
664
665 [Fact]
666 public static void CompressionStabilityTest()
667 {
668     // TODO: Fix bug (do a separate test)
669     //const ulong minNumbers = 0;
670     //const ulong maxNumbers = 1000;
671
672     const ulong minNumbers = 10000;

```

```

657     const ulong maxNumbers = 12500;
658
659     var strings = new List<string>();
660
661     for (ulong i = minNumbers; i < maxNumbers; i++)
662     {
663         strings.Add(i.ToString());
664     }
665
666     var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
667     var totalCharacters = arrays.Select(x => x.Length).Sum();
668
669     using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
        ↳ SequencesOptions<ulong> { UseCompression = true,
        ↳ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
        using (var scope2 = new TempLinksTestScope(useSequences: true))
        {
            scope1.Links.UseUnicode();
            scope2.Links.UseUnicode();
        }
        //var compressor1 = new Compressor(scope1.Links.Unsync, scope1.Sequences);
        var compressor1 = scope1.Sequences;
        var compressor2 = scope2.Sequences;
        var compressed1 = new ulong[arrays.Length];
        var compressed2 = new ulong[arrays.Length];
        var sw1 = Stopwatch.StartNew();
        var START = 0;
        var END = arrays.Length;
        // Collisions proved (cannot be solved by max doublet comparison, no stable rule)
        // Stability issue starts at 10001 or 11000
        //for (int i = START; i < END; i++)
        //{
        //    var first = compressor1.Compress(arrays[i]);
        //    var second = compressor1.Compress(arrays[i]);
        //    if (first == second)
        //        compressed1[i] = first;
        //    else
        //    {
        //        // TODO: Find a solution for this case
        //    }
        //}
        for (int i = START; i < END; i++)
        {
            var first = compressor1.Create(arrays[i].ShiftRight());
            var second = compressor1.Create(arrays[i].ShiftRight());
            if (first == second)
            {
                compressed1[i] = first;
            }
            else
            {
                // TODO: Find a solution for this case
            }
        }
        var elapsed1 = sw1.Elapsed;
        var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
        var sw2 = Stopwatch.StartNew();
        for (int i = START; i < END; i++)
        {
            var first = balancedVariantConverter.Convert(arrays[i]);
            var second = balancedVariantConverter.Convert(arrays[i]);
            if (first == second)
            {
                compressed2[i] = first;
            }
        }
        var elapsed2 = sw2.Elapsed;

```



```

735 Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
736 ↪ {elapsed2}");
737
738 Assert.True(elapsed1 > elapsed2);
739
740 // Checks
741 for (int i = START; i < END; i++)
742 {
743     var sequence1 = compressed1[i];
744     var sequence2 = compressed2[i];
745
746     if (sequence1 != _constants.Null && sequence2 != _constants.Null)
747     {
748         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
749 ↪ scope1.Links);
750
751         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
752 ↪ scope2.Links);
753
754         //var structure1 = scope1.Links.FormatStructure(sequence1, link =>
755 ↪ link.IsPartialPoint());
756         //var structure2 = scope2.Links.FormatStructure(sequence2, link =>
757 ↪ link.IsPartialPoint());
758
759         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
760 ↪ arrays[i].Length > 3)
761         //    Assert.False(structure1 == structure2);
762
763         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
764     }
765 }
766
767 Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
768 Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
769
770 Debug.WriteLine($"{{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
771 ↪ totalCharacters}} | {{(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
772 ↪ totalCharacters}}");
773
774 Assert.True(scope1.Links.Count() <= scope2.Links.Count());
775
776 //compressor1.ValidateFrequencies();
777 }
778
779 [Fact]
780 public static void RandomNumbersCompressionQualityTest()
781 {
782     const ulong N = 500;
783
784     //const ulong minNumbers = 10000;
785     //const ulong maxNumbers = 20000;
786
787     //var strings = new List<string>();
788
789     //for (ulong i = 0; i < N; i++)
790     //    strings.Add(RandomHelpers.DefaultFactory.NextUInt64(minNumbers,
791 ↪ maxNumbers).ToString());
792
793     var strings = new List<string>();
794
795     for (ulong i = 0; i < N; i++)
796     {
797         strings.Add(RandomHelpers.Default.NextUInt64().ToString());
798     }
799
800     strings = strings.Distinct().ToList();
801
802     var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
803     var totalCharacters = arrays.Select(x => x.Length).Sum();
804
805     using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
806 ↪ SequencesOptions<ulong> { UseCompression = true,
807 ↪ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
808     using (var scope2 = new TempLinksTestScope(useSequences: true))
809     {
810         scope1.Links.UseUnicode();

```

```

802     scope2.Links.UseUnicode();
803
804     var compressor1 = scope1.Sequences;
805     var compressor2 = scope2.Sequences;
806
807     var compressed1 = new ulong[arrays.Length];
808     var compressed2 = new ulong[arrays.Length];
809
810     var sw1 = Stopwatch.StartNew();
811
812     var START = 0;
813     var END = arrays.Length;
814
815     for (int i = START; i < END; i++)
816     {
817         compressed1[i] = compressor1.Create(arrays[i].ShiftRight());
818     }
819
820     var elapsed1 = sw1.Elapsed;
821
822     var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
823
824     var sw2 = Stopwatch.StartNew();
825
826     for (int i = START; i < END; i++)
827     {
828         compressed2[i] = balancedVariantConverter.Convert(arrays[i]);
829     }
830
831     var elapsed2 = sw2.Elapsed;
832
833     Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
834         ↪ {elapsed2}");
835
836     Assert.True(elapsed1 > elapsed2);
837
838     // Checks
839     for (int i = START; i < END; i++)
840     {
841         var sequence1 = compressed1[i];
842         var sequence2 = compressed2[i];
843
844         if (sequence1 != _constants.Null && sequence2 != _constants.Null)
845         {
846             var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
847                 ↪ scope1.Links);
848
849             var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
850                 ↪ scope2.Links);
851
852             Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
853         }
854     }
855
856     Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
857     Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
858
859     Debug.WriteLine($"{{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
860         ↪ totalCharacters}} | {{(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
861         ↪ totalCharacters}}");
862
863     // Can be worse than balanced variant
864     //Assert.True(scope1.Links.Count() <= scope2.Links.Count());
865
866     //compressor1.ValidateFrequencies();
867 }
868
869 [Fact]
870 public static void AllTreeBreakDownAtSequencesCreationBugTest()
871 {
872     // Made out of AllPossibleConnectionsTest test.
873
874     //const long sequenceLength = 5; //100% bug
875     const long sequenceLength = 4; //100% bug
876     //const long sequenceLength = 3; //100% _no_bug (ok)
877
878     using (var scope = new TempLinksTestScope(useSequences: true))
879     {
880         var links = scope.Links;

```

```

877     var sequences = scope.Sequences;
878
879     var sequence = new ulong[sequenceLength];
880     for (var i = 0; i < sequenceLength; i++)
881     {
882         sequence[i] = links.Create();
883     }
884
885     var createResults = sequences.CreateAllVariants2(sequence);
886
887     Global.Trash = createResults;
888
889     for (var i = 0; i < sequenceLength; i++)
890     {
891         links.Delete(sequence[i]);
892     }
893 }
894
895 [Fact]
896 public static void AllPossibleConnectionsTest()
897 {
898     const long sequenceLength = 5;
899
900     using (var scope = new TempLinksTestScope(useSequences: true))
901     {
902         var links = scope.Links;
903         var sequences = scope.Sequences;
904
905         var sequence = new ulong[sequenceLength];
906         for (var i = 0; i < sequenceLength; i++)
907         {
908             sequence[i] = links.Create();
909         }
910
911         var createResults = sequences.CreateAllVariants2(sequence);
912         var reverseResults = sequences.CreateAllVariants2(sequence.Reverse().ToArray());
913
914         for (var i = 0; i < 1; i++)
915         {
916             var sw1 = Stopwatch.StartNew();
917             var searchResults1 = sequences.GetAllConnections(sequence); sw1.Stop();
918
919             var sw2 = Stopwatch.StartNew();
920             var searchResults2 = sequences.GetAllConnections1(sequence); sw2.Stop();
921
922             var sw3 = Stopwatch.StartNew();
923             var searchResults3 = sequences.GetAllConnections2(sequence); sw3.Stop();
924
925             var sw4 = Stopwatch.StartNew();
926             var searchResults4 = sequences.GetAllConnections3(sequence); sw4.Stop();
927
928             Global.Trash = searchResults3;
929             Global.Trash = searchResults4; //-V3008
930
931             var intersection1 = createResults.Intersect(searchResults1).ToList();
932             Assert.True(intersection1.Count == createResults.Length);
933
934             var intersection2 = reverseResults.Intersect(searchResults1).ToList();
935             Assert.True(intersection2.Count == reverseResults.Length);
936
937             var intersection0 = searchResults1.Intersect(searchResults2).ToList();
938             Assert.True(intersection0.Count == searchResults2.Count);
939
940             var intersection3 = searchResults2.Intersect(searchResults3).ToList();
941             Assert.True(intersection3.Count == searchResults3.Count);
942
943             var intersection4 = searchResults3.Intersect(searchResults4).ToList();
944             Assert.True(intersection4.Count == searchResults4.Count);
945         }
946
947         for (var i = 0; i < sequenceLength; i++)
948         {
949             links.Delete(sequence[i]);
950         }
951     }
952 }
953
954 [Fact(Skip = "Correct implementation is pending")]
955 public static void CalculateAllUsagesTest()
956

```

```

957 {
958     const long sequenceLength = 3;
959
960     using (var scope = new TempLinksTestScope(useSequences: true))
961     {
962         var links = scope.Links;
963         var sequences = scope.Sequences;
964
965         var sequence = new ulong[sequenceLength];
966         for (var i = 0; i < sequenceLength; i++)
967         {
968             sequence[i] = links.Create();
969         }
970
971         var createResults = sequences.CreateAllVariants2(sequence);
972
973         //var reverseResults =
974         ↪ sequences.CreateAllVariants2(sequence.Reverse().ToArray());
975
976         for (var i = 0; i < 1; i++)
977         {
978             var linksTotalUsages1 = new ulong[links.Count() + 1];
979
980             sequences.CalculateAllUsages(linksTotalUsages1);
981
982             var linksTotalUsages2 = new ulong[links.Count() + 1];
983
984             sequences.CalculateAllUsages2(linksTotalUsages2);
985
986             var intersection1 = linksTotalUsages1.Intersect(linksTotalUsages2).ToList();
987             Assert.True(intersection1.Count == linksTotalUsages2.Length);
988         }
989
990         for (var i = 0; i < sequenceLength; i++)
991         {
992             links.Delete(sequence[i]);
993         }
994     }
995 }
996 }

```

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

```

1  using System.IO;
2  using Platform.Disposables;
3  using Platform.Data.Doublets.Sequences;
4  using Platform.Data.Doublets.Decorators;
5  using Platform.Data.Doublets.ResizableDirectMemory.Specific;
6
7  namespace Platform.Data.Doublets.Tests
8  {
9      public class TempLinksTestScope : DisposableBase
10     {
11         public ILinks<ulong> MemoryAdapter { get; }
12         public SynchronizedLinks<ulong> Links { get; }
13         public Sequences.Sequences Sequences { get; }
14         public string TempFilename { get; }
15         public string TempTransactionLogFilename { get; }
16         private readonly bool _deleteFiles;
17
18         public TempLinksTestScope(bool deleteFiles = true, bool useSequences = false, bool
19         ↪ useLog = false) : this(new SequencesOptions<ulong>(), deleteFiles, useSequences,
20         ↪ useLog) { }
21
22         public TempLinksTestScope(SequencesOptions<ulong> sequencesOptions, bool deleteFiles =
23         ↪ true, bool useSequences = false, bool useLog = false)
24         {
25             _deleteFiles = deleteFiles;
26             TempFilename = Path.GetTempFileName();
27             TempTransactionLogFilename = Path.GetTempFileName();
28             var coreMemoryAdapter = new UInt64ResizableDirectMemoryLinks(TempFilename);
29             MemoryAdapter = useLog ? (ILinks<ulong>)new
30             ↪ UInt64LinksTransactionsLayer(coreMemoryAdapter, TempTransactionLogFilename) :
31             ↪ coreMemoryAdapter;
32             Links = new SynchronizedLinks<ulong>(new UInt64Links(MemoryAdapter));
33             if (useSequences)
34             {
35                 Sequences = new Sequences.Sequences(Links, sequencesOptions);
36             }
37         }
38     }
39 }

```

```

32     }
33
34     protected override void Dispose(bool manual, bool wasDisposed)
35     {
36         if (!wasDisposed)
37         {
38             Links.Unsync.DisposeIfPossible();
39             if (_deleteFiles)
40             {
41                 DeleteFiles();
42             }
43         }
44     }
45
46     public void DeleteFiles()
47     {
48         File.Delete(TempFilename);
49         File.Delete(TempTransactionLogFilename);
50     }
51 }
52 }

```

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

```

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

```

```

58     Assert.True(equalityComparer.Equals(link.Source, constants.Null));
59     Assert.True(equalityComparer.Equals(link.Target, constants.Null));
60
61     // Delete link
62     links.Delete(linkAddress);
63
64     Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.Zero));
65
66     setter = new Setter<T>(constants.Null);
67     links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);
68
69     Assert.True(equalityComparer.Equals(setter.Result, constants.Null));
70 }
71
72 public static void TestRawNumbersCRUDOperations<T>(this ILinks<T> links)
73 {
74     // Constants
75     var constants = links.Constants;
76     var equalityComparer = EqualityComparer<T>.Default;
77
78     var h106E = new Hybrid<T>(106L, isExternal: true);
79     var h107E = new Hybrid<T>(-char.ConvertFromUtf32(107)[0]);
80     var h108E = new Hybrid<T>(-108L);
81
82     Assert.Equal(106L, h106E.AbsoluteValue);
83     Assert.Equal(107L, h107E.AbsoluteValue);
84     Assert.Equal(108L, h108E.AbsoluteValue);
85
86     // Create Link (External -> External)
87     var linkAddress1 = links.Create();
88
89     links.Update(linkAddress1, h106E, h108E);
90
91     var link1 = new Link<T>(links.GetLink(linkAddress1));
92
93     Assert.True(equalityComparer.Equals(link1.Source, h106E));
94     Assert.True(equalityComparer.Equals(link1.Target, h108E));
95
96     // Create Link (Internal -> External)
97     var linkAddress2 = links.Create();
98
99     links.Update(linkAddress2, linkAddress1, h108E);
100
101     var link2 = new Link<T>(links.GetLink(linkAddress2));
102
103     Assert.True(equalityComparer.Equals(link2.Source, linkAddress1));
104     Assert.True(equalityComparer.Equals(link2.Target, h108E));
105
106     // Create Link (Internal -> Internal)
107     var linkAddress3 = links.Create();
108
109     links.Update(linkAddress3, linkAddress1, linkAddress2);
110
111     var link3 = new Link<T>(links.GetLink(linkAddress3));
112
113     Assert.True(equalityComparer.Equals(link3.Source, linkAddress1));
114     Assert.True(equalityComparer.Equals(link3.Target, linkAddress2));
115
116     // Search for created link
117     var setter1 = new Setter<T>(constants.Null);
118     links.Each(h106E, h108E, setter1.SetAndReturnFalse);
119
120     Assert.True(equalityComparer.Equals(setter1.Result, linkAddress1));
121
122     // Search for nonexistent link
123     var setter2 = new Setter<T>(constants.Null);
124     links.Each(h106E, h107E, setter2.SetAndReturnFalse);
125
126     Assert.True(equalityComparer.Equals(setter2.Result, constants.Null));
127
128     // Update link to reference null (prepare for delete)
129     var updated = links.Update(linkAddress3, constants.Null, constants.Null);
130
131     Assert.True(equalityComparer.Equals(updated, linkAddress3));
132
133     link3 = new Link<T>(links.GetLink(linkAddress3));
134
135     Assert.True(equalityComparer.Equals(link3.Source, constants.Null));
136     Assert.True(equalityComparer.Equals(link3.Target, constants.Null));
137

```

```

138         // Delete link
139         links.Delete(linkAddress3);
140
141         Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.Two));
142
143         var setter3 = new Setter<T>(constants.Null);
144         links.Each(constants.Any, constants.Any, setter3.SetAndReturnTrue);
145
146         Assert.True(equalityComparer.Equals(setter3.Result, linkAddress2));
147     }
148
149     public static void TestMultipleRandomCreationsAndDeletions<TLink>(this ILinks<TLink>
150     ↪ links, int maximumOperationsPerCycle)
151     {
152         var comparer = Comparer<TLink>.Default;
153         for (var N = 1; N < maximumOperationsPerCycle; N++)
154         {
155             var random = new System.Random(N);
156             var created = 0;
157             var deleted = 0;
158             for (var i = 0; i < N; i++)
159             {
160                 long linksCount = (Integer<TLink>)links.Count();
161                 var createPoint = random.NextBoolean();
162                 if (linksCount > 2 && createPoint)
163                 {
164                     var linksAddressRange = new Range<ulong>(1, (ulong)linksCount);
165                     TLink source = (Integer<TLink>)random.NextUInt64(linksAddressRange);
166                     TLink target = (Integer<TLink>)random.NextUInt64(linksAddressRange);
167                     ↪ // -V3086
168                     var resultLink = links.GetOrCreate(source, target);
169                     if (comparer.Compare(resultLink, (Integer<TLink>)linksCount) > 0)
170                     {
171                         created++;
172                     }
173                 }
174                 else
175                 {
176                     links.Create();
177                     created++;
178                 }
179             }
180             Assert.True(created == (Integer<TLink>)links.Count());
181             for (var i = 0; i < N; i++)
182             {
183                 TLink link = (Integer<TLink>)(i + 1);
184                 if (links.Exists(link))
185                 {
186                     links.Delete(link);
187                     deleted++;
188                 }
189             }
190             Assert.True((Integer<TLink>)links.Count() == 0);
191         }
192     }

```

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

```

1 using System;
2 using System.Collections.Generic;
3 using System.Diagnostics;
4 using System.IO;
5 using System.Text;
6 using System.Threading;
7 using System.Threading.Tasks;
8 using Xunit;
9 using Platform.Disposables;
10 using Platform.Ranges;
11 using Platform.Random;
12 using Platform.Timestamps;
13 using Platform.Reflection;
14 using Platform.Singletons;
15 using Platform.Scopes;
16 using Platform.Counters;
17 using Platform.Diagnostics;
18 using Platform.IO;
19 using Platform.Memory;
20 using Platform.Data.Doublets.Decorators;
21 using Platform.Data.Doublets.ResizableDirectMemory.Specific;

```

```

22
23 namespace Platform.Data.Doublets.Tests
24 {
25     public static class UInt64LinksTests
26     {
27         private static readonly LinksConstants<ulong> _constants =
28             ↪ Default<LinksConstants<ulong>>.Instance;
29
30         private const long Iterations = 10 * 1024;
31
32         #region Concept
33
34         [Fact]
35         public static void MultipleCreateAndDeleteTest()
36         {
37             using (var scope = new Scope<Types<HeapResizableDirectMemory,
38                 ↪ UInt64ResizableDirectMemoryLinks>>())
39             {
40                 new UInt64Links(scope.Use<ILinks<ulong>>()).TestMultipleRandomCreationsAndDeletions(100);
41             }
42         }
43
44         [Fact]
45         public static void CascadeUpdateTest()
46         {
47             var itself = _constants.Itself;
48             using (var scope = new TempLinksTestScope(useLog: true))
49             {
50                 var links = scope.Links;
51
52                 var l1 = links.Create();
53                 var l2 = links.Create();
54
55                 l2 = links.Update(l2, l2, l1, l2);
56
57                 links.CreateAndUpdate(l2, itself);
58                 links.CreateAndUpdate(l2, itself);
59
60                 l2 = links.Update(l2, l1);
61
62                 links.Delete(l2);
63
64                 Global.Trash = links.Count();
65
66                 links.Unsync.DisposeIfPossible(); // Close links to access log
67
68                 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope ↪
69                     ↪ e.TempTransactionLogFilename);
70             }
71         }
72
73         [Fact]
74         public static void BasicTransactionLogTest()
75         {
76             using (var scope = new TempLinksTestScope(useLog: true))
77             {
78                 var links = scope.Links;
79                 var l1 = links.Create();
80                 var l2 = links.Create();
81
82                 Global.Trash = links.Update(l2, l2, l1, l2);
83
84                 links.Delete(l1);
85
86                 links.Unsync.DisposeIfPossible(); // Close links to access log
87
88                 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope ↪
89                     ↪ e.TempTransactionLogFilename);
90             }
91         }
92
93         [Fact]
94         public static void TransactionAutoRevertedTest()
95         {
96             // Auto Reverted (Because no commit at transaction)
97             using (var scope = new TempLinksTestScope(useLog: true))
98             {
99                 var links = scope.Links;
100                 var transactionsLayer = (UInt64LinksTransactionsLayer)scope.MemoryAdapter;

```



```

97         using (var transaction = transactionsLayer.BeginTransaction())
98         {
99             var l1 = links.Create();
100             var l2 = links.Create();
101
102             links.Update(l2, l2, l1, l2);
103         }
104
105         Assert.Equal(0UL, links.Count());
106
107         links.Unsync.DisposeIfPossible();
108
109         var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(s
            ↪ cope.TempTransactionLogFilename);
110         Assert.Single(transitions);
111     }
112 }
113
114 [Fact]
115 public static void TransactionUserCodeErrorNoDataSavedTest()
116 {
117     // User Code Error (Autoreverted), no data saved
118     var itself = _constants.Itself;
119
120     TempLinksTestScope lastScope = null;
121     try
122     {
123         using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
            ↪ useLog: true))
124         {
125             var links = scope.Links;
126             var transactionsLayer = (UInt64LinksTransactionsLayer)((LinksDisposableDecor
            ↪ atorBase<ulong>)links.Unsync).Links;
127             using (var transaction = transactionsLayer.BeginTransaction())
128             {
129                 var l1 = links.CreateAndUpdate(itself, itself);
130                 var l2 = links.CreateAndUpdate(itself, itself);
131
132                 l2 = links.Update(l2, l2, l1, l2);
133
134                 links.CreateAndUpdate(l2, itself);
135                 links.CreateAndUpdate(l2, itself);
136
137                 //Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transi
            ↪ tion>(scope.TempTransactionLogFilename);
138
139                 l2 = links.Update(l2, l1);
140
141                 links.Delete(l2);
142
143                 ExceptionThrower();
144
145                 transaction.Commit();
146             }
147
148             Global.Trash = links.Count();
149         }
150     }
151     catch
152     {
153         Assert.False(lastScope == null);
154
155         var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(l
            ↪ astScope.TempTransactionLogFilename);
156
157         Assert.True(transitions.Length == 1 && transitions[0].Before.IsNull() &&
            ↪ transitions[0].After.IsNull());
158
159         lastScope.DeleteFiles();
160     }
161 }
162
163 [Fact]
164 public static void TransactionUserCodeErrorSomeDataSavedTest()
165 {
166     // User Code Error (Autoreverted), some data saved
167     var itself = _constants.Itself;
168
169     TempLinksTestScope lastScope = null;

```

```

170     try
171     {
172         ulong l1;
173         ulong l2;
174
175         using (var scope = new TempLinksTestScope(useLog: true))
176         {
177             var links = scope.Links;
178             l1 = links.CreateAndUpdate(itself, itself);
179             l2 = links.CreateAndUpdate(itself, itself);
180
181             l2 = links.Update(l2, l2, l1, l2);
182
183             links.CreateAndUpdate(l2, itself);
184             links.CreateAndUpdate(l2, itself);
185
186             links.Unsync.DisposeIfPossible();
187
188             Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(
189                 ↪ scope.TempTransactionLogFilename);
190         }
191
192         using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
193             ↪ useLog: true))
194         {
195             var links = scope.Links;
196             var transactionsLayer = (UInt64LinksTransactionsLayer)links.Unsync;
197             using (var transaction = transactionsLayer.BeginTransaction())
198             {
199                 l2 = links.Update(l2, l1);
200
201                 links.Delete(l2);
202
203                 ExceptionThrower();
204
205                 transaction.Commit();
206             }
207
208             Global.Trash = links.Count();
209         }
210     }
211     catch
212     {
213         Assert.False(lastScope == null);
214
215         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(last
216             ↪ Scope.TempTransactionLogFilename);
217
218         lastScope.DeleteFiles();
219     }
220 }
221
222 [Fact]
223 public static void TransactionCommit()
224 {
225     var itself = _constants.Itself;
226
227     var tempDatabaseFilename = Path.GetTempFileName();
228     var tempTransactionLogFilename = Path.GetTempFileName();
229
230     // Commit
231     using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
232         ↪ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
233         ↪ tempTransactionLogFilename))
234     using (var links = new UInt64Links(memoryAdapter))
235     {
236         using (var transaction = memoryAdapter.BeginTransaction())
237         {
238             var l1 = links.CreateAndUpdate(itself, itself);
239             var l2 = links.CreateAndUpdate(itself, itself);
240
241             Global.Trash = links.Update(l2, l2, l1, l2);
242
243             links.Delete(l1);
244
245             transaction.Commit();
246         }
247
248         Global.Trash = links.Count();
249     }
250 }

```

```

244     }
245
246     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran_
    ↪ sactionLogFilename);
247 }
248
249 [Fact]
250 public static void TransactionDamage()
251 {
252     var itself = _constants.Itself;
253
254     var tempDatabaseFilename = Path.GetTempFileName();
255     var tempTransactionLogFilename = Path.GetTempFileName();
256
257     // Commit
258     using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
    ↪ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
    ↪ tempTransactionLogFilename))
259     using (var links = new UInt64Links(memoryAdapter))
260     {
261         using (var transaction = memoryAdapter.BeginTransaction())
262         {
263             var l1 = links.CreateAndUpdate(itself, itself);
264             var l2 = links.CreateAndUpdate(itself, itself);
265
266             Global.Trash = links.Update(l2, l2, l1, l2);
267
268             links.Delete(l1);
269
270             transaction.Commit();
271         }
272
273         Global.Trash = links.Count();
274     }
275
276     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran_
    ↪ sactionLogFilename);
277
278     // Damage database
279
280     FileHelpers.WriteFirst(tempTransactionLogFilename, new
    ↪ UInt64LinksTransactionsLayer.Transition(new UniqueTimestampFactory(), 555));
281
282     // Try load damaged database
283     try
284     {
285         // TODO: Fix
286         using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
    ↪ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
    ↪ tempTransactionLogFilename))
287         using (var links = new UInt64Links(memoryAdapter))
288         {
289             Global.Trash = links.Count();
290         }
291     }
292     catch (NotSupportedException ex)
293     {
294         Assert.True(ex.Message == "Database is damaged, autorecovery is not supported
    ↪ yet.");
295     }
296
297     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran_
    ↪ sactionLogFilename);
298
299     File.Delete(tempDatabaseFilename);
300     File.Delete(tempTransactionLogFilename);
301 }
302
303 [Fact]
304 public static void Bug1Test()
305 {
306     var tempDatabaseFilename = Path.GetTempFileName();
307     var tempTransactionLogFilename = Path.GetTempFileName();
308
309     var itself = _constants.Itself;
310
311     // User Code Error (Autoreverted), some data saved
312     try
313     {

```

```

314     ulong l1;
315     ulong l2;
316
317     using (var memory = new UInt64ResizableDirectMemoryLinks(tempDatabaseFilename))
318     using (var memoryAdapter = new UInt64LinksTransactionsLayer(memory,
319         ↪ tempTransactionLogFilename))
320     using (var links = new UInt64Links(memoryAdapter))
321     {
322         l1 = links.CreateAndUpdate(itself, itself);
323         l2 = links.CreateAndUpdate(itself, itself);
324
325         l2 = links.Update(l2, l2, l1, l2);
326
327         links.CreateAndUpdate(l2, itself);
328         links.CreateAndUpdate(l2, itself);
329     }
330
331     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
332     ↪ TransactionLogFilename);
333
334     using (var memory = new UInt64ResizableDirectMemoryLinks(tempDatabaseFilename))
335     using (var memoryAdapter = new UInt64LinksTransactionsLayer(memory,
336         ↪ tempTransactionLogFilename))
337     using (var links = new UInt64Links(memoryAdapter))
338     {
339         using (var transaction = memoryAdapter.BeginTransaction())
340         {
341             l2 = links.Update(l2, l1);
342
343             links.Delete(l2);
344
345             ExceptionThrower();
346
347             transaction.Commit();
348         }
349
350         Global.Trash = links.Count();
351     }
352 }
353
354 catch
355 {
356     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
357     ↪ TransactionLogFilename);
358 }
359
360 File.Delete(tempDatabaseFilename);
361 File.Delete(tempTransactionLogFilename);
362 }
363
364 private static void ExceptionThrower() => throw new InvalidOperationException();
365
366 [Fact]
367 public static void PathsTest()
368 {
369     var source = _constants.SourcePart;
370     var target = _constants.TargetPart;
371
372     using (var scope = new TempLinksTestScope())
373     {
374         var links = scope.Links;
375         var l1 = links.CreatePoint();
376         var l2 = links.CreatePoint();
377
378         var r1 = links.GetByKeys(l1, source, target, source);
379         var r2 = links.CheckPathExistence(l2, l2, l2, l2);
380     }
381 }
382
383 [Fact]
384 public static void RecursiveStringFormattingTest()
385 {
386     using (var scope = new TempLinksTestScope(useSequences: true))
387     {
388         var links = scope.Links;
389         var sequences = scope.Sequences; // TODO: Auto use sequences on Sequences getter.
390
391         var a = links.CreatePoint();
392         var b = links.CreatePoint();
393         var c = links.CreatePoint();
394     }
395 }

```

```

389
390     var ab = links.GetOrCreate(a, b);
391     var cb = links.GetOrCreate(c, b);
392     var ac = links.GetOrCreate(a, c);
393
394     a = links.Update(a, c, b);
395     b = links.Update(b, a, c);
396     c = links.Update(c, a, b);
397
398     Debug.WriteLine(links.FormatStructure(ab, link => link.IsFullPoint(), true));
399     Debug.WriteLine(links.FormatStructure(cb, link => link.IsFullPoint(), true));
400     Debug.WriteLine(links.FormatStructure(ac, link => link.IsFullPoint(), true));
401
402     Assert.True(links.FormatStructure(cb, link => link.IsFullPoint(), true) ==
403         ↪ "(5:(4:5 (6:5 4)) 6)");
404     Assert.True(links.FormatStructure(ac, link => link.IsFullPoint(), true) ==
405         ↪ "(6:(5:(4:5 6) 6) 4)");
406     Assert.True(links.FormatStructure(ab, link => link.IsFullPoint(), true) ==
407         ↪ "(4:(5:4 (6:5 4)) 6)");
408
409     // TODO: Think how to build balanced syntax tree while formatting structure (eg.
410     ↪ "(4:(5:4 6) (6:5 4))" instead of "(4:(5:4 (6:5 4)) 6)")
411
412     Assert.True(sequences.SafeFormatSequence(cb, DefaultFormatter, false) ==
413         ↪ "{5}{5}{4}{6}");
414     Assert.True(sequences.SafeFormatSequence(ac, DefaultFormatter, false) ==
415         ↪ "{5}{6}{6}{4}");
416     Assert.True(sequences.SafeFormatSequence(ab, DefaultFormatter, false) ==
417         ↪ "{4}{5}{4}{6}");
418 }
419
420 private static void DefaultFormatter(StringBuilder sb, ulong link)
421 {
422     sb.Append(link.ToString());
423 }
424
425 #endregion
426
427 #region Performance
428
429 /*
430 public static void RunAllPerformanceTests()
431 {
432     try
433     {
434         links.TestLinksInSteps();
435     }
436     catch (Exception ex)
437     {
438         ex.WriteToConsole();
439     }
440
441     return;
442
443     try
444     {
445         //ThreadPool.SetMaxThreads(2, 2);
446
447         // Запускаем все тесты дважды, чтобы первоначальная инициализация не повлияла на
448         ↪ результат
449         // Также это дополнительно помогает в отладке
450         // Увеличивает вероятность попадания информации в кэши
451         for (var i = 0; i < 10; i++)
452         {
453             //0 - 10 ГБ
454             //Каждые 100 МБ срез цифр
455
456             //links.TestGetSourceFunction();
457             //links.TestGetSourceFunctionInParallel();
458             //links.TestGetTargetFunction();
459             //links.TestGetTargetFunctionInParallel();
460             links.Create64BillionLinks();
461
462             links.TestRandomSearchFixed();
463             //links.Create64BillionLinksInParallel();
464             links.TestEachFunction();
465             //links.TestForeach();
466             //links.TestParallelForeach();

```

```

460     }
461
462     links.TestDeletionOfAllLinks();
463
464     }
465     catch (Exception ex)
466     {
467         ex.WriteToConsole();
468     }
469 }*/
470
471 /*
472 public static void TestLinksInSteps()
473 {
474     const long gibibyte = 1024 * 1024 * 1024;
475     const long mebibyte = 1024 * 1024;
476
477     var totalLinksToCreate = gibibyte /
↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
478     var linksStep = 102 * mebibyte /
↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
479
480     var creationMeasurements = new List<TimeSpan>();
481     var searchMeasurements = new List<TimeSpan>();
482     var deletionMeasurements = new List<TimeSpan>();
483
484     GetBaseRandomLoopOverhead(linksStep);
485     GetBaseRandomLoopOverhead(linksStep);
486
487     var stepLoopOverhead = GetBaseRandomLoopOverhead(linksStep);
488
489     ConsoleHelpers.Debug("Step loop overhead: {0}.", stepLoopOverhead);
490
491     var loops = totalLinksToCreate / linksStep;
492
493     for (int i = 0; i < loops; i++)
494     {
495         creationMeasurements.Add(Measure(() => links.RunRandomCreations(linksStep)));
496         searchMeasurements.Add(Measure(() => links.RunRandomSearches(linksStep)));
497
498         Console.WriteLine("\rC + S {0}/{1}", i + 1, loops);
499     }
500
501     ConsoleHelpers.Debug();
502
503     for (int i = 0; i < loops; i++)
504     {
505         deletionMeasurements.Add(Measure(() => links.RunRandomDeletions(linksStep)));
506
507         Console.WriteLine("\rD {0}/{1}", i + 1, loops);
508     }
509
510     ConsoleHelpers.Debug();
511
512     ConsoleHelpers.Debug("C S D");
513
514     for (int i = 0; i < loops; i++)
515     {
516         ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i],
↪ searchMeasurements[i], deletionMeasurements[i]);
517     }
518
519     ConsoleHelpers.Debug("C S D (no overhead)");
520
521     for (int i = 0; i < loops; i++)
522     {
523         ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i] - stepLoopOverhead,
↪ searchMeasurements[i] - stepLoopOverhead, deletionMeasurements[i] - stepLoopOverhead);
524     }
525
526     ConsoleHelpers.Debug("All tests done. Total links left in database: {0}.",
↪ links.Total);
527 }
528
529 private static void CreatePoints(this Platform.Links.Data.Core.Doublets.Links links, long
↪ amountToCreate)
530 {
531     for (long i = 0; i < amountToCreate; i++)
532         links.Create(0, 0);

```

```

533 }
534
535 private static TimeSpan GetBaseRandomLoopOverhead(long loops)
536 {
537     return Measure(() =>
538     {
539         ulong maxValue = RandomHelpers.DefaultFactory.NextUInt64();
540         ulong result = 0;
541         for (long i = 0; i < loops; i++)
542         {
543             var source = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
544             var target = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
545
546             result += maxValue + source + target;
547         }
548         Global.Trash = result;
549     });
550 }
551 */
552
553 [Fact(Skip = "performance test")]
554 public static void GetSourceTest()
555 {
556     using (var scope = new TempLinksTestScope())
557     {
558         var links = scope.Links;
559         ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations.",
560             ↪ Iterations);
561
562         ulong counter = 0;
563
564         //var firstLink = links.First();
565         // Создаём одну связь, из которой будет производить считывание
566         var firstLink = links.Create();
567
568         var sw = Stopwatch.StartNew();
569
570         // Тестируем саму функцию
571         for (ulong i = 0; i < Iterations; i++)
572         {
573             counter += links.GetSource(firstLink);
574         }
575
576         var elapsedTime = sw.Elapsed;
577
578         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
579
580         // Удаляем связь, из которой производилось считывание
581         links.Delete(firstLink);
582
583         ConsoleHelpers.Debug(
584             " {0} Iterations of GetSource function done in {1} ({2} Iterations per
585             ↪ second), counter result: {3}",
586             Iterations, elapsedTime, (long)iterationsPerSecond, counter);
587     }
588 }
589
590 [Fact(Skip = "performance test")]
591 public static void GetSourceInParallel()
592 {
593     using (var scope = new TempLinksTestScope())
594     {
595         var links = scope.Links;
596         ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations in
597             ↪ parallel.", Iterations);
598
599         long counter = 0;
600
601         //var firstLink = links.First();
602         var firstLink = links.Create();
603
604         var sw = Stopwatch.StartNew();
605
606         // Тестируем саму функцию
607         Parallel.For(0, Iterations, x =>
608         {
609             Interlocked.Add(ref counter, (long)links.GetSource(firstLink));
610             //Interlocked.Increment(ref counter);
611         });
612     }
613 }

```

```

609     var elapsedTime = sw.Elapsed;
610
611     var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
612
613     links.Delete(firstLink);
614
615     ConsoleHelpers.Debug(
616         "{0} Iterations of GetSource function done in {1} ({2} Iterations per
617         ↪ second), counter result: {3}",
618         Iterations, elapsedTime, (long)iterationsPerSecond, counter);
619     }
620 }
621
622 [Fact(Skip = "performance test")]
623 public static void TestGetTarget()
624 {
625     using (var scope = new TempLinksTestScope())
626     {
627         var links = scope.Links;
628         ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations.",
629         ↪ Iterations);
630
631         ulong counter = 0;
632
633         //var firstLink = links.First();
634         var firstLink = links.Create();
635
636         var sw = Stopwatch.StartNew();
637
638         for (ulong i = 0; i < Iterations; i++)
639         {
640             counter += links.GetTarget(firstLink);
641         }
642
643         var elapsedTime = sw.Elapsed;
644
645         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
646
647         links.Delete(firstLink);
648
649         ConsoleHelpers.Debug(
650             "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
651             ↪ second), counter result: {3}",
652             Iterations, elapsedTime, (long)iterationsPerSecond, counter);
653     }
654 }
655
656 [Fact(Skip = "performance test")]
657 public static void TestGetTargetInParallel()
658 {
659     using (var scope = new TempLinksTestScope())
660     {
661         var links = scope.Links;
662         ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations in
663         ↪ parallel.", Iterations);
664
665         long counter = 0;
666
667         //var firstLink = links.First();
668         var firstLink = links.Create();
669
670         var sw = Stopwatch.StartNew();
671
672         Parallel.For(0, Iterations, x =>
673         {
674             Interlocked.Add(ref counter, (long)links.GetTarget(firstLink));
675             //Interlocked.Increment(ref counter);
676         });
677
678         var elapsedTime = sw.Elapsed;
679
680         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
681
682         links.Delete(firstLink);
683
684         ConsoleHelpers.Debug(
685             "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
686             ↪ second), counter result: {3}",
687             Iterations, elapsedTime, (long)iterationsPerSecond, counter);

```



```

684     }
685 }
686
687 // TODO: Заполнить базу данных перед тестом
688 /*
689 [Fact]
690 public void TestRandomSearchFixed()
691 {
692     var tempFilename = Path.GetTempFileName();
693
694     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
↪ DefaultLinksSizeStep))
695     {
696         long iterations = 64 * 1024 * 1024 /
↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
697
698         ulong counter = 0;
699         var maxLink = links.Total;
700
701         ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.", iterations);
702
703         var sw = Stopwatch.StartNew();
704
705         for (var i = iterations; i > 0; i--)
706         {
707             var source =
↪ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
708             var target =
↪ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
709
710             counter += links.Search(source, target);
711         }
712
713         var elapsedTime = sw.Elapsed;
714
715         var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
716
717         ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
↪ Iterations per second), c: {3}", iterations, elapsedTime, (long)iterationsPerSecond,
↪ counter);
718     }
719
720     File.Delete(tempFilename);
721 }*/
722
723 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
724 public static void TestRandomSearchAll()
725 {
726     using (var scope = new TempLinksTestScope())
727     {
728         var links = scope.Links;
729         ulong counter = 0;
730
731         var maxLink = links.Count();
732
733         var iterations = links.Count();
734
735         ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.",
↪ links.Count());
736
737         var sw = Stopwatch.StartNew();
738
739         for (var i = iterations; i > 0; i--)
740         {
741             var linksAddressRange = new
↪ Range<ulong>(_constants.InternalReferencesRange.Minimum, maxLink);
742
743             var source = RandomHelpers.Default.NextUInt64(linksAddressRange);
744             var target = RandomHelpers.Default.NextUInt64(linksAddressRange);
745
746             counter += links.SearchOrDefault(source, target);
747         }
748
749         var elapsedTime = sw.Elapsed;
750
751         var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
752
753         ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
↪ Iterations per second), c: {3}",
↪ iterations, elapsedTime, (long)iterationsPerSecond, counter);
754     }

```

```

755     }
756 }
757
758 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
759 public static void TestEach()
760 {
761     using (var scope = new TempLinksTestScope())
762     {
763         var links = scope.Links;
764
765         var counter = new Counter<IList<ulong>, ulong>(links.Constants.Continue);
766
767         ConsoleHelpers.Debug("Testing Each function.");
768
769         var sw = Stopwatch.StartNew();
770
771         links.Each(counter.IncrementAndReturnTrue);
772
773         var elapsedTime = sw.Elapsed;
774
775         var linksPerSecond = counter.Count / elapsedTime.TotalSeconds;
776
777         ConsoleHelpers.Debug("{0} Iterations of Each's handler function done in {1} ({2}
778             ↪ links per second)",
779             counter, elapsedTime, (long)linksPerSecond);
780     }
781 }
782
783 /*
784 [Fact]
785 public static void TestForeach()
786 {
787     var tempFilename = Path.GetTempFileName();
788     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
789 ↪ DefaultLinksSizeStep))
790     {
791         ulong counter = 0;
792
793         ConsoleHelpers.Debug("Testing foreach through links.");
794
795         var sw = Stopwatch.StartNew();
796
797         //foreach (var link in links)
798         //{
799             counter++;
800         //}
801
802         var elapsedTime = sw.Elapsed;
803
804         var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
805
806         ConsoleHelpers.Debug("{0} Iterations of Foreach's handler block done in {1} ({2}
807             ↪ links per second)", counter, elapsedTime, (long)linksPerSecond);
808     }
809     File.Delete(tempFilename);
810 }
811 */
812
813 /*
814 [Fact]
815 public static void TestParallelForeach()
816 {
817     var tempFilename = Path.GetTempFileName();
818     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
819 ↪ DefaultLinksSizeStep))
820     {
821         long counter = 0;
822
823         ConsoleHelpers.Debug("Testing parallel foreach through links.");
824
825         var sw = Stopwatch.StartNew();
826
827         //Parallel.ForEach((IEnumerable<ulong>)links, x =>
828         //{
829             Interlocked.Increment(ref counter);
830         //});

```

```

831         var elapsedTime = sw.Elapsed;
832
833         var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
834
835         ConsoleHelpers.Debug("{0} Iterations of Parallel Foreach's handler block done in
↪ {1} ({2} links per second)", counter, elapsedTime, (long)linksPerSecond);
836     }
837
838     File.Delete(tempFilename);
839 }
840 */
841
842 [Fact(Skip = "performance test")]
843 public static void Create64BillionLinks()
844 {
845     using (var scope = new TempLinksTestScope())
846     {
847         var links = scope.Links;
848         var linksBeforeTest = links.Count();
849
850         long linksToCreate = 64 * 1024 * 1024 /
↪ UInt64ResizableDirectMemoryLinks.LinkSizeInBytes;
851
852         ConsoleHelpers.Debug("Creating {0} links.", linksToCreate);
853
854         var elapsedTime = Performance.Measure(() =>
855         {
856             for (long i = 0; i < linksToCreate; i++)
857             {
858                 links.Create();
859             }
860         });
861
862         var linksCreated = links.Count() - linksBeforeTest;
863         var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
864
865         ConsoleHelpers.Debug("Current links count: {0}.", links.Count());
866
867         ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
↪ linksCreated, elapsedTime,
868             (long)linksPerSecond);
869     }
870 }
871
872 [Fact(Skip = "performance test")]
873 public static void Create64BillionLinksInParallel()
874 {
875     using (var scope = new TempLinksTestScope())
876     {
877         var links = scope.Links;
878         var linksBeforeTest = links.Count();
879
880         var sw = Stopwatch.StartNew();
881
882         long linksToCreate = 64 * 1024 * 1024 /
↪ UInt64ResizableDirectMemoryLinks.LinkSizeInBytes;
883
884         ConsoleHelpers.Debug("Creating {0} links in parallel.", linksToCreate);
885
886         Parallel.For(0, linksToCreate, x => links.Create());
887
888         var elapsedTime = sw.Elapsed;
889
890         var linksCreated = links.Count() - linksBeforeTest;
891         var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
892
893         ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
↪ linksCreated, elapsedTime,
894             (long)linksPerSecond);
895     }
896 }
897
898 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
899 public static void TestDeletionOfAllLinks()
900 {
901     using (var scope = new TempLinksTestScope())
902     {
903         var links = scope.Links;
904         var linksBeforeTest = links.Count();
905

```

```

906         ConsoleHelpers.Debug("Deleting all links");
907
908         var elapsedTime = Performance.Measure(links.DeleteAll);
909
910         var linksDeleted = linksBeforeTest - links.Count();
911         var linksPerSecond = linksDeleted / elapsedTime.TotalSeconds;
912
913         ConsoleHelpers.Debug("{0} links deleted in {1} ({2} links per second)",
914             ↪ linksDeleted, elapsedTime,
915             (long)linksPerSecond);
916     }
917 }
918
919 #endregion
920 }
921 }

```

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

```

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

```

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

```

1  using Xunit;
2  using Platform.Converters;
3  using Platform.Memory;
4  using Platform.Reflection;
5  using Platform.Scopes;
6  using Platform.Data.Numbers.Raw;
7  using Platform.Data.Doublets.Incrementers;
8  using Platform.Data.Doublets.Numbers.Unary;
9  using Platform.Data.Doublets.PropertyOperators;
10 using Platform.Data.Doublets.Sequences.Converters;
11 using Platform.Data.Doublets.Sequences.Indexes;
12 using Platform.Data.Doublets.Sequences.Walkers;
13 using Platform.Data.Doublets.Unicode;

```

```

14 using Platform.Data.Doublents.ResizableDirectMemory.Generic;
15
16 namespace Platform.Data.Doublents.Tests
17 {
18     public static class UnicodeConvertersTests
19     {
20         [Fact]
21         public static void CharAndUnaryNumberUnicodeSymbolConvertersTest()
22         {
23             using (var scope = new TempLinksTestScope())
24             {
25                 var links = scope.Links;
26                 var meaningRoot = links.CreatePoint();
27                 var one = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
28                 var powerOf2ToUnaryNumberConverter = new
29                     ↪ PowerOf2ToUnaryNumberConverter<ulong>(links, one);
30                 var addressToUnaryNumberConverter = new
31                     ↪ AddressToUnaryNumberConverter<ulong>(links, powerOf2ToUnaryNumberConverter);
32                 var unaryNumberToAddressConverter = new
33                     ↪ UnaryNumberToAddressOrOperationConverter<ulong>(links,
34                     ↪ powerOf2ToUnaryNumberConverter);
35                 TestCharAndUnicodeSymbolConverters(links, meaningRoot,
36                     ↪ addressToUnaryNumberConverter, unaryNumberToAddressConverter);
37             }
38         }
39
40         [Fact]
41         public static void CharAndRawNumberUnicodeSymbolConvertersTest()
42         {
43             using (var scope = new Scope<Types<HeapResizableDirectMemory,
44                 ↪ ResizableDirectMemoryLinks<ulong>>>())
45             {
46                 var links = scope.Use<ILinks<ulong>>();
47                 var meaningRoot = links.CreatePoint();
48                 var addressToRawNumberConverter = new AddressToRawNumberConverter<ulong>();
49                 var rawNumberToAddressConverter = new RawNumberToAddressConverter<ulong>();
50                 TestCharAndUnicodeSymbolConverters(links, meaningRoot,
51                     ↪ addressToRawNumberConverter, rawNumberToAddressConverter);
52             }
53         }
54
55         private static void TestCharAndUnicodeSymbolConverters(ILinks<ulong> links, ulong
56             ↪ meaningRoot, IConverter<ulong> addressToNumberConverter, IConverter<ulong>
57             ↪ numberToAddressConverter)
58         {
59             var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
60             var charToUnicodeSymbolConverter = new CharToUnicodeSymbolConverter<ulong>(links,
61                 ↪ addressToNumberConverter, unicodeSymbolMarker);
62             var originalCharacter = 'H';
63             var characterLink = charToUnicodeSymbolConverter.Convert(originalCharacter);
64             var unicodeSymbolCriterionMatcher = new UnicodeSymbolCriterionMatcher<ulong>(links,
65                 ↪ unicodeSymbolMarker);
66             var unicodeSymbolToCharConverter = new UnicodeSymbolToCharConverter<ulong>(links,
67                 ↪ numberToAddressConverter, unicodeSymbolCriterionMatcher);
68             var resultingCharacter = unicodeSymbolToCharConverter.Convert(characterLink);
69             Assert.Equal(originalCharacter, resultingCharacter);
70         }
71
72         [Fact]
73         public static void StringAndUnicodeSequenceConvertersTest()
74         {
75             using (var scope = new TempLinksTestScope())
76             {
77                 var links = scope.Links;
78
79                 var itself = links.Constants.Itself;
80
81                 var meaningRoot = links.CreatePoint();
82                 var unaryOne = links.CreateAndUpdate(meaningRoot, itself);
83                 var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, itself);
84                 var unicodeSequenceMarker = links.CreateAndUpdate(meaningRoot, itself);
85                 var frequencyMarker = links.CreateAndUpdate(meaningRoot, itself);
86                 var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot, itself);
87
88                 var powerOf2ToUnaryNumberConverter = new
89                     ↪ PowerOf2ToUnaryNumberConverter<ulong>(links, unaryOne);
90                 var addressToUnaryNumberConverter = new
91                     ↪ AddressToUnaryNumberConverter<ulong>(links, powerOf2ToUnaryNumberConverter);

```

```

78     var charToUnicodeSymbolConverter = new
    ↪ CharToUnicodeSymbolConverter<ulong>(links, addressToUnaryNumberConverter,
    ↪ unicodeSymbolMarker);
79
80     var unaryNumberToAddressConverter = new
    ↪ UnaryNumberToAddressOrOperationConverter<ulong>(links,
    ↪ powerOf2ToUnaryNumberConverter);
81     var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
82     var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
    ↪ frequencyMarker, unaryOne, unaryNumberIncrementer);
83     var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
    ↪ frequencyPropertyMarker, frequencyMarker);
84     var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
    ↪ frequencyPropertyOperator, frequencyIncrementer);
85     var linkToItsFrequencyNumberConverter = new
    ↪ LinkToItsFrequencyNumberConverter<ulong>(links, frequencyPropertyOperator,
    ↪ unaryNumberToAddressConverter);
86     var sequenceToItsLocalElementLevelsConverter = new
    ↪ SequenceToItsLocalElementLevelsConverter<ulong>(links,
    ↪ linkToItsFrequencyNumberConverter);
87     var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
    ↪ sequenceToItsLocalElementLevelsConverter);
88
89     var stringToUnicodeSequenceConverter = new
    ↪ StringToUnicodeSequenceConverter<ulong>(links, charToUnicodeSymbolConverter,
    ↪ index, optimalVariantConverter, unicodeSequenceMarker);
90
91     var originalString = "Hello";
92
93     var unicodeSequenceLink =
    ↪ stringToUnicodeSequenceConverter.Convert(originalString);
94
95     var unicodeSymbolCriterionMatcher = new
    ↪ UnicodeSymbolCriterionMatcher<ulong>(links, unicodeSymbolMarker);
96     var unicodeSymbolToCharConverter = new
    ↪ UnicodeSymbolToCharConverter<ulong>(links, unaryNumberToAddressConverter,
    ↪ unicodeSymbolCriterionMatcher);
97
98     var unicodeSequenceCriterionMatcher = new
    ↪ UnicodeSequenceCriterionMatcher<ulong>(links, unicodeSequenceMarker);
99
100    var sequenceWalker = new LeveledSequenceWalker<ulong>(links,
    ↪ unicodeSymbolCriterionMatcher.IsMatched);
101
102    var unicodeSequenceToStringConverter = new
    ↪ UnicodeSequenceToStringConverter<ulong>(links,
    ↪ unicodeSequenceCriterionMatcher, sequenceWalker,
    ↪ unicodeSymbolToCharConverter);
103
104    var resultingString =
    ↪ unicodeSequenceToStringConverter.Convert(unicodeSequenceLink);
105
106    Assert.Equal(originalString, resultingString);
107
108    }
109 }
110 }

```

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