

# LinksPlatform's Platform.Data.Doublets Class Library

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

```

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

```

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

```

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

```

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

```

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

```

```

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

```

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

```

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

```

```

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

```

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

```

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

```

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

```

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

```

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

```

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

```

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

```

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

```

```

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

```

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

```

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

```

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

```

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

```

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

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

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

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

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

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

```

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

```

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

```

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

```

```

18  /// </remarks>
19  internal class UniLinks<TLink> : LinksDecoratorBase<TLink>, IUniLinks<TLink>
20  {
21      private static readonly EqualityComparer<TLink> _equalityComparer =
22          ↳ EqualityComparer<TLink>.Default;
23
24      public UniLinks(ILinks<TLink> links) : base(links) { }
25
26      private struct Transition
27      {
28          public IList<TLink> Before;
29          public IList<TLink> After;
30
31          public Transition(IList<TLink> before, IList<TLink> after)
32          {
33              Before = before;
34              After = after;
35          }
36      }
37
38      //public static readonly TLink NullConstant = Use<LinksConstants<TLink>>.Single.Null;
39      //public static readonly IReadOnlyList<TLink> NullLink = new
40      ↳ ReadOnlyCollection<TLink>(new List<TLink> { NullConstant, NullConstant, NullConstant
41      ↳ });
42
43      // TODO: Подумать о том, как реализовать древовидный Restriction и Substitution
44      ↳ (Links-Expression)
45      public TLink Trigger(IList<TLink> restriction, Func<IList<TLink>, IList<TLink>, TLink>
46      ↳ matchedHandler, IList<TLink> substitution, Func<IList<TLink>, IList<TLink>, TLink>
47      ↳ substitutedHandler)
48      {
49          ///List<Transition> transitions = null;
50          ///if (!restriction.IsNullOrEmpty())
51          ///{
52          ///    // Есть причина делать проход (чтение)
53          ///    if (matchedHandler != null)
54          ///    {
55          ///        if (!substitution.IsNullOrEmpty())
56          ///        {
57          ///            // restriction => { 0, 0, 0 } | { 0 } // Create
58          ///            // substitution => { itself, 0, 0 } | { itself, itself, itself } //
59          ↳ Create / Update
60          ///            // substitution => { 0, 0, 0 } | { 0 } // Delete
61          ///            transitions = new List<Transition>();
62          ///            if (Equals(substitution[Constants.IndexPart], Constants.Null))
63          ///            {
64          ///                // If index is Null, that means we always ignore every other
65          ↳ value (they are also Null by definition)
66          ///                var matchDecision = matchedHandler(, NullLink);
67          ///                if (Equals(matchDecision, Constants.Break))
68          ///                    return false;
69          ///                if (!Equals(matchDecision, Constants.Skip))
70          ///                    transitions.Add(new Transition(matchedLink, newValue));
71          ///            }
72          ///            else
73          ///            {
74          ///                Func<T, bool> handler;
75          ///                handler = link =>
76          ///                {
77          ///                    var matchedLink = Memory.GetLinkValue(link);
78          ///                    var newValue = Memory.GetLinkValue(link);
79          ///                    newValue[Constants.IndexPart] = Constants.Itself;
80          ///                    newValue[Constants.SourcePart] =
81          ↳ Equals(substitution[Constants.SourcePart], Constants.Itself) ?
82          ↳ matchedLink[Constants.IndexPart] : substitution[Constants.SourcePart];
83          ///                    newValue[Constants.TargetPart] =
84          ↳ Equals(substitution[Constants.TargetPart], Constants.Itself) ?
85          ↳ matchedLink[Constants.IndexPart] : substitution[Constants.TargetPart];
86          ///                    var matchDecision = matchedHandler(matchedLink, newValue);
87          ///                    if (Equals(matchDecision, Constants.Break))
88          ///                        return false;
89          ///                    if (!Equals(matchDecision, Constants.Skip))
90          ///                        transitions.Add(new Transition(matchedLink, newValue));
91          ///                    return true;
92          ///                };
93          ///            }
94          ///            if (!Memory.Each(handler, restriction))
95          ///                return Constants.Break;
96          ///        }
97      }

```



```

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

```

```

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

```

```

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

```

/// <remarks>

```

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

```

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

```

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

```

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

```

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

```

```

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

```

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

```

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

```

```

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

```

./Platform.Data.Doublets/ILinks.cs

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

./Platform.Data.Doublets/ILinksExtensions.cs

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

```

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

```



```

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 EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links, TLink
    ↳ reference, string argumentName)
302 {
303     if (links.Constants.IsInnerReference(reference) && !links.Exists(reference))
304     {
305         throw new ArgumentLinkDoesNotExistsException<TLink>(reference, argumentName);
306     }
307 }
308
309 [MethodImpl(MethodImplOptions.AggressiveInlining)]
310 public static void EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links,
    ↳ IList<TLink> restrictions, string argumentName)
311 {
312     for (int i = 0; i < restrictions.Count; i++)
313     {
314         links.EnsureInnerReferenceExists(restrictions[i], argumentName);
315     }
316 }
317
318 [MethodImpl(MethodImplOptions.AggressiveInlining)]
319 public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, IList<TLink>
    ↳ restrictions)
320 {
321     for (int i = 0; i < restrictions.Count; i++)

```

```

322     {
323         links.EnsureLinkIsAnyOrExists(restrictions[i], nameof(restrictions));
324     }
325 }
326
327 [MethodImpl(MethodImplOptions.AggressiveInlining)]
328 public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, TLink link,
329     ↪ string argumentName)
330 {
331     var equalityComparer = EqualityComparer<TLink>.Default;
332     if (!equalityComparer.Equals(link, links.Constants.Any) && !links.Exists(link))
333     {
334         throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
335     }
336 }
337
338 [MethodImpl(MethodImplOptions.AggressiveInlining)]
339 public static void EnsureLinkIsItselfOrExists<TLink>(this ILinks<TLink> links, TLink
340     ↪ link, string argumentName)
341 {
342     var equalityComparer = EqualityComparer<TLink>.Default;
343     if (!equalityComparer.Equals(link, links.Constants.Itself) && !links.Exists(link))
344     {
345         throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
346     }
347 }
348
349 /// <param name="links">Хранилище связей.</param>
350 [MethodImpl(MethodImplOptions.AggressiveInlining)]
351 public static void EnsureDoesNotExists<TLink>(this ILinks<TLink> links, TLink source,
352     ↪ TLink target)
353 {
354     if (links.Exists(source, target))
355     {
356         throw new LinkWithSameValueAlreadyExistsException();
357     }
358 }
359
360 /// <param name="links">Хранилище связей.</param>
361 public static void EnsureNoUsages<TLink>(this ILinks<TLink> links, TLink link)
362 {
363     if (links.HasUsages(link))
364     {
365         throw new ArgumentLinkHasDependenciesException<TLink>(link);
366     }
367 }
368
369 /// <param name="links">Хранилище связей.</param>
370 public static void EnsureCreated<TLink>(this ILinks<TLink> links, params TLink[]
371     ↪ addresses) => links.EnsureCreated(links.Create, addresses);
372
373 /// <param name="links">Хранилище связей.</param>
374 public static void EnsurePointsCreated<TLink>(this ILinks<TLink> links, params TLink[]
375     ↪ addresses) => links.EnsureCreated(links.CreatePoint, addresses);
376
377 /// <param name="links">Хранилище связей.</param>
378 public static void EnsureCreated<TLink>(this ILinks<TLink> links, Func<TLink> creator,
379     ↪ params TLink[] addresses)
380 {
381     var constants = links.Constants;
382
383     var nonExistentAddresses = new HashSet<TLink>(addresses.Where(x =>
384     ↪ !links.Exists(x)));
385     if (nonExistentAddresses.Count > 0)
386     {
387         var max = nonExistentAddresses.Max();
388         max = (Integer<TLink>)System.Math.Min((ulong)(Integer<TLink>)max,
389     ↪ (ulong)(Integer<TLink>)constants.PossibleInnerReferencesRange.Maximum);
390         var createdLinks = new List<TLink>();
391         var equalityComparer = EqualityComparer<TLink>.Default;
392         TLink createdLink = creator();
393         while (!equalityComparer.Equals(createdLink, max))
394         {
395             createdLinks.Add(createdLink);
396         }
397         for (var i = 0; i < createdLinks.Count; i++)
398         {
399             if (!nonExistentAddresses.Contains(createdLinks[i]))

```

```

392         {
393             links.Delete(createdLinks[i]);
394         }
395     }
396 }
397
398 #endregion
399
400
401 /// <param name="links">Хранилище связей.</param>
402 public static TLink CountUsages<TLink>(this ILinks<TLink> links, TLink link)
403 {
404     var constants = links.Constants;
405     var values = links.GetLink(link);
406     TLink usagesAsSource = links.Count(new Link<TLink>(constants.Any, link,
407         ↪ constants.Any));
408     var equalityComparer = EqualityComparer<TLink>.Default;
409     if (equalityComparer.Equals(values[constants.SourcePart], link))
410     {
411         usagesAsSource = Arithmetic<TLink>.Decrement(usagesAsSource);
412     }
413     TLink usagesAsTarget = links.Count(new Link<TLink>(constants.Any, constants.Any,
414         ↪ link));
415     if (equalityComparer.Equals(values[constants.TargetPart], link))
416     {
417         usagesAsTarget = Arithmetic<TLink>.Decrement(usagesAsTarget);
418     }
419     return Arithmetic<TLink>.Add(usagesAsSource, usagesAsTarget);
420 }
421
422 /// <param name="links">Хранилище связей.</param>
423 [MethodImpl(MethodImplOptions.AggressiveInlining)]
424 public static bool HasUsages<TLink>(this ILinks<TLink> links, TLink link) =>
425     ↪ Comparer<TLink>.Default.Compare(links.CountUsages(link), Integer<TLink>.Zero) > 0;
426
427 /// <param name="links">Хранилище связей.</param>
428 [MethodImpl(MethodImplOptions.AggressiveInlining)]
429 public static bool Equals<TLink>(this ILinks<TLink> links, TLink link, TLink source,
430     ↪ TLink target)
431 {
432     var constants = links.Constants;
433     var values = links.GetLink(link);
434     var equalityComparer = EqualityComparer<TLink>.Default;
435     return equalityComparer.Equals(values[constants.SourcePart], source) &&
436         ↪ equalityComparer.Equals(values[constants.TargetPart], target);
437 }
438
439 /// <summary>
440 /// Выполняет поиск связи с указанными Source (началом) и Target (концом).
441 /// </summary>
442 /// <param name="links">Хранилище связей.</param>
443 /// <param name="source">Индекс связи, которая является началом для искомой
444     ↪ связи.</param>
445 /// <param name="target">Индекс связи, которая является концом для искомой связи.</param>
446 /// <returns>Индекс искомой связи с указанными Source (началом) и Target
447     ↪ (концом).</returns>
448 [MethodImpl(MethodImplOptions.AggressiveInlining)]
449 public static TLink SearchOrDefault<TLink>(this ILinks<TLink> links, TLink source, TLink
450     ↪ target)
451 {
452     var constants = links.Constants;
453     var setter = new Setter<TLink, TLink>(constants.Continue, constants.Break, default);
454     links.Each(setter.SetFirstAndReturnFalse, constants.Any, source, target);
455     return setter.Result;
456 }
457
458 /// <param name="links">Хранилище связей.</param>
459 [MethodImpl(MethodImplOptions.AggressiveInlining)]
460 public static TLink Create<TLink>(this ILinks<TLink> links) => links.Create(null);
461
462 /// <param name="links">Хранилище связей.</param>
463 [MethodImpl(MethodImplOptions.AggressiveInlining)]
464 public static TLink CreatePoint<TLink>(this ILinks<TLink> links)
465 {
466     var link = links.Create();
467     return links.Update(link, link, link);
468 }

```

```

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

```

```

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

```

```

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

```



```

665     {
666         var totalUsages = usagesAsSourceCount + usagesAsTargetCount;
667         if (totalUsages > 0)
668         {
669             var usages = ArrayPool.Allocate<TLink>(totalUsages);
670             var usagesFiller = new ArrayFiller<TLink, TLink>(usages,
671                 links.Constants.Continue);
672             var i = 0L;
673             if (usagesAsSourceCount > 0)
674             {
675                 links.Each(usagesFiller.AddFirstAndReturnConstant,
676                     ↪ usagesAsSourceQuery);
677                 for (; i < usagesAsSourceCount; i++)
678                 {
679                     var usage = usages[i];
680                     if (!equalityComparer.Equals(usage, oldLinkIndex))
681                     {
682                         links.Update(usage, newLinkIndex, links.GetTarget(usage));
683                     }
684                 }
685             }
686             if (usagesAsTargetCount > 0)
687             {
688                 links.Each(usagesFiller.AddFirstAndReturnConstant,
689                     ↪ usagesAsTargetQuery);
690                 for (; i < usages.Length; i++)
691                 {
692                     var usage = usages[i];
693                     if (!equalityComparer.Equals(usage, oldLinkIndex))
694                     {
695                         links.Update(usage, links.GetSource(usage), newLinkIndex);
696                     }
697                 }
698             }
699             ArrayPool.Free(usages);
700         }
701     }
702     return newLinkIndex;
703 }
704
705 /// <summary>
706 /// Replace one link with another (replaced link is deleted, children are updated or
707 /// ↪ deleted).
708 /// </summary>
709 [MethodImpl(MethodImplOptions.AggressiveInlining)]
710 public static TLink MergeAndDelete<TLink>(this ILinks<TLink> links, TLink oldLinkIndex,
711     ↪ TLink newLinkIndex)
712 {
713     var equalityComparer = EqualityComparer<TLink>.Default;
714     if (!equalityComparer.Equals(oldLinkIndex, newLinkIndex))
715     {
716         links.MergeUsages(oldLinkIndex, newLinkIndex);
717         links.Delete(oldLinkIndex);
718     }
719     return newLinkIndex;
720 }
721
722 public static ILinks<TLink>
723     ↪ DecorateWithAutomaticUniquenessAndUsagesResolution<TLink>(this ILinks<TLink> links)
724 {
725     links = new LinksCascadeUsagesResolver<TLink>(links);
726     links = new NonNullContentsLinkDeletionResolver<TLink>(links);
727     links = new LinksCascadeUniquenessAndUsagesResolver<TLink>(links);
728     return links;
729 }
730 }
731 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Incrementers
7 {
8     public class FrequencyIncrementer<TLink> : LinksOperatorBase<TLink>, IIncrementer<TLink>

```

```

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

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Incrementers
7 {
8     public class UnaryNumberIncrementer<TLink> : LinksOperatorBase<TLink>, IIncrementer<TLink>
9     {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
            ↳ EqualityComparer<TLink>.Default;
11
12         private readonly TLink _unaryOne;
13
14         public UnaryNumberIncrementer(ILinks<TLink> links, TLink unaryOne) : base(links) =>
            ↳ _unaryOne = unaryOne;
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 }

```

./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>,
        ↳ LinksConstants<TLink>>, ILinks<TLink>
6     {
7     }
8 }

```

./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         [MethodImpl(MethodImplOptions.AggressiveInlining)]
61         public Link(TLink index, TLink source, TLink target)
62         {
63             Index = index;
64             Source = source;
65             Target = target;
66         }
67
68         [MethodImpl(MethodImplOptions.AggressiveInlining)]
69         private static void SetValues(ref Link<TLink> other, out TLink index, out TLink source,
70             ↳ out TLink target)
71         {
72             index = other.Index;
73             source = other.Source;
74             target = other.Target;
75         }
76
77         [MethodImpl(MethodImplOptions.AggressiveInlining)]
78         private static void SetValues(IList<TLink> values, out TLink index, out TLink source,
79             ↳ out TLink target)
```

```

74 {
75     switch (values.Count)
76     {
77         case 3:
78             index = values[0];
79             source = values[1];
80             target = values[2];
81             break;
82         case 2:
83             index = values[0];
84             source = values[1];
85             target = default;
86             break;
87         case 1:
88             index = values[0];
89             source = default;
90             target = default;
91             break;
92         default:
93             index = default;
94             source = default;
95             target = default;
96             break;
97     }
98 }
99
100 [MethodImpl(MethodImplOptions.AggressiveInlining)]
101 public override int GetHashCode() => (Index, Source, Target).GetHashCode();
102
103 [MethodImpl(MethodImplOptions.AggressiveInlining)]
104 public bool IsNull() => _equalityComparer.Equals(Index, _constants.Null)
105     && _equalityComparer.Equals(Source, _constants.Null)
106     && _equalityComparer.Equals(Target, _constants.Null);
107
108 [MethodImpl(MethodImplOptions.AggressiveInlining)]
109 public override bool Equals(object other) => other is Link<TLink> &&
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
129     ↳ Link<TLink>(linkArray);
130
131 [MethodImpl(MethodImplOptions.AggressiveInlining)]
132 public override string ToString() => _equalityComparer.Equals(Index, _constants.Null) ?
133     ↳ ToString(Source, Target) : ToString(Index, Source, Target);
134
135 #region IList
136
137 public int Count => Length;
138
139 public bool IsReadOnly => true;
140
141 public TLink this[int index]
142 {
143     [MethodImpl(MethodImplOptions.AggressiveInlining)]
144     get
145     {
146         Ensure.OnDebug.ArgumentInRange(index, new Range<int>(0, Length - 1),
147             ↳ nameof(index));
148         if (index == _constants.IndexPart)
149         {
150             return Index;
151         }
152         if (index == _constants.SourcePart)
153         {

```

```

149         return Source;
150     }
151     if (index == _constants.TargetPart)
152     {
153         return Target;
154     }
155     throw new NotSupportedException(); // Impossible path due to
        ↪ Ensure.ArgumentInRange
156 }
157 [MethodImpl(MethodImplOptions.AggressiveInlining)]
158 set => throw new NotSupportedException();
159 }
160
161 [MethodImpl(MethodImplOptions.AggressiveInlining)]
162 IEnumerator IEnumerable.GetEnumerator() => GetEnumerator();
163
164 [MethodImpl(MethodImplOptions.AggressiveInlining)]
165 public IEnumerator<TLink> GetEnumerator()
166 {
167     yield return Index;
168     yield return Source;
169     yield return Target;
170 }
171
172 [MethodImpl(MethodImplOptions.AggressiveInlining)]
173 public void Add(TLink item) => throw new NotSupportedException();
174
175 [MethodImpl(MethodImplOptions.AggressiveInlining)]
176 public void Clear() => throw new NotSupportedException();
177
178 [MethodImpl(MethodImplOptions.AggressiveInlining)]
179 public bool Contains(TLink item) => IndexOf(item) >= 0;
180
181 [MethodImpl(MethodImplOptions.AggressiveInlining)]
182 public void CopyTo(TLink[] array, int arrayIndex)
183 {
184     Ensure.OnDebug.ArgumentNotNull(array, nameof(array));
185     Ensure.OnDebug.ArgumentInRange(arrayIndex, new Range<int>(0, array.Length - 1),
        ↪ nameof(arrayIndex));
186     if (arrayIndex + Length > array.Length)
187     {
188         throw new InvalidOperationException();
189     }
190     array[arrayIndex++] = Index;
191     array[arrayIndex++] = Source;
192     array[arrayIndex] = Target;
193 }
194
195 [MethodImpl(MethodImplOptions.AggressiveInlining)]
196 public bool Remove(TLink item) => Throw.A.NotSupportedExceptionAndReturn<bool>();
197
198 [MethodImpl(MethodImplOptions.AggressiveInlining)]
199 public int IndexOf(TLink item)
200 {
201     if (_equalityComparer.Equals(Index, item))
202     {
203         return _constants.IndexPart;
204     }
205     if (_equalityComparer.Equals(Source, item))
206     {
207         return _constants.SourcePart;
208     }
209     if (_equalityComparer.Equals(Target, item))
210     {
211         return _constants.TargetPart;
212     }
213     return -1;
214 }
215
216 [MethodImpl(MethodImplOptions.AggressiveInlining)]
217 public void Insert(int index, TLink item) => throw new NotSupportedException();
218
219 [MethodImpl(MethodImplOptions.AggressiveInlining)]
220 public void RemoveAt(int index) => throw new NotSupportedException();
221
222 #endregion
223 }
224 }

```

./Platform.Data.Doublets/LinkExtensions.cs

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

./Platform.Data.Doublets/LinksOperatorBase.cs

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

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

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

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

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

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

```
1  using System.Collections.Generic;
2  using Platform.Interfaces;
3  using Platform.Reflection;
4  using Platform.Numbers;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Numbers.Unary
9  {
10     public class AddressToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
11         ⇨ IConverter<TLink>
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
14             ⇨ EqualityComparer<TLink>.Default;
15
16         private readonly IConverter<int, TLink> _powerOf2ToUnaryNumberConverter;
17
18         public AddressToUnaryNumberConverter(ILinks<TLink> links, IConverter<int, TLink>
19             ⇨ powerOf2ToUnaryNumberConverter) : base(links) => _powerOf2ToUnaryNumberConverter =
20             ⇨ powerOf2ToUnaryNumberConverter;
21
22         public TLink Convert(TLink number)
23         {
24             var nullConstant = Links.Constants.Null;
25         }
26     }
27 }
```

```

21     var one = Integer<TLink>.One;
22     var target = nullConstant;
23     for (int i = 0; !_equalityComparer.Equals(number, default) && i <
    ↪ NumericType<TLink>.BitsLength; i++)
24     {
25         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 }

```

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

```

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

```

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

```

1  using System.Collections.Generic;
2  using Platform.Exceptions;
3  using Platform.Interfaces;
4  using Platform.Ranges;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Numbers.Unary
9  {
10     public class PowerOf2ToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<int, TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
    ↪ EqualityComparer<TLink>.Default;
13

```

```

14     private readonly TLink[] _unaryNumberPowersOf2;
15
16     public PowerOf2ToUnaryNumberConverter(ILinks<TLink> links, TLink one) : base(links)
17     {
18         _unaryNumberPowersOf2 = new TLink[64];
19         _unaryNumberPowersOf2[0] = one;
20     }
21
22     public TLink Convert(int power)
23     {
24         Ensure.Always.ArgumentInRange(power, new Range<int>(0, _unaryNumberPowersOf2.Length
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 }

```

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

```

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

```



```

54     {
55         return _unaryToUInt64[unaryNumber];
56     }
57     else
58     {
59         var result = _unaryToUInt64[source];
60         TLink lastValue;
61         while (!_unaryToUInt64.TryGetValue(target, out lastValue))
62         {
63             source = Links.GetSource(target);
64             result = Arithmetic<TLink>.Add(result, _unaryToUInt64[source]);
65             target = Links.GetTarget(target);
66         }
67         result = Arithmetic<TLink>.Add(result, lastValue);
68         return result;
69     }
70 }
71
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 private static TLink Double(TLink number) => (Integer<TLink>)((Integer<TLink>)number *
    ↪ 2UL);
74 }
75 }

```

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

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Interfaces;
4  using Platform.Reflection;
5  using Platform.Numbers;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets.Numbers.Unary
10 {
11     public class UnaryNumberToAddressOrOperationConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ 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>.BitsLength; 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
52     [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

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

```

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

```

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

```

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

```

1  using System.Collections.Generic;
2  using Platform.Interfaces;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.PropertyOperators
7  {
8      public class PropertyOperator<TLink> : LinksOperatorBase<TLink>, IPropertyOperator<TLink,
           ↪ TLink>
9      {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
           ↪ EqualityComparer<TLink>.Default;
11
12         private readonly TLink _propertyMarker;
13         private readonly TLink _propertyValueMarker;
14
15         public PropertyOperator(ILinks<TLink> links, TLink propertyMarker, TLink
           ↪ propertyValueMarker) : base(links)
16         {
17             _propertyMarker = propertyMarker;
18             _propertyValueMarker = propertyValueMarker;
19         }
20
21         public TLink Get(TLink link)
22         {
23             var property = Links.SearchOrDefault(link, _propertyMarker);
24             var container = GetContainer(property);
25             var value = GetValue(container);
26             return value;
27         }
28
29         private TLink GetContainer(TLink property)
30         {

```

```

31     var valueContainer = default(TLink);
32     if (_equalityComparer.Equals(property, default))
33     {
34         return valueContainer;
35     }
36     var constants = Links.Constants;
37     var countinueConstant = 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 countinueConstant;
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 }

```

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

```

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

```

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

```

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

```

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

```

1  using System;
2  using System.Text;
3  using System.Collections.Generic;
4  using System.Runtime.CompilerServices;
5  using Platform.Numbers;

```

```

6 using Platform.Collections.Methods.Trees;
7 using static System.Runtime.CompilerServices.Unsafe;
8
9 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
10
11 namespace Platform.Data.Doublets.ResizableDirectMemory
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
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         [MethodImpl(MethodImplOptions.AggressiveInlining)]
45         protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
46             ↳ AsRef<LinksHeader<TLink>>(Header);
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
50             ↳ AsRef<RawLink<TLink>>(Links + RawLink<TLink>.SizeInBytes * (Integer<TLink>)link);
51
52         [MethodImpl(MethodImplOptions.AggressiveInlining)]
53         protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
54         {
55             ref var link = ref GetLinkReference(linkIndex);
56             return new Link<TLink>(linkIndex, link.Source, link.Target);
57         }
58
59         [MethodImpl(MethodImplOptions.AggressiveInlining)]
60         protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
61         {
62             ref var firstLink = ref GetLinkReference(first);
63             ref var secondLink = ref GetLinkReference(second);
64             return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
65                 ↳ secondLink.Source, secondLink.Target);
66         }
67
68         [MethodImpl(MethodImplOptions.AggressiveInlining)]
69         protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
70         {
71             ref var firstLink = ref GetLinkReference(first);
72             ref var secondLink = ref GetLinkReference(second);
73             return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
74                 ↳ secondLink.Source, secondLink.Target);
75         }
76
77         [MethodImpl(MethodImplOptions.AggressiveInlining)]
78         protected virtual TLink GetSizeValue(TLink value) => Bit<TLink>.PartialRead(value, 5,
79             ↳ -5);
80
81         [MethodImpl(MethodImplOptions.AggressiveInlining)]
82         protected virtual void SetSizeValue(ref TLink storedValue, TLink size) => storedValue =
83             ↳ Bit<TLink>.PartialWrite(storedValue, size, 5, -5);
84     }
85 }

```

```

75 [MethodImpl(MethodImplOptions.AggressiveInlining)]
76 protected virtual bool GetLeftIsChildValue(TLink value)
77 {
78     unchecked
79     {
80         //return (Integer<TLink>)Bit<TLink>.PartialRead(previousValue, 4, 1);
81         return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 4, 1), default);
82     }
83 }
84
85 [MethodImpl(MethodImplOptions.AggressiveInlining)]
86 protected virtual void SetLeftIsChildValue(ref TLink storedValue, bool value)
87 {
88     unchecked
89     {
90         var previousValue = storedValue;
91         var modified = Bit<TLink>.PartialWrite(previousValue, (Integer<TLink>)value, 4,
92         ↪ 1);
93         storedValue = modified;
94     }
95 }
96
97 [MethodImpl(MethodImplOptions.AggressiveInlining)]
98 protected virtual bool GetRightIsChildValue(TLink value)
99 {
100     unchecked
101     {
102         //return (Integer<TLink>)Bit<TLink>.PartialRead(previousValue, 3, 1);
103         return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 3, 1), default);
104     }
105 }
106
107 [MethodImpl(MethodImplOptions.AggressiveInlining)]
108 protected virtual void SetRightIsChildValue(ref TLink storedValue, bool value)
109 {
110     unchecked
111     {
112         var previousValue = storedValue;
113         var modified = Bit<TLink>.PartialWrite(previousValue, (Integer<TLink>)value, 3,
114         ↪ 1);
115         storedValue = modified;
116     }
117 }
118
119 [MethodImpl(MethodImplOptions.AggressiveInlining)]
120 protected virtual sbyte GetBalanceValue(TLink storedValue)
121 {
122     unchecked
123     {
124         var value = (int)(Integer<TLink>)Bit<TLink>.PartialRead(storedValue, 0, 3);
125         value |= 0xF8 * ((value & 4) >> 2); // if negative, then continue ones to the
126         ↪ end of sbyte
127         return (sbyte)value;
128     }
129 }
130
131 [MethodImpl(MethodImplOptions.AggressiveInlining)]
132 protected virtual void SetBalanceValue(ref TLink storedValue, sbyte value)
133 {
134     unchecked
135     {
136         var packagedValue = (TLink)(Integer<TLink>)((((byte)value >> 5) & 4) | value &
137         ↪ 3);
138         var modified = Bit<TLink>.PartialWrite(storedValue, packagedValue, 0, 3);
139         storedValue = modified;
140     }
141 }
142
143 public TLink this[TLink index]
144 {
145     get
146     {
147         var root = GetTreeRoot();
148         if (GreaterOrEqualThan(index, GetSize(root)))
149         {
150             return Zero;
151         }
152         while (!EqualToZero(root))
153         {

```

```

150     var left = GetLeftOrDefault(root);
151     var leftSize = GetSizeOrZero(left);
152     if (LessThan(index, leftSize))
153     {
154         root = left;
155         continue;
156     }
157     if (IsEquals(index, leftSize))
158     {
159         return root;
160     }
161     root = GetRightOrDefault(root);
162     index = Subtract(index, Increment(leftSize));
163 }
164 return Zero; // TODO: Impossible situation exception (only if tree structure
    ↳ broken)
165 }
166 }
167
168 /// <summary>
169 /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
    ↳ (концом).
170 /// </summary>
171 /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
172 /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
173 /// <returns>Индекс искомой связи.</returns>
174 public TLink Search(TLink source, TLink target)
175 {
176     var root = GetTreeRoot();
177     while (!EqualToZero(root))
178     {
179         ref var rootLink = ref GetLinkReference(root);
180         var rootSource = rootLink.Source;
181         var rootTarget = rootLink.Target;
182         if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
            ↳ node.Key < root.Key
183         {
184             root = GetLeftOrDefault(root);
185         }
186         else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget)) //
            ↳ node.Key > root.Key
187         {
188             root = GetRightOrDefault(root);
189         }
190         else // node.Key == root.Key
191         {
192             return root;
193         }
194     }
195     return Zero;
196 }
197
198 // TODO: Return indices range instead of references count
199 public TLink CountUsages(TLink link)
200 {
201     var root = GetTreeRoot();
202     var total = GetSize(root);
203     var totalRightIgnore = Zero;
204     while (!EqualToZero(root))
205     {
206         var @base = GetBasePartValue(root);
207         if (LessOrEqualThan(@base, link))
208         {
209             root = GetRightOrDefault(root);
210         }
211         else
212         {
213             totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
214             root = GetLeftOrDefault(root);
215         }
216     }
217     root = GetTreeRoot();
218     var totalLeftIgnore = Zero;
219     while (!EqualToZero(root))
220     {
221         var @base = GetBasePartValue(root);
222         if (GreaterOrEqualThan(@base, link))
223         {

```

```

224         root = GetLeftOrDefault(root);
225     }
226     else
227     {
228         totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
229
230         root = GetRightOrDefault(root);
231     }
232 }
233 return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
234 }
235
236 public TLink EachUsage(TLink link, Func<IList<TLink>, TLink> handler)
237 {
238     var root = GetTreeRoot();
239     if (EqualToZero(root))
240     {
241         return Continue;
242     }
243     TLink first = Zero, current = root;
244     while (!EqualToZero(current))
245     {
246         var @base = GetBasePartValue(current);
247         if (GreaterOrEqualThan(@base, link))
248         {
249             if (IsEquals(@base, link))
250             {
251                 first = current;
252             }
253             current = GetLeftOrDefault(current);
254         }
255         else
256         {
257             current = GetRightOrDefault(current);
258         }
259     }
260     if (!EqualToZero(first))
261     {
262         current = first;
263         while (true)
264         {
265             if (IsEquals(handler(GetLinkValues(current)), Break))
266             {
267                 return Break;
268             }
269             current = GetNext(current);
270             if (EqualToZero(current) || !IsEquals(GetBasePartValue(current), link))
271             {
272                 break;
273             }
274         }
275     }
276     return Continue;
277 }
278
279 protected override void PrintNodeValue(TLink node, StringBuilder sb)
280 {
281     ref var link = ref GetLinkReference(node);
282     sb.Append(' ');
283     sb.Append(link.Source);
284     sb.Append('-');
285     sb.Append('>');
286     sb.Append(link.Target);
287 }
288 }
289 }

```

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

```

1 using Platform.Unsafe;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.ResizableDirectMemory
6 {
7     public struct LinksHeader<TLink>
8     {
9         public static readonly long SizeInBytes = Structure<LinksHeader<TLink>>.Size;
10
11         public TLink AllocatedLinks;

```

```

12     public TLink ReservedLinks;
13     public TLink FreeLinks;
14     public TLink FirstFreeLink;
15     public TLink FirstAsSource;
16     public TLink FirstAsTarget;
17     public TLink LastFreeLink;
18     public TLink Reserved8;
19 }
20 }

```

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

```



```

55     [MethodImpl(MethodImplOptions.AggressiveInlining)]
56     protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Source;
57
58     [MethodImpl(MethodImplOptions.AggressiveInlining)]
59     protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
60     ↪ TLink secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) ||
        ↪ (IsEquals(firstSource, secondSource) && LessThan(firstTarget, secondTarget));
61
62     [MethodImpl(MethodImplOptions.AggressiveInlining)]
63     protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
        ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) ||
        ↪ (IsEquals(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget));
64
65     [MethodImpl(MethodImplOptions.AggressiveInlining)]
66     protected override void ClearNode(TLink node)
67     {
68         ref var link = ref GetLinkReference(node);
69         link.LeftAsSource = Zero;
70         link.RightAsSource = Zero;
71         link.SizeAsSource = Zero;
72     }
73 }
74 }

```

./Platform.Data.Doublets/ResizableDirectMemory/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
6  {
7      public unsafe class LinksTargetsAVLBalancedTreeMethods<TLink> :
8      ↪ LinksAVLBalancedTreeMethodsBase<TLink>
9      {
10         public LinksTargetsAVLBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
11         ↪ byte* header) : base(constants, links, header) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         protected unsafe override ref TLink GetLeftReference(TLink node) => ref
15         ↪ GetLinkReference(node).LeftAsTarget;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         protected unsafe override ref TLink GetRightReference(TLink node) => ref
19         ↪ GetLinkReference(node).RightAsTarget;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsTarget;
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsTarget;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected override void SetLeft(TLink node, TLink left) =>
29         ↪ GetLinkReference(node).LeftAsTarget = left;
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected override void SetRight(TLink node, TLink right) =>
33         ↪ GetLinkReference(node).RightAsTarget = right;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override TLink GetSize(TLink node) =>
37         ↪ GetSizeValue(GetLinkReference(node).SizeAsTarget);
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override void SetSize(TLink node, TLink size) => SetSizeValue(ref
41         ↪ GetLinkReference(node).SizeAsTarget, size);
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         protected override bool GetLeftIsChild(TLink node) =>
45         ↪ GetLeftIsChildValue(GetLinkReference(node).SizeAsTarget);
46
47         [MethodImpl(MethodImplOptions.AggressiveInlining)]
48         protected override void SetLeftIsChild(TLink node, bool value) =>
49         ↪ SetLeftIsChildValue(ref GetLinkReference(node).SizeAsTarget, value);
50
51         [MethodImpl(MethodImplOptions.AggressiveInlining)]
52         protected override bool GetRightIsChild(TLink node) =>
53         ↪ GetRightIsChildValue(GetLinkReference(node).SizeAsTarget);
54     }
55 }

```

```

43     [MethodImpl(MethodImplOptions.AggressiveInlining)]
44     protected override void SetRightIsChild(TLink node, bool value) =>
45     ↪ SetRightIsChildValue(ref GetLinkReference(node).SizeAsTarget, value);
46
47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     protected override sbyte GetBalance(TLink node) =>
49     ↪ GetBalanceValue(GetLinkReference(node).SizeAsTarget);
50
51     [MethodImpl(MethodImplOptions.AggressiveInlining)]
52     protected override void SetBalance(TLink node, sbyte value) => SetBalanceValue(ref
53     ↪ GetLinkReference(node).SizeAsTarget, value);
54
55     [MethodImpl(MethodImplOptions.AggressiveInlining)]
56     protected override TLink GetTreeRoot() => GetHeaderReference().FirstAsTarget;
57
58     [MethodImpl(MethodImplOptions.AggressiveInlining)]
59     protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Target;
60
61     [MethodImpl(MethodImplOptions.AggressiveInlining)]
62     protected override bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget,
63     ↪ TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
64     ↪ (IsEquals(firstTarget, secondTarget) && LessThan(firstSource, secondSource));
65
66     [MethodImpl(MethodImplOptions.AggressiveInlining)]
67     protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
68     ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
69     ↪ (IsEquals(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource));
70
71     [MethodImpl(MethodImplOptions.AggressiveInlining)]
72     protected override void ClearNode(TLink node)
73     {
74         ref var link = ref GetLinkReference(node);
75         link.LeftAsTarget = Zero;
76         link.RightAsTarget = Zero;
77         link.SizeAsTarget = Zero;
78     }
79 }

```

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

```

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

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Collections.Arrays;
5  using Platform.Data.Exceptions;
6  using Platform.Disposables;
7  using Platform.Memory;
8  using Platform.Numbers;
9  using Platform.Singletons;
10
11  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
12
13  namespace Platform.Data.Doublets.ResizeableDirectMemory
14  {
15      public abstract class ResizableDirectMemoryLinksBase<TLink> : DisposableBase, ILinks<TLink>
16      {
17          protected static readonly EqualityComparer<TLink> EqualityComparer =
18          ↪ EqualityComparer<TLink>.Default;
19      }
20 }

```

```

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     protected readonly IResizableDirectMemory _memory;
28     protected readonly long _memoryReservationStep;
29
30     protected ILinksTreeMethods<TLink> TargetsTreeMethods;
31     protected ILinksTreeMethods<TLink> SourcesTreeMethods;
32     // TODO: Возможно чтобы гарантированно проверять на то, является ли связь удалённой,
33     //     ↪ нужно использовать не список а дерево, так как так можно быстрее проверить на
34     //     ↪ наличие связи внутри
35     protected ILinksListMethods<TLink> UnusedLinksListMethods;
36
37     /// <summary>
38     ///     Возвращает общее число связей находящихся в хранилище.
39     /// </summary>
40     protected virtual TLink Total
41     {
42         get
43         {
44             ref var header = ref GetHeaderReference();
45             return Subtract(header.AllocatedLinks, header.FreeLinks);
46         }
47     }
48
49     public virtual LinksConstants<TLink> Constants { get; }
50
51     [MethodImpl(MethodImplOptions.AggressiveInlining)]
52     public ResizableDirectMemoryLinksBase(IResizableDirectMemory memory, long
53     ↪ memoryReservationStep)
54     {
55         _memory = memory;
56         _memoryReservationStep = memoryReservationStep;
57         Constants = Default<LinksConstants<TLink>>.Instance;
58     }
59
60     [MethodImpl(MethodImplOptions.AggressiveInlining)]
61     public virtual TLink Count(IList<TLink> restrictions)
62     {
63         // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
64         if (restrictions.Count == 0)
65         {
66             return Total;
67         }
68         var constants = Constants;
69         var any = constants.Any;
70         var index = restrictions[constants.IndexPart];
71         if (restrictions.Count == 1)
72         {
73             if (AreEqual(index, any))
74             {
75                 return Total;
76             }
77             return Exists(index) ? GetOne() : GetZero();
78         }
79         if (restrictions.Count == 2)
80         {
81             var value = restrictions[1];
82             if (AreEqual(index, any))
83             {
84                 if (AreEqual(value, any))
85                 {
86                     return Total; // Any - как отсутствие ограничения
87                 }
88                 return Add(SourcesTreeMethods.CountUsages(value),
89                 ↪ TargetsTreeMethods.CountUsages(value));
90             }
91             else
92             {
93                 if (!Exists(index))
94                 {
95                     return GetZero();
96                 }
97             }
98         }
99     }

```

```

93         if (AreEqual(value, any))
94         {
95             return GetOne();
96         }
97         ref var storedLinkValue = ref GetLinkReference(index);
98         if (AreEqual(storedLinkValue.Source, value) ||
99             ⇨ AreEqual(storedLinkValue.Target, value))
100         {
101             return GetOne();
102         }
103         return GetZero();
104     }
105     if (restrictions.Count == 3)
106     {
107         var source = restrictions[constants.SourcePart];
108         var target = restrictions[constants.TargetPart];
109         if (AreEqual(index, any))
110         {
111             if (AreEqual(source, any) && AreEqual(target, any))
112             {
113                 return Total;
114             }
115             else if (AreEqual(source, any))
116             {
117                 return TargetsTreeMethods.CountUsages(target);
118             }
119             else if (AreEqual(target, any))
120             {
121                 return SourcesTreeMethods.CountUsages(source);
122             }
123             else //if(source != Any && target != Any)
124             {
125                 // Эквивалент Exists(source, target) => Count(Any, source, target) > 0
126                 var link = SourcesTreeMethods.Search(source, target);
127                 return AreEqual(link, constants.Null) ? GetZero() : GetOne();
128             }
129         }
130         else
131         {
132             if (!Exists(index))
133             {
134                 return GetZero();
135             }
136             if (AreEqual(source, any) && AreEqual(target, any))
137             {
138                 return GetOne();
139             }
140             ref var storedLinkValue = ref GetLinkReference(index);
141             if (!AreEqual(source, any) && !AreEqual(target, any))
142             {
143                 if (AreEqual(storedLinkValue.Source, source) &&
144                     ⇨ AreEqual(storedLinkValue.Target, target))
145                 {
146                     return GetOne();
147                 }
148                 return GetZero();
149             }
150             var value = default(TLink);
151             if (AreEqual(source, any))
152             {
153                 value = target;
154             }
155             if (AreEqual(target, any))
156             {
157                 value = source;
158             }
159             if (AreEqual(storedLinkValue.Source, value) ||
160                 ⇨ AreEqual(storedLinkValue.Target, value))
161             {
162                 return GetOne();
163             }
164             return GetZero();
165         }
166     }
167     throw new NotSupportedException("Другие размеры и способы ограничений не
168     ⇨ поддерживаются.");

```

```

166 }
167
168 [MethodImpl(MethodImplOptions.AggressiveInlining)]
169 public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
170 {
171     var constants = Constants;
172     var @break = constants.Break;
173     if (restrictions.Count == 0)
174     {
175         for (var link = GetOne(); LessOrEqualThan(link,
176             ↪ GetHeaderReference().AllocatedLinks); link = Increment(link))
177         {
178             if (Exists(link) && AreEqual(handler(GetLinkStruct(link)), @break))
179             {
180                 return @break;
181             }
182         }
183         return @break;
184     }
185     var @continue = constants.Continue;
186     var any = constants.Any;
187     var index = restrictions[constants.IndexPart];
188     if (restrictions.Count == 1)
189     {
190         if (AreEqual(index, any))
191         {
192             return Each(handler, GetEmptyList());
193         }
194         if (!Exists(index))
195         {
196             return @continue;
197         }
198         return handler(GetLinkStruct(index));
199     }
200     if (restrictions.Count == 2)
201     {
202         var value = restrictions[1];
203         if (AreEqual(index, any))
204         {
205             if (AreEqual(value, any))
206             {
207                 return Each(handler, GetEmptyList());
208             }
209             if (AreEqual(Each(handler, new Link<TLink>(index, value, any)), @break))
210             {
211                 return @break;
212             }
213             return Each(handler, new Link<TLink>(index, any, value));
214         }
215         else
216         {
217             if (!Exists(index))
218             {
219                 return @continue;
220             }
221             if (AreEqual(value, any))
222             {
223                 return handler(GetLinkStruct(index));
224             }
225             ref var storedLinkValue = ref GetLinkReference(index);
226             if (AreEqual(storedLinkValue.Source, value) ||
227                 AreEqual(storedLinkValue.Target, value))
228             {
229                 return handler(GetLinkStruct(index));
230             }
231             return @continue;
232         }
233     }
234     if (restrictions.Count == 3)
235     {
236         var source = restrictions[constants.SourcePart];
237         var target = restrictions[constants.TargetPart];
238         if (AreEqual(index, any))
239         {
240             if (AreEqual(source, any) && AreEqual(target, any))
241             {
242                 return Each(handler, GetEmptyList());
243             }
244         }
245     }
246 }

```

```

243     else if (AreEqual(source, any))
244     {
245         return TargetsTreeMethods.EachUsage(target, handler);
246     }
247     else if (AreEqual(target, any))
248     {
249         return SourcesTreeMethods.EachUsage(source, handler);
250     }
251     else //if(source != Any && target != Any)
252     {
253         var link = SourcesTreeMethods.Search(source, target);
254         return AreEqual(link, constants.Null) ? @continue :
            ↪ handler(GetLinkStruct(link));
255     }
256 }
257 else
258 {
259     if (!Exists(index))
260     {
261         return @continue;
262     }
263     if (AreEqual(source, any) && AreEqual(target, any))
264     {
265         return handler(GetLinkStruct(index));
266     }
267     ref var storedLinkValue = ref GetLinkReference(index);
268     if (!AreEqual(source, any) && !AreEqual(target, any))
269     {
270         if (AreEqual(storedLinkValue.Source, source) &&
271             AreEqual(storedLinkValue.Target, target))
272         {
273             return handler(GetLinkStruct(index));
274         }
275         return @continue;
276     }
277     var value = default(TLink);
278     if (AreEqual(source, any))
279     {
280         value = target;
281     }
282     if (AreEqual(target, any))
283     {
284         value = source;
285     }
286     if (AreEqual(storedLinkValue.Source, value) ||
287         AreEqual(storedLinkValue.Target, value))
288     {
289         return handler(GetLinkStruct(index));
290     }
291     return @continue;
292 }
293 }
294 throw new NotSupportedException("Другие размеры и способы ограничений не
    ↪ поддерживаются.");
295 }
296
297 /// <remarks>
298 /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
    ↪ в другом месте (но не в менеджере памяти, а в логике Links)
299 /// </remarks>
300 [MethodImpl(MethodImplOptions.AggressiveInlining)]
301 public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
302 {
303     var constants = Constants;
304     var @null = constants.Null;
305     var linkIndex = restrictions[constants.IndexPart];
306     ref var link = ref GetLinkReference(linkIndex);
307     ref var header = ref GetHeaderReference();
308     ref var firstAsSource = ref header.FirstAsSource;
309     ref var firstAsTarget = ref header.FirstAsTarget;
310     // Будет корректно работать только в том случае, если пространство выделенной связи
    ↪ предварительно заполнено нулями
311     if (!AreEqual(link.Source, @null))
312     {
313         SourcesTreeMethods.Detach(ref firstAsSource, linkIndex);
314     }
315     if (!AreEqual(link.Target, @null))
316     {

```

```

317     TargetsTreeMethods.Detach(ref firstAsTarget, linkIndex);
318 }
319 link.Source = substitution[constants.SourcePart];
320 link.Target = substitution[constants.TargetPart];
321 if (!AreEqual(link.Source, @null))
322 {
323     SourcesTreeMethods.Attach(ref firstAsSource, linkIndex);
324 }
325 if (!AreEqual(link.Target, @null))
326 {
327     TargetsTreeMethods.Attach(ref firstAsTarget, linkIndex);
328 }
329 return linkIndex;
330 }
331
332 /// <remarks>
333 /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
334   ↳ пространство
335 /// </remarks>
336 public virtual TLink Create(IList<TLink> restrictions)
337 {
338     ref var header = ref GetHeaderReference();
339     var freeLink = header.FirstFreeLink;
340     if (!AreEqual(freeLink, Constants.Null))
341     {
342         UnusedLinksListMethods.Detach(freeLink);
343     }
344     else
345     {
346         var maximumPossibleInnerReference =
347             ↳ Constants.PossibleInnerReferencesRange.Maximum;
348         if (GreaterThan(header.AllocatedLinks, maximumPossibleInnerReference))
349         {
350             throw new LinksLimitReachedException<TLink>(maximumPossibleInnerReference);
351         }
352         if (GreaterOrEqualThan(header.AllocatedLinks, Decrement(header.ReservedLinks)))
353         {
354             _memory.ReservedCapacity += _memory.ReservationStep;
355             SetPointers(_memory);
356             header.ReservedLinks = ConvertToAddress(_memory.ReservedCapacity /
357                 ↳ LinkSizeInBytes);
358         }
359         header.AllocatedLinks = Increment(header.AllocatedLinks);
360         _memory.UsedCapacity += LinkSizeInBytes;
361         freeLink = header.AllocatedLinks;
362     }
363     return freeLink;
364 }
365
366 [MethodImpl(MethodImplOptions.AggressiveInlining)]
367 public virtual void Delete(IList<TLink> restrictions)
368 {
369     ref var header = ref GetHeaderReference();
370     var link = restrictions[Constants.IndexPart];
371     if (LessThan(link, header.AllocatedLinks)
372     {
373         UnusedLinksListMethods.AttachAsFirst(link);
374     }
375     else if (AreEqual(link, header.AllocatedLinks))
376     {
377         header.AllocatedLinks = Decrement(header.AllocatedLinks);
378         _memory.UsedCapacity -= LinkSizeInBytes;
379         // Убираем все связи, находящиеся в списке свободных в конце файла, до тех пор,
380         ↳ пока не дойдём до первой существующей связи
381         // Позволяет оптимизировать количество выделенных связей (AllocatedLinks)
382         while (GreaterThan(header.AllocatedLinks, GetZero()) &&
383             ↳ IsUnusedLink(header.AllocatedLinks))
384         {
385             UnusedLinksListMethods.Detach(header.AllocatedLinks);
386             header.AllocatedLinks = Decrement(header.AllocatedLinks);
387             _memory.UsedCapacity -= LinkSizeInBytes;
388         }
389     }
390 }
391
392 [MethodImpl(MethodImplOptions.AggressiveInlining)]
393 public IList<TLink> GetLinkStruct(TLink linkIndex)

```

```

391 {
392     ref var link = ref GetLinkReference(linkIndex);
393     return new Link<TLink>(linkIndex, link.Source, link.Target);
394 }
395
396 [MethodImpl(MethodImplOptions.AggressiveInlining)]
397 protected abstract void SetPointers(IResizableDirectMemory memory);
398
399 [MethodImpl(MethodImplOptions.AggressiveInlining)]
400 protected abstract ref LinksHeader<TLink> GetHeaderReference();
401
402 [MethodImpl(MethodImplOptions.AggressiveInlining)]
403 protected abstract ref RawLink<TLink> GetLinkReference(TLink linkIndex);
404
405 [MethodImpl(MethodImplOptions.AggressiveInlining)]
406 protected virtual bool Exists(TLink link)
407     => GreaterOrEqualThan(link, Constants.PossibleInnerReferencesRange.Minimum)
408     && LessOrEqualThan(link, GetHeaderReference().AllocatedLinks)
409     && !IsUnusedLink(link);
410
411 [MethodImpl(MethodImplOptions.AggressiveInlining)]
412 protected virtual bool IsUnusedLink(TLink linkIndex)
413 {
414     if (!AreEqual(GetHeaderReference().FirstFreeLink, linkIndex)) // May be this check
415         ↪ is not needed
416     {
417         ref var link = ref GetLinkReference(linkIndex);
418         return AreEqual(link.SizeAsSource, default) && !AreEqual(link.Source, default);
419     }
420     else
421     {
422         return true;
423     }
424 }
425
426 [MethodImpl(MethodImplOptions.AggressiveInlining)]
427 protected virtual TLink GetOne() => Integer<TLink>.One;
428
429 [MethodImpl(MethodImplOptions.AggressiveInlining)]
430 protected virtual TLink GetZero() => Integer<TLink>.Zero;
431
432 [MethodImpl(MethodImplOptions.AggressiveInlining)]
433 protected virtual bool AreEqual(TLink first, TLink second) =>
434     ↪ EqualityComparer.Equals(first, second);
435
436 [MethodImpl(MethodImplOptions.AggressiveInlining)]
437 protected virtual bool LessThan(TLink first, TLink second) => Comparer.Compare(first,
438     ↪ second) < 0;
439
440 [MethodImpl(MethodImplOptions.AggressiveInlining)]
441 protected virtual bool LessOrEqualThan(TLink first, TLink second) =>
442     ↪ Comparer.Compare(first, second) <= 0;
443
444 [MethodImpl(MethodImplOptions.AggressiveInlining)]
445 protected virtual bool GreaterThan(TLink first, TLink second) => Comparer.Compare(first,
446     ↪ second) > 0;
447
448 [MethodImpl(MethodImplOptions.AggressiveInlining)]
449 protected virtual bool GreaterOrEqualThan(TLink first, TLink second) =>
450     ↪ Comparer.Compare(first, second) >= 0;
451
452 [MethodImpl(MethodImplOptions.AggressiveInlining)]
453 protected virtual TLink ConvertToAddress(long value) => (Integer<TLink>)value;
454
455 [MethodImpl(MethodImplOptions.AggressiveInlining)]
456 protected virtual TLink Add(TLink first, TLink second) => Arithmetic<TLink>.Add(first,
457     ↪ second);
458
459 [MethodImpl(MethodImplOptions.AggressiveInlining)]
460 protected virtual TLink Subtract(TLink first, TLink second) =>
461     ↪ Arithmetic<TLink>.Subtract(first, second);
462
463 [MethodImpl(MethodImplOptions.AggressiveInlining)]
464 protected virtual TLink Increment(TLink link) => Arithmetic<TLink>.Increment(link);
465
466 [MethodImpl(MethodImplOptions.AggressiveInlining)]
467 protected virtual TLink Decrement(TLink link) => Arithmetic<TLink>.Decrement(link);
468
469 [MethodImpl(MethodImplOptions.AggressiveInlining)]

```



```

462     protected virtual IList<TLink> GetEmptyList() => ArrayPool<TLink>.Empty;
463
464     #region Disposable
465
466     protected override bool AllowMultipleDisposeCalls => true;
467
468     protected override void Dispose(bool manual, bool wasDisposed)
469     {
470         if (!wasDisposed)
471         {
472             SetPointers(null);
473             _memory.DisposeIfPossible();
474         }
475     }
476
477     #endregion
478 }
479 }

```

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

```

1  using System.Runtime.CompilerServices;
2  using Platform.Numbers;
3  using Platform.Memory;
4  using static System.Runtime.CompilerServices.Unsafe;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.ResizableDirectMemory
9  {
10     public unsafe partial class ResizableDirectMemoryLinks<TLink> :
11         ↳ ResizableDirectMemoryLinksBase<TLink>
12     {
13         public static readonly long LinkHeaderSizeInBytes = LinkHeader<TLink>.SizeInBytes;
14         public static readonly long DefaultLinksSizeStep = LinkSizeInBytes * 1024 * 1024;
15
16         private byte* _header;
17         private byte* _links;
18
19         public ResizableDirectMemoryLinks(string address) : this(address, DefaultLinksSizeStep)
20             ↳ { }
21
22         /// <summary>
23         /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
24         /// ↳ минимальным шагом расширения базы данных.
25         /// </summary>
26         /// <param name="address">Полный путь к файлу базы данных.</param>
27         /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
28         /// ↳ байтах.</param>
29         public ResizableDirectMemoryLinks(string address, long memoryReservationStep) : this(new
30             ↳ FileMappedResizableDirectMemory(address, memoryReservationStep),
31             ↳ memoryReservationStep) { }
32
33         public ResizableDirectMemoryLinks(IResizableDirectMemory memory) : this(memory,
34             ↳ DefaultLinksSizeStep) { }
35
36         public ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
37             ↳ memoryReservationStep)
38             : base(memory, memoryReservationStep)
39         {
40             if (memory.ReservedCapacity < memoryReservationStep)
41             {
42                 memory.ReservedCapacity = memoryReservationStep;
43             }
44             SetPointers(_memory);
45             ref var header = ref GetHeaderReference();
46             // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
47             _memory.UsedCapacity = ((Integer<TLink>)header.AllocatedLinks * LinkSizeInBytes) +
48             ↳ LinkHeaderSizeInBytes;
49             // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
50             header.ReservedLinks = (Integer<TLink>)((_memory.ReservedCapacity -
51             ↳ LinkHeaderSizeInBytes) / LinkSizeInBytes);
52         }
53
54         /// <remarks>
55         /// TODO: Возможно это должно быть событием, вызываемым из IMemory, в том случае, если
56         /// ↳ адрес реально поменялся
57         ///
58         /// Указатель this.links может быть в том же месте,
59         /// так как 0-я связь не используется и имеет такой же размер как Header,

```

```

49     /// поэтому header размещается в том же месте, что и 0-я связь
50     /// </remarks>
51     [MethodImpl(MethodImplOptions.AggressiveInlining)]
52     protected override void SetPointers(IResizableDirectMemory memory)
53     {
54         if (memory == null)
55         {
56             _links = null;
57             _header = _links;
58             SourcesTreeMethods = null;
59             TargetsTreeMethods = null;
60             UnusedLinksListMethods = null;
61         }
62         else
63         {
64             _links = (byte*)(void*)memory.Pointer;
65             _header = _links;
66             SourcesTreeMethods = new LinksSourcesAVLBalancedTreeMethods<TLink>(Constants,
67                                     ↪ _links, _header);
68             TargetsTreeMethods = new LinksTargetsAVLBalancedTreeMethods<TLink>(Constants,
69                                     ↪ _links, _header);
70             UnusedLinksListMethods = new UnusedLinksListMethods<TLink>(_links, _header);
71         }
72     }
73     [MethodImpl(MethodImplOptions.AggressiveInlining)]
74     protected override ref LinksHeader<TLink> GetHeaderReference() => ref
75     ↪ AsRef<LinksHeader<TLink>>(_header);
76     [MethodImpl(MethodImplOptions.AggressiveInlining)]
77     protected override ref RawLink<TLink> GetLinkReference(TLink linkIndex) => ref
78     ↪ AsRef<RawLink<TLink>>(_links + LinkSizeInBytes * (Integer<TLink>)linkIndex);
79 }

```

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

```

1  using System.Runtime.CompilerServices;
2  using static System.Runtime.CompilerServices.Unsafe;
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 unsafe abstract class UInt64LinksAVLBalancedTreeMethodsBase :
9      ↪ LinksAVLBalancedTreeMethodsBase<ulong>
10     {
11         protected new readonly RawLink<ulong>* Links;
12         protected new readonly LinksHeader<ulong>* Header;
13
14         public UInt64LinksAVLBalancedTreeMethodsBase(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
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected override ulong GetZero() => OUL;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected override bool EqualToZero(ulong value) => value == OUL;
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected override bool IsEquals(ulong first, ulong second) => first == second;
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected override bool GreaterThanZero(ulong value) => value > OUL;
33
34         [MethodImpl(MethodImplOptions.AggressiveInlining)]
35         protected override bool GreaterThan(ulong first, ulong second) => first > second;
36
37         [MethodImpl(MethodImplOptions.AggressiveInlining)]
38         protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
42         ↪ always true for ulong
43
44         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

42     protected override bool LessOrEqualThanZero(ulong value) => value == 0UL; // value is
    ↪ always >= 0 for ulong
43
44     [MethodImpl(MethodImplOptions.AggressiveInlining)]
45     protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
46
47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     protected override bool LessThanZero(ulong value) => false; // value < 0 is always false
    ↪ for ulong
49
50     [MethodImpl(MethodImplOptions.AggressiveInlining)]
51     protected override bool LessThan(ulong first, ulong second) => first < second;
52
53     [MethodImpl(MethodImplOptions.AggressiveInlining)]
54     protected override ulong Increment(ulong value) => ++value;
55
56     [MethodImpl(MethodImplOptions.AggressiveInlining)]
57     protected override ulong Decrement(ulong value) => --value;
58
59     [MethodImpl(MethodImplOptions.AggressiveInlining)]
60     protected override ulong Add(ulong first, ulong second) => first + second;
61
62     [MethodImpl(MethodImplOptions.AggressiveInlining)]
63     protected override ulong Subtract(ulong first, ulong second) => first - second;
64
65     [MethodImpl(MethodImplOptions.AggressiveInlining)]
66     protected override bool FirstIsToLeftOfSecond(ulong first, ulong second)
67     {
68         ref var firstLink = ref Links[first];
69         ref var secondLink = ref Links[second];
70         return FirstIsToLeftOfSecond(firstLink.Source, firstLink.Target,
    ↪ secondLink.Source, secondLink.Target);
71     }
72
73     [MethodImpl(MethodImplOptions.AggressiveInlining)]
74     protected override bool FirstIsToTheRightOfSecond(ulong first, ulong second)
75     {
76         ref var firstLink = ref Links[first];
77         ref var secondLink = ref Links[second];
78         return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
    ↪ secondLink.Source, secondLink.Target);
79     }
80
81     [MethodImpl(MethodImplOptions.AggressiveInlining)]
82     protected override ulong GetSizeValue(ulong value) => unchecked((value & 4294967264UL)
    ↪ >> 5);
83
84     [MethodImpl(MethodImplOptions.AggressiveInlining)]
85     protected override void SetSizeValue(ref ulong storedValue, ulong size) => storedValue =
    ↪ unchecked((storedValue & 31UL) | ((size & 134217727UL) << 5));
86
87     [MethodImpl(MethodImplOptions.AggressiveInlining)]
88     protected override bool GetLeftIsChildValue(ulong value) => unchecked((value & 16UL) >>
    ↪ 4 == 1UL);
89
90     [MethodImpl(MethodImplOptions.AggressiveInlining)]
91     protected override void SetLeftIsChildValue(ref ulong storedValue, bool value) =>
    ↪ storedValue = unchecked((storedValue & 4294967279UL) | ((As<bool, byte>(ref value) &
    ↪ 1UL) << 4));
92
93     [MethodImpl(MethodImplOptions.AggressiveInlining)]
94     protected override bool GetRightIsChildValue(ulong value) => unchecked((value & 8UL) >>
    ↪ 3 == 1UL);
95
96     [MethodImpl(MethodImplOptions.AggressiveInlining)]
97     protected override void SetRightIsChildValue(ref ulong storedValue, bool value) =>
    ↪ storedValue = unchecked((storedValue & 4294967287UL) | ((As<bool, byte>(ref value) &
    ↪ 1UL) << 3));
98
99     [MethodImpl(MethodImplOptions.AggressiveInlining)]
100    protected override sbyte GetBalanceValue(ulong value) => unchecked((sbyte)((value & 7UL)
    ↪ | 0xF8UL * ((value & 4UL) >> 2))); // if negative, then continue ones to the end of
    ↪ sbyte
101
102     [MethodImpl(MethodImplOptions.AggressiveInlining)]
103    protected override void SetBalanceValue(ref ulong storedValue, sbyte value) =>
    ↪ storedValue = unchecked((storedValue & 4294967288UL) | ((ulong)(((byte)value >> 5)
    ↪ & 4) | value & 3) & 7UL));

```

```

104     [MethodImpl(MethodImplOptions.AggressiveInlining)]
105     protected override ref LinksHeader<ulong> GetHeaderReference() => ref *Header;
106
107     [MethodImpl(MethodImplOptions.AggressiveInlining)]
108     protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref Links[link];
109 }
110 }
111
./Platform.Data.Doublets/ResizableDirectMemory/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
6  {
7      public unsafe class UInt64LinksSourcesAVLBalancedTreeMethods :
8          ↳ UInt64LinksAVLBalancedTreeMethodsBase
9      {
10
11         public UInt64LinksSourcesAVLBalancedTreeMethods(LinksConstants<ulong> constants,
12             ↳ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
13             ↳ { }
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         protected override ref ulong GetLeftReference(ulong node) => ref
17             ↳ Links[node].LeftAsSource;
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         protected override ref ulong GetRightReference(ulong node) => ref
21             ↳ Links[node].RightAsSource;
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected override ulong GetLeft(ulong node) => Links[node].LeftAsSource;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         protected override ulong GetRight(ulong node) => Links[node].RightAsSource;
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsSource =
31             ↳ left;
32
33         [MethodImpl(MethodImplOptions.AggressiveInlining)]
34         protected override void SetRight(ulong node, ulong right) => Links[node].RightAsSource =
35             ↳ right;
36
37         [MethodImpl(MethodImplOptions.AggressiveInlining)]
38         protected override ulong GetSize(ulong node) => GetSizeValue(Links[node].SizeAsSource);
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         protected override void SetSize(ulong node, ulong size) => SetSizeValue(ref
42             ↳ Links[node].SizeAsSource, size);
43
44         [MethodImpl(MethodImplOptions.AggressiveInlining)]
45         protected override bool GetLeftIsChild(ulong node) =>
46             ↳ GetLeftIsChildValue(Links[node].SizeAsSource);
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         protected override void SetLeftIsChild(ulong node, bool value) =>
50             ↳ SetLeftIsChildValue(ref Links[node].SizeAsSource, value);
51
52         [MethodImpl(MethodImplOptions.AggressiveInlining)]
53         protected override bool GetRightIsChild(ulong node) =>
54             ↳ GetRightIsChildValue(Links[node].SizeAsSource);
55
56         [MethodImpl(MethodImplOptions.AggressiveInlining)]
57         protected override void SetRightIsChild(ulong node, bool value) =>
58             ↳ SetRightIsChildValue(ref Links[node].SizeAsSource, value);
59
60         [MethodImpl(MethodImplOptions.AggressiveInlining)]
61         protected override sbyte GetBalance(ulong node) =>
62             ↳ GetBalanceValue(Links[node].SizeAsSource);
63
64         [MethodImpl(MethodImplOptions.AggressiveInlining)]
65         protected override void SetBalance(ulong node, sbyte value) => SetBalanceValue(ref
66             ↳ Links[node].SizeAsSource, value);
67
68         [MethodImpl(MethodImplOptions.AggressiveInlining)]
69         protected override ulong GetTreeRoot() => Header->FirstAsSource;
70

```

```

56 [MethodImpl(MethodImplOptions.AggressiveInlining)]
57 protected override ulong GetBasePartValue(ulong link) => Links[link].Source;
58
59 [MethodImpl(MethodImplOptions.AggressiveInlining)]
60 protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
61     ↳ ulong secondSource, ulong secondTarget)
62     => firstSource < secondSource || (firstSource == secondSource && firstTarget <
63     ↳ secondTarget);
64
65 [MethodImpl(MethodImplOptions.AggressiveInlining)]
66 protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
67     ↳ ulong secondSource, ulong secondTarget)
68     => firstSource > secondSource || (firstSource == secondSource && firstTarget >
69     ↳ secondTarget);
70
71 [MethodImpl(MethodImplOptions.AggressiveInlining)]
72 protected override void ClearNode(ulong node)
73 {
74     ref RawLink<ulong> link = ref Links[node];
75     link.LeftAsSource = OUL;
76     link.RightAsSource = OUL;
77     link.SizeAsSource = OUL;
78 }
79 }
80 }

```

./Platform.Data.Doublets/ResizableDirectMemory/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
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         //protected override IntPtr GetLeft(ulong node) => new IntPtr(&Links[node].LeftAsTarget);
15
16         //protected override IntPtr GetRight(ulong node) => new
17     ↳ IntPtr(&Links[node].RightAsTarget);
18
19         //protected override ulong GetSize(ulong node) => Links[node].SizeAsTarget;
20
21         //protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsTarget =
22     ↳ left;
23
24         //protected override void SetRight(ulong node, ulong right) => Links[node].RightAsTarget
25     ↳ = right;
26
27         //protected override void SetSize(ulong node, ulong size) => Links[node].SizeAsTarget =
28     ↳ size;
29
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]
31         protected override ref ulong GetLeftReference(ulong node) => ref
32     ↳ Links[node].LeftAsTarget;
33
34         [MethodImpl(MethodImplOptions.AggressiveInlining)]
35         protected override ref ulong GetRightReference(ulong node) => ref
36     ↳ Links[node].RightAsTarget;
37
38         [MethodImpl(MethodImplOptions.AggressiveInlining)]
39         protected override ulong GetLeft(ulong node) => Links[node].LeftAsTarget;
40
41         [MethodImpl(MethodImplOptions.AggressiveInlining)]
42         protected override ulong GetRight(ulong node) => Links[node].RightAsTarget;
43
44         [MethodImpl(MethodImplOptions.AggressiveInlining)]
45         protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsTarget =
46     ↳ left;
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         protected override void SetRight(ulong node, ulong right) => Links[node].RightAsTarget =
50     ↳ right;
51
52         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

protected override ulong GetSize(ulong node) => GetSizeValue(Links[node].SizeAsTarget);

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

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

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

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

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

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

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

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

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

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

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

[MethodImpl(MethodImplOptions.AggressiveInlining)]
protected override void ClearNode(ulong node)
{
    ref RawLink<ulong> link = ref Links[node];
    link.LeftAsTarget = OUL;
    link.RightAsTarget = OUL;
    link.SizeAsTarget = OUL;
}
}
}

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3 using Platform.Memory;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Data.Doublets.ResizableDirectMemory
8 {
9     public unsafe class UInt64ResizableDirectMemoryLinks : ResizableDirectMemoryLinksBase<ulong>
10     {
11         public static readonly long DefaultLinksSizeStep = LinkSizeInBytes * 1024 * 1024;
12
13         private LinksHeader<ulong>* _header;
14         private RawLink<ulong>* _links;
15
16         public UInt64ResizableDirectMemoryLinks(string address) : this(address,
17             ↳ DefaultLinksSizeStep) { }
18
19         ///<summary>

```

```

19  /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
    ↳ минимальным шагом расширения базы данных.
20  /// </summary>
21  /// <param name="address">Полный путь к файлу базы данных.</param>
22  /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
    ↳ байтах.</param>
23  public UInt64ResizableDirectMemoryLinks(string address, long memoryReservationStep) :
    ↳ this(new FileMappedResizableDirectMemory(address, memoryReservationStep),
    ↳ memoryReservationStep) { }
24
25  public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory) : this(memory,
    ↳ DefaultLinksSizeStep) { }
26
27  public UInt64ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
    ↳ memoryReservationStep)
28      : base(memory, memoryReservationStep)
29  {
30      if (memory.ReservedCapacity < memoryReservationStep)
31      {
32          memory.ReservedCapacity = memoryReservationStep;
33      }
34      SetPointers(_memory);
35      // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
36      _memory.UsedCapacity = ((long)_header->AllocatedLinks * sizeof(RawLink<ulong>)) +
    ↳ sizeof(LinksHeader<ulong>);
37      // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
38      _header->ReservedLinks = (ulong)((_memory.ReservedCapacity -
    ↳ sizeof(LinksHeader<ulong>)) / sizeof(RawLink<ulong>));
39  }
40
41  /// <remarks>
42  /// TODO: Возможно это должно быть событием, вызываемым из IMemory, в том случае, если
    ↳ адрес реально поменялся
43  ///
44  /// Указатель this.links может быть в том же месте,
45  /// так как 0-я связь не используется и имеет такой же размер как Header,
46  /// поэтому header размещается в том же месте, что и 0-я связь
47  /// </remarks>
48  [MethodImpl(MethodImplOptions.AggressiveInlining)]
49  protected override void SetPointers(IResizableDirectMemory memory)
50  {
51      if (memory == null)
52      {
53          _header = null;
54          _links = null;
55          SourcesTreeMethods = null;
56          TargetsTreeMethods = null;
57          UnusedLinksListMethods = null;
58      }
59      else
60      {
61          _header = (LinksHeader<ulong>*)(void*)memory.Pointer;
62          _links = (RawLink<ulong>*)(void*)memory.Pointer;
63          SourcesTreeMethods = new UInt64LinksSourcesAVLBalancedTreeMethods(Constants,
    ↳ _links, _header);
64          TargetsTreeMethods = new UInt64LinksTargetsAVLBalancedTreeMethods(Constants,
    ↳ _links, _header);
65          UnusedLinksListMethods = new UInt64UnusedLinksListMethods(_links, _header);
66      }
67  }
68
69  [MethodImpl(MethodImplOptions.AggressiveInlining)]
70  protected override ref LinksHeader<ulong> GetHeaderReference() => ref *_header;
71
72  [MethodImpl(MethodImplOptions.AggressiveInlining)]
73  protected override ref RawLink<ulong> GetLinkReference(ulong linkIndex) => ref
    ↳ _links[linkIndex];
74
75  [MethodImpl(MethodImplOptions.AggressiveInlining)]
76  protected override bool AreEqual(ulong first, ulong second) => first == second;
77
78  [MethodImpl(MethodImplOptions.AggressiveInlining)]
79  protected override bool LessThan(ulong first, ulong second) => first < second;
80
81  [MethodImpl(MethodImplOptions.AggressiveInlining)]
82  protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
83
84  [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

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

```

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

```

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

```

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

```

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

```



```

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

```

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

```

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

```

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

```

1  using System.Collections.Generic;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Sequences.Converters
6  {
7      public class BalancedVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
8      {
9         public BalancedVariantConverter(ILinks<TLink> links) : base(links) { }
10
11         public override TLink Convert(IList<TLink> sequence)
12         {

```

```

13     var length = sequence.Count;
14     if (length < 1)
15     {
16         return default;
17     }
18     if (length == 1)
19     {
20         return sequence[0];
21     }
22     // Make copy of next layer
23     if (length > 2)
24     {
25         // TODO: Try to use stackalloc (which at the moment is not working with
26         // ↳ generics) but will be possible with Sigil
27         var halvedSequence = new TLink[(length / 2) + (length % 2)];
28         HalveSequence(halvedSequence, sequence, length);
29         sequence = halvedSequence;
30         length = halvedSequence.Length;
31     }
32     // 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(IList<TLink> destination, IList<TLink> source, int length)
41 {
42     var loopedLength = length - (length % 2);
43     for (var i = 0; i < loopedLength; i += 2)
44     {
45         destination[i / 2] = Links.GetOrCreate(source[i], source[i + 1]);
46     }
47     if (length > loopedLength)
48     {
49         destination[length / 2] = source[length - 1];
50     }
51 }
52 }
53 }

```

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

```

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

```

```

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

```

```

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

```

```

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 }

```

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

```

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

```

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

```

1 using System.Collections.Generic;
2 using System.Linq;
3 using Platform.Interfaces;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Data.Doublets.Sequences.Converters
8 {
9     public class OptimalVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>

```

```

10 {
11     private static readonly EqualityComparer<TLink> _equalityComparer =
12         ↳ EqualityComparer<TLink>.Default;
13     private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
14     private readonly IConverter<IList<TLink>> _sequenceToItsLocalElementLevelsConverter;
15
16     public OptimalVariantConverter(ILinks<TLink> links, IConverter<IList<TLink>>
17         ↳ sequenceToItsLocalElementLevelsConverter) : base(links)
18         => _sequenceToItsLocalElementLevelsConverter =
19             ↳ sequenceToItsLocalElementLevelsConverter;
20
21     public override TLink Convert(IList<TLink> sequence)
22     {
23         var length = sequence.Count;
24         if (length == 1)
25         {
26             return sequence[0];
27         }
28         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                     if (i == length - 1)
87                     {
88                         sequence[w] = sequence[i];
89                     }
90                 }
91             }
92         }
93     }
94 }

```

```

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 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences.Converters
7 {
8     public class SequenceToItsLocalElementLevelsConverter<TLink> : LinksOperatorBase<TLink>,
↪ 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 }

```

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

```

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

```

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

```
1 using System.Collections.Generic;
2 using Platform.Interfaces;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences.CreteriaMatchers
7 {
8     public class MarkedSequenceCriterionMatcher<TLink> : ICriterionMatcher<TLink>
9     {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11             ↳ EqualityComparer<TLink>.Default;
12
13         private readonly ILinks<TLink> _links;
14         private readonly TLink _sequenceMarkerLink;
15
16         public MarkedSequenceCriterionMatcher(ILinks<TLink> links, TLink sequenceMarkerLink)
17         {
18             _links = links;
19             _sequenceMarkerLink = sequenceMarkerLink;
20
21             public bool IsMatched(TLink sequenceCandidate)
22                 => _equalityComparer.Equals(_links.GetSource(sequenceCandidate), _sequenceMarkerLink)
23                 || !_equalityComparer.Equals(_links.SearchOrDefault(_sequenceMarkerLink,
24                     ↳ sequenceCandidate), _links.Constants.Null);
25     }
26 }
```

./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             public TLink Append(TLink sequence, TLink appendant)
27             {
28                 var cursor = sequence;
29                 while (!_equalityComparer.Equals(_heightProvider.Get(cursor), default))
30                 {
31                     var source = Links.GetSource(cursor);
32                     var target = Links.GetTarget(cursor);
33                     if (_equalityComparer.Equals(_heightProvider.Get(source),
34                         ↳ _heightProvider.Get(target)))
35                     {
36                         break;
37                     }
38                     else
39                     {
40                         _stack.Push(source);
41                         cursor = target;
42                     }
43                 }
44                 var left = cursor;
45                 var right = appendant;
46                 while (!_equalityComparer.Equals(cursor = _stack.Pop(), Links.Constants.Null))
47                 {
48                     right = Links.GetOrCreate(left, right);
49                     left = cursor;
50                 }
51             }
52         }
53     }
```



```

47         }
48         return Links.GetOrCreate(left, right);
49     }
50 }
51 }

```

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

```

1  using System.Collections.Generic;
2  using System.Linq;
3  using Platform.Interfaces;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Sequences
8  {
9      public class DuplicateSegmentsCounter<TLink> : ICounter<int>
10     {
11         private readonly IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
12             ↪ _duplicateFragmentsProvider;
13         public DuplicateSegmentsCounter(IProvider<IList<KeyValuePair<IList<TLink>,
14             ↪ IList<TLink>>>> duplicateFragmentsProvider) => _duplicateFragmentsProvider =
15             ↪ duplicateFragmentsProvider;
16         public int Count() => _duplicateFragmentsProvider.Get().Sum(x => x.Value.Count);
17     }
18 }

```

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

```

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

```

```

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.AddAllValuesAndReturnConstant, new
72                 ↪ LinkAddress<TLink>(linkIndex));
73             if (sequenceElements.Count > 2)
74             {
75                 WalkAll(sequenceElements);
76             }
77         }
78         return _links.Constants.Continue;
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.ConvertToRestrictionsValues();
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)))
120     {
121         return new List<TLink>();
122     }
123 }

```

```

117         foreach (var duplicate in duplicates)
118         {
119             var duplicateBitIndex = (long)(Integer<TLink>)duplicate;
120             _visited.Set(duplicateBitIndex);
121         }
122         if (_sequences is Sequences sequencesExperiments)
123         {
124             var partiallyMatched = sequencesExperiments.GetAllPartiallyMatchingSequences4((H_
125                 ↪ ashSet<ulong>)(object)readAsElement,
126                 ↪ (IList<ulong>)segment);
127             foreach (var partiallyMatchedSequence in partiallyMatched)
128             {
129                 TLink sequenceIndex = (Integer<TLink>)partiallyMatchedSequence;
130                 duplicates.Add(sequenceIndex);
131             }
132         }
133         duplicates.Sort();
134         return duplicates;
135     }
136
137     private void PrintDuplicates(KeyValuePair<IList<TLink>, IList<TLink>> duplicatesItem)
138     {
139         if (!(_links is ILinks<ulong> ulongLinks))
140         {
141             return;
142         }
143         var duplicatesKey = duplicatesItem.Key;
144         var keyString = UnicodeMap.FromLinksToString((IList<ulong>)duplicatesKey);
145         Console.WriteLine($"> {keyString} ({string.Join(", ", duplicatesKey)})");
146         var duplicatesList = duplicatesItem.Value;
147         for (int i = 0; i < duplicatesList.Count; i++)
148         {
149             ulong sequenceIndex = (Integer<TLink>)duplicatesList[i];
150             var formattedSequenceStructure = ulongLinks.FormatStructure(sequenceIndex, x =>
151                 ↪ Point<ulong>.IsPartialPoint(x), (sb, link) => _ =
152                 ↪ UnicodeMap.IsCharLink(link.Index) ?
153                 ↪ sb.Append(UnicodeMap.FromLinkToChar(link.Index)) : sb.Append(link.Index));
154             Console.WriteLine(formattedSequenceStructure);
155             var sequenceString = UnicodeMap.FromSequenceLinkToString(sequenceIndex,
156                 ↪ ulongLinks);
157             Console.WriteLine(sequenceString);
158         }
159         Console.WriteLine();
160     }
161 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Interfaces;
5  using Platform.Numbers;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
10 {
11     /// <remarks>
12     /// Can be used to operate with many CompressingConverters (to keep global frequencies data
13     ↪ between them).
14     /// TODO: Extract interface to implement frequencies storage inside Links storage
15     /// </remarks>
16     public class LinkFrequenciesCache<TLink> : LinksOperatorBase<TLink>
17     {
18         private static readonly EqualityComparer<TLink> _equalityComparer =
19             ↪ EqualityComparer<TLink>.Default;
20         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
21
22         private readonly Dictionary<Doublet<TLink>, LinkFrequency<TLink>> _doubletsCache;
23         private readonly ICounter<TLink, TLink> _frequencyCounter;
24
25         public LinkFrequenciesCache(ILinks<TLink> links, ICounter<TLink, TLink> frequencyCounter)
26             : base(links)
27         {
28             _doubletsCache = new Dictionary<Doublet<TLink>, LinkFrequency<TLink>>(4096,
29                 ↪ DoubletComparer<TLink>.Default);
30             _frequencyCounter = frequencyCounter;
31         }
32     }
33 }

```

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

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

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

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

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

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

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

public void ValidateFrequencies()
{
    foreach (var entry in _doubletsCache)
    {
        var value = entry.Value;
        var linkIndex = value.Link;
        if (!_equalityComparer.Equals(linkIndex, default))
        {
            var frequency = value.Frequency;
            var count = _frequencyCounter.Count(linkIndex);
            // TODO: Why `frequency` always greater than `count` by 1?
            if (((_comparer.Compare(frequency, count) > 0) &&
                ↪ (_comparer.Compare(Arithmetic.Subtract(frequency, count),
                ↪ Integer<TLink>.One) > 0))
```

```

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 }

```

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

```

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

```

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

```

1 using Platform.Interfaces;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
6 {
7     public class FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<TLink> :
           ↳ 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 }

```

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

```

1 using Platform.Interfaces;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

```

```

4
5 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
6 {
7     public class MarkedSequenceSymbolFrequencyOneOffCounter<TLink> :
8         ↳ SequenceSymbolFrequencyOneOffCounter<TLink>
9     {
10         private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
11
12         public MarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
13             ↳ ICriterionMatcher<TLink> markedSequenceMatcher, TLink sequenceLink, TLink symbol)
14             : base(links, sequenceLink, symbol)
15             => _markedSequenceMatcher = markedSequenceMatcher;
16
17         public override TLink Count()
18         {
19             if (!_markedSequenceMatcher.IsMatched(_sequenceLink))
20             {
21                 return default;
22             }
23             return base.Count();
24         }
25     }
26 }

```

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

```

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

```

```

./Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalMarkedSequenceSymbolFrequencyCounter.cs
1  using Platform.Interfaces;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
6  {
7      public class TotalMarkedSequenceSymbolFrequencyCounter<TLink> : ICounter<TLink, TLink>
8      {
9          private readonly ILinks<TLink> _links;
10         private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
11
12         public TotalMarkedSequenceSymbolFrequencyCounter(ILinks<TLink> links,
13             ↪ ICriterionMatcher<TLink> markedSequenceMatcher)
14         {
15             _links = links;
16             _markedSequenceMatcher = markedSequenceMatcher;
17         }
18
19         public TLink Count(TLink argument) => new
20             ↪ TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
21             ↪ _markedSequenceMatcher, argument).Count();
22     }
23 }

```

```

./Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalMarkedSequenceSymbolFrequencyOneOffCounter.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.Frequencies.Counters
7  {
8      public class TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink> :
9          ↪ TotalSequenceSymbolFrequencyOneOffCounter<TLink>
10      {
11         private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
12
13         public TotalMarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
14             ↪ ICriterionMatcher<TLink> markedSequenceMatcher, TLink symbol)
15             : base(links, symbol)
16             => _markedSequenceMatcher = markedSequenceMatcher;
17
18         protected override void CountSequenceSymbolFrequency(TLink link)
19         {
20             var symbolFrequencyCounter = new
21                 ↪ MarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
22                 ↪ _markedSequenceMatcher, link, _symbol);
23             _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
24         }
25     }
26 }

```

```

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

```

```

./Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalSequenceSymbolFrequencyOneOffCounter.cs
1  using System.Collections.Generic;
2  using Platform.Interfaces;
3  using Platform.Numbers;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
8  {
9      public class TotalSequenceSymbolFrequencyOneOffCounter<TLink> : ICounter<TLink>

```

```

10 {
11     private static readonly EqualityComparer<TLink> _equalityComparer =
12         ↪ EqualityComparer<TLink>.Default;
13     private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
14
15     protected readonly ILinks<TLink> _links;
16     protected readonly TLink _symbol;
17     protected readonly HashSet<TLink> _visits;
18     protected TLink _total;
19
20     public TotalSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink symbol)
21     {
22         _links = links;
23         _symbol = symbol;
24         _visits = new HashSet<TLink>();
25         _total = default;
26     }
27
28     public TLink Count()
29     {
30         if (_comparer.Compare(_total, default) > 0 || _visits.Count > 0)
31         {
32             return _total;
33         }
34         CountCore(_symbol);
35         return _total;
36     }
37
38     private void CountCore(TLink link)
39     {
40         var any = _links.Constants.Any;
41         if (_equalityComparer.Equals(_links.Count(any, link), default))
42         {
43             CountSequenceSymbolFrequency(link);
44         }
45         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 }

```

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

```

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

```



```

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

```

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

```

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

```

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

```

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

```

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

```

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

```

```

3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences
7 {
8     public static class IListExtensions
9     {
10         public static TLink[] ExtractValues<TLink>(this IList<TLink> restrictions)
11         {
12             if(restrictions.IsNullOrEmpty() || restrictions.Count == 1)
13             {
14                 return new TLink[0];
15             }
16             var values = new TLink[restrictions.Count - 1];
17             for (int i = 1, j = 0; i < restrictions.Count; i++, j++)
18             {
19                 values[j] = restrictions[i];
20             }
21             return values;
22         }
23
24         public static IList<TLink> ConvertToRestrictionsValues<TLink>(this IList<TLink> list)
25         {
26             var restrictions = new TLink[list.Count + 1];
27             for (int i = 0, j = 1; i < list.Count; i++, j++)
28             {
29                 restrictions[j] = list[i];
30             }
31             return restrictions;
32         }
33     }
34 }

```

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

```

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

```

```

44     {
45         var indexed = true;
46         var i = sequence.Count;
47         while (--i >= 1 && (indexed = IsIndexed(sequence[i - 1], sequence[i]))) { }
48         return indexed;
49     }
50
51     private bool IsIndexed(TLink source, TLink target)
52     {
53         var frequency = _cache.GetFrequency(source, target);
54         if (frequency == null)
55         {
56             return false;
57         }
58         return !_equalityComparer.Equals(frequency.Frequency, default);
59     }
60 }
61 }

```

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

```

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

```

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

```

1  using System.Collections.Generic;
2

```

```

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

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

./Platform.Data.Doublets/Sequences/Indexes/SynchronizedSequenceIndex.cs
1  using System.Collections.Generic;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Sequences.Indexes
6  {
7      public class SynchronizedSequenceIndex<TLink> : ISequenceIndex<TLink>
8      {
9          private static readonly EqualityComparer<TLink> _equalityComparer =
10             ↳ EqualityComparer<TLink>.Default;
11
12         private readonly ISynchronizedLinks<TLink> _links;
13
14         public SynchronizedSequenceIndex(ISynchronizedLinks<TLink> links) => _links = links;
15
16         public bool Add(IList<TLink> sequence)
17         {
18             var indexed = true;
19             var i = sequence.Count;
20             var links = _links.Unsync;
21             _links.SyncRoot.ExecuteReadOperation(() =>

```

```

22         while (--i >= 1 && (indexed =
           ↳ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
           ↳ sequence[i]), default))) { }
23     });
24     if (!indexed)
25     {
26         _links.SyncRoot.ExecuteWriteOperation(() =>
27         {
28             for (; i >= 1; i--)
29             {
30                 links.GetOrCreate(sequence[i - 1], sequence[i]);
31             }
32         });
33     }
34     return indexed;
35 }
36
37 public bool MightContain(ICollection<TLink> sequence)
38 {
39     var links = _links.Unsync;
40     return _links.SyncRoot.ExecuteReadOperation(() =>
41     {
42         var indexed = true;
43         var i = sequence.Count;
44         while (--i >= 1 && (indexed =
           ↳ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
           ↳ sequence[i]), default))) { }
45         return indexed;
46     });
47 }
48 }
49 }

```

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

```

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

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences
7 {
8     public class ListFiller<TElement, TReturnConstant>
9     {
10         protected readonly List<TElement> _list;
11         protected readonly TReturnConstant _returnConstant;
12
13         public ListFiller(List<TElement> list, TReturnConstant returnConstant)
14         {
15             _list = list;
16             _returnConstant = returnConstant;
17         }
18
19         public ListFiller(List<TElement> list) : this(list, default) { }
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public void Add(TElement element) => _list.Add(element);
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         public bool AddAndReturnTrue(TElement element)
26         {
27             _list.Add(element);
28             return true;
29         }
30     }

```

```

31     [MethodImpl(MethodImplOptions.AggressiveInlining)]
32     public bool AddFirstAndReturnTrue(IList<TElement> collection)
33     {
34         _list.Add(collection[0]);
35         return true;
36     }
37
38     [MethodImpl(MethodImplOptions.AggressiveInlining)]
39     public TReturnConstant AddAndReturnConstant(TElement element)
40     {
41         _list.Add(element);
42         return _returnConstant;
43     }
44
45     [MethodImpl(MethodImplOptions.AggressiveInlining)]
46     public TReturnConstant AddFirstAndReturnConstant(IList<TElement> collection)
47     {
48         _list.Add(collection[0]);
49         return _returnConstant;
50     }
51
52     [MethodImpl(MethodImplOptions.AggressiveInlining)]
53     public TReturnConstant AddAllValuesAndReturnConstant(IList<TElement> collection)
54     {
55         for (int i = 1; i < collection.Count; i++)
56         {
57             _list.Add(collection[i]);
58         }
59         return _returnConstant;
60     }
61 }
62 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Linq;
4  using System.Runtime.CompilerServices;
5  using Platform.Collections;
6  using Platform.Collections.Lists;
7  using Platform.Threading.Synchronization;
8  using Platform.Singletons;
9  using LinkIndex = System.UInt64;
10 using Platform.Data.Doublets.Sequences.Walkers;
11 using Platform.Collections.Stacks;
12 using Platform.Collections.Arrays;
13
14 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
15
16 namespace Platform.Data.Doublets.Sequences
17 {
18     /// <summary>
19     /// Представляет коллекцию последовательностей связей.
20     /// </summary>
21     /// <remarks>
22     /// Обязательно реализовать атомарность каждого публичного метода.
23     ///
24     /// TODO:
25     ///
26     /// !!! Повышение вероятности повторного использования групп (подпоследовательностей),
27     /// через естественную группировку по unicode типам, все whitespace вместе, все символы
28     /// ↪ вместе, все числа вместе и т.п.
29     /// + использовать ровно сбалансированный вариант, чтобы уменьшать вложенность (глубину
30     /// ↪ графа)
31     ///
32     /// х*у - найти все связи между, в последовательностях любой формы, если не стоит
33     /// ↪ ограничитель на то, что является последовательностью, а что нет,
34     /// то находятся любые структуры связей, которые содержат эти элементы именно в таком
35     /// ↪ порядке.
36     ///
37     /// Рост последовательности слева и справа.
38     /// Поиск со звёздочкой.
39     /// URL, PURL - реестр используемых во вне ссылок на ресурсы,
40     /// так же проблема может быть решена при реализации дистанционных триггеров.
41     /// Нужны ли уникальные указатели вообще?
42     /// Что если обращение к информации будет происходить через содержимое всегда?
43     ///
44     /// Писать тесты.
45     ///
46     ///
47     ///

```

```

43  /// Можно убрать зависимость от конкретной реализации Links,
44  /// на зависимость от абстрактного элемента, который может быть представлен несколькими
45  /// способами.
46  ///
47  /// Можно ли как-то сделать один общий интерфейс
48  ///
49  /// Блокчейн и/или гит для распределённой записи транзакций.
50  ///
51  /// </remarks>
52  public partial class Sequences : ILinks<LinkIndex> // IList<string>, IList<LinkIndex[]>
53  {
54      /// <summary>Возвращает значение LinkIndex, обозначающее любое количество
55      /// связей.</summary>
56      public const LinkIndex ZeroOrMany = LinkIndex.MaxValue;
57
58      public SequencesOptions<LinkIndex> Options { get; }
59      public SynchronizedLinks<LinkIndex> Links { get; }
60      private readonly ISynchronization _sync;
61
62      public LinksConstants<LinkIndex> Constants { get; }
63
64      public Sequences(SynchronizedLinks<LinkIndex> links, SequencesOptions<LinkIndex> options)
65      {
66          Links = links;
67          _sync = links.SyncRoot;
68          Options = options;
69          Options.ValidateOptions();
70          Options.InitOptions(Links);
71          Constants = Default<LinksConstants<LinkIndex>>.Instance;
72      }
73
74      public Sequences(SynchronizedLinks<LinkIndex> links)
75      : this(links, new SequencesOptions<LinkIndex>())
76      {
77      }
78
79      public bool IsSequence(LinkIndex sequence)
80      {
81          return _sync.ExecuteReadOperation(() =>
82          {
83              if (Options.UseSequenceMarker)
84              {
85                  return Options.MarkedSequenceMatcher.IsMatched(sequence);
86              }
87              return !Links.Unsync.IsPartialPoint(sequence);
88          });
89      }
90
91      [MethodImpl(MethodImplOptions.AggressiveInlining)]
92      private LinkIndex GetSequenceByElements(LinkIndex sequence)
93      {
94          if (Options.UseSequenceMarker)
95          {
96              return Links.SearchOrDefault(Options.SequenceMarkerLink, sequence);
97          }
98          return sequence;
99      }
100
101      private LinkIndex GetSequenceElements(LinkIndex sequence)
102      {
103          if (Options.UseSequenceMarker)
104          {
105              var linkContents = new Link<ulong>(Links.GetLink(sequence));
106              if (linkContents.Source == Options.SequenceMarkerLink)
107              {
108                  return linkContents.Target;
109              }
110              if (linkContents.Target == Options.SequenceMarkerLink)
111              {
112                  return linkContents.Source;
113              }
114          }
115          return sequence;
116      }
117
118      #region Count

```

```

119 public LinkIndex Count(IList<LinkIndex> restrictions)
120 {
121     if (restrictions.IsNullOrEmpty())
122     {
123         return Links.Count(Constants.Any, Options.SequenceMarkerLink, Constants.Any);
124     }
125     if (restrictions.Count == 1) // Первая связь это адрес
126     {
127         var sequenceIndex = restrictions[0];
128         if (sequenceIndex == Constants.Null)
129         {
130             return 0;
131         }
132         if (sequenceIndex == Constants.Any)
133         {
134             return Count(null);
135         }
136         if (Options.UseSequenceMarker)
137         {
138             return Links.Count(Constants.Any, Options.SequenceMarkerLink, sequenceIndex);
139         }
140         return Links.Exists(sequenceIndex) ? 1UL : 0;
141     }
142     throw new NotImplementedException();
143 }
144
145 private LinkIndex CountUsages(params LinkIndex[] restrictions)
146 {
147     if (restrictions.Length == 0)
148     {
149         return 0;
150     }
151     if (restrictions.Length == 1) // Первая связь это адрес
152     {
153         if (restrictions[0] == Constants.Null)
154         {
155             return 0;
156         }
157         if (Options.UseSequenceMarker)
158         {
159             var elementsLink = GetSequenceElements(restrictions[0]);
160             var sequenceLink = GetSequenceByElements(elementsLink);
161             if (sequenceLink != Constants.Null)
162             {
163                 return Links.Count(sequenceLink) + Links.Count(elementsLink) - 1;
164             }
165             return Links.Count(elementsLink);
166         }
167         return Links.Count(restrictions[0]);
168     }
169     throw new NotImplementedException();
170 }
171
172 #endregion
173
174 #region Create
175
176 public LinkIndex Create(IList<LinkIndex> restrictions)
177 {
178     return _sync.ExecuteWriteOperation(() =>
179     {
180         if (restrictions.IsNullOrEmpty())
181         {
182             return Constants.Null;
183         }
184         Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
185         return CreateCore(restrictions);
186     });
187 }
188
189 private LinkIndex CreateCore(IList<LinkIndex> restrictions)
190 {
191     LinkIndex[] sequence = restrictions.ExtractValues();
192     if (Options.UseIndex)
193     {
194         Options.Index.Add(sequence);
195     }
196     var sequenceRoot = default(LinkIndex);
197     if (Options.EnforceSingleSequenceVersionOnWriteBasedOnExisting)

```



```

198     {
199         var matches = Each(restrictions);
200         if (matches.Count > 0)
201         {
202             sequenceRoot = matches[0];
203         }
204     }
205     else if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew)
206     {
207         return CompactCore(sequence);
208     }
209     if (sequenceRoot == default)
210     {
211         sequenceRoot = Options.LinksToSequenceConverter.Convert(sequence);
212     }
213     if (Options.UseSequenceMarker)
214     {
215         Links.Unsync.CreateAndUpdate(Options.SequenceMarkerLink, sequenceRoot);
216     }
217     return sequenceRoot; // Возвращаем корень последовательности (т.е. сами элементы)
218 }
219
220 #endregion
221
222 #region Each
223
224 public List<LinkIndex> Each(IList<LinkIndex> sequence)
225 {
226     var results = new List<LinkIndex>();
227     var filler = new ListFiller<LinkIndex, LinkIndex>(results, Constants.Continue);
228     Each(filler.AddFirstAndReturnConstant, sequence);
229     return results;
230 }
231
232 public LinkIndex Each(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
    ↪ restrictions)
233 {
234     return _sync.ExecuteReadOperation(() =>
235     {
236         if (restrictions.IsNullOrEmpty())
237         {
238             return Constants.Continue;
239         }
240         Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
241         if (restrictions.Count == 1)
242         {
243             var link = restrictions[0];
244             var any = Constants.Any;
245             if (link == any)
246             {
247                 if (Options.UseSequenceMarker)
248                 {
249                     return Links.Unsync.Each(handler, new Link<LinkIndex>(any,
    ↪ Options.SequenceMarkerLink, any));
250                 }
251                 else
252                 {
253                     return Links.Unsync.Each(handler, new Link<LinkIndex>(any, any,
    ↪ any));
254                 }
255             }
256             var sequence =
    ↪ Options.Walker.Walk(link).ToArray().ConvertToRestrictionsValues();
257             sequence[0] = link;
258             return handler(sequence);
259         }
260         else if (restrictions.Count == 2)
261         {
262             throw new NotImplementedException();
263         }
264         else if (restrictions.Count == 3)
265         {
266             return Links.Unsync.Each(handler, restrictions);
267         }
268         else
269         {
270             var sequence = restrictions.ExtractValues();
271             if (Options.UseIndex && !Options.Index.MightContain(sequence))

```

```

272         {
273             return Constants.Break;
274         }
275         return EachCore(handler, sequence);
276     }
277     });
278 }
279
280 private LinkIndex EachCore(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
    ↪ values)
281 {
282     var matcher = new Matcher(this, values, new HashSet<LinkIndex>(), handler);
283     // TODO: Find out why matcher.HandleFullMatched executed twice for the same sequence
    ↪ Id.
284     Func<IList<LinkIndex>, LinkIndex> innerHandler = Options.UseSequenceMarker ?
    ↪ (Func<IList<LinkIndex>, LinkIndex>)matcher.HandleFullMatchedSequence :
    ↪ matcher.HandleFullMatched;
285     //if (sequence.Length >= 2)
286     if (StepRight(innerHandler, values[0], values[1]) != Constants.Continue)
287     {
288         return Constants.Break;
289     }
290     var last = values.Count - 2;
291     for (var i = 1; i < last; i++)
292     {
293         if (PartialStepRight(innerHandler, values[i], values[i + 1]) !=
    ↪ Constants.Continue)
294         {
295             return Constants.Break;
296         }
297     }
298     if (values.Count >= 3)
299     {
300         if (StepLeft(innerHandler, values[values.Count - 2], values[values.Count - 1])
    ↪ != Constants.Continue)
301         {
302             return Constants.Break;
303         }
304     }
305     return Constants.Continue;
306 }
307
308 private LinkIndex PartialStepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
    ↪ left, LinkIndex right)
309 {
310     return Links.Unsync.Each(doublet =>
311     {
312         var doubletIndex = doublet[Constants.IndexPart];
313         if (StepRight(handler, doubletIndex, right) != Constants.Continue)
314         {
315             return Constants.Break;
316         }
317         if (left != doubletIndex)
318         {
319             return PartialStepRight(handler, doubletIndex, right);
320         }
321         return Constants.Continue;
322     }, new Link<LinkIndex>(Constants.Any, Constants.Any, left));
323 }
324
325 private LinkIndex StepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex left,
    ↪ LinkIndex right) => Links.Unsync.Each(rightStep => TryStepRightUp(handler, right,
    ↪ rightStep[Constants.IndexPart]), new Link<LinkIndex>(Constants.Any, left,
    ↪ Constants.Any));
326
327 private LinkIndex TryStepRightUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
    ↪ right, LinkIndex stepFrom)
328 {
329     var upStep = stepFrom;
330     var firstSource = Links.Unsync.GetTarget(upStep);
331     while (firstSource != right && firstSource != upStep)
332     {
333         upStep = firstSource;
334         firstSource = Links.Unsync.GetSource(upStep);
335     }
336     if (firstSource == right)
337     {
338         return handler(new LinkAddress<LinkIndex>(stepFrom));

```

```

339     }
340     return Constants.Continue;
341 }
342
343 private LinkIndex StepLeft(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex left,
    ↪ LinkIndex right) => Links.Unsync.Each(leftStep => TryStepLeftUp(handler, left,
    ↪ leftStep[Constants.IndexPart]), new Link<LinkIndex>(Constants.Any, Constants.Any,
    ↪ right));
344
345 private LinkIndex TryStepLeftUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
    ↪ left, LinkIndex stepFrom)
346 {
347     var upStep = stepFrom;
348     var firstTarget = Links.Unsync.GetSource(upStep);
349     while (firstTarget != left && firstTarget != upStep)
350     {
351         upStep = firstTarget;
352         firstTarget = Links.Unsync.GetTarget(upStep);
353     }
354     if (firstTarget == left)
355     {
356         return handler(new LinkAddress<LinkIndex>(stepFrom));
357     }
358     return Constants.Continue;
359 }
360
361 #endregion
362
363 #region Update
364
365 public LinkIndex Update(IList<LinkIndex> restrictions, IList<LinkIndex> substitution)
366 {
367     var sequence = restrictions.ExtractValues();
368     var newSequence = substitution.ExtractValues();
369
370     if (sequence.IsNullOrEmpty() && newSequence.IsNullOrEmpty())
371     {
372         return Constants.Null;
373     }
374     if (sequence.IsNullOrEmpty())
375     {
376         return Create(substitution);
377     }
378     if (newSequence.IsNullOrEmpty())
379     {
380         Delete(restrictions);
381         return Constants.Null;
382     }
383     return _sync.ExecuteWriteOperation(() =>
384     {
385         Links.EnsureEachLinkIsAnyOrExists(sequence);
386         Links.EnsureEachLinkExists(newSequence);
387         return UpdateCore(sequence, newSequence);
388     });
389 }
390
391 private LinkIndex UpdateCore(LinkIndex[] sequence, LinkIndex[] newSequence)
392 {
393     LinkIndex bestVariant;
394     if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew &&
    ↪ !sequence.EqualTo(newSequence))
395     {
396         bestVariant = CompactCore(newSequence);
397     }
398     else
399     {
400         bestVariant = CreateCore(newSequence);
401     }
402     // TODO: Check all options only ones before loop execution
403     // Возможно нужно две версии Each, возвращающий фактические последовательности и с
    ↪ маркером,
404     // или возможно даже возвращать и тот и тот вариант. С другой стороны все варианты
    ↪ можно получить имея только фактические последовательности.
405     foreach (var variant in Each(sequence))
406     {
407         if (variant != bestVariant)
408         {
409             UpdateOneCore(variant, bestVariant);
410         }
411     }

```

```

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

```

```

489         {
490             Links.Unsync.Delete(sequenceLink);
491         }
492         Links.Unsync.Delete(link);
493     }
494     ClearGarbage(sequenceElementsContents.Source);
495     ClearGarbage(sequenceElementsContents.Target);
496 }
497 else
498 {
499     if (Options.UseSequenceMarker)
500     {
501         var sequenceElements = GetSequenceElements(link);
502         var sequenceLink = GetSequenceByElements(sequenceElements);
503         if (Options.UseCascadeDelete || CountUsages(link) == 0)
504         {
505             if (sequenceLink != Constants.Null)
506             {
507                 Links.Unsync.Delete(sequenceLink);
508             }
509             Links.Unsync.Delete(link);
510         }
511     }
512     else
513     {
514         if (Options.UseCascadeDelete || CountUsages(link) == 0)
515         {
516             Links.Unsync.Delete(link);
517         }
518     }
519 }
520 }
521
522 #endregion
523
524 #region Compactification
525
526 /// <remarks>
527 /// bestVariant можно выбирать по максимальному числу использований,
528 /// но балансированный позволяет гарантировать уникальность (если есть возможность,
529 /// гарантировать его использование в других местах).
530 ///
531 /// Получается этот метод должен игнорировать Options.EnforceSingleSequenceVersionOnWrite
532 /// </remarks>
533 public LinkIndex Compact(params LinkIndex[] sequence)
534 {
535     return _sync.ExecuteWriteOperation(() =>
536     {
537         if (sequence.IsNullOrEmpty())
538         {
539             return Constants.Null;
540         }
541         Links.EnsureEachLinkExists(sequence);
542         return CompactCore(sequence);
543     });
544 }
545
546 [MethodImpl(MethodImplOptions.AggressiveInlining)]
547 private LinkIndex CompactCore(params LinkIndex[] sequence) => UpdateCore(sequence,
548     ↪ sequence);
549
550 #endregion
551
552 #region Garbage Collection
553
554 /// <remarks>
555 /// TODO: Добавить дополнительный обработчик / событие CanBeDeleted которое можно
556 /// ↪ определить извне или в унаследованном классе
557 /// </remarks>
558 [MethodImpl(MethodImplOptions.AggressiveInlining)]
559 private bool IsGarbage(LinkIndex link) => link != Options.SequenceMarkerLink &&
560     ↪ !Links.Unsync.IsPartialPoint(link) && Links.Count(link) == 0;
561
562 private void ClearGarbage(LinkIndex link)
563 {
564     if (IsGarbage(link))
565     {
566         var contents = new Link<ulong>(Links.GetLink(link));
567         Links.Unsync.Delete(link);
568     }
569 }

```

```

565         ClearGarbage(contents.Source);
566         ClearGarbage(contents.Target);
567     }
568 }
569
570 #endregion
571
572 #region Walkers
573
574 public bool EachPart(Func<LinkIndex, bool> handler, LinkIndex sequence)
575 {
576     return _sync.ExecuteReadOperation(() =>
577     {
578         var links = Links.Unsync;
579         foreach (var part in Options.Walker.Walk(sequence))
580         {
581             if (!handler(part))
582             {
583                 return false;
584             }
585         }
586         return true;
587     });
588 }
589
590 public class Matcher : RightSequenceWalker<LinkIndex>
591 {
592     private readonly Sequences _sequences;
593     private readonly IList<LinkIndex> _patternSequence;
594     private readonly HashSet<LinkIndex> _linksInSequence;
595     private readonly HashSet<LinkIndex> _results;
596     private readonly Func<IList<LinkIndex>, LinkIndex> _stopableHandler;
597     private readonly HashSet<LinkIndex> _readAsElements;
598     private int _filterPosition;
599
600     public Matcher(Sequences sequences, IList<LinkIndex> patternSequence,
601         ↳ HashSet<LinkIndex> results, Func<IList<LinkIndex>, LinkIndex> stopableHandler,
602         ↳ HashSet<LinkIndex> readAsElements = null)
603         : base(sequences.Links.Unsync, new DefaultStack<LinkIndex>())
604     {
605         _sequences = sequences;
606         _patternSequence = patternSequence;
607         _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
608             ↳ Links.Constants.Any && x != ZeroOrMany));
609         _results = results;
610         _stopableHandler = stopableHandler;
611         _readAsElements = readAsElements;
612     }
613
614     protected override bool IsElement(LinkIndex link) => base.IsElement(link) ||
615         ↳ (_readAsElements != null && _readAsElements.Contains(link)) ||
616         ↳ _linksInSequence.Contains(link);
617
618     public bool FullMatch(LinkIndex sequenceToMatch)
619     {
620         _filterPosition = 0;
621         foreach (var part in Walk(sequenceToMatch))
622         {
623             if (!FullMatchCore(part))
624             {
625                 break;
626             }
627         }
628         return _filterPosition == _patternSequence.Count;
629     }
630
631     private bool FullMatchCore(LinkIndex element)
632     {
633         if (_filterPosition == _patternSequence.Count)
634         {
635             _filterPosition = -2; // Длиннее чем нужно
636             return false;
637         }
638         if (_patternSequence[_filterPosition] != Links.Constants.Any
639             && element != _patternSequence[_filterPosition])
640         {
641             _filterPosition = -1;
642             return false; // Начинается/Продолжается иначе
643         }
644         _filterPosition++;
645     }
646 }

```

```

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

```

```

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

```

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

```

1  using System;
2  using LinkIndex = System.UInt64;
3  using System.Collections.Generic;
4  using Stack = System.Collections.Generic.Stack<ulong>;
5  using System.Linq;
6  using System.Text;
7  using Platform.Collections;
8  using Platform.Data.Exceptions;
9  using Platform.Data.Sequences;
10 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
11 using Platform.Data.Doublets.Sequences.Walkers;
12 using Platform.Collections.Stacks;
13
14 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
15
16 namespace Platform.Data.Doublets.Sequences
17 {
18     partial class Sequences
19     {
20         #region Create All Variants (Not Practical)
21
22         /// <remarks>
23         /// Number of links that is needed to generate all variants for
24         /// sequence of length N corresponds to https://oeis.org/A014143/list sequence.
25         /// </remarks>
26         public ulong[] CreateAllVariants2(ulong[] sequence)
27         {
28             return _sync.ExecuteWriteOperation(() =>
29             {
30                 if (sequence.IsNullOrEmpty())
31                 {
32                     return new ulong[0];
33                 }
34                 Links.EnsureEachLinkExists(sequence);

```



```

35         if (sequence.Length == 1)
36         {
37             return sequence;
38         }
39         return CreateAllVariants2Core(sequence, 0, sequence.Length - 1);
40     });
41 }
42
43 private ulong[] CreateAllVariants2Core(ulong[] sequence, long startAt, long stopAt)
44 {
45     #if DEBUG
46         if ((stopAt - startAt) < 0)
47         {
48             throw new ArgumentOutOfRangeException(nameof(startAt), "startAt должен быть
49                 ↳ меньше или равен stopAt");
50         }
51         #endif
52         if ((stopAt - startAt) == 0)
53         {
54             return new[] { sequence[startAt] };
55         }
56         if ((stopAt - startAt) == 1)
57         {
58             return new[] { Links.Unsync.CreateAndUpdate(sequence[startAt], sequence[stopAt])
59                 ↳ };
60         }
61         var variants = new ulong[(ulong)Platform.Numbers.Math.Catalan(stopAt - startAt)];
62         var last = 0;
63         for (var splitter = startAt; splitter < stopAt; splitter++)
64         {
65             var left = CreateAllVariants2Core(sequence, startAt, splitter);
66             var right = CreateAllVariants2Core(sequence, splitter + 1, stopAt);
67             for (var i = 0; i < left.Length; i++)
68             {
69                 for (var j = 0; j < right.Length; j++)
70                 {
71                     var variant = Links.Unsync.CreateAndUpdate(left[i], right[j]);
72                     if (variant == Constants.Null)
73                     {
74                         throw new NotImplementedException("Creation cancellation is not
75                             ↳ implemented.");
76                     }
77                     variants[last++] = variant;
78                 }
79             }
80         }
81         return variants;
82     }
83
84 public List<ulong> CreateAllVariants1(params ulong[] sequence)
85 {
86     return _sync.ExecuteWriteOperation(() =>
87     {
88         if (sequence.IsNullOrEmpty())
89         {
90             return new List<ulong>();
91         }
92         Links.Unsync.EnsureEachLinkExists(sequence);
93         if (sequence.Length == 1)
94         {
95             return new List<ulong> { sequence[0] };
96         }
97         var results = new
98             ↳ List<ulong>((int)Platform.Numbers.Math.Catalan(sequence.Length));
99         return CreateAllVariants1Core(sequence, results);
100     });
101 }
102
103 private List<ulong> CreateAllVariants1Core(ulong[] sequence, List<ulong> results)
104 {
105     if (sequence.Length == 2)
106     {
107         var link = Links.Unsync.CreateAndUpdate(sequence[0], sequence[1]);
108         if (link == Constants.Null)
109         {
110             throw new NotImplementedException("Creation cancellation is not
111                 ↳ implemented.");
112         }
113     }

```

```

108         results.Add(link);
109         return results;
110     }
111     var innerSequenceLength = sequence.Length - 1;
112     var innerSequence = new ulong[innerSequenceLength];
113     for (var li = 0; li < innerSequenceLength; li++)
114     {
115         var link = Links.Unsync.CreateAndUpdate(sequence[li], sequence[li + 1]);
116         if (link == Constants.Null)
117         {
118             throw new NotImplementedException("Creation cancellation is not
119                 ↳ implemented.");
120         }
121         for (var isi = 0; isi < li; isi++)
122         {
123             innerSequence[isi] = sequence[isi];
124         }
125         innerSequence[li] = link;
126         for (var isi = li + 1; isi < innerSequenceLength; isi++)
127         {
128             innerSequence[isi] = sequence[isi + 1];
129         }
130         CreateAllVariants1Core(innerSequence, results);
131     }
132     return results;
133 }
134 #endregion
135
136 public HashSet<ulong> Each1(params ulong[] sequence)
137 {
138     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
139     Each1(link =>
140     {
141         if (!visitedLinks.Contains(link))
142         {
143             visitedLinks.Add(link); // изучить почему случаются повторы
144         }
145         return true;
146     }, sequence);
147     return visitedLinks;
148 }
149
150 private void Each1(Func<ulong, bool> handler, params ulong[] sequence)
151 {
152     if (sequence.Length == 2)
153     {
154         Links.Unsync.Each(sequence[0], sequence[1], handler);
155     }
156     else
157     {
158         var innerSequenceLength = sequence.Length - 1;
159         for (var li = 0; li < innerSequenceLength; li++)
160         {
161             var left = sequence[li];
162             var right = sequence[li + 1];
163             if (left == 0 && right == 0)
164             {
165                 continue;
166             }
167             var linkIndex = li;
168             ulong[] innerSequence = null;
169             Links.Unsync.Each(doublet =>
170             {
171                 if (innerSequence == null)
172                 {
173                     innerSequence = new ulong[innerSequenceLength];
174                     for (var isi = 0; isi < linkIndex; isi++)
175                     {
176                         innerSequence[isi] = sequence[isi];
177                     }
178                     for (var isi = linkIndex + 1; isi < innerSequenceLength; isi++)
179                     {
180                         innerSequence[isi] = sequence[isi + 1];
181                     }
182                 }
183                 innerSequence[linkIndex] = doublet[Constants.IndexPart];
184                 Each1(handler, innerSequence);
185                 return Constants.Continue;

```

```

186         }, Constants.Any, left, right);
187     }
188 }
189
190
191 public HashSet<ulong> EachPart(params ulong[] sequence)
192 {
193     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
194     EachPartCore(link =>
195     {
196         var linkIndex = link[Constants.IndexPart];
197         if (!visitedLinks.Contains(linkIndex))
198         {
199             visitedLinks.Add(linkIndex); // изучить почему случаются повторы
200         }
201         return Constants.Continue;
202     }, sequence);
203     return visitedLinks;
204 }
205
206 public void EachPart(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[] sequence)
207 {
208     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
209     EachPartCore(link =>
210     {
211         var linkIndex = link[Constants.IndexPart];
212         if (!visitedLinks.Contains(linkIndex))
213         {
214             visitedLinks.Add(linkIndex); // изучить почему случаются повторы
215             return handler(new LinkAddress<LinkIndex>(linkIndex));
216         }
217         return Constants.Continue;
218     }, sequence);
219 }
220
221 private void EachPartCore(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[]
222     => sequence)
223 {
224     if (sequence.IsNullOrEmpty())
225     {
226         return;
227     }
228     Links.EnsureEachLinkIsAnyOrExists(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         }
265     }
266 }

```

```

263         return true;
264     });
265     //      . x o .
266     //      |___|
267     PartialStepRight(x => handler(x), sequence[0], sequence[1]);
268 }
269 else
270 {
271     throw new NotImplementedException();
272 }
273 }
274
275 private void PartialStepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
276 {
277     Links.Unsync.Each(Constants.Any, left, doublet =>
278     {
279         StepRight(handler, doublet, right);
280         if (left != doublet)
281         {
282             PartialStepRight(handler, doublet, right);
283         }
284         return true;
285     });
286 }
287
288 private void StepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
289 {
290     Links.Unsync.Each(left, Constants.Any, rightStep =>
291     {
292         TryStepRightUp(handler, right, rightStep);
293         return true;
294     });
295 }
296
297 private void TryStepRightUp(Action<IList<LinkIndex>> handler, ulong right, ulong
298 ↪ stepFrom)
299 {
300     var upStep = stepFrom;
301     var firstSource = Links.Unsync.GetTarget(upStep);
302     while (firstSource != right && firstSource != upStep)
303     {
304         upStep = firstSource;
305         firstSource = Links.Unsync.GetSource(upStep);
306     }
307     if (firstSource == right)
308     {
309         handler(new LinkAddress<LinkIndex>(stepFrom));
310     }
311 }
312
313 // TODO: Test
314 private void PartialStepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
315 {
316     Links.Unsync.Each(right, Constants.Any, doublet =>
317     {
318         StepLeft(handler, left, doublet);
319         if (right != doublet)
320         {
321             PartialStepLeft(handler, left, doublet);
322         }
323         return true;
324     });
325 }
326
327 private void StepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
328 {
329     Links.Unsync.Each(Constants.Any, right, leftStep =>
330     {
331         TryStepLeftUp(handler, left, leftStep);
332         return true;
333     });
334 }
335
336 private void TryStepLeftUp(Action<IList<LinkIndex>> handler, ulong left, ulong stepFrom)
337 {
338     var upStep = stepFrom;
339     var firstTarget = Links.Unsync.GetSource(upStep);
340     while (firstTarget != left && firstTarget != upStep)
341     {

```

```

341         upStep = firstTarget;
342         firstTarget = Links.Unsync.GetTarget(upStep);
343     }
344     if (firstTarget == left)
345     {
346         handler(new LinkAddress<LinkIndex>(stepFrom));
347     }
348 }
349
350 private bool StartsWith(ulong sequence, ulong link)
351 {
352     var upStep = sequence;
353     var firstSource = Links.Unsync.GetSource(upStep);
354     while (firstSource != link && firstSource != upStep)
355     {
356         upStep = firstSource;
357         firstSource = Links.Unsync.GetSource(upStep);
358     }
359     return firstSource == link;
360 }
361
362 private bool EndsWith(ulong sequence, ulong link)
363 {
364     var upStep = sequence;
365     var lastTarget = Links.Unsync.GetTarget(upStep);
366     while (lastTarget != link && lastTarget != upStep)
367     {
368         upStep = lastTarget;
369         lastTarget = Links.Unsync.GetTarget(upStep);
370     }
371     return lastTarget == link;
372 }
373
374 public List<ulong> GetAllMatchingSequences0(params ulong[] sequence)
375 {
376     return _sync.ExecuteReadOperation(() =>
377     {
378         var results = new List<ulong>();
379         if (sequence.Length > 0)
380         {
381             Links.EnsureEachLinkExists(sequence);
382             var firstElement = sequence[0];
383             if (sequence.Length == 1)
384             {
385                 results.Add(firstElement);
386                 return results;
387             }
388             if (sequence.Length == 2)
389             {
390                 var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
391                 if (doublet != Constants.Null)
392                 {
393                     results.Add(doublet);
394                 }
395                 return results;
396             }
397             var linksInSequence = new HashSet<ulong>(sequence);
398             void handler(ICollection<LinkIndex> result)
399             {
400                 var resultIndex = result[Links.Constants.IndexPart];
401                 var filterPosition = 0;
402                 StopableSequenceWalker.WalkRight(resultIndex, Links.Unsync.GetSource,
403                     ↪ Links.Unsync.GetTarget,
404                     ↪ x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
405                     ↪ x =>
406                     {
407                         if (filterPosition == sequence.Length)
408                         {
409                             filterPosition = -2; // Длиннее чем нужно
410                             return false;
411                         }
412                         if (x != sequence[filterPosition])
413                         {
414                             filterPosition = -1;
415                             return false; // Начинается иначе
416                         }
417                         filterPosition++;
418                     }
419                     return true;
420                 }
421             }
422         }
423     });
424 }

```

```

418         });
419         if (filterPosition == sequence.Length)
420         {
421             results.Add(resultIndex);
422         }
423     }
424     if (sequence.Length >= 2)
425     {
426         StepRight(handler, sequence[0], sequence[1]);
427     }
428     var last = sequence.Length - 2;
429     for (var i = 1; i < last; i++)
430     {
431         PartialStepRight(handler, sequence[i], sequence[i + 1]);
432     }
433     if (sequence.Length >= 3)
434     {
435         StepLeft(handler, sequence[sequence.Length - 2],
436             ↪ sequence[sequence.Length - 1]);
437     }
438     return results;
439 });
440 }
441
442 public HashSet<ulong> GetAllMatchingSequences1(params ulong[] sequence)
443 {
444     return _sync.ExecuteReadOperation(() =>
445     {
446         var results = new HashSet<ulong>();
447         if (sequence.Length > 0)
448         {
449             Links.EnsureEachLinkExists(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
486 public const int MaxSequenceFormatSize = 200;
487
488 public string FormatSequence(LinkIndex sequenceLink, params LinkIndex[] knownElements)
489     ↪ => FormatSequence(sequenceLink, (sb, x) => sb.Append(x), true, knownElements);
490
491 public string FormatSequence(LinkIndex sequenceLink, Action<StringBuilder, LinkIndex>
492     ↪ elementToString, bool insertComma, params LinkIndex[] knownElements) =>
493     ↪ Links.SyncRoot.ExecuteReadOperation(() => FormatSequence(Links.Unsync, sequenceLink,
494     ↪ elementToString, insertComma, knownElements));

```

```

489 private string FormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
490     ↳ Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
491     ↳ LinkIndex[] knownElements)
492 {
493     var linksInSequence = new HashSet<ulong>(knownElements);
494     //var entered = new HashSet<ulong>();
495     var sb = new StringBuilder();
496     sb.Append('{');
497     if (links.Exists(sequenceLink))
498     {
499         StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
500             x => linksInSequence.Contains(x) || links.IsPartialPoint(x), element => //
501             ↳ entered.AddAndReturnVoid, x => { }, entered.DoNotContains
502             {
503                 if (insertComma && sb.Length > 1)
504                 {
505                     sb.Append(',');
506                 }
507                 //if (entered.Contains(element))
508                 //{
509                 //    sb.Append('{');
510                 //    elementToString(sb, element);
511                 //    sb.Append('}');
512                 //}
513                 //else
514                 elementToString(sb, element);
515                 if (sb.Length < MaxSequenceFormatSize)
516                 {
517                     return true;
518                 }
519                 sb.Append(insertComma ? ", ..." : "...");
520                 return false;
521             });
522     }
523     sb.Append('}');
524     return sb.ToString();
525 }
526
527 public string SafeFormatSequence(LinkIndex sequenceLink, params LinkIndex[]
528     ↳ knownElements) => SafeFormatSequence(sequenceLink, (sb, x) => sb.Append(x), true,
529     ↳ knownElements);
530
531 public string SafeFormatSequence(LinkIndex sequenceLink, Action<StringBuilder,
532     ↳ LinkIndex> elementToString, bool insertComma, params LinkIndex[] knownElements) =>
533     ↳ Links.SyncRoot.ExecuteReadOperation(() => SafeFormatSequence(Links.Unsync,
534     ↳ sequenceLink, elementToString, insertComma, knownElements));
535
536 private string SafeFormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
537     ↳ Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
538     ↳ LinkIndex[] knownElements)
539 {
540     var linksInSequence = new HashSet<ulong>(knownElements);
541     var entered = new HashSet<ulong>();
542     var sb = new StringBuilder();
543     sb.Append('{');
544     if (links.Exists(sequenceLink))
545     {
546         StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
547             x => linksInSequence.Contains(x) || links.IsFullPoint(x),
548             ↳ entered.AddAndReturnVoid, x => { }, entered.DoNotContains, element =>
549             {
550                 if (insertComma && sb.Length > 1)
551                 {
552                     sb.Append(',');
553                 }
554                 if (entered.Contains(element))
555                 {
556                     sb.Append('{');
557                     elementToString(sb, element);
558                     sb.Append('}');
559                 }
560                 else
561                 {
562                     elementToString(sb, element);
563                 }
564                 if (sb.Length < MaxSequenceFormatSize)

```

```

    {
        return true;
    }
    sb.Append(insertComma ? ", ..." : "...");
    return false;
});
}
sb.Append('}');
return sb.ToString();
}

public List<ulong> GetAllPartiallyMatchingSequences0(params ulong[] sequence)
{
    return _sync.ExecuteReadOperation(() =>
    {
        if (sequence.Length > 0)
        {
            Links.EnsureEachLinkExists(sequence);
            var results = new HashSet<ulong>();
            for (var i = 0; i < sequence.Length; i++)
            {
                AllUsagesCore(sequence[i], results);
            }
            var filteredResults = new List<ulong>();
            var linksInSequence = new HashSet<ulong>(sequence);
            foreach (var result in results)
            {
                var filterPosition = -1;
                StopableSequenceWalker.WalkRight(result, Links.Unsync.GetSource,
                ↪ Links.Unsync.GetTarget,
                x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
                ↪ x =>
                {
                    if (filterPosition == (sequence.Length - 1))
                    {
                        return false;
                    }
                    if (filterPosition >= 0)
                    {
                        if (x == sequence[filterPosition + 1])
                        {
                            filterPosition++;
                        }
                        else
                        {
                            return false;
                        }
                    }
                    if (filterPosition < 0)
                    {
                        if (x == sequence[0])
                        {
                            filterPosition = 0;
                        }
                    }
                    return true;
                });
                if (filterPosition == (sequence.Length - 1))
                {
                    filteredResults.Add(result);
                }
            }
            return filteredResults;
        }
        return new List<ulong>();
    });
}

public HashSet<ulong> GetAllPartiallyMatchingSequences1(params ulong[] sequence)
{
    return _sync.ExecuteReadOperation(() =>
    {
        if (sequence.Length > 0)
        {
            Links.EnsureEachLinkExists(sequence);
            var results = new HashSet<ulong>();
            for (var i = 0; i < sequence.Length; i++)
            {
                AllUsagesCore(sequence[i], results);
            }
        }
    });
}

```



```

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

```

```

710         AllUsagesCore(last, lastResults);
711         firstResults.IntersectWith(lastResults);
712         //for (var i = 0; i < sequence.Length; i++)
713         //    AllUsagesCore(sequence[i], results);
714         var filteredResults = new HashSet<ulong>();
715         var matcher = new Matcher(this, sequence, filteredResults, null);
716         matcher.AddAllPartialMatchedToResults(firstResults);
717         return filteredResults;
718     }
719     return new HashSet<ulong>();
720 });
721 }
722
723 public HashSet<ulong> GetAllPartiallyMatchingSequences4(HashSet<ulong> readAsElements,
724     ↳ IList<ulong> sequence)
725 {
726     return _sync.ExecuteReadOperation(() =>
727     {
728         if (sequence.Count > 0)
729         {
730             Links.EnsureEachLinkExists(sequence);
731             var results = new HashSet<LinkIndex>();
732             //var nextResults = new HashSet<ulong>();
733             //for (var i = 0; i < sequence.Length; i++)
734             //{
735             //    AllUsagesCore(sequence[i], nextResults);
736             //    if (results.IsNullOrEmpty())
737             //    {
738             //        results = nextResults;
739             //        nextResults = new HashSet<ulong>();
740             //    }
741             //    else
742             //    {
743             //        results.IntersectWith(nextResults);
744             //        nextResults.Clear();
745             //    }
746             //}
747             var collector1 = new AllUsagesCollector1(Links.Unsync, results);
748             collector1.Collect(Links.Unsync.GetLink(sequence[0]));
749             var next = new HashSet<ulong>();
750             for (var i = 1; i < sequence.Count; i++)
751             {
752                 var collector = new AllUsagesCollector1(Links.Unsync, next);
753                 collector.Collect(Links.Unsync.GetLink(sequence[i]));
754
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
769 // Does not work
770 //public HashSet<ulong> GetAllPartiallyMatchingSequences5(HashSet<ulong> readAsElements,
771 //    ↳ params ulong[] sequence)
772 //{
773 //    var visited = new HashSet<ulong>();
774 //    var results = new HashSet<ulong>();
775 //    var matcher = new Matcher(this, sequence, visited, x => { results.Add(x); return
776 //    ↳ true; }, readAsElements);
777 //    var last = sequence.Length - 1;
778 //    for (var i = 0; i < last; i++)
779 //    {
780 //        PartialStepRight(matcher.PartialMatch, sequence[i], sequence[i + 1]);
781 //    }
782 //    return results;
783 //}
784
785 public List<ulong> GetAllPartiallyMatchingSequences(params ulong[] sequence)
786 {
787     return _sync.ExecuteReadOperation(() =>

```

```

783 {
784     if (sequence.Length > 0)
785     {
786         Links.EnsureEachLinkExists(sequence);
787         //var firstElement = sequence[0];
788         //if (sequence.Length == 1)
789         //{
790             //results.Add(firstElement);
791             //return results;
792         //}
793         //if (sequence.Length == 2)
794         //{
795             //var doublet = _links.SearchCore(firstElement, sequence[1]);
796             //if (doublet != Doublets.Links.Null)
797             //    results.Add(doublet);
798             //return results;
799         //}
800         //var lastElement = sequence[sequence.Length - 1];
801         //Func<ulong, bool> handler = x =>
802         //{
803             //    if (StartsWith(x, firstElement) && EndsWith(x, lastElement))
804             //        results.Add(x);
805             //    return true;
806         //};
807         //if (sequence.Length >= 2)
808         //    StepRight(handler, sequence[0], sequence[1]);
809         //var last = sequence.Length - 2;
810         //for (var i = 1; i < last; i++)
811         //    PartialStepRight(handler, sequence[i], sequence[i + 1]);
812         //if (sequence.Length >= 3)
813         //    StepLeft(handler, sequence[sequence.Length - 2],
814             //        sequence[sequence.Length - 1]);
815         //if (sequence.Length == 1)
816         //{
817             //    throw new NotImplementedException(); // all sequences, containing
818             //    this element?
819         //}
820         //if (sequence.Length == 2)
821         //{
822             //    var results = new List<ulong>();
823             //    PartialStepRight(results.Add, sequence[0], sequence[1]);
824             //    return results;
825         //}
826         //var matches = new List<List<ulong>>();
827         //var last = sequence.Length - 1;
828         //for (var i = 0; i < last; i++)
829         //{
830             //    var results = new List<ulong>();
831             //    //StepRight(results.Add, sequence[i], sequence[i + 1]);
832             //    PartialStepRight(results.Add, sequence[i], sequence[i + 1]);
833             //    if (results.Count > 0)
834             //        matches.Add(results);
835             //    else
836             //        return results;
837             //    if (matches.Count == 2)
838             //    {
839                 //    var merged = new List<ulong>();
840                 //    for (var j = 0; j < matches[0].Count; j++)
841                 //        for (var k = 0; k < matches[1].Count; k++)
842                 //            CloseInnerConnections(merged.Add, matches[0][j],
843                     //                matches[1][k]);
844                 //    if (merged.Count > 0)
845                 //        matches = new List<List<ulong>> { merged };
846                 //    else
847                 //        return new List<ulong>();
848             //    }
849             //}
850         //if (matches.Count > 0)
851         //{
852             //    var usages = new HashSet<ulong>();
853             //    for (int i = 0; i < sequence.Length; i++)
854             //    {
855                 //    AllUsagesCore(sequence[i], usages);
856             //    }
857             //    //for (int i = 0; i < matches[0].Count; i++)
858             //    //    AllUsagesCore(matches[0][i], usages);
859             //    //usages.UnionWith(matches[0]);

```

```

856         return usages.ToList();
857     }
858     var firstLinkUsages = new HashSet<ulong>();
859     AllUsagesCore(sequence[0], firstLinkUsages);
860     firstLinkUsages.Add(sequence[0]);
861     //var previousMatchings = firstLinkUsages.ToList(); //new List<ulong>() {
862     //    sequence[0] }; // or all sequences, containing this element?
863     //return GetAllPartiallyMatchingSequencesCore(sequence, firstLinkUsages,
864     //    1).ToList();
865     var results = new HashSet<ulong>();
866     foreach (var match in GetAllPartiallyMatchingSequencesCore(sequence,
867         firstLinkUsages, 1))
868     {
869         AllUsagesCore(match, results);
870     }
871     return results.ToList();
872 }
873
874 /// <remarks>
875 /// TODO: Может потребоваться ограничение на уровень глубины рекурсии
876 /// </remarks>
877 public HashSet<ulong> AllUsages(ulong link)
878 {
879     return _sync.ExecuteReadOperation(() =>
880     {
881         var usages = new HashSet<ulong>();
882         AllUsagesCore(link, usages);
883         return usages;
884     });
885 }
886
887 // При сборе всех использований (последовательностей) можно сохранять обратный путь к
888 // той связи с которой начинался поиск (STTTSSSTT),
889 // причём достаточно одного бита для хранения перехода влево или вправо
890 private void AllUsagesCore(ulong link, HashSet<ulong> usages)
891 {
892     bool handler(ulong doublet)
893     {
894         if (usages.Add(doublet))
895         {
896             AllUsagesCore(doublet, usages);
897         }
898         return true;
899     }
900     Links.Unsync.Each(link, Constants.Any, handler);
901     Links.Unsync.Each(Constants.Any, link, handler);
902 }
903
904 public HashSet<ulong> AllBottomUsages(ulong link)
905 {
906     return _sync.ExecuteReadOperation(() =>
907     {
908         var visits = new HashSet<ulong>();
909         var usages = new HashSet<ulong>();
910         AllBottomUsagesCore(link, visits, usages);
911         return usages;
912     });
913 }
914
915 private void AllBottomUsagesCore(ulong link, HashSet<ulong> visits, HashSet<ulong>
916     usages)
917 {
918     bool handler(ulong doublet)
919     {
920         if (visits.Add(doublet))
921         {
922             AllBottomUsagesCore(doublet, visits, usages);
923         }
924         return true;
925     }
926     if (Links.Unsync.Count(Constants.Any, link) == 0)
927     {
928         usages.Add(link);
929     }
930     else

```

```

929     {
930         Links.Unsync.Each(link, Constants.Any, handler);
931         Links.Unsync.Each(Constants.Any, link, handler);
932     }
933 }
934
935 public ulong CalculateTotalSymbolFrequencyCore(ulong symbol)
936 {
937     if (Options.UseSequenceMarker)
938     {
939         var counter = new TotalMarkedSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
940             ↪ Options.MarkedSequenceMatcher, symbol);
941         return counter.Count();
942     }
943     else
944     {
945         var counter = new TotalSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
946             ↪ symbol);
947         return counter.Count();
948     }
949 }
950
951 private bool AllUsagesCore1(ulong link, HashSet<ulong> usages, Func<IList<LinkIndex>,
952     ↪ LinkIndex> outerHandler)
953 {
954     bool handler(ulong doublet)
955     {
956         if (usages.Add(doublet))
957         {
958             if (outerHandler(new LinkAddress<LinkIndex>(doublet)) != Constants.Continue)
959             {
960                 return false;
961             }
962             if (!AllUsagesCore1(doublet, usages, outerHandler))
963             {
964                 return false;
965             }
966         }
967         return true;
968     }
969     return Links.Unsync.Each(link, Constants.Any, handler)
970         && Links.Unsync.Each(Constants.Any, link, handler);
971 }
972
973 public void CalculateAllUsages(ulong[] totals)
974 {
975     var calculator = new AllUsagesCalculator(Links, totals);
976     calculator.Calculate();
977 }
978
979 public void CalculateAllUsages2(ulong[] totals)
980 {
981     var calculator = new AllUsagesCalculator2(Links, totals);
982     calculator.Calculate();
983 }
984
985 private class AllUsagesCalculator
986 {
987     private readonly SynchronizedLinks<ulong> _links;
988     private readonly ulong[] _totals;
989
990     public AllUsagesCalculator(SynchronizedLinks<ulong> links, ulong[] totals)
991     {
992         _links = links;
993         _totals = totals;
994     }
995
996     public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
997         ↪ CalculateCore);
998
999     private bool CalculateCore(ulong link)
1000     {
1001         if (_totals[link] == 0)
1002         {
1003             var total = 1UL;
1004             _totals[link] = total;
1005             var visitedChildren = new HashSet<ulong>();
1006             bool linkCalculator(ulong child)
1007             {

```

```

1004         if (link != child && visitedChildren.Add(child))
1005         {
1006             total += _totals[child] == 0 ? 1 : _totals[child];
1007         }
1008         return true;
1009     }
1010     _links.Unsync.Each(link, _links.Constants.Any, linkCalculator);
1011     _links.Unsync.Each(_links.Constants.Any, link, linkCalculator);
1012     _totals[link] = total;
1013 }
1014 return true;
1015 }
1016 }
1017
1018 private class AllUsagesCalculator2
1019 {
1020     private readonly SynchronizedLinks<ulong> _links;
1021     private readonly ulong[] _totals;
1022
1023     public AllUsagesCalculator2(SynchronizedLinks<ulong> links, ulong[] totals)
1024     {
1025         _links = links;
1026         _totals = totals;
1027     }
1028
1029     public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
        ↪ CalculateCore);
1030
1031     private bool IsElement(ulong link)
1032     {
1033         // _linksInSequence.Contains(link) ||
1034         return _links.Unsync.GetTarget(link) == link || _links.Unsync.GetSource(link) ==
        ↪ link;
1035     }
1036
1037     private bool CalculateCore(ulong link)
1038     {
1039         // TODO: Проработать защиту от заикливания
1040         // Основано на SequenceWalker.WalkLeft
1041         Func<ulong, ulong> getSource = _links.Unsync.GetSource;
1042         Func<ulong, ulong> getTarget = _links.Unsync.GetTarget;
1043         Func<ulong, bool> isElement = IsElement;
1044         void visitLeaf(ulong parent)
1045         {
1046             if (link != parent)
1047             {
1048                 _totals[parent]++;
1049             }
1050         }
1051         void visitNode(ulong parent)
1052         {
1053             if (link != parent)
1054             {
1055                 _totals[parent]++;
1056             }
1057         }
1058         var stack = new Stack();
1059         var element = link;
1060         if (isElement(element))
1061         {
1062             visitLeaf(element);
1063         }
1064         else
1065         {
1066             while (true)
1067             {
1068                 if (isElement(element))
1069                 {
1070                     if (stack.Count == 0)
1071                     {
1072                         break;
1073                     }
1074                     element = stack.Pop();
1075                     var source = getSource(element);
1076                     var target = getTarget(element);
1077                     // Обработка элемента
1078                     if (isElement(target))
1079                     {
1080                         visitLeaf(target);

```

```

1081         }
1082         if (isElement(source))
1083         {
1084             visitLeaf(source);
1085         }
1086         element = source;
1087     }
1088     else
1089     {
1090         stack.Push(element);
1091         visitNode(element);
1092         element = getTarget(element);
1093     }
1094 }
1095 }
1096 _totals[link]++;
1097 return true;
1098 }
1099 }
1100
1101 private class AllUsagesCollector
1102 {
1103     private readonly ILinks<ulong> _links;
1104     private readonly HashSet<ulong> _usages;
1105
1106     public AllUsagesCollector(ILinks<ulong> links, HashSet<ulong> usages)
1107     {
1108         _links = links;
1109         _usages = usages;
1110     }
1111
1112     public bool Collect(ulong link)
1113     {
1114         if (_usages.Add(link))
1115         {
1116             _links.Each(link, _links.Constants.Any, Collect);
1117             _links.Each(_links.Constants.Any, link, Collect);
1118         }
1119         return true;
1120     }
1121 }
1122
1123 private class AllUsagesCollector1
1124 {
1125     private readonly ILinks<ulong> _links;
1126     private readonly HashSet<ulong> _usages;
1127     private readonly ulong _continue;
1128
1129     public AllUsagesCollector1(ILinks<ulong> links, HashSet<ulong> usages)
1130     {
1131         _links = links;
1132         _usages = usages;
1133         _continue = _links.Constants.Continue;
1134     }
1135
1136     public ulong Collect(IList<ulong> link)
1137     {
1138         var linkIndex = _links.GetIndex(link);
1139         if (_usages.Add(linkIndex))
1140         {
1141             _links.Each(Collect, _links.Constants.Any, linkIndex);
1142         }
1143         return _continue;
1144     }
1145 }
1146
1147 private class AllUsagesCollector2
1148 {
1149     private readonly ILinks<ulong> _links;
1150     private readonly BitString _usages;
1151
1152     public AllUsagesCollector2(ILinks<ulong> links, BitString usages)
1153     {
1154         _links = links;
1155         _usages = usages;
1156     }
1157
1158     public bool Collect(ulong link)
1159     {
1160         if (_usages.Add((long)link))

```

```

1161         {
1162             _links.Each(link, _links.Constants.Any, Collect);
1163             _links.Each(_links.Constants.Any, link, Collect);
1164         }
1165         return true;
1166     }
1167 }
1168
1169 private class AllUsagesIntersectingCollector
1170 {
1171     private readonly SynchronizedLinks<ulong> _links;
1172     private readonly HashSet<ulong> _intersectWith;
1173     private readonly HashSet<ulong> _usages;
1174     private readonly HashSet<ulong> _enter;
1175
1176     public AllUsagesIntersectingCollector(SynchronizedLinks<ulong> links, HashSet<ulong>
↪ intersectWith, HashSet<ulong> usages)
1177     {
1178         _links = links;
1179         _intersectWith = intersectWith;
1180         _usages = usages;
1181         _enter = new HashSet<ulong>(); // защита от зацикливания
1182     }
1183
1184     public bool Collect(ulong link)
1185     {
1186         if (_enter.Add(link))
1187         {
1188             if (_intersectWith.Contains(link))
1189             {
1190                 _usages.Add(link);
1191             }
1192             _links.Unsync.Each(link, _links.Constants.Any, Collect);
1193             _links.Unsync.Each(_links.Constants.Any, link, Collect);
1194         }
1195         return true;
1196     }
1197 }
1198
1199 private void CloseInnerConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
↪ right)
1200 {
1201     TryStepLeftUp(handler, left, right);
1202     TryStepRightUp(handler, right, left);
1203 }
1204
1205 private void AllCloseConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
↪ right)
1206 {
1207     // Direct
1208     if (left == right)
1209     {
1210         handler(new LinkAddress<LinkIndex>(left));
1211     }
1212     var doublet = Links.Unsync.SearchOrDefault(left, right);
1213     if (doublet != Constants.Null)
1214     {
1215         handler(new LinkAddress<LinkIndex>(doublet));
1216     }
1217     // Inner
1218     CloseInnerConnections(handler, left, right);
1219     // Outer
1220     StepLeft(handler, left, right);
1221     StepRight(handler, left, right);
1222     PartialStepRight(handler, left, right);
1223     PartialStepLeft(handler, left, right);
1224 }
1225
1226 private HashSet<ulong> GetAllPartiallyMatchingSequencesCore(ulong[] sequence,
↪ HashSet<ulong> previousMatchings, long startAt)
1227 {
1228     if (startAt >= sequence.Length) // ?
1229     {
1230         return previousMatchings;
1231     }
1232     var secondLinkUsages = new HashSet<ulong>();
1233     AllUsagesCore(sequence[startAt], secondLinkUsages);
1234     secondLinkUsages.Add(sequence[startAt]);
1235     var matchings = new HashSet<ulong>();

```



```

1236 var filler = new SetFiller<LinkIndex, LinkIndex>(matchings, Constants.Continue);
1237 //for (var i = 0; i < previousMatchings.Count; i++)
1238 foreach (var secondLinkUsage in secondLinkUsages)
1239 {
1240     foreach (var previousMatching in previousMatchings)
1241     {
1242         //AllCloseConnections(matchings.AddAndReturnVoid, previousMatching,
1243         ↪ secondLinkUsage);
1244         StepRight(filler.AddFirstAndReturnConstant, previousMatching,
1245         ↪ secondLinkUsage);
1246         TryStepRightUp(filler.AddFirstAndReturnConstant, secondLinkUsage,
1247         ↪ previousMatching);
1248         //PartialStepRight(matchings.AddAndReturnVoid, secondLinkUsage,
1249         ↪ sequence[startAt]); // почему-то эта ошибочная запись приводит к
1250         ↪ желаемым результатам.
1251         PartialStepRight(filler.AddFirstAndReturnConstant, previousMatching,
1252         ↪ secondLinkUsage);
1253     }
1254 }
1255 if (matchings.Count == 0)
1256 {
1257     return matchings;
1258 }
1259 return GetAllPartiallyMatchingSequencesCore(sequence, matchings, startAt + 1); // ??
1260 }
1261
1262 private static void EnsureEachLinkIsAnyOrZeroOrManyOrExists(SynchronizedLinks<ulong>
1263 ↪ links, params ulong[] sequence)
1264 {
1265     if (sequence == null)
1266     {
1267         return;
1268     }
1269     for (var i = 0; i < sequence.Length; i++)
1270     {
1271         if (sequence[i] != links.Constants.Any && sequence[i] != ZeroOrMany &&
1272         ↪ !links.Exists(sequence[i]))
1273         {
1274             throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
1275             ↪ $"patternSequence[{i}]");
1276         }
1277     }
1278 }
1279
1280 // Pattern Matching -> Key To Triggers
1281 public HashSet<ulong> MatchPattern(params ulong[] patternSequence)
1282 {
1283     return _sync.ExecuteReadOperation(() =>
1284     {
1285         patternSequence = Simplify(patternSequence);
1286         if (patternSequence.Length > 0)
1287         {
1288             EnsureEachLinkIsAnyOrZeroOrManyOrExists(Links, patternSequence);
1289             var uniqueSequenceElements = new HashSet<ulong>();
1290             for (var i = 0; i < patternSequence.Length; i++)
1291             {
1292                 if (patternSequence[i] != Constants.Any && patternSequence[i] !=
1293                 ↪ ZeroOrMany)
1294                 {
1295                     uniqueSequenceElements.Add(patternSequence[i]);
1296                 }
1297             }
1298             var results = new HashSet<ulong>();
1299             foreach (var uniqueSequenceElement in uniqueSequenceElements)
1300             {
1301                 AllUsagesCore(uniqueSequenceElement, results);
1302             }
1303             var filteredResults = new HashSet<ulong>();
1304             var matcher = new PatternMatcher(this, patternSequence, filteredResults);
1305             matcher.AddAllPatternMatchedToResults(results);
1306             return filteredResults;
1307         }
1308         return new HashSet<ulong>();
1309     });
1310 }
1311
1312 // Найти все возможные связи между указанным списком связей.

```

```

1303 // Находит связи между всеми указанными связями в любом порядке.
1304 // TODO: решить что делать с повторами (когда одни и те же элементы встречаются
1305 //        → несколько раз в последовательности)
1306 public HashSet<ulong> GetAllConnections(params ulong[] linksToConnect)
1307 {
1308     return _sync.ExecuteReadOperation(() =>
1309     {
1310         var results = new HashSet<ulong>();
1311         if (linksToConnect.Length > 0)
1312         {
1313             Links.EnsureEachLinkExists(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 public HashSet<ulong> GetAllConnections1(params ulong[] linksToConnect)
1326 {
1327     return _sync.ExecuteReadOperation(() =>
1328     {
1329         var results = new HashSet<ulong>();
1330         if (linksToConnect.Length > 0)
1331         {
1332             Links.EnsureEachLinkExists(linksToConnect);
1333             var collector1 = new AllUsagesCollector(Links.Unsync, results);
1334             collector1.Collect(linksToConnect[0]);
1335             var next = new HashSet<ulong>();
1336             for (var i = 1; i < linksToConnect.Length; i++)
1337             {
1338                 var collector = new AllUsagesCollector(Links.Unsync, next);
1339                 collector.Collect(linksToConnect[i]);
1340                 results.IntersectWith(next);
1341                 next.Clear();
1342             }
1343             return results;
1344         });
1345 }
1346
1347 public HashSet<ulong> GetAllConnections2(params ulong[] linksToConnect)
1348 {
1349     return _sync.ExecuteReadOperation(() =>
1350     {
1351         var results = new HashSet<ulong>();
1352         if (linksToConnect.Length > 0)
1353         {
1354             Links.EnsureEachLinkExists(linksToConnect);
1355             var collector1 = new AllUsagesCollector(Links, results);
1356             collector1.Collect(linksToConnect[0]);
1357             //AllUsagesCore(linksToConnect[0], results);
1358             for (var i = 1; i < linksToConnect.Length; i++)
1359             {
1360                 var next = new HashSet<ulong>();
1361                 var collector = new AllUsagesIntersectingCollector(Links, results, next);
1362                 collector.Collect(linksToConnect[i]);
1363                 //AllUsagesCore(linksToConnect[i], next);
1364                 //results.IntersectWith(next);
1365                 results = next;
1366             }
1367             return results;
1368         });
1369 }
1370
1371 public List<ulong> GetAllConnections3(params ulong[] linksToConnect)
1372 {
1373     return _sync.ExecuteReadOperation(() =>
1374     {
1375         var results = new BitString((long)Links.Unsync.Count() + 1); // new
1376         //        → BitArray((int)_links.Total + 1);
1377         if (linksToConnect.Length > 0)
1378

```

```

1379     {
1380         Links.EnsureEachLinkExists(linksToConnect);
1381         var collector1 = new AllUsagesCollector2(Links.Unsync, results);
1382         collector1.Collect(linksToConnect[0]);
1383         for (var i = 1; i < linksToConnect.Length; i++)
1384         {
1385             var next = new BitString((long)Links.Unsync.Count() + 1); //new
1386             ↪ BitArray((int)_links.Total + 1);
1387             var collector = new AllUsagesCollector2(Links.Unsync, next);
1388             collector.Collect(linksToConnect[i]);
1389             results = results.And(next);
1390         }
1391         return results.GetSetUInt64Indices();
1392     });
1393 }
1394
1395 private static ulong[] Simplify(ulong[] sequence)
1396 {
1397     // Считаем новый размер последовательности
1398     long newLength = 0;
1399     var zeroOrManyStepped = false;
1400     for (var i = 0; i < sequence.Length; i++)
1401     {
1402         if (sequence[i] == ZeroOrMany)
1403         {
1404             if (zeroOrManyStepped)
1405             {
1406                 continue;
1407             }
1408             zeroOrManyStepped = true;
1409         }
1410         else
1411         {
1412             //if (zeroOrManyStepped) Is it efficient?
1413             zeroOrManyStepped = false;
1414         }
1415         newLength++;
1416     }
1417     // Строим новую последовательность
1418     zeroOrManyStepped = false;
1419     var newSequence = new ulong[newLength];
1420     long j = 0;
1421     for (var i = 0; i < sequence.Length; i++)
1422     {
1423         //var current = zeroOrManyStepped;
1424         //zeroOrManyStepped = patternSequence[i] == zeroOrMany;
1425         //if (current && zeroOrManyStepped)
1426         //    continue;
1427         //var newZeroOrManyStepped = patternSequence[i] == zeroOrMany;
1428         //if (zeroOrManyStepped && newZeroOrManyStepped)
1429         //    continue;
1430         //zeroOrManyStepped = newZeroOrManyStepped;
1431         if (sequence[i] == ZeroOrMany)
1432         {
1433             if (zeroOrManyStepped)
1434             {
1435                 continue;
1436             }
1437             zeroOrManyStepped = true;
1438         }
1439         else
1440         {
1441             //if (zeroOrManyStepped) Is it efficient?
1442             zeroOrManyStepped = false;
1443         }
1444         newSequence[j++] = sequence[i];
1445     }
1446     return newSequence;
1447 }
1448
1449 public static void TestSimplify()
1450 {
1451     var sequence = new ulong[] { ZeroOrMany, ZeroOrMany, 2, 3, 4, ZeroOrMany,
1452     ↪ ZeroOrMany, ZeroOrMany, 4, ZeroOrMany, ZeroOrMany, ZeroOrMany };
1453     var simplifiedSequence = Simplify(sequence);
1454 }
1455
1456 public List<ulong> GetSimilarSequences() => new List<ulong>();

```

```

1456 public void Prediction()
1457 {
1458     //_links
1459     //_sequences
1460 }
1461
1462 #region From Triplets
1463
1464 //public static void DeleteSequence(Link sequence)
1465 //{
1466 //}
1467
1468 public List<ulong> CollectMatchingSequences(ulong[] links)
1469 {
1470     if (links.Length == 1)
1471     {
1472         throw new Exception("Подпоследовательности с одним элементом не
1473             ↳ поддерживаются.");
1474     }
1475     var leftBound = 0;
1476     var rightBound = links.Length - 1;
1477     var left = links[leftBound++];
1478     var right = links[rightBound--];
1479     var results = new List<ulong>();
1480     CollectMatchingSequences(left, leftBound, links, right, rightBound, ref results);
1481     return results;
1482 }
1483
1484 private void CollectMatchingSequences(ulong leftLink, int leftBound, ulong[]
1485     ↳ 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,
1501                         ↳ rightLink, rightBound, ref results);
1502                 }
1503             }
1504         }
1505         else
1506         {
1507             for (var i = elements.Length - 1; i >= 0; i--)
1508             {
1509                 var element = elements[i];
1510                 if (element != 0)
1511                 {
1512                     results.Add(element);
1513                 }
1514             }
1515         }
1516     }
1517     else
1518     {
1519         var nextRightLink = middleLinks[rightBound];
1520         var elements = GetLeftElements(rightLink, nextRightLink);
1521         if (leftBound <= rightBound)
1522         {
1523             for (var i = elements.Length - 1; i >= 0; i--)
1524             {
1525                 var element = elements[i];
1526                 if (element != 0)
1527                 {
1528                     CollectMatchingSequences(leftLink, leftBound, middleLinks,
1529                         ↳ elements[i], rightBound - 1, ref results);
1530                 }
1531             }
1532         }
1533     }
1534 }

```

```

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

```

```

1608     }
1609     return true;
1610 });
1611 if (Links.GetSource(Links.GetSource(leftLink)) == startLink)
1612 {
1613     result[4] = leftLink;
1614 }
1615 return result;
1616 }
1617
1618 public bool TryStepLeft(ulong startLink, ulong leftLink, ulong[] result, int offset)
1619 {
1620     var added = 0;
1621     Links.Each(Constants.Any, startLink, couple =>
1622     {
1623         if (couple != startLink)
1624         {
1625             var coupleSource = Links.GetSource(couple);
1626             if (coupleSource == leftLink)
1627             {
1628                 result[offset] = couple;
1629                 if (++added == 2)
1630                 {
1631                     return false;
1632                 }
1633             }
1634             else if (Links.GetTarget(coupleSource) == leftLink) // coupleSource.Linker
1635                 ↪ == Net.And &&
1636             {
1637                 result[offset + 1] = couple;
1638                 if (++added == 2)
1639                 {
1640                     return false;
1641                 }
1642             }
1643             return true;
1644         });
1645     return added > 0;
1646 }
1647
1648 #endregion
1649
1650 #region Walkers
1651
1652 public class PatternMatcher : RightSequenceWalker<ulong>
1653 {
1654     private readonly Sequences _sequences;
1655     private readonly ulong[] _patternSequence;
1656     private readonly HashSet<LinkIndex> _linksInSequence;
1657     private readonly HashSet<LinkIndex> _results;
1658
1659     #region Pattern Match
1660
1661     enum PatternBlockType
1662     {
1663         Undefined,
1664         Gap,
1665         Elements
1666     }
1667
1668     struct PatternBlock
1669     {
1670         public PatternBlockType Type;
1671         public long Start;
1672         public long Stop;
1673     }
1674
1675     private readonly List<PatternBlock> _pattern;
1676     private int _patternPosition;
1677     private long _sequencePosition;
1678
1679     #endregion
1680
1681     public PatternMatcher(Sequences sequences, LinkIndex[] patternSequence,
1682         ↪ HashSet<LinkIndex> results)
1683         : base(sequences.Links.Unsync, new DefaultStack<ulong>())
1684     {
1685         _sequences = sequences;
1686         _patternSequence = patternSequence;

```

```

1686         _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
1687         ↪ _sequences.Constants.Any && x != ZeroOrMany));
1688         _results = results;
1689         _pattern = CreateDetailedPattern();
1690     }
1691
1692     protected override bool IsElement(ulong link) => _linksInSequence.Contains(link) ||
1693     ↪ base.IsElement(link);
1694
1695     public bool PatternMatch(LinkIndex sequenceToMatch)
1696     {
1697         _patternPosition = 0;
1698         _sequencePosition = 0;
1699         foreach (var part in Walk(sequenceToMatch))
1700         {
1701             if (!PatternMatchCore(part))
1702             {
1703                 break;
1704             }
1705         }
1706         return _patternPosition == _pattern.Count || (_patternPosition == _pattern.Count
1707         ↪ - 1 && _pattern[_patternPosition].Start == 0);
1708     }
1709
1710     private List<PatternBlock> CreateDetailedPattern()
1711     {
1712         var pattern = new List<PatternBlock>();
1713         var patternBlock = new PatternBlock();
1714         for (var i = 0; i < _patternSequence.Length; i++)
1715         {
1716             if (patternBlock.Type == PatternBlockType.Undefined)
1717             {
1718                 if (_patternSequence[i] == _sequences.Constants.Any)
1719                 {
1720                     patternBlock.Type = PatternBlockType.Gap;
1721                     patternBlock.Start = 1;
1722                     patternBlock.Stop = 1;
1723                 }
1724                 else if (_patternSequence[i] == ZeroOrMany)
1725                 {
1726                     patternBlock.Type = PatternBlockType.Gap;
1727                     patternBlock.Start = 0;
1728                     patternBlock.Stop = long.MaxValue;
1729                 }
1730                 else
1731                 {
1732                     patternBlock.Type = PatternBlockType.Elements;
1733                     patternBlock.Start = i;
1734                     patternBlock.Stop = i;
1735                 }
1736             }
1737             else if (patternBlock.Type == PatternBlockType.Elements)
1738             {
1739                 if (_patternSequence[i] == _sequences.Constants.Any)
1740                 {
1741                     pattern.Add(patternBlock);
1742                     patternBlock = new PatternBlock
1743                     {
1744                         Type = PatternBlockType.Gap,
1745                         Start = 1,
1746                         Stop = 1
1747                     };
1748                 }
1749                 else if (_patternSequence[i] == ZeroOrMany)
1750                 {
1751                     pattern.Add(patternBlock);
1752                     patternBlock = new PatternBlock
1753                     {
1754                         Type = PatternBlockType.Gap,
1755                         Start = 0,
1756                         Stop = long.MaxValue
1757                     };
1758                 }
1759                 else
1760                 {
1761                     patternBlock.Stop = i;
1762                 }
1763             }
1764             else // patternBlock.Type == PatternBlockType.Gap
1765             {

```

```

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     if (patternBlock.Type != PatternBlockType.Undefined)
1787     {
1788         pattern.Add(patternBlock);
1789     }
1790     return pattern;
1791 }
1792
1793 // match: search for regexp anywhere in text
1794 //int match(char* regexp, char* text)
1795 //{
1796 //    do
1797 //    {
1798 //    } while (*text++ != '\0');
1799 //    return 0;
1800 //}
1801
1802 // matchhere: search for regexp at beginning of text
1803 //int matchhere(char* regexp, char* text)
1804 //{
1805 //    if (regexp[0] == '\0')
1806 //        return 1;
1807 //    if (regexp[1] == '*')
1808 //        return matchstar(regexp[0], regexp + 2, text);
1809 //    if (regexp[0] == '$' && regexp[1] == '\0')
1810 //        return *text == '\0';
1811 //    if (*text != '\0' && (regexp[0] == '.' || regexp[0] == *text))
1812 //        return matchhere(regexp + 1, text + 1);
1813 //    return 0;
1814 //}
1815
1816 // matchstar: search for c*regexp at beginning of text
1817 //int matchstar(int c, char* regexp, char* text)
1818 //{
1819 //    do
1820 //    {
1821 //        /* a * matches zero or more instances */
1822 //        if (matchhere(regexp, text))
1823 //            return 1;
1824 //    } while (*text != '\0' && (*text++ == c || c == '.'));
1825 //    return 0;
1826 //}
1827
1828 //private void GetNextPatternElement(out LinkIndex element, out long mininumGap, out
1829 //    long maximumGap)
1830 //{
1831 //    mininumGap = 0;
1832 //    maximumGap = 0;
1833 //    element = 0;
1834 //    for (; _patternPosition < _patternSequence.Length; _patternPosition++)
1835 //    {
1836 //        if (_patternSequence[_patternPosition] == Doublets.Links.Null)
1837 //            mininumGap++;
1838 //        else if (_patternSequence[_patternPosition] == ZeroOrMany)
1839 //            maximumGap = long.MaxValue;
1840 //        else
1841 //            break;

```



```

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

```

```

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

```

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

```

1  using System;
2  using System.Collections.Generic;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Sequences
7  {
8      public static class SequencesExtensions
9      {
10         public static TLink Create<TLink>(this ILinks<TLink> sequences, IList<TLink[]>
            ↳ groupedSequence)
11         {
12             var finalSequence = new TLink[groupedSequence.Count];
13             for (var i = 0; i < finalSequence.Length; i++)
14             {
15                 var part = groupedSequence[i];
16                 finalSequence[i] = part.Length == 1 ? part[0] :
                    ↳ sequences.Create(part.ConvertToRestrictionsValues());
17             }
18             return sequences.Create(finalSequence.ConvertToRestrictionsValues());
19         }
20
21         public static IList<TLink> ToList<TLink>(this ILinks<TLink> sequences, TLink sequence)
22         {
23             var list = new List<TLink>();
24             var filler = new ListFiller<TLink, TLink>(list, sequences.Constants.Break);
25             sequences.Each(filler.AddAllValuesAndReturnConstant, new
                ↳ LinkAddress<TLink>(sequence));
26             return list;
27         }
28     }
29 }

```

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

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

```

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

```

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

```

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

```

```

35         return true;
36     }
37
38     [MethodImpl(MethodImplOptions.AggressiveInlining)]
39     public TReturnConstant AddAndReturnConstant(TElement element)
40     {
41         _set.Add(element);
42         return _returnConstant;
43     }
44
45     [MethodImpl(MethodImplOptions.AggressiveInlining)]
46     public TReturnConstant AddFirstAndReturnConstant(ICollection<TElement> collection)
47     {
48         _set.Add(collection[0]);
49         return _returnConstant;
50     }
51 }
52 }

```

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

```

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

```

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

```

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

```

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

```

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

```

```

4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 // #define USEARRAYPOOL
8 #if USEARRAYPOOL
9 using Platform.Collections;
10 #endif
11
12 namespace Platform.Data.Doublets.Sequences.Walkers
13 {
14     public class LeveledSequenceWalker<TLink> : LinksOperatorBase<TLink>, ISequenceWalker<TLink>
15     {
16         private static readonly EqualityComparer<TLink> _equalityComparer =
17             ↳ EqualityComparer<TLink>.Default;
18
19         private readonly Func<TLink, bool> _isElement;
20
21         public LeveledSequenceWalker(ILinks<TLink> links, Func<TLink, bool> isElement) :
22             ↳ base(links) => _isElement = isElement;
23
24         public LeveledSequenceWalker(ILinks<TLink> links) : base(links) => _isElement =
25             ↳ Links.IsPartialPoint;
26
27         public IEnumerable<TLink> Walk(TLink sequence) => ToArray(sequence);
28
29         public TLink[] ToArray(TLink sequence)
30         {
31             var length = 1;
32             var array = new TLink[length];
33             array[0] = sequence;
34             if (_isElement(sequence))
35             {
36                 return array;
37             }
38             bool hasElements;
39             do
40             {
41                 length *= 2;
42                 #if USEARRAYPOOL
43                     var nextArray = ArrayPool.Allocate<ulong>(length);
44                 #else
45                     var nextArray = new TLink[length];
46                 #endif
47                 hasElements = false;
48                 for (var i = 0; i < array.Length; i++)
49                 {
50                     var candidate = array[i];
51                     if (_equalityComparer.Equals(array[i], default))
52                     {
53                         continue;
54                     }
55                     var doubletOffset = i * 2;
56                     if (_isElement(candidate))
57                     {
58                         nextArray[doubletOffset] = candidate;
59                     }
60                     else
61                     {
62                         var link = Links.GetLink(candidate);
63                         var linkSource = Links.GetSource(link);
64                         var linkTarget = Links.GetTarget(link);
65                         nextArray[doubletOffset] = linkSource;
66                         nextArray[doubletOffset + 1] = linkTarget;
67                         if (!hasElements)
68                         {
69                             hasElements = !(_isElement(linkSource) && _isElement(linkTarget));
70                         }
71                     }
72                 }
73             }
74             #if USEARRAYPOOL
75                 if (array.Length > 1)
76                 {
77                     ArrayPool.Free(array);
78                 }
79             #endif
80             array = nextArray;
81         }
82         while (hasElements);
83         var filledElementsCount = CountFilledElements(array);
84         if (filledElementsCount == array.Length)

```

```

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

```

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

```

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

```

```

32     }
33 }
34 }
35 }
36 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Collections.Stacks;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Sequences.Walkers
9  {
10     public abstract class SequenceWalkerBase<TLink> : LinksOperatorBase<TLink>,
11         ↳ ISequenceWalker<TLink>
12     {
13         private readonly IStack<TLink> _stack;
14         private readonly Func<TLink, bool> _isElement;
15
16         protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
17             ↳ isElement) : base(links)
18         {
19             _stack = stack;
20             _isElement = isElement;
21         }
22
23         protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack) : this(links,
24             ↳ stack, links.IsPartialPoint)
25         {
26         }
27
28         public IEnumerable<TLink> Walk(TLink sequence)
29         {
30             _stack.Clear();
31             var element = sequence;
32             if (IsElement(element))
33             {
34                 yield return element;
35             }
36             else
37             {
38                 while (true)
39                 {
40                     if (IsElement(element))
41                     {
42                         if (_stack.IsEmpty)
43                         {
44                             break;
45                         }
46                         element = _stack.Pop();
47                         foreach (var output in WalkContents(element))
48                         {
49                             yield return output;
50                         }
51                         element = GetNextElementAfterPop(element);
52                     }
53                     else
54                     {
55                         _stack.Push(element);
56                         element = GetNextElementAfterPush(element);
57                     }
58                 }
59             }
60         }
61
62         [MethodImpl(MethodImplOptions.AggressiveInlining)]
63         protected virtual bool IsElement(TLink elementLink) => _isElement(elementLink);
64
65         [MethodImpl(MethodImplOptions.AggressiveInlining)]
66         protected abstract TLink GetNextElementAfterPop(TLink element);
67
68         [MethodImpl(MethodImplOptions.AggressiveInlining)]
69         protected abstract TLink GetNextElementAfterPush(TLink element);
70
71         [MethodImpl(MethodImplOptions.AggressiveInlining)]
72         protected abstract IEnumerable<TLink> WalkContents(TLink element);

```



```
70     }
71 }
```

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

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

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

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

./Platform.Data.Doublets/SynchronizedLinks.cs

```
1 using System;
2 using System.Collections.Generic;
3 using Platform.Data.Doublets;
4 using Platform.Threading.Synchronization;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets
9 {
10     /// <remarks>
11     /// TODO: Autogeneration of synchronized wrapper (decorator).
```

```

12  /// TODO: Try to unfold code of each method using IL generation for performance improvements.
13  /// TODO: Or even to unfold multiple layers of implementations.
14  /// </remarks>
15  public class SynchronizedLinks<TLinkAddress> : ISynchronizedLinks<TLinkAddress>
16  {
17      public LinksConstants<TLinkAddress> Constants { get; }
18      public ISynchronization SyncRoot { get; }
19      public ILinks<TLinkAddress> Sync { get; }
20      public ILinks<TLinkAddress> Unsync { get; }
21
22      public SynchronizedLinks(ILinks<TLinkAddress> links) : this(new
        ↳ ReaderWriterLockSynchronization(), links) { }
23
24      public SynchronizedLinks(ISynchronization synchronization, ILinks<TLinkAddress> links)
25      {
26          SyncRoot = synchronization;
27          Sync = this;
28          Unsync = links;
29          Constants = links.Constants;
30      }
31
32      public TLinkAddress Count(IList<TLinkAddress> restriction) =>
        ↳ SyncRoot.ExecuteReadOperation(restriction, Unsync.Count);
33      public TLinkAddress Each(Func<IList<TLinkAddress>, TLinkAddress> handler,
        ↳ IList<TLinkAddress> restrictions) => SyncRoot.ExecuteReadOperation(handler,
        ↳ restrictions, (handler1, restrictions1) => Unsync.Each(handler1, restrictions1));
34      public TLinkAddress Create(IList<TLinkAddress> restrictions) =>
        ↳ SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Create);
35      public TLinkAddress Update(IList<TLinkAddress> restrictions, IList<TLinkAddress>
        ↳ substitution) => SyncRoot.ExecuteWriteOperation(restrictions, substitution,
        ↳ Unsync.Update);
36      public void Delete(IList<TLinkAddress> restrictions) =>
        ↳ SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Delete);
37
38      //public T Trigger(IList<T> restriction, Func<IList<T>, IList<T>, T> matchedHandler,
        ↳ IList<T> substitution, Func<IList<T>, IList<T>, T> substitutedHandler)
39      //{
40      //    if (restriction != null && substitution != null &&
41      //        ↳ !substitution.EqualTo(restriction))
42      //        return SyncRoot.ExecuteWriteOperation(restriction, matchedHandler,
43      //        ↳ substitution, substitutedHandler, Unsync.Trigger);
44      //    return SyncRoot.ExecuteReadOperation(restriction, matchedHandler, substitution,
45      //        ↳ substitutedHandler, Unsync.Trigger);
46      //}

```

./Platform.Data.Doublets/UInt64LinksExtensions.cs

```

1  using System;
2  using System.Text;
3  using System.Collections.Generic;
4  using Platform.Singletons;
5  using Platform.Data.Exceptions;
6  using Platform.Data.Doublets.Unicode;
7
8  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets
11 {
12     public static class UInt64LinksExtensions
13     {
14         public static readonly LinksConstants<ulong> Constants =
            ↳ Default<LinksConstants<ulong>>.Instance;
15
16         public static void UseUnicode(this ILinks<ulong> links) => UnicodeMap.InitNew(links);
17
18         public static void EnsureEachLinkExists(this ILinks<ulong> links, IList<ulong> sequence)
19         {
20             if (sequence == null)
21             {
22                 return;
23             }
24             for (var i = 0; i < sequence.Count; i++)
25             {
26                 if (!links.Exists(sequence[i]))
27                 {
28                     throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
                        ↳ $"sequence[{i}]");

```

```

29     }
30 }
31 }
32
33 public static void EnsureEachLinkIsAnyOrExists(this ILinks<ulong> links, IList<ulong>
↪ sequence)
34 {
35     if (sequence == null)
36     {
37         return;
38     }
39     for (var i = 0; i < sequence.Count; i++)
40     {
41         if (sequence[i] != Constants.Any && !links.Exists(sequence[i]))
42         {
43             throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
↪ $"sequence[{i}]");
44         }
45     }
46 }
47
48 public static bool AnyLinkIsAny(this ILinks<ulong> links, params ulong[] sequence)
49 {
50     if (sequence == null)
51     {
52         return false;
53     }
54     var constants = links.Constants;
55     for (var i = 0; i < sequence.Length; i++)
56     {
57         if (sequence[i] == constants.Any)
58         {
59             return true;
60         }
61     }
62     return false;
63 }
64
65 public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
↪ Func<Link<ulong>, bool> isElement, bool renderIndex = false, bool renderDebug =
↪ false)
66 {
67     var sb = new StringBuilder();
68     var visited = new HashSet<ulong>();
69     links.AppendStructure(sb, visited, linkIndex, isElement, (innerSb, link) =>
↪ innerSb.Append(link.Index), renderIndex, renderDebug);
70     return sb.ToString();
71 }
72
73 public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
↪ Func<Link<ulong>, bool> isElement, Action<StringBuilder, Link<ulong>> appendElement,
↪ bool renderIndex = false, bool renderDebug = false)
74 {
75     var sb = new StringBuilder();
76     var visited = new HashSet<ulong>();
77     links.AppendStructure(sb, visited, linkIndex, isElement, appendElement, renderIndex,
↪ renderDebug);
78     return sb.ToString();
79 }
80
81 public static void AppendStructure(this ILinks<ulong> links, StringBuilder sb,
↪ HashSet<ulong> visited, ulong linkIndex, Func<Link<ulong>, bool> isElement,
↪ Action<StringBuilder, Link<ulong>> appendElement, bool renderIndex = false, bool
↪ renderDebug = false)
82 {
83     if (sb == null)
84     {
85         throw new ArgumentNullException(nameof(sb));
86     }
87     if (linkIndex == Constants.Null || linkIndex == Constants.Any || linkIndex ==
↪ Constants.Itself)
88     {
89         return;
90     }
91     if (links.Exists(linkIndex))
92     {
93         if (visited.Add(linkIndex))
94         {

```

```

95         sb.Append('(');
96         var link = new Link<ulong>(links.GetLink(linkIndex));
97         if (renderIndex)
98         {
99             sb.Append(link.Index);
100             sb.Append(':');
101         }
102         if (link.Source == link.Index)
103         {
104             sb.Append(link.Index);
105         }
106         else
107         {
108             var source = new Link<ulong>(links.GetLink(link.Source));
109             if (isElement(source))
110             {
111                 appendElement(sb, source);
112             }
113             else
114             {
115                 links.AppendStructure(sb, visited, source.Index, isElement,
116                                     ↪ appendElement, renderIndex);
117             }
118         }
119         sb.Append(' ');
120         if (link.Target == link.Index)
121         {
122             sb.Append(link.Index);
123         }
124         else
125         {
126             var target = new Link<ulong>(links.GetLink(link.Target));
127             if (isElement(target))
128             {
129                 appendElement(sb, target);
130             }
131             else
132             {
133                 links.AppendStructure(sb, visited, target.Index, isElement,
134                                     ↪ appendElement, renderIndex);
135             }
136         }
137         sb.Append(')');
138     }
139     else
140     {
141         if (renderDebug)
142         {
143             sb.Append('*');
144         }
145         sb.Append(linkIndex);
146     }
147 }
148 else
149 {
150     if (renderDebug)
151     {
152         sb.Append('~');
153     }
154     sb.Append(linkIndex);
155 }
156 }

```

./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.Max(x => x.TransactionId);
259 _uniqueTimestampFactory = new UniqueTimestampFactory();
260 _logAddress = logAddress;
261 _log = FileHelpers.Append(logAddress);
262 _transitions = new Queue<Transition>();
263 _transitionsPusher = new Task(TransitionsPusher);
264 _transitionsPusher.Start();
265 }
266
267 public IList<ulong> GetLinkValue(ulong link) => Links.GetLink(link);
268
269 public override ulong Create(IList<ulong> restrictions)
270 {
271     var createdLinkIndex = Links.Create();
272     var createdLink = new Link<ulong>(Links.GetLink(createdLinkIndex));
273     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↳ default, createdLink));
274     return createdLinkIndex;
275 }
276
277 public override ulong Update(IList<ulong> restrictions, IList<ulong> substitution)
278 {
279     var linkIndex = restrictions[Constants.IndexPart];
280     var beforeLink = new Link<ulong>(Links.GetLink(linkIndex));
281     linkIndex = Links.Update(restrictions, substitution);
282     var afterLink = new Link<ulong>(Links.GetLink(linkIndex));
283     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↳ beforeLink, afterLink));
284     return linkIndex;
285 }
286
287 public override void Delete(IList<ulong> restrictions)
288 {
289     var link = restrictions[Constants.IndexPart];
290     var deletedLink = new Link<ulong>(Links.GetLink(link));
291     Links.Delete(link);
292     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↳ deletedLink, default));
293 }
294
295 [MethodImpl(MethodImplOptions.AggressiveInlining)]
296 private Queue<Transition> GetCurrentTransitions() => _currentTransactionTransitions ??
    ↳ _transitions;
297
298 private void CommitTransition(Transition transition)
299 {
300     if (_currentTransaction != null)
301     {
302         Transaction.EnsureTransactionAllowsWriteOperations(_currentTransaction);
303     }
304     var transitions = GetCurrentTransitions();
305     transitions.Enqueue(transition);
306 }
307
308 private void RevertTransition(Transition transition)
309 {
310     if (transition.After.IsNull()) // Revert Deletion with Creation
311     {
312         Links.Create();

```



```

313     }
314     else if (transition.Before.IsNull()) // Revert Creation with Deletion
315     {
316         Links.Delete(transition.After.Index);
317     }
318     else // Revert Update
319     {
320         Links.Update(new[] { transition.After.Index, transition.Before.Source,
321             ↪ transition.Before.Target });
322     }
323 }
324 private void ResetCurrentTransation()
325 {
326     _currentTransactionId = 0;
327     _currentTransactionTransitions = null;
328     _currentTransaction = null;
329 }
330 private void PushTransitions()
331 {
332     if (_log == null || _transitions == null)
333     {
334         return;
335     }
336     for (var i = 0; i < _transitions.Count; i++)
337     {
338         var transition = _transitions.Dequeue();
339
340         _log.Write(transition);
341         _lastCommittedTransition = transition;
342     }
343 }
344 }
345 private void TransitionsPusher()
346 {
347     while (!IsDisposed && _transitionsPusher != null)
348     {
349         Thread.Sleep(DefaultPushDelay);
350         PushTransitions();
351     }
352 }
353 }
354 public Transaction BeginTransaction() => new Transaction(this);
355 private void DisposeTransitions()
356 {
357     try
358     {
359         {
360             var pusher = _transitionsPusher;
361             if (pusher != null)
362             {
363                 _transitionsPusher = null;
364                 pusher.Wait();
365             }
366             if (_transitions != null)
367             {
368                 PushTransitions();
369             }
370             _log.DisposeIfPossible();
371             FileHelpers.WriteFirst(_logAddress, _lastCommittedTransition);
372         }
373         catch (Exception ex)
374         {
375             ex.Ignore();
376         }
377     }
378 }
379 #region DisposalBase
380 protected override void Dispose(bool manual, bool wasDisposed)
381 {
382     if (!wasDisposed)
383     {
384         DisposeTransitions();
385     }
386     base.Dispose(manual, wasDisposed);
387 }
388 }
389
390

```

```
#endregion
```

```
391 }  
392 }  
393 }
```

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

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

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

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

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

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

```

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

```

```

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 }
119 public static List<ulong[]> FromStringToLinkArrayGroups(string sequence)
120 {
121     var result = new List<ulong[]>();
122     var offset = 0;
123     while (offset < sequence.Length)
124     {
125         var currentCategory = CharUnicodeInfo.GetUnicodeCategory(sequence[offset]);
126         var relativeLength = 1;
127         var absoluteLength = offset + relativeLength;
128         while (absoluteLength < sequence.Length &&
129             currentCategory ==
130             ↪ CharUnicodeInfo.GetUnicodeCategory(sequence[absoluteLength]))
131         {
132             relativeLength++;
133             absoluteLength++;
134         }
135         // char array to ulong array
136         var innerSequence = new ulong[relativeLength];
137         var maxLength = offset + relativeLength;
138         for (var i = offset; i < maxLength; i++)
139         {
140             innerSequence[i - offset] = FromCharToLink(sequence[i]);
141         }
142         result.Add(innerSequence);
143         offset += relativeLength;
144     }
145     return result;
146 }
147 public static List<ulong[]> FromLinkArrayToLinkArrayGroups(ulong[] array)
148 {
149     var result = new List<ulong[]>();
150     var offset = 0;
151     while (offset < array.Length)
152     {
153         var relativeLength = 1;
154         if (array[offset] <= LastCharLink)
155         {
156             var currentCategory =
157                 ↪ CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(array[offset]));

```

```

158         var absoluteLength = offset + relativeLength;
159         while (absoluteLength < array.Length &&
160             array[absoluteLength] <= LastCharLink &&
161             currentCategory == CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(
162                 ↪ array[absoluteLength])))
163         {
164             relativeLength++;
165             absoluteLength++;
166         }
167     else
168     {
169         var absoluteLength = offset + relativeLength;
170         while (absoluteLength < array.Length && array[absoluteLength] > LastCharLink)
171         {
172             relativeLength++;
173             absoluteLength++;
174         }
175     }
176     // copy array
177     var innerSequence = new ulong[relativeLength];
178     var maxLength = offset + relativeLength;
179     for (var i = offset; i < maxLength; i++)
180     {
181         innerSequence[i - offset] = array[i];
182     }
183     result.Add(innerSequence);
184     offset += relativeLength;
185 }
186 return result;
187 }
188 }
189 }

```

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

```

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

```

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

```

1 using System;
2 using System.Linq;
3 using Platform.Data.Doublets.Sequences.Walkers;
4 using Platform.Interfaces;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Unicode
9 {
10     public class UnicodeSequenceToStringConverter<TLink> : LinksOperatorBase<TLink>,
11         ↪ IConverter<TLink, string>
12     {
13         private readonly ICriterionMatcher<TLink> _unicodeSequenceCriterionMatcher;
14         private readonly ISequenceWalker<TLink> _sequenceWalker;
15         private readonly IConverter<TLink, char> _unicodeSymbolToCharConverter;
16
17         public UnicodeSequenceToStringConverter(ILinks<TLink> links, ICriterionMatcher<TLink>
18             ↪ unicodeSequenceCriterionMatcher, ISequenceWalker<TLink> sequenceWalker,
19             ↪ IConverter<TLink, char> unicodeSymbolToCharConverter) : base(links)
20         {
21             _unicodeSequenceCriterionMatcher = unicodeSequenceCriterionMatcher;
22             _sequenceWalker = sequenceWalker;
23             _unicodeSymbolToCharConverter = unicodeSymbolToCharConverter;
24         }
25     }
26 }

```

```

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

```

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

```

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

```

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

```

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

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Xunit;
4  using Platform.Diagnostics;

```

```

5
6 namespace Platform.Data.Doublets.Tests
7 {
8     public static class ComparisonTests
9     {
10         private class UInt64Comparer : IComparer

```

./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 }

```

```

15     }
16
17     private static bool Equals1<T>(T x, T y) => Equals(x, y);
18
19     private static bool Equals2<T>(T x, T y) => x.Equals(y);
20
21     private static bool Equals3(ulong x, ulong y) => x == y;
22
23     [Fact]
24     public static void EqualsPerfomanceTest()
25     {
26         const int N = 1000000;
27
28         ulong x = 10;
29         ulong y = 500;
30
31         bool result = false;
32
33         var ts1 = Performance.Measure(() =>
34         {
35             for (int i = 0; i < N; i++)
36             {
37                 result = Equals1(x, y);
38             }
39         });
40
41         var ts2 = Performance.Measure(() =>
42         {
43             for (int i = 0; i < N; i++)
44             {
45                 result = Equals2(x, y);
46             }
47         });
48
49         var ts3 = Performance.Measure(() =>
50         {
51             for (int i = 0; i < N; i++)
52             {
53                 result = Equals3(x, y);
54             }
55         });
56
57         var equalityComparer1 = EqualityComparer<ulong>.Default;
58
59         var ts4 = Performance.Measure(() =>
60         {
61             for (int i = 0; i < N; i++)
62             {
63                 result = equalityComparer1.Equals(x, y);
64             }
65         });
66
67         var equalityComparer2 = new UInt64EqualityComparer();
68
69         var ts5 = Performance.Measure(() =>
70         {
71             for (int i = 0; i < N; i++)
72             {
73                 result = equalityComparer2.Equals(x, y);
74             }
75         });
76
77         Func<ulong, ulong, bool> equalityComparer3 = equalityComparer2.Equals;
78
79         var ts6 = Performance.Measure(() =>
80         {
81             for (int i = 0; i < N; i++)
82             {
83                 result = equalityComparer3(x, y);
84             }
85         });
86
87         var comparer = Comparer<ulong>.Default;
88
89         var ts7 = Performance.Measure(() =>
90         {
91             for (int i = 0; i < N; i++)
92             {
93                 result = comparer.Compare(x, y) == 0;
94             }
95         });
96     }

```



```

95     });
96
97     Assert.True(ts2 < ts1);
98     Assert.True(ts3 < ts2);
99     Assert.True(ts5 < ts4);
100    Assert.True(ts5 < ts6);
101
102    Console.WriteLine($"{ts1} {ts2} {ts3} {ts4} {ts5} {ts6} {ts7} {result}");
103 }
104 }
105 }

```

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

```

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

```

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

```

1  using System;
2  using System.Linq;
3  using System.Collections.Generic;
4  using Xunit;
5  using Platform.Data.Doublets.Sequences;
6  using Platform.Data.Doublets.Sequences.Frequencies.Cache;
7  using Platform.Data.Doublets.Sequences.Frequencies.Counters;
8  using Platform.Data.Doublets.Sequences.Converters;
9  using Platform.Data.Doublets.PropertyOperators;
10 using Platform.Data.Doublets.Incrementers;
11 using Platform.Data.Doublets.Sequences.Walkers;

```

```

12 using Platform.Data.Doublets.Sequences.Indexes;
13 using Platform.Data.Doublets.Unicode;
14 using Platform.Data.Doublets.Numbers.Unary;
15
16 namespace Platform.Data.Doublets.Tests
17 {
18     public static class OptimalVariantSequenceTests
19     {
20         private const string SequenceExample = "зеленела зелёная зелень";
21
22         [Fact]
23         public static void LinksBasedFrequencyStoredOptimalVariantSequenceTest()
24         {
25             using (var scope = new TempLinksTestScope(useSequences: false))
26             {
27                 var links = scope.Links;
28                 var constants = links.Constants;
29
30                 links.UseUnicode();
31
32                 var sequence = UnicodeMap.FromStringToLinkArray(SequenceExample);
33
34                 var meaningRoot = links.CreatePoint();
35                 var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
36                 var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
37                 var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
38                     ↪ constants.Itself);
39
40                 var unaryNumberToAddressConverter = new
41                     ↪ UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
42                 var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
43                 var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
44                     ↪ frequencyMarker, unaryOne, unaryNumberIncrementer);
45                 var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
46                     ↪ frequencyPropertyMarker, frequencyMarker);
47                 var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
48                     ↪ frequencyPropertyOperator, frequencyIncrementer);
49                 var linkToItsFrequencyNumberConverter = new
50                     ↪ LinkToItsFrequencyNumberConverter<ulong>(links, frequencyPropertyOperator,
51                     ↪ unaryNumberToAddressConverter);
52                 var sequenceToItsLocalElementLevelsConverter = new
53                     ↪ SequenceToItsLocalElementLevelsConverter<ulong>(links,
54                     ↪ linkToItsFrequencyNumberConverter);
55                 var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
56                     ↪ sequenceToItsLocalElementLevelsConverter);
57
58                 var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
59                     ↪ Walker = new LeveledSequenceWalker<ulong>(links) });
60
61                 ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
62                     ↪ index, optimalVariantConverter);
63             }
64         }
65
66         [Fact]
67         public static void DictionaryBasedFrequencyStoredOptimalVariantSequenceTest()
68         {
69             using (var scope = new TempLinksTestScope(useSequences: false))
70             {
71                 var links = scope.Links;
72
73                 links.UseUnicode();
74
75                 var sequence = UnicodeMap.FromStringToLinkArray(SequenceExample);
76
77                 var linksToFrequencies = new Dictionary<ulong, ulong>();
78
79                 var totalSequenceSymbolFrequencyCounter = new
80                     ↪ TotalSequenceSymbolFrequencyCounter<ulong>(links);
81
82                 var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
83                     ↪ totalSequenceSymbolFrequencyCounter);
84
85                 var index = new
86                     ↪ CachedFrequencyIncrementingSequenceIndex<ulong>(linkFrequenciesCache);
87                 var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFreque
88                     ↪ ncyNumberConverter<ulong>(linkFrequenciesCache);

```

```

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

```

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

```

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

```



```

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 }

```

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

```

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

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Diagnostics;
4  using System.Linq;
5  using Xunit;
6  using Platform.Collections;
7  using Platform.Random;
8  using Platform.IO;
9  using Platform.Singletons;
10 using Platform.Data.Doublets.Sequences;

```

```

11 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
12 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
13 using Platform.Data.Doublets.Sequences.Converters;
14 using Platform.Data.Doublets.Unicode;
15
16 namespace Platform.Data.Doublets.Tests
17 {
18     public static class SequencesTests
19     {
20         private static readonly LinksConstants<ulong> _constants =
21             ↳ Default<LinksConstants<ulong>>.Instance;
22
23         static SequencesTests()
24         {
25             // Trigger static constructor to not mess with performance measurements
26             _ = BitString.GetBitMaskFromIndex(1);
27         }
28
29         [Fact]
30         public static void CreateAllVariantsTest()
31         {
32             const long sequenceLength = 8;
33
34             using (var scope = new TempLinksTestScope(useSequences: true))
35             {
36                 var links = scope.Links;
37                 var sequences = scope.Sequences;
38
39                 var sequence = new ulong[sequenceLength];
40                 for (var i = 0; i < sequenceLength; i++)
41                 {
42                     sequence[i] = links.Create();
43                 }
44
45                 var sw1 = Stopwatch.StartNew();
46                 var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
47
48                 var sw2 = Stopwatch.StartNew();
49                 var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();
50
51                 Assert.True(results1.Count > results2.Length);
52                 Assert.True(sw1.Elapsed > sw2.Elapsed);
53
54                 for (var i = 0; i < sequenceLength; i++)
55                 {
56                     links.Delete(sequence[i]);
57                 }
58
59                 Assert.True(links.Count() == 0);
60             }
61
62             //[Fact]
63             //public void CUDDTest()
64             //{
65             //    var tempFilename = Path.GetTempFileName();
66
67             //    const long sequenceLength = 8;
68
69             //    const ulong itself = LinksConstants.Itself;
70
71             //    using (var memoryAdapter = new ResizableDirectMemoryLinks(tempFilename,
72             //        ↳ DefaultLinksSizeStep))
73             //    using (var links = new Links(memoryAdapter))
74             //    {
75             //        var sequence = new ulong[sequenceLength];
76             //        for (var i = 0; i < sequenceLength; i++)
77             //            sequence[i] = links.Create(itself, itself);
78
79             //        SequencesOptions o = new SequencesOptions();
80
81             //        TODO: Из числа в bool значения o.UseSequenceMarker = ((value & 1) != 0)
82             //        o.
83
84             //        var sequences = new Sequences(links);
85
86             //        var sw1 = Stopwatch.StartNew();
87             //        var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
88
89             //        var sw2 = Stopwatch.StartNew();

```

```

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

```

```

168     for (var i = 0; i < sequenceLength; i++)
169     {
170         sequence[i] = links.Create();
171     }
172
173     var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
174
175     var sw1 = Stopwatch.StartNew();
176     var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();
177
178     var sw2 = Stopwatch.StartNew();
179     var searchResults2 = sequences.GetAllMatchingSequences0(sequence); sw2.Stop();
180
181     var sw3 = Stopwatch.StartNew();
182     var searchResults3 = sequences.GetAllMatchingSequences1(sequence); sw3.Stop();
183
184     // На количестве в 200 элементов это будет занимать вечность
185     //var sw4 = Stopwatch.StartNew();
186     //var searchResults4 = sequences.Each(sequence); sw4.Stop();
187
188     Assert.True(searchResults2.Count == 1 && balancedVariant == searchResults2[0]);
189
190     Assert.True(searchResults3.Count == 1 && balancedVariant ==
191         ↪ searchResults3.First());
192
193     //Assert.True(sw1.Elapsed < sw2.Elapsed);
194
195     for (var i = 0; i < sequenceLength; i++)
196     {
197         links.Delete(sequence[i]);
198     }
199 }
200
201 [Fact]
202 public static void AllPartialVariantsSearchTest()
203 {
204     const long sequenceLength = 8;
205
206     using (var scope = new TempLinksTestScope(useSequences: true))
207     {
208         var links = scope.Links;
209         var sequences = scope.Sequences;
210
211         var sequence = new ulong[sequenceLength];
212         for (var i = 0; i < sequenceLength; i++)
213         {
214             sequence[i] = links.Create();
215         }
216
217         var createResults = sequences.CreateAllVariants2(sequence);
218
219         //var createResultsStrings = createResults.Select(x => x + ": " +
220             ↪ sequences.FormatSequence(x)).ToList();
221         //Global.Trash = createResultsStrings;
222
223         var partialSequence = new ulong[sequenceLength - 2];
224
225         Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
226
227         var sw1 = Stopwatch.StartNew();
228         var searchResults1 =
229             ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
230
231         var sw2 = Stopwatch.StartNew();
232         var searchResults2 =
233             ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
234
235         //var sw3 = Stopwatch.StartNew();
236         //var searchResults3 =
237             ↪ sequences.GetAllPartiallyMatchingSequences2(partialSequence); sw3.Stop();
238
239         var sw4 = Stopwatch.StartNew();
240         var searchResults4 =
241             ↪ sequences.GetAllPartiallyMatchingSequences3(partialSequence); sw4.Stop();
242
243         //Global.Trash = searchResults3;
244
245         //var searchResults1Strings = searchResults1.Select(x => x + ": " +
246             ↪ sequences.FormatSequence(x)).ToList();

```



```

241 //Global.Trash = searchResults1Strings;
242
243 var intersection1 = createResults.Intersect(searchResults1).ToList();
244 Assert.True(intersection1.Count == createResults.Length);
245
246 var intersection2 = createResults.Intersect(searchResults2).ToList();
247 Assert.True(intersection2.Count == createResults.Length);
248
249 var intersection4 = createResults.Intersect(searchResults4).ToList();
250 Assert.True(intersection4.Count == createResults.Length);
251
252 for (var i = 0; i < sequenceLength; i++)
253 {
254     links.Delete(sequence[i]);
255 }
256 }
257 }
258
259 [Fact]
260 public static void BalancedPartialVariantsSearchTest()
261 {
262     const long sequenceLength = 200;
263
264     using (var scope = new TempLinksTestScope(useSequences: true))
265     {
266         var links = scope.Links;
267         var sequences = scope.Sequences;
268
269         var sequence = new ulong[sequenceLength];
270         for (var i = 0; i < sequenceLength; i++)
271         {
272             sequence[i] = links.Create();
273         }
274
275         var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
276
277         var balancedVariant = balancedVariantConverter.Convert(sequence);
278
279         var partialSequence = new ulong[sequenceLength - 2];
280
281         Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
282
283         var sw1 = Stopwatch.StartNew();
284         var searchResults1 =
285             ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
286
287         var sw2 = Stopwatch.StartNew();
288         var searchResults2 =
289             ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
290
291         Assert.True(searchResults1.Count == 1 && balancedVariant == searchResults1[0]);
292
293         Assert.True(searchResults2.Count == 1 && balancedVariant ==
294             ↪ searchResults2.First());
295
296         for (var i = 0; i < sequenceLength; i++)
297         {
298             links.Delete(sequence[i]);
299         }
300     }
301 }
302
303 [Fact(Skip = "Correct implementation is pending")]
304 public static void PatternMatchTest()
305 {
306     var zeroOrMany = Sequences.Sequences.ZeroOrMany;
307
308     using (var scope = new TempLinksTestScope(useSequences: true))
309     {
310         var links = scope.Links;
311         var sequences = scope.Sequences;
312
313         var e1 = links.Create();
314         var e2 = links.Create();
315
316         var sequence = new[]
317         {
318             e1, e2, e1, e2 // mama / papa
319         };

```

```

318     var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
319
320     var balancedVariant = balancedVariantConverter.Convert(sequence);
321
322     // 1: [1]
323     // 2: [2]
324     // 3: [1,2]
325     // 4: [1,2,1,2]
326
327     var doublet = links.GetSource(balancedVariant);
328
329     var matchedSequences1 = sequences.MatchPattern(e2, e1, zeroOrMany);
330
331     Assert.True(matchedSequences1.Count == 0);
332
333     var matchedSequences2 = sequences.MatchPattern(zeroOrMany, e2, e1);
334
335     Assert.True(matchedSequences2.Count == 0);
336
337     var matchedSequences3 = sequences.MatchPattern(e1, zeroOrMany, e1);
338
339     Assert.True(matchedSequences3.Count == 0);
340
341     var matchedSequences4 = sequences.MatchPattern(e1, zeroOrMany, e2);
342
343     Assert.Contains(doublet, matchedSequences4);
344     Assert.Contains(balancedVariant, matchedSequences4);
345
346     for (var i = 0; i < sequence.Length; i++)
347     {
348         links.Delete(sequence[i]);
349     }
350 }
351 }
352
353 [Fact]
354 public static void IndexTest()
355 {
356     using (var scope = new TempLinksTestScope(new SequencesOptions<ulong> { UseIndex =
357         ↪ true }, useSequences: true))
358     {
359         var links = scope.Links;
360         var sequences = scope.Sequences;
361         var index = sequences.Options.Index;
362
363         var e1 = links.Create();
364         var e2 = links.Create();
365
366         var sequence = new[]
367         {
368             e1, e2, e1, e2 // mama / papa
369         };
370
371         Assert.False(index.MightContain(sequence));
372
373         index.Add(sequence);
374
375         Assert.True(index.MightContain(sequence));
376     }
377 }
378
379 /// <summary>Imported from https://raw.githubusercontent.com/wiki/Konard/LinksPlatform/%
380 ↪ DO%9E-%D1%82%D0%BE%D0%BC%2C-%D0%BA%D0%B0%D0%BA-%D0%B2%D1%81%D1%91-%D0%BD%D0%B0%D1%87
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?

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

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

387  
388 [![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)

389  
390 А что если повторить? Сделать копию? Создать дубликат? Из одного сделать два? Может это быть  
→ так? Инверсия? Отражение? Сумма?

391  
392 [![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)

393  
394 А что если мы вообразим движение? Нужно ли время? Каким самым коротким будет путь? Что будет  
→ если этот путь зафиксировать? Запомнить след? Как две точки становятся линией? Чертой?  
→ Гранью? Разделителем? Единицей?

395  
396 [![две белые точки, чёрная вертикальная  
→ линия](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/4.png "две  
→ белые точки, чёрная вертикальная  
→ линия")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/4.png)

397  
398 Можно ли замкнуть движение? Может ли это быть кругом? Можно ли замкнуть время? Или остаётся  
→ только спираль? Но что если замкнуть предел? Создать ограничение, разделение? Получится  
→ замкнутая область? Полностью отделённая от всего остального? Но что это всё остальное? Что  
→ можно делить? В каком направлении? Ничего или всё? Пустота или полнота? Начало или конец?  
→ Или может быть это единица и ноль? Дуальность? Противоположность? А что будет с кругом если  
→ у него нет размера? Будет ли круг точкой? Точка состоящая из точек?

399  
400 [![белая вертикальная линия, чёрный  
→ круг](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/5.png "белая  
→ вертикальная линия, чёрный  
→ круг")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/5.png)

401  
402 Как ещё можно использовать грань, черту, линию? А что если она может что-то соединять, может  
→ тогда её нужно повернуть? Почему то, что перпендикулярно вертикальному горизонтально?  
→ Горизонт? Инвертирует ли это смысл? Что такое смысл? Из чего состоит смысл? Существует ли  
→ элементарная единица смысла?

403  
404 [![белый круг, чёрная горизонтальная  
→ линия](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/6.png "белый  
→ круг, чёрная горизонтальная  
→ линия")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/6.png)

405  
406 Соединять, допустим, а какой смысл в этом есть ещё? Что если помимо смысла "соединить",  
→ связать", есть ещё и смысл направления "от начала к концу"? От предка к потомку? От  
→ родителя к ребёнку? От общего к частному?

407  
408 [![белая горизонтальная линия, чёрная горизонтальная  
→ стрелка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/7.png  
→ "белая горизонтальная линия, чёрная горизонтальная  
→ стрелка")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/7.png)

409  
410 Шаг назад. Возьмём опять отделённую область, которая лишь та же замкнутая линия, что ещё она  
→ может представлять собой? Объект? Но в чём его суть? Разве не в том, что у него есть  
→ граница, разделяющая внутреннее и внешнее? Допустим связь, стрелка, линия соединяет два  
→ объекта, как бы это выглядело?

411  
412 [![белая связь, чёрная направленная  
→ связь](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/8.png "белая  
→ связь, чёрная направленная  
→ связь")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/8.png)

413  
414 Допустим у нас есть смысл "связать" и смысл "направления", много ли это нам даёт? Много ли  
→ вариантов интерпретации? А что если уточнить, каким именно образом выполнена связь? Что если  
→ можно задать ей чёткий, конкретный смысл? Что это будет? Тип? Глагол? Связка? Действие?  
→ Трансформация? Переход из состояния в состояние? Или всё это и есть объект, суть которого в  
→ его конечном состоянии, если конечно конец определён направлением?

415  
416 [![белая обычная и направленная связи, чёрная типизированная  
→ связь](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/9.png "белая  
→ обычная и направленная связи, чёрная типизированная  
→ связь")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/9.png)

417  
418 А что если всё это время, мы смотрели на суть как бы снаружи? Можно ли взглянуть на это изнутри?  
→ Что будет внутри объектов? Объекты ли это? Или это связи? Может ли эта структура описать  
→ сама себя? Но что тогда получится, разве это не рекурсия? Может это фрактал?

419

```

420  [![белая обычная и направленная связи с рекурсивной внутренней структурой, чёрная типизированная
      ↳ связь с рекурсивной внутренней
      ↳ структурой](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/10.png
      ↳ ""белая обычная и направленная связи с рекурсивной внутренней структурой, чёрная
      ↳ типизированная связь с рекурсивной внутренней структурой"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/10.png)
421
422  На один уровень внутрь (вниз)? Или на один уровень во вне (вверх)? Или это можно назвать шагом
      ↳ рекурсии или фрактала?
423
424  [![белая обычная и направленная связи с двойной рекурсивной внутренней структурой, чёрная
      ↳ типизированная связь с двойной рекурсивной внутренней
      ↳ структурой](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/11.png
      ↳ ""белая обычная и направленная связи с двойной рекурсивной внутренней структурой, чёрная
      ↳ типизированная связь с двойной рекурсивной внутренней структурой"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/11.png)
425
426  Последовательность? Массив? Список? Множество? Объект? Таблица? Элементы? Цвета? Символы? Буквы?
      ↳ Слово? Цифры? Число? Алфавит? Дерево? Сеть? Граф? Гиперграф?
427
428  [![белая обычная и направленная связи со структурой из 8 цветных элементов последовательности,
      ↳ чёрная типизированная связь со структурой из 8 цветных элементов последовательности](https://
      ↳ raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/12.png ""белая обычная и
      ↳ направленная связи со структурой из 8 цветных элементов последовательности, чёрная
      ↳ типизированная связь со структурой из 8 цветных элементов последовательности"")](https://raw
      ↳ .githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/12.png)
429
430  ...
431
432  [![анимация](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro-anim
      ↳ ation-500.gif
      ↳ ""анимация"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro
      ↳ -animation-500.gif)";
433
434      private static readonly string _exampleLoremIpsumText =
435          @"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor
            ↳ incididunt ut labore et dolore magna aliqua.
436  Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo
      ↳ consequat.";
437
438      [Fact]
439      public static void CompressionTest()
440      {
441          using (var scope = new TempLinksTestScope(useSequences: true))
442          {
443              var links = scope.Links;
444              var sequences = scope.Sequences;
445
446              var e1 = links.Create();
447              var e2 = links.Create();
448
449              var sequence = new[]
450              {
451                  e1, e2, e1, e2 // mama / papa / template [(m/p), a] { [1] [2] [1] [2] }
452              };
453
454              var balancedVariantConverter = new BalancedVariantConverter<ulong>(links.Unsync);
455              var totalSequenceSymbolFrequencyCounter = new
            ↳ TotalSequenceSymbolFrequencyCounter<ulong>(links.Unsync);
456              var doubletFrequenciesCache = new LinkFrequenciesCache<ulong>(links.Unsync,
            ↳ totalSequenceSymbolFrequencyCounter);
457              var compressingConverter = new CompressingConverter<ulong>(links.Unsync,
            ↳ balancedVariantConverter, doubletFrequenciesCache);
458
459              var compressedVariant = compressingConverter.Convert(sequence);
460
461              // 1: [1]          (1->1) point
462              // 2: [2]          (2->2) point
463              // 3: [1,2]        (1->2) doublet
464              // 4: [1,2,1,2]    (3->3) doublet
465
466              Assert.True(links.GetSource(links.GetSource(compressedVariant)) == sequence[0]);
467              Assert.True(links.GetTarget(links.GetSource(compressedVariant)) == sequence[1]);
468              Assert.True(links.GetSource(links.GetTarget(compressedVariant)) == sequence[2]);
469              Assert.True(links.GetTarget(links.GetTarget(compressedVariant)) == sequence[3]);
470
471              var source = _constants.SourcePart;
472              var target = _constants.TargetPart;
473

```

```

474 Assert.True(links.GetByKeys(compressedVariant, source, source) == sequence[0]);
475 Assert.True(links.GetByKeys(compressedVariant, source, target) == sequence[1]);
476 Assert.True(links.GetByKeys(compressedVariant, target, source) == sequence[2]);
477 Assert.True(links.GetByKeys(compressedVariant, target, target) == sequence[3]);
478
479 // 4 - length of sequence
480 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 0)
481     ↪ == sequence[0]);
482 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 1)
483     ↪ == sequence[1]);
484 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 2)
485     ↪ == sequence[2]);
486 Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 3)
487     ↪ == sequence[3]);
488 }
489 }
490
491 [Fact]
492 public static void CompressionEfficiencyTest()
493 {
494     var strings = _exampleLoremIpsumText.Split(new[] { '\n', '\r' },
495         ↪ StringSplitOptions.RemoveEmptyEntries);
496     var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
497     var totalCharacters = arrays.Select(x => x.Length).Sum();
498
499     using (var scope1 = new TempLinksTestScope(useSequences: true))
500     using (var scope2 = new TempLinksTestScope(useSequences: true))
501     using (var scope3 = new TempLinksTestScope(useSequences: true))
502     {
503         scope1.Links.Unsync.UseUnicode();
504         scope2.Links.Unsync.UseUnicode();
505         scope3.Links.Unsync.UseUnicode();
506
507         var balancedVariantConverter1 = new
508             ↪ BalancedVariantConverter<ulong>(scope1.Links.Unsync);
509         var totalSequenceSymbolFrequencyCounter = new
510             ↪ TotalSequenceSymbolFrequencyCounter<ulong>(scope1.Links.Unsync);
511         var linkFrequenciesCache1 = new LinkFrequenciesCache<ulong>(scope1.Links.Unsync,
512             ↪ totalSequenceSymbolFrequencyCounter);
513         var compressor1 = new CompressingConverter<ulong>(scope1.Links.Unsync,
514             ↪ balancedVariantConverter1, linkFrequenciesCache1,
515             ↪ doInitialFrequenciesIncrement: false);
516
517         //var compressor2 = scope2.Sequences;
518         var compressor3 = scope3.Sequences;
519
520         var constants = Default<LinksConstants<ulong>>.Instance;
521
522         var sequences = compressor3;
523         //var meaningRoot = links.CreatePoint();
524         //var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
525         //var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
526         //var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
527             ↪ constants.Itself);
528
529         //var unaryNumberToAddressConverter = new
530             ↪ UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
531         //var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links,
532             ↪ unaryOne);
533         //var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
534             ↪ frequencyMarker, unaryOne, unaryNumberIncrementer);
535         //var frequencyPropertyOperator = new FrequencyPropertyOperator<ulong>(links,
536             ↪ frequencyPropertyMarker, frequencyMarker);
537         //var linkFrequencyIncrementer = new LinkFrequencyIncrementer<ulong>(links,
538             ↪ frequencyPropertyOperator, frequencyIncrementer);
539         //var linkToItsFrequencyNumberConverter = new
540             ↪ LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
541             ↪ unaryNumberToAddressConverter);
542
543         var linkFrequenciesCache3 = new LinkFrequenciesCache<ulong>(scope3.Links.Unsync,
544             ↪ totalSequenceSymbolFrequencyCounter);
545
546         var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFreque
547             ↪ ncyNumberConverter<ulong>(linkFrequenciesCache3);
548

```

```

529 var sequenceToItsLocalElementLevelsConverter = new
    ↳ SequenceToItsLocalElementLevelsConverter<ulong>(scope3.Links.Unsync,
    ↳ linkToItsFrequencyNumberConverter);
530 var optimalVariantConverter = new
    ↳ OptimalVariantConverter<ulong>(scope3.Links.Unsync,
    ↳ sequenceToItsLocalElementLevelsConverter);

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

```

```

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

```

```

662     strings.Add(i.ToString());
663 }
664
665 var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
666 var totalCharacters = arrays.Select(x => x.Length).Sum();
667
668 using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
    ↳ SequencesOptions<ulong> { UseCompression = true,
    ↳ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
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].ConvertToRestrictionsValues());
        var second = compressor1.Create(arrays[i].ConvertToRestrictionsValues());

        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;

    Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
    ↳ {elapsed2}");

    Assert.True(elapsed1 > elapsed2);

```



```

739 // Checks
740 for (int i = START; i < END; i++)
741 {
742     var sequence1 = compressed1[i];
743     var sequence2 = compressed2[i];
744
745     if (sequence1 != _constants.Null && sequence2 != _constants.Null)
746     {
747         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
748             ↪ scope1.Links);
749
750         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
751             ↪ scope2.Links);
752
753         //var structure1 = scope1.Links.FormatStructure(sequence1, link =>
754             ↪ link.IsPartialPoint());
755         //var structure2 = scope2.Links.FormatStructure(sequence2, link =>
756             ↪ link.IsPartialPoint());
757
758         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
759             ↪ arrays[i].Length > 3)
760         //    Assert.False(structure1 == structure2);
761
762         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
763     }
764 }
765
766 Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
767 Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
768
769 Debug.WriteLine($"{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
770     ↪ totalCharacters} | {(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
771     ↪ totalCharacters}");
772
773 Assert.True(scope1.Links.Count() <= scope2.Links.Count());
774
775 //compressor1.ValidateFrequencies();
776 }
777
778 [Fact]
779 public static void RandomNumbersCompressionQualityTest()
780 {
781     const ulong N = 500;
782
783     //const ulong minNumbers = 10000;
784     //const ulong maxNumbers = 20000;
785
786     //var strings = new List<string>();
787
788     //for (ulong i = 0; i < N; i++)
789     //    strings.Add(RandomHelpers.DefaultFactory.NextUInt64(minNumbers,
790         ↪ maxNumbers).ToString());
791
792     var strings = new List<string>();
793
794     for (ulong i = 0; i < N; i++)
795     {
796         strings.Add(RandomHelpers.Default.NextUInt64().ToString());
797     }
798
799     strings = strings.Distinct().ToList();
800
801     var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
802     var totalCharacters = arrays.Select(x => x.Length).Sum();
803
804     using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
805         ↪ SequencesOptions<ulong> { UseCompression = true,
806         ↪ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
807     using (var scope2 = new TempLinksTestScope(useSequences: true))
808     {
809         scope1.Links.UseUnicode();
810         scope2.Links.UseUnicode();
811
812         var compressor1 = scope1.Sequences;
813         var compressor2 = scope2.Sequences;
814
815         var compressed1 = new ulong[arrays.Length];
816         var compressed2 = new ulong[arrays.Length];

```

```

808
809     var sw1 = Stopwatch.StartNew();
810
811     var START = 0;
812     var END = arrays.Length;
813
814     for (int i = START; i < END; i++)
815     {
816         compressed1[i] = compressor1.Create(arrays[i].ConvertToRestrictionsValues());
817     }
818
819     var elapsed1 = sw1.Elapsed;
820
821     var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
822
823     var sw2 = Stopwatch.StartNew();
824
825     for (int i = START; i < END; i++)
826     {
827         compressed2[i] = balancedVariantConverter.Convert(arrays[i]);
828     }
829
830     var elapsed2 = sw2.Elapsed;
831
832     Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
833         ↳ {elapsed2}");
834
835     Assert.True(elapsed1 > elapsed2);
836
837     // Checks
838     for (int i = START; i < END; i++)
839     {
840         var sequence1 = compressed1[i];
841         var sequence2 = compressed2[i];
842
843         if (sequence1 != _constants.Null && sequence2 != _constants.Null)
844         {
845             var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
846                 ↳ scope1.Links);
847
848             var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
849                 ↳ scope2.Links);
850
851             Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
852         }
853     }
854
855     Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
856     Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
857
858     Debug.WriteLine($"{{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
859         ↳ totalCharacters}} | {{(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
860         ↳ totalCharacters}}");
861
862     // Can be worse than balanced variant
863     //Assert.True(scope1.Links.Count() <= scope2.Links.Count());
864
865     //compressor1.ValidateFrequencies();
866 }
867
868 [Fact]
869 public static void AllTreeBreakDownAtSequencesCreationBugTest()
870 {
871     // Made out of AllPossibleConnectionsTest test.
872
873     //const long sequenceLength = 5; //100% bug
874     const long sequenceLength = 4; //100% bug
875     //const long sequenceLength = 3; //100% _no_bug (ok)
876
877     using (var scope = new TempLinksTestScope(useSequences: true))
878     {
879         var links = scope.Links;
880         var sequences = scope.Sequences;
881
882         var sequence = new ulong[sequenceLength];
883         for (var i = 0; i < sequenceLength; i++)
884         {
885             sequence[i] = links.Create();
886         }
887     }
888 }

```

```

882     }
883
884     var createResults = sequences.CreateAllVariants2(sequence);
885
886     Global.Trash = createResults;
887
888     for (var i = 0; i < sequenceLength; i++)
889     {
890         links.Delete(sequence[i]);
891     }
892 }
893
894 [Fact]
895 public static void AllPossibleConnectionsTest()
896 {
897     const long sequenceLength = 5;
898
899     using (var scope = new TempLinksTestScope(useSequences: true))
900     {
901         var links = scope.Links;
902         var sequences = scope.Sequences;
903
904         var sequence = new ulong[sequenceLength];
905         for (var i = 0; i < sequenceLength; i++)
906         {
907             sequence[i] = links.Create();
908         }
909
910         var createResults = sequences.CreateAllVariants2(sequence);
911         var reverseResults = sequences.CreateAllVariants2(sequence.Reverse().ToArray());
912
913         for (var i = 0; i < 1; i++)
914         {
915             var sw1 = Stopwatch.StartNew();
916             var searchResults1 = sequences.GetAllConnections(sequence); sw1.Stop();
917
918             var sw2 = Stopwatch.StartNew();
919             var searchResults2 = sequences.GetAllConnections1(sequence); sw2.Stop();
920
921             var sw3 = Stopwatch.StartNew();
922             var searchResults3 = sequences.GetAllConnections2(sequence); sw3.Stop();
923
924             var sw4 = Stopwatch.StartNew();
925             var searchResults4 = sequences.GetAllConnections3(sequence); sw4.Stop();
926
927             Global.Trash = searchResults3;
928             Global.Trash = searchResults4; //-V3008
929
930             var intersection1 = createResults.Intersect(searchResults1).ToList();
931             Assert.True(intersection1.Count == createResults.Length);
932
933             var intersection2 = reverseResults.Intersect(searchResults1).ToList();
934             Assert.True(intersection2.Count == reverseResults.Length);
935
936             var intersection0 = searchResults1.Intersect(searchResults2).ToList();
937             Assert.True(intersection0.Count == searchResults2.Count);
938
939             var intersection3 = searchResults2.Intersect(searchResults3).ToList();
940             Assert.True(intersection3.Count == searchResults3.Count);
941
942             var intersection4 = searchResults3.Intersect(searchResults4).ToList();
943             Assert.True(intersection4.Count == searchResults4.Count);
944         }
945
946         for (var i = 0; i < sequenceLength; i++)
947         {
948             links.Delete(sequence[i]);
949         }
950     }
951 }
952
953 [Fact(Skip = "Correct implementation is pending")]
954 public static void CalculateAllUsagesTest()
955 {
956     const long sequenceLength = 3;
957
958     using (var scope = new TempLinksTestScope(useSequences: true))
959     {
960         var links = scope.Links;

```

```

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

```

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

```

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

```

```

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 }

```

./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.CreateAndUpdate(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     }

```

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

```

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

```

```

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

```



```

103         links.Update(l2, l2, l1, l2);
104     }
105
106     Assert.Equal(OUL, links.Count());
107
108     links.Unsync.DisposeIfPossible();
109
110     var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope
        ↳ cope.TempTransactionLogFilename);
111     Assert.Single(transitions);
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))

```

```

177     {
178         var links = scope.Links;
179         l1 = links.CreateAndUpdate(itself, itself);
180         l2 = links.CreateAndUpdate(itself, itself);
181
182         l2 = links.Update(l2, l2, l1, l2);
183
184         links.CreateAndUpdate(l2, itself);
185         links.CreateAndUpdate(l2, itself);
186
187         links.Unsync.DisposeIfPossible();
188
189         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(
190             ↪ scope.TempTransactionLogFilename);
191     }
192
193     using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
194         ↪ useLog: true))
195     {
196         var links = scope.Links;
197         var transactionsLayer = (UInt64LinksTransactionsLayer)links.Unsync;
198         using (var transaction = transactionsLayer.BeginTransaction())
199         {
200             l2 = links.Update(l2, l1);
201
202             links.Delete(l2);
203
204             ExceptionThrower();
205
206             transaction.Commit();
207         }
208
209         Global.Trash = links.Count();
210     }
211 }
212 catch
213 {
214     Assert.False(lastScope == null);
215
216     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(last
217         ↪ Scope.TempTransactionLogFilename);
218
219     lastScope.DeleteFiles();
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             {
239                 var l1 = links.CreateAndUpdate(itself, itself);
240                 var l2 = links.CreateAndUpdate(itself, itself);
241
242                 Global.Trash = links.Update(l2, l2, l1, l2);
243
244                 links.Delete(l1);
245
246                 transaction.Commit();
247             }
248
249             Global.Trash = links.Count();
250         }
251
252         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
253             ↪ sactionLogFilename);
254     }
255 }

```

```

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

```

```

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

```

```

394     b = links.Update(b, a, c);
395     c = links.Update(c, a, b);
396
397     Debug.WriteLine(links.FormatStructure(ab, link => link.IsFullPoint(), true));
398     Debug.WriteLine(links.FormatStructure(cb, link => link.IsFullPoint(), true));
399     Debug.WriteLine(links.FormatStructure(ac, link => link.IsFullPoint(), true));
400
401     Assert.True(links.FormatStructure(cb, link => link.IsFullPoint(), true) ==
402         ↪ " (5:(4:5 (6:5 4)) 6)");
403     Assert.True(links.FormatStructure(ac, link => link.IsFullPoint(), true) ==
404         ↪ " (6:(5:(4:5 6) 6) 4)");
405     Assert.True(links.FormatStructure(ab, link => link.IsFullPoint(), true) ==
406         ↪ " (4:(5:4 (6:5 4)) 6)");
407
408     // TODO: Think how to build balanced syntax tree while formatting structure (eg.
409     ↪ " (4:(5:4 6) (6:5 4))" instead of " (4:(5:4 (6:5 4)) 6) "
410
411     Assert.True(sequences.SafeFormatSequence(cb, DefaultFormatter, false) ==
412         ↪ "{{5}{5}{4}{6}}");
413     Assert.True(sequences.SafeFormatSequence(ac, DefaultFormatter, false) ==
414         ↪ "{{5}{6}{6}{4}}");
415     Assert.True(sequences.SafeFormatSequence(ab, DefaultFormatter, false) ==
416         ↪ "{{4}{5}{4}{6}}");
417 }
418
419 private static void DefaultFormatter(StringBuilder sb, ulong link)
420 {
421     sb.Append(link.ToString());
422 }
423
424 #endregion
425
426 #region Performance
427
428 /*
429 public static void RunAllPerformanceTests()
430 {
431     try
432     {
433         links.TestLinksInSteps();
434     }
435     catch (Exception ex)
436     {
437         ex.WriteToConsole();
438     }
439
440     return;
441
442     try
443     {
444         //ThreadPool.SetMaxThreads(2, 2);
445
446         // Запускаем все тесты дважды, чтобы первоначальная инициализация не повлияла на
447         ↪ результат
448         // Также это дополнительно помогает в отладке
449         // Увеличивает вероятность попадания информации в кэши
450         for (var i = 0; i < 10; i++)
451         {
452             //0 - 10 ГБ
453             //Каждые 100 МБ срез цифр
454
455             //links.TestGetSourceFunction();
456             //links.TestGetSourceFunctionInParallel();
457             //links.TestGetTargetFunction();
458             //links.TestGetTargetFunctionInParallel();
459             links.Create64BillionLinks();
460
461             links.TestRandomSearchFixed();
462             //links.Create64BillionLinksInParallel();
463             links.TestEachFunction();
464             //links.TestForeach();
465             //links.TestParallelForeach();
466         }
467
468         links.TestDeletionOfAllLinks();
469     }
470     catch (Exception ex)

```

```

465         {
466             ex.WriteLineToConsole();
467         }
468     }*/
469
470     /*
471     public static void TestLinksInSteps()
472     {
473         const long gibibyte = 1024 * 1024 * 1024;
474         const long mebibyte = 1024 * 1024;
475
476         var totalLinksToCreate = gibibyte /
↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
477         var linksStep = 102 * mebibyte /
↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
478
479         var creationMeasurements = new List<TimeSpan>();
480         var searchMeasurements = new List<TimeSpan>();
481         var deletionMeasurements = new List<TimeSpan>();
482
483         GetBaseRandomLoopOverhead(linksStep);
484         GetBaseRandomLoopOverhead(linksStep);
485
486         var stepLoopOverhead = GetBaseRandomLoopOverhead(linksStep);
487
488         ConsoleHelpers.Debug("Step loop overhead: {0}.", stepLoopOverhead);
489
490         var loops = totalLinksToCreate / linksStep;
491
492         for (int i = 0; i < loops; i++)
493         {
494             creationMeasurements.Add(Measure(() => links.RunRandomCreations(linksStep)));
495             searchMeasurements.Add(Measure(() => links.RunRandomSearches(linksStep)));
496
497             Console.WriteLine("\rC + S {0}/{1}", i + 1, loops);
498         }
499
500         ConsoleHelpers.Debug();
501
502         for (int i = 0; i < loops; i++)
503         {
504             deletionMeasurements.Add(Measure(() => links.RunRandomDeletions(linksStep)));
505
506             Console.WriteLine("\rD {0}/{1}", i + 1, loops);
507         }
508
509         ConsoleHelpers.Debug();
510
511         ConsoleHelpers.Debug("C S D");
512
513         for (int i = 0; i < loops; i++)
514         {
515             ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i],
↪ searchMeasurements[i], deletionMeasurements[i]);
516         }
517
518         ConsoleHelpers.Debug("C S D (no overhead)");
519
520         for (int i = 0; i < loops; i++)
521         {
522             ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i] - stepLoopOverhead,
↪ searchMeasurements[i] - stepLoopOverhead, deletionMeasurements[i] - stepLoopOverhead);
523         }
524
525         ConsoleHelpers.Debug("All tests done. Total links left in database: {0}.",
↪ links.Total);
526     }
527
528     private static void CreatePoints(this Platform.Links.Data.Core.Doublets.Links links, long
↪ amountToCreate)
529     {
530         for (long i = 0; i < amountToCreate; i++)
531             links.Create(0, 0);
532     }
533
534     private static TimeSpan GetBaseRandomLoopOverhead(long loops)
535     {
536         return Measure(() =>
537         {

```

```

538         ulong maxValue = RandomHelpers.DefaultFactory.NextUInt64();
539         ulong result = 0;
540         for (long i = 0; i < loops; i++)
541         {
542             var source = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
543             var target = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
544
545             result += maxValue + source + target;
546         }
547         Global.Trash = result;
548     });
549 }
550 */
551
552 [Fact(Skip = "performance test")]
553 public static void GetSourceTest()
554 {
555     using (var scope = new TempLinksTestScope())
556     {
557         var links = scope.Links;
558         ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations.",
559             ↪ Iterations);
560
561         ulong counter = 0;
562
563         //var firstLink = links.First();
564         // Создаём одну связь, из которой будет производить считывание
565         var firstLink = links.Create();
566
567         var sw = Stopwatch.StartNew();
568
569         // Тестируем саму функцию
570         for (ulong i = 0; i < Iterations; i++)
571         {
572             counter += links.GetSource(firstLink);
573         }
574
575         var elapsedTime = sw.Elapsed;
576
577         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
578
579         // Удаляем связь, из которой производилось считывание
580         links.Delete(firstLink);
581
582         ConsoleHelpers.Debug(
583             "{0} Iterations of GetSource function done in {1} ({2} Iterations per
584             ↪ second), counter result: {3}",
585             Iterations, elapsedTime, (long)iterationsPerSecond, counter);
586     }
587 }
588
589 [Fact(Skip = "performance test")]
590 public static void GetSourceInParallel()
591 {
592     using (var scope = new TempLinksTestScope())
593     {
594         var links = scope.Links;
595         ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations in
596             ↪ parallel.", Iterations);
597
598         long counter = 0;
599
600         //var firstLink = links.First();
601         var firstLink = links.Create();
602
603         var sw = Stopwatch.StartNew();
604
605         // Тестируем саму функцию
606         Parallel.For(0, Iterations, x =>
607         {
608             Interlocked.Add(ref counter, (long)links.GetSource(firstLink));
609             //Interlocked.Increment(ref counter);
610         });
611
612         var elapsedTime = sw.Elapsed;
613
614         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
615
616         links.Delete(firstLink);
617     }
618 }

```

```

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

```



```

689     public void TestRandomSearchFixed()
690     {
691         var tempFilename = Path.GetTempFileName();
692
693         using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
↵ DefaultLinksSizeStep))
694         {
695             long iterations = 64 * 1024 * 1024 /
↵ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
696
697             ulong counter = 0;
698             var maxLink = links.Total;
699
700             ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.", iterations);
701
702             var sw = Stopwatch.StartNew();
703
704             for (var i = iterations; i > 0; i--)
705             {
706                 var source =
↵ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
707                 var target =
↵ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
708
709                 counter += links.Search(source, target);
710             }
711
712             var elapsedTime = sw.Elapsed;
713
714             var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
715
716             ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
↵ Iterations per second), c: {3}", iterations, elapsedTime, (long)iterationsPerSecond,
↵ counter);
717         }
718
719         File.Delete(tempFilename);
720     }*/
721
722     [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
723     public static void TestRandomSearchAll()
724     {
725         using (var scope = new TempLinksTestScope())
726         {
727             var links = scope.Links;
728             ulong counter = 0;
729
730             var maxLink = links.Count();
731
732             var iterations = links.Count();
733
734             ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.",
↵ links.Count());
735
736             var sw = Stopwatch.StartNew();
737
738             for (var i = iterations; i > 0; i--)
739             {
740                 var linksAddressRange = new
↵ Range<ulong>(_constants.PossibleInnerReferencesRange.Minimum, maxLink);
741
742                 var source = RandomHelpers.Default.NextUInt64(linksAddressRange);
743                 var target = RandomHelpers.Default.NextUInt64(linksAddressRange);
744
745                 counter += links.SearchOrDefault(source, target);
746             }
747
748             var elapsedTime = sw.Elapsed;
749
750             var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
751
752             ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
↵ Iterations per second), c: {3}",
↵ iterations, elapsedTime, (long)iterationsPerSecond, counter);
753         }
754     }
755
756     [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
757     public static void TestEach()
758     {
759

```

```

760     using (var scope = new TempLinksTestScope())
761     {
762         var links = scope.Links;
763
764         var counter = new Counter<IList<ulong>, ulong>(links.Constants.Continue);
765
766         ConsoleHelpers.Debug("Testing Each function.");
767
768         var sw = Stopwatch.StartNew();
769
770         links.Each(counter.IncrementAndReturnTrue);
771
772         var elapsedTime = sw.Elapsed;
773
774         var linksPerSecond = counter.Count / elapsedTime.TotalSeconds;
775
776         ConsoleHelpers.Debug("{0} Iterations of Each's handler function done in {1} ({2}
↪      links per second)",
            counter, elapsedTime, (long)linksPerSecond);
777     }
778 }
779
780
781 /*
782 [Fact]
783 public static void TestForeach()
784 {
785     var tempFilename = Path.GetTempFileName();
786
787     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
↪      DefaultLinksSizeStep))
788     {
789         ulong counter = 0;
790
791         ConsoleHelpers.Debug("Testing foreach through links.");
792
793         var sw = Stopwatch.StartNew();
794
795         //foreach (var link in links)
796         //{
797             counter++;
798         //}
799
800         var elapsedTime = sw.Elapsed;
801
802         var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
803
804         ConsoleHelpers.Debug("{0} Iterations of Foreach's handler block done in {1} ({2}
↪      links per second)", counter, elapsedTime, (long)linksPerSecond);
805     }
806
807     File.Delete(tempFilename);
808 }
809 */
810
811 /*
812 [Fact]
813 public static void TestParallelForeach()
814 {
815     var tempFilename = Path.GetTempFileName();
816
817     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
↪      DefaultLinksSizeStep))
818     {
819
820         long counter = 0;
821
822         ConsoleHelpers.Debug("Testing parallel foreach through links.");
823
824         var sw = Stopwatch.StartNew();
825
826         //Parallel.ForEach((IEnumerable<ulong>)links, x =>
827         //{
828             Interlocked.Increment(ref counter);
829         //});
830
831         var elapsedTime = sw.Elapsed;
832
833         var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
834

```

```

835         ConsoleHelpers.Debug("{0} Iterations of Parallel Foreach's handler block done in
↪ {1} ({2} links per second)", counter, elapsedTime, (long)linksPerSecond);
836     }
837
838     File.Delete(tempFilename);
839 }
840 */
841
842 [Fact(Skip = "performance test")]
843 public static void Create64BillionLinks()
844 {
845     using (var scope = new TempLinksTestScope())
846     {
847         var links = scope.Links;
848         var linksBeforeTest = links.Count();
849
850         long linksToCreate = 64 * 1024 * 1024 /
↪ UInt64ResizableDirectMemoryLinks.LinkSizeInBytes;
851
852         ConsoleHelpers.Debug("Creating {0} links.", linksToCreate);
853
854         var elapsedTime = Performance.Measure(() =>
855         {
856             for (long i = 0; i < linksToCreate; i++)
857             {
858                 links.Create();
859             }
860         });
861
862         var linksCreated = links.Count() - linksBeforeTest;
863         var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
864
865         ConsoleHelpers.Debug("Current links count: {0}.", links.Count());
866
867         ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
↪ linksCreated, elapsedTime,
868             (long)linksPerSecond);
869     }
870 }
871
872 [Fact(Skip = "performance test")]
873 public static void Create64BillionLinksInParallel()
874 {
875     using (var scope = new TempLinksTestScope())
876     {
877         var links = scope.Links;
878         var linksBeforeTest = links.Count();
879
880         var sw = Stopwatch.StartNew();
881
882         long linksToCreate = 64 * 1024 * 1024 /
↪ UInt64ResizableDirectMemoryLinks.LinkSizeInBytes;
883
884         ConsoleHelpers.Debug("Creating {0} links in parallel.", linksToCreate);
885
886         Parallel.For(0, linksToCreate, x => links.Create());
887
888         var elapsedTime = sw.Elapsed;
889
890         var linksCreated = links.Count() - linksBeforeTest;
891         var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
892
893         ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
↪ linksCreated, elapsedTime,
894             (long)linksPerSecond);
895     }
896 }
897
898 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
899 public static void TestDeletionOfAllLinks()
900 {
901     using (var scope = new TempLinksTestScope())
902     {
903         var links = scope.Links;
904         var linksBeforeTest = links.Count();
905
906         ConsoleHelpers.Debug("Deleting all links");
907
908         var elapsedTime = Performance.Measure(links.DeleteAll);
909

```

```

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 #endregion
919 }
920 }

```

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

```

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

```

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

```

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

```

```

19 {
20     [Fact]
21     public static void CharAndUnaryNumberUnicodeSymbolConvertersTest()
22     {
23         using (var scope = new TempLinksTestScope())
24         {
25             var links = scope.Links;
26             var meaningRoot = links.CreatePoint();
27             var one = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
28             var powerOf2ToUnaryNumberConverter = new
29                 ↪ PowerOf2ToUnaryNumberConverter<ulong>(links, one);
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);
92             var charToUnicodeSymbolConverter = new
93                 ↪ CharToUnicodeSymbolConverter<ulong>(links, addressToUnaryNumberConverter,
94                 ↪ unicodeSymbolMarker);
95         }
96     }
97
98     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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