

LinksPlatform's Platform.Data.Doublets Class Library

1.1 ./csharp/Platform.Data.Doublets/Decorators/LinksCascadeUniquenessAndUsagesResolver.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.Decorators
6 {
7     public class LinksCascadeUniquenessAndUsagesResolver<TLink> : LinksUniquenessResolver<TLink>
8     {
9         [MethodImpl(MethodImplOptions.AggressiveInlining)]
10         public LinksCascadeUniquenessAndUsagesResolver(ILinks<TLink> links) : base(links) { }
11
12         [MethodImpl(MethodImplOptions.AggressiveInlining)]
13         protected override TLink ResolveAddressChangeConflict(TLink oldLinkAddress, TLink
14             ↪ newLinkAddress)
15         {
16             // Use Facade (the last decorator) to ensure recursion working correctly
17             _facade.MergeUsages(oldLinkAddress, newLinkAddress);
18             return base.ResolveAddressChangeConflict(oldLinkAddress, newLinkAddress);
19         }
20     }
```

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

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

1.3 ./csharp/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         protected readonly LinksConstants<TLink> _constants;
12
13         public LinksConstants<TLink> Constants
14         {
15             [MethodImpl(MethodImplOptions.AggressiveInlining)]
16             get => _constants;
17         }
18
19         protected ILinks<TLink> _facade;
20
21         public ILinks<TLink> Facade
22         {
23             [MethodImpl(MethodImplOptions.AggressiveInlining)]
24             get => _facade;
25             [MethodImpl(MethodImplOptions.AggressiveInlining)]
26             set
27             {
28             }
```

```

28         _facade = value;
29         if (_links is LinksDecoratorBase<TLink> decorator)
30         {
31             decorator.Facade = value;
32         }
33     }
34 }
35
36 [MethodImpl(MethodImplOptions.AggressiveInlining)]
37 protected LinksDecoratorBase(ILinks<TLink> links) : base(links)
38 {
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);
49
50 [MethodImpl(MethodImplOptions.AggressiveInlining)]
51 public virtual TLink Create(IList<TLink> restrictions) => _links.Create(restrictions);
52
53 [MethodImpl(MethodImplOptions.AggressiveInlining)]
54 public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution) =>
55     _links.Update(restrictions, substitution);
56
57 [MethodImpl(MethodImplOptions.AggressiveInlining)]
58 public virtual void Delete(IList<TLink> restrictions) => _links.Delete(restrictions);
59 }

```

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

```

1 using System.Runtime.CompilerServices;
2 using Platform.Disposables;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5 #pragma warning disable CA1063 // Implement IDisposable Correctly
6
7 namespace Platform.Data.Doublets.Decorators
8 {
9     public abstract class LinksDisposableDecoratorBase<TLink> : LinksDecoratorBase<TLink>,
10         ILinks<TLink>, System.IDisposable
11     {
12         protected class DisposableWithMultipleCallsAllowed : Disposable
13         {
14             [MethodImpl(MethodImplOptions.AggressiveInlining)]
15             public DisposableWithMultipleCallsAllowed(Disposal disposal) : base(disposal) { }
16
17             protected override bool AllowMultipleDisposeCalls
18             {
19                 [MethodImpl(MethodImplOptions.AggressiveInlining)]
20                 get => true;
21             }
22         }
23
24         protected readonly DisposableWithMultipleCallsAllowed Disposable;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         protected LinksDisposableDecoratorBase(ILinks<TLink> links) : base(links) => Disposable
28             = new DisposableWithMultipleCallsAllowed(Dispose);
29
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]
31         ~LinksDisposableDecoratorBase() => Disposable.Destruct();
32
33         [MethodImpl(MethodImplOptions.AggressiveInlining)]
34         public void Dispose() => Disposable.Dispose();
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected virtual void Dispose(bool manual, bool wasDisposed)
38         {
39             if (!wasDisposed)
40             {
41                 _links.DisposeIfPossible();
42             }
43         }
44     }
45 }

```

1.5 ./csharp/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             var links = _links;
20             links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
21             return links.Each(handler, restrictions);
22         }
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
26         {
27             // TODO: Possible values: null, ExistentLink or NonExistentHybrid(ExternalReference)
28             var links = _links;
29             links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
30             links.EnsureInnerReferenceExists(substitution, nameof(substitution));
31             return links.Update(restrictions, substitution);
32         }
33
34         [MethodImpl(MethodImplOptions.AggressiveInlining)]
35         public override void Delete(IList<TLink> restrictions)
36         {
37             var link = restrictions[_constants.IndexPart];
38             var links = _links;
39             links.EnsureLinkExists(link, nameof(link));
40             links.Delete(link);
41         }
42     }

```

1.6 ./csharp/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         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         public LinksItselfConstantToSelfReferenceResolver(ILinks<TLink> links) : base(links) { }
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         public override TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
19         {
20             var constants = _constants;
21             var itselfConstant = constants.Itself;
22             if (!_equalityComparer.Equals(constants.Any, itselfConstant) &&
23             ↪ restrictions.Contains(itselfConstant))
24             {
25                 // Itself constant is not supported for Each method right now, skipping execution
26                 return constants.Continue;
27             }
28             return _links.Each(handler, restrictions);
29         }
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution) =>
33         ↪ _links.Update(restrictions, _links.ResolveConstantAsSelfReference(_constants.Itself,
34         ↪ restrictions, substitution));

```

```

31     }
32 }

```

1.7 ./csharp/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            var links = _links;
25            links.EnsureCreated(substitution[constants.SourcePart],
26                ↪ substitution[constants.TargetPart]);
27            return links.Update(restrictions, substitution);
28        }
29    }
30 }

```

1.8 ./csharp/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) => _links.CreatePoint();
15
16        [MethodImpl(MethodImplOptions.AggressiveInlining)]
17        public override TLink Update(IList<TLink> restrictions, IList<TLink> substitution) =>
18        ↪ _links.Update(restrictions, _links.ResolveConstantAsSelfReference(_constants.Null,
19        ↪ restrictions, substitution));
20    }
21 }

```

1.9 ./csharp/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 constants = _constants;
20            var links = _links;

```

```

20     var newLinkAddress = links.SearchOrDefault(substitution[constants.SourcePart],
21         ↪ substitution[constants.TargetPart]);
22     if (_equalityComparer.Equals(newLinkAddress, default))
23     {
24         return links.Update(restrictions, substitution);
25     }
26     return ResolveAddressChangeConflict(restrictions[constants.IndexPart],
27         ↪ newLinkAddress);
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 }

```

1.10 ./csharp/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             var links = _links;
17             var constants = _constants;
18             links.EnsureDoesNotExists(substitution[constants.SourcePart],
19                 ↪ substitution[constants.TargetPart]);
20             return links.Update(restrictions, substitution);
21         }
22     }
23 }

```

1.11 ./csharp/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             var links = _links;
17             links.EnsureNoUsages(restrictions[_constants.IndexPart]);
18             return links.Update(restrictions, substitution);
19         }
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public override void Delete(IList<TLink> restrictions)
23         {
24             var link = restrictions[_constants.IndexPart];
25             var links = _links;
26             links.EnsureNoUsages(link);
27             links.Delete(link);
28         }
29     }
30 }

```

```

29     }
30 }

```

1.12 ./csharp/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             var links = _links;
18             links.EnforceResetValues(linkIndex);
19             links.Delete(linkIndex);
20         }
21     }
22 }

```

1.13 ./csharp/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     /// <para>Represents a combined decorator that implements the basic logic for interacting
10     ///   ↪ with the links storage for links with addresses represented as <see cref="System.UInt64">
11     ///   ↪ </para>
12     /// <para>Представляет комбинированный декоратор, реализующий основную логику по
13     ///   ↪ взаимодействию с хранилищем связей, для связей с адресами представленными в виде <see
14     ///   ↪ cref="System.UInt64"/>.</para>
15     /// </summary>
16     /// <remarks>
17     /// Возможные оптимизации:
18     /// Объединение в одном поле Source и Target с уменьшением до 32 бит.
19     ///   + меньше объём БД
20     ///   - меньше производительность
21     ///   - больше ограничение на количество связей в БД)
22     /// Ленивое хранение размеров поддеревьев (расчитываемое по мере использования БД)
23     ///   + меньше объём БД
24     ///   - больше сложность
25     ///
26     /// Текущее теоретическое ограничение на индекс связи, из-за использования 5 бит в размере
27     ///   ↪ поддеревьев для AVL баланса и флагов нитей: 2 в степени(64 минус 5 равно 59 ) равно 576
28     ///   ↪ 460 752 303 423 488
29     /// Желательно реализовать поддержку переключения между деревьями и битовыми индексами
30     ///   ↪ (битовыми строками) - вариант матрицы (выстраиваемой лениво).
31     ///
32     /// Решить отключать ли проверки при компиляции под Release. Т.е. исключения будут
33     ///   ↪ выбрасываться только при #if DEBUG
34     /// </remarks>
35     public class UInt64Links : LinksDisposableDecoratorBase<ulong>
36     {
37         [MethodImpl(MethodImplOptions.AggressiveInlining)]
38         public UInt64Links(ILinks<ulong> links) : base(links) { }
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         public override ulong Create(IList<ulong> restrictions) => _links.CreatePoint();
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         public override ulong Update(IList<ulong> restrictions, IList<ulong> substitution)
45         {
46             var constants = _constants;
47             var indexPartConstant = constants.IndexPart;
48             var sourcePartConstant = constants.SourcePart;
49             var targetPartConstant = constants.TargetPart;
50             var nullConstant = constants.Null;
51             var itselfConstant = constants.Itself;

```

```

44     var existedLink = nullConstant;
45     var updatedLink = restrictions[indexPartConstant];
46     var newSource = substitution[sourcePartConstant];
47     var newTarget = substitution[targetPartConstant];
48     var links = _links;
49     if (newSource != itselfConstant && newTarget != itselfConstant)
50     {
51         existedLink = links.SearchOrDefault(newSource, newTarget);
52     }
53     if (existedLink == nullConstant)
54     {
55         var before = links.GetLink(updatedLink);
56         if (before[sourcePartConstant] != newSource || before[targetPartConstant] !=
57             ↪ newTarget)
58         {
59             links.Update(updatedLink, newSource == itselfConstant ? updatedLink :
60                 ↪ newSource,
61                                     newTarget == itselfConstant ? updatedLink :
62                 ↪ newTarget);
63         }
64         return updatedLink;
65     }
66     else
67     {
68         return _facade.MergeAndDelete(updatedLink, existedLink);
69     }
70 }
71
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 public override void Delete(ICollection<ulong> restrictions)
74 {
75     var linkIndex = restrictions[_constants.IndexPart];
76     var links = _links;
77     links.EnforceResetValues(linkIndex);
78     _facade.DeleteAllUsages(linkIndex);
79     links.Delete(linkIndex);
80 }
81 }
82 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Linq;
4  using Platform.Collections;
5  using Platform.Collections.Lists;
6  using Platform.Data.Universal;
7
8  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
9
10 namespace Platform.Data.Doublets.Decorators
11 {
12     /// <remarks>
13     /// What does empty pattern (for condition or substitution) mean? Nothing or Everything?
14     /// Now we go with nothing. And nothing is something one, but empty, and cannot be changed
15     ↪ 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
18     ↪ DefaultUniLinksBase, that contains logic itself and can be implemented using both
19     ↪ IDoubletLinks and ILinks.)
20     /// </remarks>
21     internal class UniLinks<TLink> : LinksDecoratorBase<TLink>, IUniLinks<TLink>
22     {
23         private static readonly EqualityComparer<TLink> _equalityComparer =
24             ↪ EqualityComparer<TLink>.Default;
25
26         public UniLinks(ILinks<TLink> links) : base(links) { }
27
28         private struct Transition
29         {
30             public IList<TLink> Before;
31             public IList<TLink> After;
32
33             public Transition(IList<TLink> before, IList<TLink> after)
34             {
35                 Before = before;
36                 After = after;
37             }
38         }
39     }
40 }

```

```

36 //public static readonly TLink NullConstant = Use<LinksConstants<TLink>>.Single.Null;
37 //public static readonly IReadOnlyList<TLink> NullLink = new
    ↳ ReadOnlyCollection<TLink>(new List<TLink> { NullConstant, NullConstant, NullConstant
    ↳ });
38
39 // TODO: Подумать о том, как реализовать древовидный Restriction и Substitution
    ↳ (Links-Expression)
40 public TLink Trigger(IList<TLink> restriction, Func<IList<TLink>, IList<TLink>, TLink>
    ↳ matchedHandler, IList<TLink> substitution, Func<IList<TLink>, IList<TLink>, TLink>
    ↳ substitutedHandler)
41 {
42     /////List<Transition> transitions = null;
43     /////if (!restriction.IsNullOrEmpty())
44     /////{
45     /////    // Есть причина делать проход (чтение)
46     /////    if (matchedHandler != null)
47     /////    {
48     /////        if (!substitution.IsNullOrEmpty())
49     /////        {
50     /////            // restriction => { 0, 0, 0 } | { 0 } // Create
51     /////            // substitution => { itself, 0, 0 } | { itself, itself, itself } //
    ↳ Create / Update
52     /////            // substitution => { 0, 0, 0 } | { 0 } // Delete
53     /////            transitions = new List<Transition>();
54     /////            if (Equals(substitution[Constants.IndexPart], Constants.Null))
55     /////            {
56     /////                // If index is Null, that means we always ignore every other
    ↳ value (they are also Null by definition)
57     /////                var matchDecision = matchedHandler(, NullLink);
58     /////                if (Equals(matchDecision, Constants.Break))
59     /////                {
60     /////                    return false;
61     /////                }
62     /////                if (!Equals(matchDecision, Constants.Skip))
63     /////                {
64     /////                    transitions.Add(new Transition(matchedLink, newValue));
65     /////                }
66     /////            }
67     /////            else
68     /////            {
69     /////                Func<T, bool> handler;
70     /////                handler = link =>
71     /////                {
72     /////                    var matchedLink = Memory.GetLinkValue(link);
73     /////                    var newValue = Memory.GetLinkValue(link);
74     /////                    newValue[Constants.IndexPart] = Constants.Itself;
75     /////                    newValue[Constants.SourcePart] =
    ↳ Equals(substitution[Constants.SourcePart], Constants.Itself) ?
    ↳ matchedLink[Constants.IndexPart] : substitution[Constants.SourcePart];
76     /////                    newValue[Constants.TargetPart] =
    ↳ Equals(substitution[Constants.TargetPart], Constants.Itself) ?
    ↳ matchedLink[Constants.IndexPart] : substitution[Constants.TargetPart];
77     /////                    var matchDecision = matchedHandler(matchedLink, newValue);
78     /////                    if (Equals(matchDecision, Constants.Break))
79     /////                    {
80     /////                        return false;
81     /////                    }
82     /////                    if (!Equals(matchDecision, Constants.Skip))
83     /////                    {
84     /////                        transitions.Add(new Transition(matchedLink, newValue));
85     /////                    }
86     /////                    return true;
87     /////                };
88     /////                if (!Memory.Each(handler, restriction))
89     /////                {
90     /////                    return Constants.Break;
91     /////                }
92     /////            }
93     /////        }
94     /////    }
95     /////    else
96     /////    {
97     /////        Func<T, bool> handler = link =>
98     /////        {
99     /////            var matchedLink = Memory.GetLinkValue(link);
100     /////            var matchDecision = matchedHandler(matchedLink, matchedLink);
101     /////            return !Equals(matchDecision, Constants.Break);
102     /////        };
103     /////        if (!Memory.Each(handler, restriction))
104     /////        {
105     /////            return Constants.Break;
106     /////        }
107     /////    }
108     /////    if (substitution != null)
109     /////    {
110     /////        transitions = new List<Transition>();
111     /////        Func<T, bool> handler = link =>

```



```

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

```

```

176         //         return Constants.Break;
177         //         if (Equals(substitutedDecision, Constants.Continue))
178         //         {
179         //             // Actual update here
180         //             Memory.SetLinkValue(newValue);
181         //         }
182         //         if (Equals(substitutedDecision, Constants.Skip))
183         //         {
184         //             // Cancel the update. TODO: decide use separate Cancel
185         //             // constant or Skip is enough?
186         //         }
187         //     }
188     }
189 }
190 return _constants.Continue;
191 }
192
193 public TLink Trigger(IList<TLink> patternOrCondition, Func<IList<TLink>, TLink>
194     → matchHandler, IList<TLink> substitution, Func<IList<TLink>, IList<TLink>, TLink>
195     → substitutionHandler)
196 {
197     var constants = _constants;
198     if (patternOrCondition.IsNullOrEmpty() && substitution.IsNullOrEmpty())
199     {
200         return constants.Continue;
201     }
202     else if (patternOrCondition.EqualTo(substitution)) // Should be Each here TODO:
203     → Check if it is a correct condition
204     {
205         // Or it only applies to trigger without matchHandler.
206         throw new NotImplementedException();
207     }
208     else if (!substitution.IsNullOrEmpty()) // Creation
209     {
210         var before = Array.Empty<TLink>();
211         // Что должно означать False здесь? Остановиться (перестать идти) или пропустить
212         → (пройти мимо) или пустить (взять)?
213         if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
214             → constants.Break))
215         {
216             return constants.Break;
217         }
218         var after = (IList<TLink>)substitution.ToArray();
219         if (_equalityComparer.Equals(after[0], default))
220         {
221             var newLink = _links.Create();
222             after[0] = newLink;
223         }
224         if (substitution.Count == 1)
225         {
226             after = _links.GetLink(substitution[0]);
227         }
228         else if (substitution.Count == 3)
229         {
230             //Links.Create(after);
231         }
232         else
233         {
234             throw new NotSupportedException();
235         }
236         if (matchHandler != null)
237         {
238             return substitutionHandler(before, after);
239         }
240         return constants.Continue;
241     }
242     else if (!patternOrCondition.IsNullOrEmpty()) // Deletion
243     {
244         if (patternOrCondition.Count == 1)
245         {
246             var linkToDelete = patternOrCondition[0];
247             var before = _links.GetLink(linkToDelete);
248             if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
249                 → constants.Break))
250             {
251                 return constants.Break;
252             }
253         }
254     }

```

```

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

/// <remarks>
/// IList[IList[IList[T]]]
/// |         |         |         |||
/// |         |         ----- |||
/// |         |         link     |||
/// |         -----
/// |         change             |||
/// |-----
/// | changes
/// </remarks>
public IList<IList<IList<TLink>>> Trigger(IList<TLink> condition, IList<TLink>
↪ substitution)
{
    var changes = new List<IList<IList<TLink>>>();
    var @continue = _constants.Continue;
    Trigger(condition, AlwaysContinue, substitution, (before, after) =>
    {
        var change = new[] { before, after };

```

```

323         changes.Add(change);
324         return @continue;
325     });
326     return changes;
327 }
328
329     private TLink AlwaysContinue(IList<TLink> linkToMatch) => _constants.Continue;
330 }
331 }

```

1.15 ./csharp/Platform.Data.Doublets/Doublet.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
8  {
9      public struct Doublet<T> : IEquatable<Doublet<T>>
10     {
11         private static readonly EqualityComparer<T> _equalityComparer =
12             EqualityComparer<T>.Default;
13
14         public T Source
15         {
16             [MethodImpl(MethodImplOptions.AggressiveInlining)]
17             get;
18             [MethodImpl(MethodImplOptions.AggressiveInlining)]
19             set;
20         }
21         public T Target
22         {
23             [MethodImpl(MethodImplOptions.AggressiveInlining)]
24             get;
25             [MethodImpl(MethodImplOptions.AggressiveInlining)]
26             set;
27         }
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         public Doublet(T source, T target)
31         {
32             Source = source;
33             Target = target;
34         }
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         public override string ToString() => $"{Source}->{Target}";
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         public bool Equals(Doublet<T> other) => _equalityComparer.Equals(Source, other.Source)
41             && _equalityComparer.Equals(Target, other.Target);
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         public override bool Equals(object obj) => obj is Doublet<T> doublet ?
45             base.Equals(doublet) : false;
46
47         [MethodImpl(MethodImplOptions.AggressiveInlining)]
48         public override int GetHashCode() => (Source, Target).GetHashCode();
49
50         [MethodImpl(MethodImplOptions.AggressiveInlining)]
51         public static bool operator ==(Doublet<T> left, Doublet<T> right) => left.Equals(right);
52
53         [MethodImpl(MethodImplOptions.AggressiveInlining)]
54         public static bool operator !=(Doublet<T> left, Doublet<T> right) => !(left == right);
55     }
56 }

```

1.16 ./csharp/Platform.Data.Doublets/DoubletComparer.cs

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets
7  {
8      /// <remarks>
9      /// TODO: Может стоит попробовать ref во всех методах (IRefEqualityComparer)
10     /// 2x faster with comparer
11     /// </remarks>

```

```

12 public class DoubletComparer<T> : IEqualityComparer<Doublet<T>>
13 {
14     public static readonly DoubletComparer<T> Default = new DoubletComparer<T>();
15
16     [MethodImpl(MethodImplOptions.AggressiveInlining)]
17     public bool Equals(Doublet<T> x, Doublet<T> y) => x.Equals(y);
18
19     [MethodImpl(MethodImplOptions.AggressiveInlining)]
20     public int GetHashCode(Doublet<T> obj) => obj.GetHashCode();
21 }
22 }

```

1.17 ./csharp/Platform.Data.Doublets/ILinks.cs

```

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

```

1.18 ./csharp/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.Random;
9 using Platform.Setters;
10 using Platform.Converters;
11 using Platform.Numbers;
12 using Platform.Data.Exceptions;
13 using Platform.Data.Doublets.Decorators;
14
15 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
16
17 namespace Platform.Data.Doublets
18 {
19     public static class ILinksExtensions
20     {
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public static void RunRandomCreations<TLink>(this ILinks<TLink> links, ulong
23             ↪ amountOfCreations)
24         {
25             var random = RandomHelpers.Default;
26             var addressToUInt64Converter = UncheckedConverter<TLink, ulong>.Default;
27             var uInt64ToAddressConverter = UncheckedConverter<ulong, TLink>.Default;
28             for (var i = 0UL; i < amountOfCreations; i++)
29             {
30                 var linksAddressRange = new Range<ulong>(0,
31                     ↪ addressToUInt64Converter.Convert(links.Count()));
32                 var source =
33                     ↪ uInt64ToAddressConverter.Convert(random.NextUInt64(linksAddressRange));
34                 var target =
35                     ↪ uInt64ToAddressConverter.Convert(random.NextUInt64(linksAddressRange));
36                 links.GetOrCreate(source, target);
37             }
38         }
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         public static void RunRandomSearches<TLink>(this ILinks<TLink> links, ulong
42             ↪ amountOfSearches)
43         {
44             var random = RandomHelpers.Default;
45             var addressToUInt64Converter = UncheckedConverter<TLink, ulong>.Default;
46             var uInt64ToAddressConverter = UncheckedConverter<ulong, TLink>.Default;
47             for (var i = 0UL; i < amountOfSearches; i++)
48             {
49                 var linksAddressRange = new Range<ulong>(0,
50                     ↪ addressToUInt64Converter.Convert(links.Count()));
51                 var source =
52                     ↪ uInt64ToAddressConverter.Convert(random.NextUInt64(linksAddressRange));
53                 var target =
54                     ↪ uInt64ToAddressConverter.Convert(random.NextUInt64(linksAddressRange));
55                 links.SearchOrDefault(source, target);
56             }
57         }
58     }
59 }

```

```

48     }
49 }
50
51 [MethodImpl(MethodImplOptions.AggressiveInlining)]
52 public static void RunRandomDeletions<TLink>(this ILinks<TLink> links, ulong
↳ amountOfDeletions)
53 {
54     var random = RandomHelpers.Default;
55     var addressToUInt64Converter = UncheckedConverter<TLink, ulong>.Default;
56     var uint64ToAddressConverter = UncheckedConverter<ulong, TLink>.Default;
57     var linksCount = addressToUInt64Converter.Convert(links.Count());
58     var min = amountOfDeletions > linksCount ? OUL : linksCount - amountOfDeletions;
59     for (var i = OUL; i < amountOfDeletions; i++)
60     {
61         linksCount = addressToUInt64Converter.Convert(links.Count());
62         if (linksCount <= min)
63         {
64             break;
65         }
66         var linksAddressRange = new Range<ulong>(min, linksCount);
67         var link =
↳ uint64ToAddressConverter.Convert(random.NextUInt64(linksAddressRange));
68         links.Delete(link);
69     }
70 }
71
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 public static void Delete<TLink>(this ILinks<TLink> links, TLink linkToDelete) =>
↳ links.Delete(new LinkAddress<TLink>(linkToDelete));
74
75 /// <remarks>
76 /// TODO: Возможно есть очень простой способ это сделать.
77 /// (Например просто удалить файл, или изменить его размер таким образом,
78 /// чтобы удалился весь контент)
79 /// Например через _header->AllocatedLinks в ResizableDirectMemoryLinks
80 /// </remarks>
81 [MethodImpl(MethodImplOptions.AggressiveInlining)]
82 public static void DeleteAll<TLink>(this ILinks<TLink> links)
83 {
84     var equalityComparer = EqualityComparer<TLink>.Default;
85     var comparer = Comparer<TLink>.Default;
86     for (var i = links.Count(); comparer.Compare(i, default) > 0; i =
↳ Arithmetic.Decrement(i))
87     {
88         links.Delete(i);
89         if (!equalityComparer.Equals(links.Count(), Arithmetic.Decrement(i)))
90         {
91             i = links.Count();
92         }
93     }
94 }
95
96 [MethodImpl(MethodImplOptions.AggressiveInlining)]
97 public static TLink First<TLink>(this ILinks<TLink> links)
98 {
99     TLink firstLink = default;
100     var equalityComparer = EqualityComparer<TLink>.Default;
101     if (equalityComparer.Equals(links.Count(), default))
102     {
103         throw new InvalidOperationException("В хранилище нет связей.");
104     }
105     links.Each(links.Constants.Any, links.Constants.Any, link =>
106     {
107         firstLink = link[links.Constants.IndexPart];
108         return links.Constants.Break;
109     });
110     if (equalityComparer.Equals(firstLink, default))
111     {
112         throw new InvalidOperationException("В процессе поиска по хранилищу не было
↳ найдено связей.");
113     }
114     return firstLink;
115 }
116
117 #region Paths
118
119 /// <remarks>
120 /// TODO: Как так? Как то что ниже может быть корректно?
121 /// Скорее всего практически не применимо

```

```

122  /// Предполагалось, что можно было конвертировать формируемый в проходе через
123  ↪ SequenceWalker
124  /// Stack в конкретный путь из Source, Target до связи, но это не всегда так.
125  /// TODO: Возможно нужен метод, который именно выбрасывает исключения (EnsurePathExists)
126  /// </remarks>
127  [MethodImpl(MethodImplOptions.AggressiveInlining)]
128  public static bool CheckPathExistance<TLink>(this ILinks<TLink> links, params TLink[]
129  ↪ path)
130  {
131      var current = path[0];
132      //EnsureLinkExists(current, "path");
133      if (!links.Exists(current))
134      {
135          return false;
136      }
137      var equalityComparer = EqualityComparer<TLink>.Default;
138      var constants = links.Constants;
139      for (var i = 1; i < path.Length; i++)
140      {
141          var next = path[i];
142          var values = links.GetLink(current);
143          var source = values[constants.SourcePart];
144          var target = values[constants.TargetPart];
145          if (equalityComparer.Equals(source, target) && equalityComparer.Equals(source,
146          ↪ next))
147          {
148              //throw new InvalidOperationException(string.Format("Невозможно выбрать
149              ↪ путь, так как и Source и Target совпадают с элементом пути {0}.", next));
150              return false;
151          }
152          if (!equalityComparer.Equals(next, source) && !equalityComparer.Equals(next,
153          ↪ target))
154          {
155              //throw new InvalidOperationException(string.Format("Невозможно продолжить
156              ↪ путь через элемент пути {0}", next));
157              return false;
158          }
159          current = next;
160      }
161      return true;
162  }
163
164  /// <remarks>
165  /// Может потребовать дополнительного стека для PathElement's при использовании
166  ↪ SequenceWalker.
167  /// </remarks>
168  [MethodImpl(MethodImplOptions.AggressiveInlining)]
169  public static TLink GetByKeyes<TLink>(this ILinks<TLink> links, TLink root, params int[]
170  ↪ path)
171  {
172      links.EnsureLinkExists(root, "root");
173      var currentLink = root;
174      for (var i = 0; i < path.Length; i++)
175      {
176          currentLink = links.GetLink(currentLink)[path[i]];
177      }
178      return currentLink;
179  }
180
181  [MethodImpl(MethodImplOptions.AggressiveInlining)]
182  public static TLink GetSquareMatrixSequenceElementByIndex<TLink>(this ILinks<TLink>
183  ↪ links, TLink root, ulong size, ulong index)
184  {
185      var constants = links.Constants;
186      var source = constants.SourcePart;
187      var target = constants.TargetPart;
188      if (!Platform.Numbers.Math.IsPowerOfTwo(size))
189      {
190          throw new ArgumentOutOfRangeException(nameof(size), "Sequences with sizes other
191          ↪ than powers of two are not supported.");
192      }
193      var path = new BitArray(BitConverter.GetBytes(index));
194      var length = Bit.GetLowestPosition(size);
195      links.EnsureLinkExists(root, "root");
196      var currentLink = root;
197      for (var i = length - 1; i >= 0; i--)
198      {
199          currentLink = links.GetLink(currentLink)[path[i] ? target : source];
200      }
201  }

```

```

190     }
191     return currentLink;
192 }
193
194 #endregion
195
196 /// <summary>
197 /// Возвращает индекс указанной связи.
198 /// </summary>
199 /// <param name="links">Хранилище связей.</param>
200 /// <param name="link">Связь представленная списком, состоящим из её адреса и
    → содержимого.</param>
201 /// <returns>Индекс начальной связи для указанной связи.</returns>
202 [MethodImpl(MethodImplOptions.AggressiveInlining)]
203 public static TLink GetIndex<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
    → link[links.Constants.IndexPart];
204
205 /// <summary>
206 /// Возвращает индекс начальной (Source) связи для указанной связи.
207 /// </summary>
208 /// <param name="links">Хранилище связей.</param>
209 /// <param name="link">Индекс связи.</param>
210 /// <returns>Индекс начальной связи для указанной связи.</returns>
211 [MethodImpl(MethodImplOptions.AggressiveInlining)]
212 public static TLink GetSource<TLink>(this ILinks<TLink> links, TLink link) =>
    → links.GetLink(link)[links.Constants.SourcePart];
213
214 /// <summary>
215 /// Возвращает индекс начальной (Source) связи для указанной связи.
216 /// </summary>
217 /// <param name="links">Хранилище связей.</param>
218 /// <param name="link">Связь представленная списком, состоящим из её адреса и
    → содержимого.</param>
219 /// <returns>Индекс начальной связи для указанной связи.</returns>
220 [MethodImpl(MethodImplOptions.AggressiveInlining)]
221 public static TLink GetSource<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
    → link[links.Constants.SourcePart];
222
223 /// <summary>
224 /// Возвращает индекс конечной (Target) связи для указанной связи.
225 /// </summary>
226 /// <param name="links">Хранилище связей.</param>
227 /// <param name="link">Индекс связи.</param>
228 /// <returns>Индекс конечной связи для указанной связи.</returns>
229 [MethodImpl(MethodImplOptions.AggressiveInlining)]
230 public static TLink GetTarget<TLink>(this ILinks<TLink> links, TLink link) =>
    → links.GetLink(link)[links.Constants.TargetPart];
231
232 /// <summary>
233 /// Возвращает индекс конечной (Target) связи для указанной связи.
234 /// </summary>
235 /// <param name="links">Хранилище связей.</param>
236 /// <param name="link">Связь представленная списком, состоящим из её адреса и
    → содержимого.</param>
237 /// <returns>Индекс конечной связи для указанной связи.</returns>
238 [MethodImpl(MethodImplOptions.AggressiveInlining)]
239 public static TLink GetTarget<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
    → link[links.Constants.TargetPart];
240
241 /// <summary>
242 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
    → (handler) для каждой подходящей связи.
243 /// </summary>
244 /// <param name="links">Хранилище связей.</param>
245 /// <param name="handler">Обработчик каждой подходящей связи.</param>
246 /// <param name="restrictions">Ограничения на содержимое связей. Каждое ограничение
    → может иметь значения: Constants.Null - 0-я связь, обозначающая ссылку на пустоту,
    → Any - отсутствие ограничения, 1..∞ конкретный адрес связи.</param>
247 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
    → случае.</returns>
248 [MethodImpl(MethodImplOptions.AggressiveInlining)]
249 public static bool Each<TLink>(this ILinks<TLink> links, Func<IList<TLink>, TLink>
    → handler, params TLink[] restrictions)
    => EqualityComparer<TLink>.Default.Equals(links.Each(handler, restrictions),
    → links.Constants.Continue);
250
251 /// <summary>
252

```



```

253 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
254   ↳ (handler) для каждой подходящей связи.
255 /// </summary>
256 /// <param name="links">Хранилище связей.</param>
257 /// <param name="source">Значение, определяющее соответствующие шаблону связи.
258   ↳ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве начала,
259   ↳ Constants.Any - любое начало, 1..∞ конкретное начало)</param>
260 /// <param name="target">Значение, определяющее соответствующие шаблону связи.
261   ↳ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве конца,
262   ↳ Constants.Any - любой конец, 1..∞ конкретный конец)</param>
263 /// <param name="handler">Обработчик каждой подходящей связи.</param>
264 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
265   ↳ случае.</returns>
266 [MethodImpl(MethodImplOptions.AggressiveInlining)]
267 public static bool Each<TLink>(this ILinks<TLink> links, TLink source, TLink target,
268   ↳ Func<TLink, bool> handler)
269 {
270     var constants = links.Constants;
271     return links.Each(link => handler(link[constants.IndexPart]) ? constants.Continue :
272       ↳ constants.Break, constants.Any, source, target);
273 }
274
275 /// <summary>
276 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
277   ↳ (handler) для каждой подходящей связи.
278 /// </summary>
279 /// <param name="links">Хранилище связей.</param>
280 /// <param name="source">Значение, определяющее соответствующие шаблону связи.
281   ↳ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве начала,
282   ↳ Constants.Any - любое начало, 1..∞ конкретное начало)</param>
283 /// <param name="target">Значение, определяющее соответствующие шаблону связи.
284   ↳ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве конца,
285   ↳ Constants.Any - любой конец, 1..∞ конкретный конец)</param>
286 /// <param name="handler">Обработчик каждой подходящей связи.</param>
287 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
288   ↳ случае.</returns>
289 [MethodImpl(MethodImplOptions.AggressiveInlining)]
290 public static bool Each<TLink>(this ILinks<TLink> links, TLink source, TLink target,
291   ↳ Func<IList<TLink>, TLink> handler) => links.Each(handler, links.Constants.Any,
292   ↳ source, target);
293
294 [MethodImpl(MethodImplOptions.AggressiveInlining)]
295 public static IList<IList<TLink>> All<TLink>(this ILinks<TLink> links, params TLink[]
296   ↳ restrictions)
297 {
298     var arraySize = CheckedConverter<TLink,
299       ↳ long>.Default.Convert(links.Count(restrictions));
300     if (arraySize > 0)
301     {
302         var array = new IList<TLink>[arraySize];
303         var filler = new ArrayFiller<IList<TLink>, TLink>(array,
304           ↳ links.Constants.Continue);
305         links.Each(filler.AddAndReturnConstant, restrictions);
306         return array;
307     }
308     else
309     {
310         return Array.Empty<IList<TLink>>();
311     }
312 }
313
314 [MethodImpl(MethodImplOptions.AggressiveInlining)]
315 public static IList<TLink> AllIndices<TLink>(this ILinks<TLink> links, params TLink[]
316   ↳ restrictions)
317 {
318     var arraySize = CheckedConverter<TLink,
319       ↳ long>.Default.Convert(links.Count(restrictions));
320     if (arraySize > 0)
321     {
322         var array = new TLink[arraySize];
323         var filler = new ArrayFiller<TLink, TLink>(array, links.Constants.Continue);
324         links.Each(filler.AddFirstAndReturnConstant, restrictions);
325         return array;
326     }
327     else
328     {
329         return Array.Empty<TLink>();
330     }
331 }

```

```

309     }
310 }
311
312 /// <summary>
313 /// Возвращает значение, определяющее существует ли связь с указанными началом и концом
314   ↳ в хранилище связей.
315 /// </summary>
316 /// <param name="links">Хранилище связей.</param>
317 /// <param name="source">Начало связи.</param>
318 /// <param name="target">Конец связи.</param>
319 /// <returns>Значение, определяющее существует ли связь.</returns>
320 [MethodImpl(MethodImplOptions.AggressiveInlining)]
321 public static bool Exists<TLink>(this ILinks<TLink> links, TLink source, TLink target)
322   ↳ => Comparer<TLink>.Default.Compare(links.Count(links.Constants.Any, source, target),
323   ↳ default) > 0;
324
325 #region Ensure
326 // TODO: May be move to EnsureExtensions or make it both there and here
327
328 [MethodImpl(MethodImplOptions.AggressiveInlining)]
329 public static void EnsureLinkExists<TLink>(this ILinks<TLink> links, IList<TLink>
330   ↳ restrictions)
331 {
332     for (var i = 0; i < restrictions.Count; i++)
333     {
334         if (!links.Exists(restrictions[i]))
335         {
336             throw new ArgumentLinkDoesNotExistsException<TLink>(restrictions[i],
337                 ↳ $"sequence[{i}]");
338         }
339     }
340 }
341
342 [MethodImpl(MethodImplOptions.AggressiveInlining)]
343 public static void EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links, TLink
344   ↳ reference, string argumentName)
345 {
346     if (links.Constants.IsInternalReference(reference) && !links.Exists(reference))
347     {
348         throw new ArgumentLinkDoesNotExistsException<TLink>(reference, argumentName);
349     }
350 }
351
352 [MethodImpl(MethodImplOptions.AggressiveInlining)]
353 public static void EnsureInnerReferenceExists<TLink>(this ILinks<TLink> links,
354   ↳ IList<TLink> restrictions, string argumentName)
355 {
356     for (int i = 0; i < restrictions.Count; i++)
357     {
358         links.EnsureInnerReferenceExists(restrictions[i], argumentName);
359     }
360 }
361
362 [MethodImpl(MethodImplOptions.AggressiveInlining)]
363 public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, IList<TLink>
364   ↳ restrictions)
365 {
366     var equalityComparer = EqualityComparer<TLink>.Default;
367     var any = links.Constants.Any;
368     for (var i = 0; i < restrictions.Count; i++)
369     {
370         if (!equalityComparer.Equals(restrictions[i], any) &&
371             ↳ !links.Exists(restrictions[i]))
372         {
373             throw new ArgumentLinkDoesNotExistsException<TLink>(restrictions[i],
374                 ↳ $"sequence[{i}]");
375         }
376     }
377 }
378
379 [MethodImpl(MethodImplOptions.AggressiveInlining)]
380 public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, TLink link,
381   ↳ string argumentName)
382 {
383     var equalityComparer = EqualityComparer<TLink>.Default;
384     if (!equalityComparer.Equals(link, links.Constants.Any) && !links.Exists(link))
385     {

```

```

375         throw new ArgumentException<TLink>(link, argumentName);
376     }
377 }
378
379 [MethodImpl(MethodImplOptions.AggressiveInlining)]
380 public static void EnsureLinkIsItselfOrExists<TLink>(this ILinks<TLink> links, TLink
    ↳ link, string argumentName)
381 {
382     var equalityComparer = EqualityComparer<TLink>.Default;
383     if (!equalityComparer.Equals(link, links.Constants.Itself) && !links.Exists(link))
384     {
385         throw new ArgumentException<TLink>(link, argumentName);
386     }
387 }
388
389 /// <param name="links">Хранилище связей.</param>
390 [MethodImpl(MethodImplOptions.AggressiveInlining)]
391 public static void EnsureDoesNotExists<TLink>(this ILinks<TLink> links, TLink source,
    ↳ TLink target)
392 {
393     if (links.Exists(source, target))
394     {
395         throw new LinkWithSameValueAlreadyExistsException();
396     }
397 }
398
399 /// <param name="links">Хранилище связей.</param>
400 [MethodImpl(MethodImplOptions.AggressiveInlining)]
401 public static void EnsureNoUsages<TLink>(this ILinks<TLink> links, TLink link)
402 {
403     if (links.HasUsages(link))
404     {
405         throw new ArgumentException<TLink>(link);
406     }
407 }
408
409 /// <param name="links">Хранилище связей.</param>
410 [MethodImpl(MethodImplOptions.AggressiveInlining)]
411 public static void EnsureCreated<TLink>(this ILinks<TLink> links, params TLink[]
    ↳ addresses) => links.EnsureCreated(links.Create, addresses);
412
413 /// <param name="links">Хранилище связей.</param>
414 [MethodImpl(MethodImplOptions.AggressiveInlining)]
415 public static void EnsurePointsCreated<TLink>(this ILinks<TLink> links, params TLink[]
    ↳ addresses) => links.EnsureCreated(links.CreatePoint, addresses);
416
417 /// <param name="links">Хранилище связей.</param>
418 [MethodImpl(MethodImplOptions.AggressiveInlining)]
419 public static void EnsureCreated<TLink>(this ILinks<TLink> links, Func<TLink> creator,
    ↳ params TLink[] addresses)
420 {
421     var addressToUInt64Converter = CheckedConverter<TLink, ulong>.Default;
422     var uint64ToAddressConverter = CheckedConverter<ulong, TLink>.Default;
423     var nonExistentAddresses = new HashSet<TLink>(addresses.Where(x =>
    ↳ !links.Exists(x)));
424     if (nonExistentAddresses.Count > 0)
425     {
426         var max = nonExistentAddresses.Max();
427         max = uint64ToAddressConverter.Convert(System.Math.Min(addressToUInt64Converter.
    ↳ Convert(max),
    ↳ addressToUInt64Converter.Convert(links.Constants.InternalReferencesRange.Max
    ↳ imum)));
428         var createdLinks = new List<TLink>();
429         var equalityComparer = EqualityComparer<TLink>.Default;
430         TLink createdLink = creator();
431         while (!equalityComparer.Equals(createdLink, max))
432         {
433             createdLinks.Add(createdLink);
434         }
435         for (var i = 0; i < createdLinks.Count; i++)
436         {
437             if (!nonExistentAddresses.Contains(createdLinks[i]))
438             {
439                 links.Delete(createdLinks[i]);
440             }
441         }
442     }
443 }

```

```

444 #endregion
445
446
447 /// <param name="links">Хранилище связей.</param>
448 [MethodImpl(MethodImplOptions.AggressiveInlining)]
449 public static TLink CountUsages<TLink>(this ILinks<TLink> links, TLink link)
450 {
451     var constants = links.Constants;
452     var values = links.GetLink(link);
453     TLink usagesAsSource = links.Count(new Link<TLink>(constants.Any, link,
454         ↪ constants.Any));
455     var equalityComparer = EqualityComparer<TLink>.Default;
456     if (equalityComparer.Equals(values[constants.SourcePart], link))
457     {
458         usagesAsSource = Arithmetic<TLink>.Decrement(usagesAsSource);
459     }
460     TLink usagesAsTarget = links.Count(new Link<TLink>(constants.Any, constants.Any,
461         ↪ link));
462     if (equalityComparer.Equals(values[constants.TargetPart], link))
463     {
464         usagesAsTarget = Arithmetic<TLink>.Decrement(usagesAsTarget);
465     }
466     return Arithmetic<TLink>.Add(usagesAsSource, usagesAsTarget);
467 }
468
469 /// <param name="links">Хранилище связей.</param>
470 [MethodImpl(MethodImplOptions.AggressiveInlining)]
471 public static bool HasUsages<TLink>(this ILinks<TLink> links, TLink link) =>
472     ↪ Comparer<TLink>.Default.Compare(links.CountUsages(link), default) > 0;
473
474 /// <param name="links">Хранилище связей.</param>
475 [MethodImpl(MethodImplOptions.AggressiveInlining)]
476 public static bool Equals<TLink>(this ILinks<TLink> links, TLink link, TLink source,
477     ↪ TLink target)
478 {
479     var constants = links.Constants;
480     var values = links.GetLink(link);
481     var equalityComparer = EqualityComparer<TLink>.Default;
482     return equalityComparer.Equals(values[constants.SourcePart], source) &&
483         ↪ equalityComparer.Equals(values[constants.TargetPart], target);
484 }
485
486 /// <summary>
487 /// Выполняет поиск связи с указанными Source (началом) и Target (концом).
488 /// </summary>
489 /// <param name="links">Хранилище связей.</param>
490 /// <param name="source">Индекс связи, которая является началом для искомой
491     ↪ связи.</param>
492 /// <param name="target">Индекс связи, которая является концом для искомой связи.</param>
493 /// <returns>Индекс искомой связи с указанными Source (началом) и Target
494     ↪ (концом).</returns>
495 [MethodImpl(MethodImplOptions.AggressiveInlining)]
496 public static TLink SearchOrDefault<TLink>(this ILinks<TLink> links, TLink source, TLink
497     ↪ target)
498 {
499     var constants = links.Constants;
500     var setter = new Setter<TLink, TLink>(constants.Continue, constants.Break, default);
501     links.Each(setter.SetFirstAndReturnFalse, constants.Any, source, target);
502     return setter.Result;
503 }
504
505 /// <param name="links">Хранилище связей.</param>
506 [MethodImpl(MethodImplOptions.AggressiveInlining)]
507 public static TLink Create<TLink>(this ILinks<TLink> links) => links.Create(null);
508
509 /// <param name="links">Хранилище связей.</param>
510 [MethodImpl(MethodImplOptions.AggressiveInlining)]
511 public static TLink CreatePoint<TLink>(this ILinks<TLink> links)
512 {
513     var link = links.Create();
514     return links.Update(link, link, link);
515 }
516
517 /// <param name="links">Хранилище связей.</param>
518 [MethodImpl(MethodImplOptions.AggressiveInlining)]
519 public static TLink CreateAndUpdate<TLink>(this ILinks<TLink> links, TLink source, TLink
520     ↪ target) => links.Update(links.Create(), source, target);

```

```

513 /// <summary>
514 /// Обновляет связь с указанными началом (Source) и концом (Target)
515 /// на связь с указанными началом (NewSource) и концом (NewTarget).
516 /// </summary>
517 /// <param name="links">Хранилище связей.</param>
518 /// <param name="link">Индекс обновляемой связи.</param>
519 /// <param name="newSource">Индекс связи, которая является началом связи, на которую
    ↳ выполняется обновление.</param>
520 /// <param name="newTarget">Индекс связи, которая является концом связи, на которую
    ↳ выполняется обновление.</param>
521 /// <returns>Индекс обновлённой связи.</returns>
522 [MethodImpl(MethodImplOptions.AggressiveInlining)]
523 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));

524 /// <summary>
525 /// Обновляет связь с указанными началом (Source) и концом (Target)
526 /// на связь с указанными началом (NewSource) и концом (NewTarget).
527 /// </summary>
528 /// <param name="links">Хранилище связей.</param>
529 /// <param name="restrictions">Ограничения на содержимое связей. Каждое ограничение
    ↳ может иметь значения: Constants.Null - 0-я связь, обозначающая ссылку на пустоту,
    ↳ Itself - требование установить ссылку на себя, 1.. $\infty$  конкретный адрес другой
    ↳ связи.</param>
531 /// <returns>Индекс обновлённой связи.</returns>
532 [MethodImpl(MethodImplOptions.AggressiveInlining)]
533 public static TLink Update<TLink>(this ILinks<TLink> links, params TLink[] restrictions)
534 {
535     if (restrictions.Length == 2)
536     {
537         return links.MergeAndDelete(restrictions[0], restrictions[1]);
538     }
539     if (restrictions.Length == 4)
540     {
541         return links.UpdateOrCreateOrGet(restrictions[0], restrictions[1],
    ↳ restrictions[2], restrictions[3]);
542     }
543     else
544     {
545         return links.Update(new LinkAddress<TLink>(restrictions[0]), restrictions);
546     }
547 }

548 [MethodImpl(MethodImplOptions.AggressiveInlining)]
549 public static IList<TLink> ResolveConstantAsSelfReference<TLink>(this ILinks<TLink>
    ↳ links, TLink constant, IList<TLink> restrictions, IList<TLink> substitution)
550 {
551     var equalityComparer = EqualityComparer<TLink>.Default;
552     var constants = links.Constants;
553     var restrictionsIndex = restrictions[constants.IndexPart];
554     var substitutionIndex = substitution[constants.IndexPart];
555     if (equalityComparer.Equals(substitutionIndex, default))
556     {
557         substitutionIndex = restrictionsIndex;
558     }
559     var source = substitution[constants.SourcePart];
560     var target = substitution[constants.TargetPart];
561     source = equalityComparer.Equals(source, constant) ? substitutionIndex : source;
562     target = equalityComparer.Equals(target, constant) ? substitutionIndex : target;
563     return new Link<TLink>(substitutionIndex, source, target);
564 }

565 /// <summary>
566 /// Создаёт связь (если она не существовала), либо возвращает индекс существующей связи
    ↳ с указанными Source (началом) и Target (концом).
567 /// </summary>
568 /// <param name="links">Хранилище связей.</param>
569 /// <param name="source">Индекс связи, которая является началом на создаваемой
    ↳ связи.</param>
570 /// <param name="target">Индекс связи, которая является концом для создаваемой
    ↳ связи.</param>
571 /// <returns>Индекс связи, с указанным Source (началом) и Target (концом)</returns>
572 [MethodImpl(MethodImplOptions.AggressiveInlining)]
573 public static TLink GetOrCreate<TLink>(this ILinks<TLink> links, TLink source, TLink
    ↳ target)
574 {
575

```

```

577     var link = links.SearchOrDefault(source, target);
578     if (EqualityComparer<TLink>.Default.Equals(link, default))
579     {
580         link = links.CreateAndUpdate(source, target);
581     }
582     return link;
583 }
584
585 /// <summary>
586 /// Обновляет связь с указанными началом (Source) и концом (Target)
587 /// на связь с указанными началом (NewSource) и концом (NewTarget).
588 /// </summary>
589 /// <param name="links">Хранилище связей.</param>
590 /// <param name="source">Индекс связи, которая является началом обновляемой
    → связи.</param>
591 /// <param name="target">Индекс связи, которая является концом обновляемой связи.</param>
592 /// <param name="newSource">Индекс связи, которая является началом связи, на которую
    → выполняется обновление.</param>
593 /// <param name="newTarget">Индекс связи, которая является концом связи, на которую
    → выполняется обновление.</param>
594 /// <returns>Индекс обновлённой связи.</returns>
595 [MethodImpl(MethodImplOptions.AggressiveInlining)]
596 public static TLink UpdateOrCreateOrGet<TLink>(this ILinks<TLink> links, TLink source,
    → TLink target, TLink newSource, TLink newTarget)
597 {
598     var equalityComparer = EqualityComparer<TLink>.Default;
599     var link = links.SearchOrDefault(source, target);
600     if (equalityComparer.Equals(link, default))
601     {
602         return links.CreateAndUpdate(newSource, newTarget);
603     }
604     if (equalityComparer.Equals(newSource, source) && equalityComparer.Equals(newTarget,
    → target))
605     {
606         return link;
607     }
608     return links.Update(link, newSource, newTarget);
609 }
610
611 /// <summary>Удаляет связь с указанными началом (Source) и концом (Target).</summary>
612 /// <param name="links">Хранилище связей.</param>
613 /// <param name="source">Индекс связи, которая является началом удаляемой связи.</param>
614 /// <param name="target">Индекс связи, которая является концом удаляемой связи.</param>
615 [MethodImpl(MethodImplOptions.AggressiveInlining)]
616 public static TLink DeleteIfExists<TLink>(this ILinks<TLink> links, TLink source, TLink
    → target)
617 {
618     var link = links.SearchOrDefault(source, target);
619     if (!EqualityComparer<TLink>.Default.Equals(link, default))
620     {
621         links.Delete(link);
622         return link;
623     }
624     return default;
625 }
626
627 /// <summary>Удаляет несколько связей.</summary>
628 /// <param name="links">Хранилище связей.</param>
629 /// <param name="deletedLinks">Список адресов связей к удалению.</param>
630 [MethodImpl(MethodImplOptions.AggressiveInlining)]
631 public static void DeleteMany<TLink>(this ILinks<TLink> links, IList<TLink> deletedLinks)
632 {
633     for (int i = 0; i < deletedLinks.Count; i++)
634     {
635         links.Delete(deletedLinks[i]);
636     }
637 }
638
639 /// <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>
640 [MethodImpl(MethodImplOptions.AggressiveInlining)]
641 public static void DeleteAllUsages<TLink>(this ILinks<TLink> links, TLink linkIndex)
642 {
643     var anyConstant = links.Constants.Any;
644     var usagesAsSourceQuery = new Link<TLink>(anyConstant, linkIndex, anyConstant);
645     links.DeleteByQuery(usagesAsSourceQuery);
646     var usagesAsTargetQuery = new Link<TLink>(anyConstant, linkIndex, anyConstant);

```

```

647     links.DeleteByQuery(usagesAsTargetQuery);
648 }
649
650 [MethodImpl(MethodImplOptions.AggressiveInlining)]
651 public static void DeleteByQuery<TLink>(this ILinks<TLink> links, Link<TLink> query)
652 {
653     var count = CheckedConverter<TLink, long>.Default.Convert(links.Count(query));
654     if (count > 0)
655     {
656         var queryResult = new TLink[count];
657         var queryResultFiller = new ArrayFiller<TLink, TLink>(queryResult,
658             ↪ links.Constants.Continue);
659         links.Each(queryResultFiller.AddFirstAndReturnConstant, query);
660         for (var i = count - 1; i >= 0; i--)
661         {
662             links.Delete(queryResult[i]);
663         }
664     }
665
666     // TODO: Move to Platform.Data
667     [MethodImpl(MethodImplOptions.AggressiveInlining)]
668     public static bool AreValuesReset<TLink>(this ILinks<TLink> links, TLink linkIndex)
669     {
670         var nullConstant = links.Constants.Null;
671         var equalityComparer = EqualityComparer<TLink>.Default;
672         var link = links.GetLink(linkIndex);
673         for (int i = 1; i < link.Count; i++)
674         {
675             if (!equalityComparer.Equals(link[i], nullConstant))
676             {
677                 return false;
678             }
679         }
680         return true;
681     }
682
683     // TODO: Create a universal version of this method in Platform.Data (with using of for
684     ↪ loop)
685     [MethodImpl(MethodImplOptions.AggressiveInlining)]
686     public static void ResetValues<TLink>(this ILinks<TLink> links, TLink linkIndex)
687     {
688         var nullConstant = links.Constants.Null;
689         var updateRequest = new Link<TLink>(linkIndex, nullConstant, nullConstant);
690         links.Update(updateRequest);
691     }
692
693     // TODO: Create a universal version of this method in Platform.Data (with using of for
694     ↪ loop)
695     [MethodImpl(MethodImplOptions.AggressiveInlining)]
696     public static void EnforceResetValues<TLink>(this ILinks<TLink> links, TLink linkIndex)
697     {
698         if (!links.AreValuesReset(linkIndex))
699         {
700             links.ResetValues(linkIndex);
701         }
702     }
703
704     /// <summary>
705     /// Merging two usages graphs, all children of old link moved to be children of new link
706     ↪ or deleted.
707     /// </summary>
708     [MethodImpl(MethodImplOptions.AggressiveInlining)]
709     public static TLink MergeUsages<TLink>(this ILinks<TLink> links, TLink oldLinkIndex,
710     ↪ TLink newLinkIndex)
711     {
712         var addressToInt64Converter = CheckedConverter<TLink, long>.Default;
713         var equalityComparer = EqualityComparer<TLink>.Default;
714         if (!equalityComparer.Equals(oldLinkIndex, newLinkIndex))
715         {
716             var constants = links.Constants;
717             var usagesAsSourceQuery = new Link<TLink>(constants.Any, oldLinkIndex,
718                 ↪ constants.Any);
719             var usagesAsSourceCount =
720                 ↪ addressToInt64Converter.Convert(links.Count(usagesAsSourceQuery));
721             var usagesAsTargetQuery = new Link<TLink>(constants.Any, constants.Any,
722                 ↪ oldLinkIndex);

```

```

716     var usagesAsTargetCount =
717         ↪ addressToInt64Converter.Convert(links.Count(usagesAsTargetQuery));
718     var isStandalonePoint = Point<TLink>.IsFullPoint(links.GetLink(oldLinkIndex)) &&
719         ↪ usagesAsSourceCount == 1 && usagesAsTargetCount == 1;
720     if (!isStandalonePoint)
721     {
722         var totalUsages = usagesAsSourceCount + usagesAsTargetCount;
723         if (totalUsages > 0)
724         {
725             var usages = ArrayPool.Allocate<TLink>(totalUsages);
726             var usagesFiller = new ArrayFiller<TLink, TLink>(usages,
727                 ↪ links.Constants.Continue);
728             var i = 0L;
729             if (usagesAsSourceCount > 0)
730             {
731                 links.Each(usagesFiller.AddFirstAndReturnConstant,
732                     ↪ usagesAsSourceQuery);
733                 for (; i < usagesAsSourceCount; i++)
734                 {
735                     var usage = usages[i];
736                     if (!equalityComparer.Equals(usage, oldLinkIndex))
737                     {
738                         links.Update(usage, newLinkIndex, links.GetTarget(usage));
739                     }
740                 }
741             }
742             if (usagesAsTargetCount > 0)
743             {
744                 links.Each(usagesFiller.AddFirstAndReturnConstant,
745                     ↪ usagesAsTargetQuery);
746                 for (; i < usages.Length; i++)
747                 {
748                     var usage = usages[i];
749                     if (!equalityComparer.Equals(usage, oldLinkIndex))
750                     {
751                         links.Update(usage, links.GetSource(usage), newLinkIndex);
752                     }
753                 }
754             }
755             ArrayPool.Free(usages);
756         }
757     }
758     return newLinkIndex;
759 }
760
761 /// <summary>
762 /// Replace one link with another (replaced link is deleted, children are updated or
763 /// ↪ deleted).
764 /// </summary>
765 [MethodImpl(MethodImplOptions.AggressiveInlining)]
766 public static TLink MergeAndDelete<TLink>(this ILinks<TLink> links, TLink oldLinkIndex,
767     ↪ TLink newLinkIndex)
768 {
769     var equalityComparer = EqualityComparer<TLink>.Default;
770     if (!equalityComparer.Equals(oldLinkIndex, newLinkIndex))
771     {
772         links.MergeUsages(oldLinkIndex, newLinkIndex);
773         links.Delete(oldLinkIndex);
774     }
775     return newLinkIndex;
776 }
777
778 [MethodImpl(MethodImplOptions.AggressiveInlining)]
779 public static ILinks<TLink>
780     ↪ DecorateWithAutomaticUniquenessAndUsagesResolution<TLink>(this ILinks<TLink> links)
781 {
782     links = new LinksCascadeUsagesResolver<TLink>(links);
783     links = new NonNullContentsLinkDeletionResolver<TLink>(links);
784     links = new LinksCascadeUniquenessAndUsagesResolver<TLink>(links);
785     return links;
786 }
787
788 [MethodImpl(MethodImplOptions.AggressiveInlining)]
789 public static string Format<TLink>(this ILinks<TLink> links, IList<TLink> link)
790 {
791     var constants = links.Constants;

```



```

785         return $"({link[constants.IndexPart]}: {link[constants.SourcePart]})
           ↪ {link[constants.TargetPart]}";
786     }
787
788     [MethodImpl(MethodImplOptions.AggressiveInlining)]
789     public static string Format<TLink>(this ILinks<TLink> links, TLink link) =>
           ↪ links.Format(links.GetLink(link));
790 }
791 }

```

1.19 ./csharp/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  }

```

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

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Incrementers;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Incrementers
8  {
9      public class FrequencyIncrementer<TLink> : LinksOperatorBase<TLink>, IIncrementer<TLink>
10     {
11         private static readonly EqualityComparer<TLink> _equalityComparer =
           ↪ EqualityComparer<TLink>.Default;
12
13         private readonly TLink _frequencyMarker;
14         private readonly TLink _unaryOne;
15         private readonly IIncrementer<TLink> _unaryNumberIncrementer;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         public FrequencyIncrementer(ILinks<TLink> links, TLink frequencyMarker, TLink unaryOne,
           ↪ IIncrementer<TLink> unaryNumberIncrementer)
           : base(links)
19         {
20             _frequencyMarker = frequencyMarker;
21             _unaryOne = unaryOne;
22             _unaryNumberIncrementer = unaryNumberIncrementer;
23         }
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         public TLink Increment(TLink frequency)
27         {
28             var links = _links;
29             if (_equalityComparer.Equals(frequency, default))
30             {
31                 return links.GetOrCreate(_unaryOne, _frequencyMarker);
32             }
33             var incrementedSource =
           ↪ _unaryNumberIncrementer.Increment(links.GetSource(frequency));
34             return links.GetOrCreate(incrementedSource, _frequencyMarker);
35         }
36     }
37 }
38 }

```

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

```

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

```

```

14     [MethodImpl(MethodImplOptions.AggressiveInlining)]
15     public UnaryNumberIncrementer(ILinks<TLink> links, TLink unaryOne) : base(links) =>
16         ↪ _unaryOne = unaryOne;
17
18     [MethodImpl(MethodImplOptions.AggressiveInlining)]
19     public TLink Increment(TLink unaryNumber)
20     {
21         var links = _links;
22         if (_equalityComparer.Equals(unaryNumber, _unaryOne))
23         {
24             return links.GetOrCreate(_unaryOne, _unaryOne);
25         }
26         var source = links.GetSource(unaryNumber);
27         var target = links.GetTarget(unaryNumber);
28         if (_equalityComparer.Equals(source, target))
29         {
30             return links.GetOrCreate(unaryNumber, _unaryOne);
31         }
32         else
33         {
34             return links.GetOrCreate(source, Increment(target));
35         }
36     }
37 }
38 }

```

1.22 ./csharp/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 }

```

```

50     }
51 }
52
53 [MethodImpl(MethodImplOptions.AggressiveInlining)]
54 public Link(ref Link<TLink> other) => SetValues(ref other, out Index, out Source, out
    ↳ Target);
55
56 [MethodImpl(MethodImplOptions.AggressiveInlining)]
57 public Link(TLink index, TLink source, TLink target)
58 {
59     Index = index;
60     Source = source;
61     Target = target;
62 }
63
64 [MethodImpl(MethodImplOptions.AggressiveInlining)]
65 private static void SetValues(ref Link<TLink> other, out TLink index, out TLink source,
    ↳ out TLink target)
66 {
67     index = other.Index;
68     source = other.Source;
69     target = other.Target;
70 }
71
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 private static void SetValues(ICollection<TLink> values, out TLink index, out TLink source,
    ↳ 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> &&
    ↳ Equals((Link<TLink>)other);
110
111 [MethodImpl(MethodImplOptions.AggressiveInlining)]
112 public bool Equals(Link<TLink> other) => _equalityComparer.Equals(Index, other.Index)
113     && _equalityComparer.Equals(Source, other.Source)
114     && _equalityComparer.Equals(Target, other.Target);
115
116 [MethodImpl(MethodImplOptions.AggressiveInlining)]
117 public static string ToString(TLink index, TLink source, TLink target) => $"{index}:
    ↳ {source}->{target}";
118
119 [MethodImpl(MethodImplOptions.AggressiveInlining)]
120 public static string ToString(TLink source, TLink target) => $"{source}->{target}";
121
122 [MethodImpl(MethodImplOptions.AggressiveInlining)]
123 public static implicit operator TLink[] (Link<TLink> link) => link.ToArray();
124

```

```

125 [MethodImpl(MethodImplOptions.AggressiveInlining)]
126 public static implicit operator Link<TLink>(TLink[] linkArray) => new
    ↳ Link<TLink>(linkArray);
127
128 [MethodImpl(MethodImplOptions.AggressiveInlining)]
129 public override string ToString() => _equalityComparer.Equals(Index, _constants.Null) ?
    ↳ ToString(Source, Target) : ToString(Index, Source, Target);
130
131 #region IList
132
133 public int Count
134 {
135     [MethodImpl(MethodImplOptions.AggressiveInlining)]
136     get => Length;
137 }
138
139 public bool IsReadOnly
140 {
141     [MethodImpl(MethodImplOptions.AggressiveInlining)]
142     get => true;
143 }
144
145 public TLink this[int index]
146 {
147     [MethodImpl(MethodImplOptions.AggressiveInlining)]
148     get
149     {
150         Ensure.OnDebug.ArgumentInRange(index, new Range<int>(0, Length - 1),
            ↳ nameof(index));
151         if (index == _constants.IndexPart)
152         {
153             return Index;
154         }
155         if (index == _constants.SourcePart)
156         {
157             return Source;
158         }
159         if (index == _constants.TargetPart)
160         {
161             return Target;
162         }
163         throw new NotSupportedException(); // Impossible path due to
            ↳ Ensure.ArgumentInRange
164     }
165     [MethodImpl(MethodImplOptions.AggressiveInlining)]
166     set => throw new NotSupportedException();
167 }
168
169 [MethodImpl(MethodImplOptions.AggressiveInlining)]
170 IEnumerator IEnumerable.GetEnumerator() => GetEnumerator();
171
172 [MethodImpl(MethodImplOptions.AggressiveInlining)]
173 public IEnumerator<TLink> GetEnumerator()
174 {
175     yield return Index;
176     yield return Source;
177     yield return Target;
178 }
179
180 [MethodImpl(MethodImplOptions.AggressiveInlining)]
181 public void Add(TLink item) => throw new NotSupportedException();
182
183 [MethodImpl(MethodImplOptions.AggressiveInlining)]
184 public void Clear() => throw new NotSupportedException();
185
186 [MethodImpl(MethodImplOptions.AggressiveInlining)]
187 public bool Contains(TLink item) => IndexOf(item) >= 0;
188
189 [MethodImpl(MethodImplOptions.AggressiveInlining)]
190 public void CopyTo(TLink[] array, int arrayIndex)
191 {
192     Ensure.OnDebug.ArgumentNotNull(array, nameof(array));
193     Ensure.OnDebug.ArgumentInRange(arrayIndex, new Range<int>(0, array.Length - 1),
        ↳ nameof(arrayIndex));
194     if (arrayIndex + Length > array.Length)
195     {
196         throw new InvalidOperationException();
197     }
198     array[arrayIndex++] = Index;

```

```

199         array[arrayIndex++] = Source;
200         array[arrayIndex] = Target;
201     }
202
203     [MethodImpl(MethodImplOptions.AggressiveInlining)]
204     public bool Remove(TLink item) => Throw.A.NotSupportedExceptionAndReturn<bool>();
205
206     [MethodImpl(MethodImplOptions.AggressiveInlining)]
207     public int IndexOf(TLink item)
208     {
209         if (_equalityComparer.Equals(Index, item))
210         {
211             return _constants.IndexPart;
212         }
213         if (_equalityComparer.Equals(Source, item))
214         {
215             return _constants.SourcePart;
216         }
217         if (_equalityComparer.Equals(Target, item))
218         {
219             return _constants.TargetPart;
220         }
221         return -1;
222     }
223
224     [MethodImpl(MethodImplOptions.AggressiveInlining)]
225     public void Insert(int index, TLink item) => throw new NotSupportedException();
226
227     [MethodImpl(MethodImplOptions.AggressiveInlining)]
228     public void RemoveAt(int index) => throw new NotSupportedException();
229
230     [MethodImpl(MethodImplOptions.AggressiveInlining)]
231     public static bool operator ==(Link<TLink> left, Link<TLink> right) =>
232         ↪ left.Equals(right);
233
234     [MethodImpl(MethodImplOptions.AggressiveInlining)]
235     public static bool operator !=(Link<TLink> left, Link<TLink> right) => !(left == right);
236
237     #endregion
238 }

```

1.23 ./csharp/Platform.Data.Doublets/LinkExtensions.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
6 {
7     public static class LinkExtensions
8     {
9         [MethodImpl(MethodImplOptions.AggressiveInlining)]
10        public static bool IsFullPoint<TLink>(this Link<TLink> link) =>
11            ↪ Point<TLink>.IsFullPoint(link);
12
13        [MethodImpl(MethodImplOptions.AggressiveInlining)]
14        public static bool IsPartialPoint<TLink>(this Link<TLink> link) =>
15            ↪ Point<TLink>.IsPartialPoint(link);
16    }
17 }

```

1.24 ./csharp/Platform.Data.Doublets/LinksOperatorBase.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
6 {
7     public abstract class LinksOperatorBase<TLink>
8     {
9         protected readonly ILinks<TLink> _links;
10
11         public ILinks<TLink> Links
12         {
13             [MethodImpl(MethodImplOptions.AggressiveInlining)]
14             get => _links;
15         }
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

18         protected LinksOperatorBase(ILinks<TLink> links) => _links = links;
19     }
20 }

```

1.25 ./csharp/Platform.Data.Doublets/Memory/ILinksListMethods.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.Memory
6 {
7     public interface ILinksListMethods<TLink>
8     {
9         [MethodImpl(MethodImplOptions.AggressiveInlining)]
10         void Detach(TLink freeLink);
11
12         [MethodImpl(MethodImplOptions.AggressiveInlining)]
13         void AttachAsFirst(TLink link);
14     }
15 }

```

1.26 ./csharp/Platform.Data.Doublets/Memory/ILinksTreeMethods.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.Memory
8 {
9     public interface ILinksTreeMethods<TLink>
10    {
11        [MethodImpl(MethodImplOptions.AggressiveInlining)]
12        TLink CountUsages(TLink root);
13
14        [MethodImpl(MethodImplOptions.AggressiveInlining)]
15        TLink Search(TLink source, TLink target);
16
17        [MethodImpl(MethodImplOptions.AggressiveInlining)]
18        TLink EachUsage(TLink root, Func<IList<TLink>, TLink> handler);
19
20        [MethodImpl(MethodImplOptions.AggressiveInlining)]
21        void Detach(ref TLink root, TLink linkIndex);
22
23        [MethodImpl(MethodImplOptions.AggressiveInlining)]
24        void Attach(ref TLink root, TLink linkIndex);
25    }
26 }

```

1.27 ./csharp/Platform.Data.Doublets/Memory/LinksHeader.cs

```

1 using System;
2 using System.Collections.Generic;
3 using System.Runtime.CompilerServices;
4 using Platform.Unsafe;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Memory
9 {
10     public struct LinksHeader<TLink> : IEquatable<LinksHeader<TLink>>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
13             ↪ EqualityComparer<TLink>.Default;
14
15         public static readonly long SizeInBytes = Structure<LinksHeader<TLink>>.Size;
16
17         public TLink AllocatedLinks;
18         public TLink ReservedLinks;
19         public TLink FreeLinks;
20         public TLink FirstFreeLink;
21         public TLink RootAsSource;
22         public TLink RootAsTarget;
23         public TLink LastFreeLink;
24         public TLink Reserved8;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         public override bool Equals(object obj) => obj is LinksHeader<TLink> linksHeader ?
28             ↪ Equals(linksHeader) : false;
29
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

29     public bool Equals(LinksHeader<TLink> other)
30     => _equalityComparer.Equals(AllocatedLinks, other.AllocatedLinks)
31         && _equalityComparer.Equals(ReservedLinks, other.ReservedLinks)
32         && _equalityComparer.Equals(FreeLinks, other.FreeLinks)
33         && _equalityComparer.Equals(FirstFreeLink, other.FirstFreeLink)
34         && _equalityComparer.Equals(RootAsSource, other.RootAsSource)
35         && _equalityComparer.Equals(RootAsTarget, other.RootAsTarget)
36         && _equalityComparer.Equals>LastFreeLink, other.LastFreeLink)
37         && _equalityComparer.Equals(Reserved8, other.Reserved8);
38
39     [MethodImpl(MethodImplOptions.AggressiveInlining)]
40     public override int GetHashCode() => (AllocatedLinks, ReservedLinks, FreeLinks,
41     ↪ FirstFreeLink, RootAsSource, RootAsTarget, LastFreeLink, Reserved8).GetHashCode();
42
43     [MethodImpl(MethodImplOptions.AggressiveInlining)]
44     public static bool operator ==(LinksHeader<TLink> left, LinksHeader<TLink> right) =>
45     ↪ left.Equals(right);
46
47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     public static bool operator !=(LinksHeader<TLink> left, LinksHeader<TLink> right) =>
49     ↪ !(left == right);
50 }
51 }

```

1.28 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/ExternalLinksSizeBalancedTreeMethodsBase.cs

```

1  using System;
2  using System.Text;
3  using System.Collections.Generic;
4  using System.Runtime.CompilerServices;
5  using Platform.Collections.Methods.Trees;
6  using Platform.Converters;
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.Memory.Split.Generic
12 {
13     public unsafe abstract class ExternalLinksSizeBalancedTreeMethodsBase<TLink> :
14     ↪ SizeBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
15     {
16         private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
17         ↪ UncheckedConverter<TLink, long>.Default;
18
19         protected readonly TLink Break;
20         protected readonly TLink Continue;
21         protected readonly byte* LinksDataParts;
22         protected readonly byte* LinksIndexParts;
23         protected readonly byte* Header;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected ExternalLinksSizeBalancedTreeMethodsBase(LinksConstants<TLink> constants,
27         ↪ byte* linksDataParts, byte* linksIndexParts, byte* header)
28         {
29             LinksDataParts = linksDataParts;
30             LinksIndexParts = linksIndexParts;
31             Header = header;
32             Break = constants.Break;
33             Continue = constants.Continue;
34         }
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected abstract TLink GetTreeRoot();
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected abstract TLink GetBasePartValue(TLink link);
41
42         [MethodImpl(MethodImplOptions.AggressiveInlining)]
43         protected abstract bool FirstIsToTheRightOfSecond(TLink source, TLink target, TLink
44         ↪ rootSource, TLink rootTarget);
45
46         [MethodImpl(MethodImplOptions.AggressiveInlining)]
47         protected abstract bool FirstIsToTheLeftOfSecond(TLink source, TLink target, TLink
48         ↪ rootSource, TLink rootTarget);
49
50         [MethodImpl(MethodImplOptions.AggressiveInlining)]
51         protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
52         ↪ AsRef<LinksHeader<TLink>>(Header);
53
54         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

49     protected virtual ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) => ref
    ↪ AsRef<RawLinkDataPart<TLink>>(LinksDataParts + RawLinkDataPart<TLink>.SizeInBytes *
    ↪ _addressToInt64Converter.Convert(link));

50
51     [MethodImpl(MethodImplOptions.AggressiveInlining)]
52     protected virtual ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink link) =>
    ↪ ref AsRef<RawLinkIndexPart<TLink>>(LinksIndexParts +
    ↪ RawLinkIndexPart<TLink>.SizeInBytes * _addressToInt64Converter.Convert(link));

53
54     [MethodImpl(MethodImplOptions.AggressiveInlining)]
55     protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
56     {
57         ref var link = ref GetLinkDataPartReference(linkIndex);
58         return new Link<TLink>(linkIndex, link.Source, link.Target);
59     }
60
61     [MethodImpl(MethodImplOptions.AggressiveInlining)]
62     protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
63     {
64         ref var firstLink = ref GetLinkDataPartReference(first);
65         ref var secondLink = ref GetLinkDataPartReference(second);
66         return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
    ↪ secondLink.Source, secondLink.Target);
67     }
68
69     [MethodImpl(MethodImplOptions.AggressiveInlining)]
70     protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
71     {
72         ref var firstLink = ref GetLinkDataPartReference(first);
73         ref var secondLink = ref GetLinkDataPartReference(second);
74         return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
    ↪ secondLink.Source, secondLink.Target);
75     }
76
77     public TLink this[TLink index]
78     {
79         [MethodImpl(MethodImplOptions.AggressiveInlining)]
80         get
81         {
82             var root = GetTreeRoot();
83             if (GreaterOrEqualThan(index, GetSize(root)))
84             {
85                 return Zero;
86             }
87             while (!EqualToZero(root))
88             {
89                 var left = GetLeftOrDefault(root);
90                 var leftSize = GetSizeOrZero(left);
91                 if (LessThan(index, leftSize))
92                 {
93                     root = left;
94                     continue;
95                 }
96                 if (AreEqual(index, leftSize))
97                 {
98                     return root;
99                 }
100                 root = GetRightOrDefault(root);
101                 index = Subtract(index, Increment(leftSize));
102             }
103             return Zero; // TODO: Impossible situation exception (only if tree structure
    ↪ broken)
104         }
105     }
106
107     /// <summary>
108     /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
    ↪ (концом).
109     /// </summary>
110     /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
111     /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
112     /// <returns>Индекс искомой связи.</returns>
113     [MethodImpl(MethodImplOptions.AggressiveInlining)]
114     public TLink Search(TLink source, TLink target)
115     {
116         var root = GetTreeRoot();
117         while (!EqualToZero(root))
118         {

```



```

119     ref var rootLink = ref GetLinkDataPartReference(root);
120     var rootSource = rootLink.Source;
121     var rootTarget = rootLink.Target;
122     if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
        ↳ node.Key < root.Key
123     {
124         root = GetLeftOrDefault(root);
125     }
126     else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget)) //
        ↳ node.Key > root.Key
127     {
128         root = GetRightOrDefault(root);
129     }
130     else // node.Key == root.Key
131     {
132         return root;
133     }
134 }
135 return Zero;
136 }
137
138 // TODO: Return indices range instead of references count
139 [MethodImpl(MethodImplOptions.AggressiveInlining)]
140 public TLink CountUsages(TLink link)
141 {
142     var root = GetTreeRoot();
143     var total = GetSize(root);
144     var totalRightIgnore = Zero;
145     while (!EqualToZero(root))
146     {
147         var @base = GetBasePartValue(root);
148         if (LessOrEqualThan(@base, link))
149         {
150             root = GetRightOrDefault(root);
151         }
152         else
153         {
154             totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
155             root = GetLeftOrDefault(root);
156         }
157     }
158     root = GetTreeRoot();
159     var totalLeftIgnore = Zero;
160     while (!EqualToZero(root))
161     {
162         var @base = GetBasePartValue(root);
163         if (GreaterOrEqualThan(@base, link))
164         {
165             root = GetLeftOrDefault(root);
166         }
167         else
168         {
169             totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
170             root = GetRightOrDefault(root);
171         }
172     }
173     return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
174 }
175
176 [MethodImpl(MethodImplOptions.AggressiveInlining)]
177 public TLink EachUsage(TLink @base, Func<IList<TLink>, TLink> handler) =>
    ↳ EachUsageCore(@base, GetTreeRoot(), handler);
178
179 // TODO: 1. Move target, handler to separate object. 2. Use stack or walker 3. Use
    ↳ low-level MSIL stack.
180 [MethodImpl(MethodImplOptions.AggressiveInlining)]
181 private TLink EachUsageCore(TLink @base, TLink link, Func<IList<TLink>, TLink> handler)
182 {
183     var @continue = Continue;
184     if (EqualToZero(link))
185     {
186         return @continue;
187     }
188     var linkBasePart = GetBasePartValue(link);
189     var @break = Break;
190     if (GreaterThan(linkBasePart, @base))
191     {
192         if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
193         {

```

```

194         return @break;
195     }
196 }
197 else if (LessThan(linkBasePart, @base))
198 {
199     if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
200     {
201         return @break;
202     }
203 }
204 else //if (linkBasePart == @base)
205 {
206     if (AreEqual(handler(GetLinkValues(link)), @break))
207     {
208         return @break;
209     }
210     if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
211     {
212         return @break;
213     }
214     if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
215     {
216         return @break;
217     }
218 }
219 return @continue;
220 }
221
222 [MethodImpl(MethodImplOptions.AggressiveInlining)]
223 protected override void PrintNodeValue(TLink node, StringBuilder sb)
224 {
225     ref var link = ref GetLinkDataPartReference(node);
226     sb.Append(' ');
227     sb.Append(link.Source);
228     sb.Append('-');
229     sb.Append('>');
230     sb.Append(link.Target);
231 }
232 }
233 }

```

1.29 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/ExternalLinksSourcesSizeBalancedTreeMethods.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.Memory.Split.Generic
6 {
7     public unsafe class ExternalLinksSourcesSizeBalancedTreeMethods<TLink> :
8         ↳ ExternalLinksSizeBalancedTreeMethodsBase<TLink>
9     {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public ExternalLinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink> constants,
12             ↳ byte* linksDataParts, byte* linksIndexParts, byte* header) : base(constants,
13             ↳ linksDataParts, linksIndexParts, header) { }
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         protected override ref TLink GetLeftReference(TLink node) => ref
17             ↳ GetLinkIndexPartReference(node).LeftAsSource;
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         protected override ref TLink GetRightReference(TLink node) => ref
21             ↳ GetLinkIndexPartReference(node).RightAsSource;
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected override TLink GetLeft(TLink node) =>
25             ↳ GetLinkIndexPartReference(node).LeftAsSource;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected override TLink GetRight(TLink node) =>
29             ↳ GetLinkIndexPartReference(node).RightAsSource;
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected override void SetLeft(TLink node, TLink left) =>
33             ↳ GetLinkIndexPartReference(node).LeftAsSource = left;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override void SetRight(TLink node, TLink right) =>
37             ↳ GetLinkIndexPartReference(node).RightAsSource = right;
38     }
39 }

```

```

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

```

1.30 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/ExternalLinksTargetsSizeBalancedTreeMethods.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.Memory.Split.Generic
6  {
7      public unsafe class ExternalLinksTargetsSizeBalancedTreeMethods<TLink> :
8          ↪ ExternalLinksSizeBalancedTreeMethodsBase<TLink>
9      {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public ExternalLinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink> constants,
12             ↪ byte* linksDataParts, byte* linksIndexParts, byte* header) : base(constants,
13             ↪ linksDataParts, linksIndexParts, header) { }
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         protected override ref TLink GetLeftReference(TLink node) => ref
17             ↪ GetLinkIndexPartReference(node).LeftAsTarget;
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         protected override ref TLink GetRightReference(TLink node) => ref
21             ↪ GetLinkIndexPartReference(node).RightAsTarget;
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected override TLink GetLeft(TLink node) =>
25             ↪ GetLinkIndexPartReference(node).LeftAsTarget;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected override TLink GetRight(TLink node) =>
29             ↪ GetLinkIndexPartReference(node).RightAsTarget;
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected override void SetLeft(TLink node, TLink left) =>
33             ↪ GetLinkIndexPartReference(node).LeftAsTarget = left;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override void SetRight(TLink node, TLink right) =>
37             ↪ GetLinkIndexPartReference(node).RightAsTarget = right;
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

31     protected override TLink GetSize(TLink node) =>
32         ↪ GetLinkIndexPartReference(node).SizeAsTarget;
33
34     [MethodImpl(MethodImplOptions.AggressiveInlining)]
35     protected override void SetSize(TLink node, TLink size) =>
36         ↪ GetLinkIndexPartReference(node).SizeAsTarget = size;
37
38     [MethodImpl(MethodImplOptions.AggressiveInlining)]
39     protected override TLink GetTreeRoot() => GetHeaderReference().RootAsTarget;
40
41     [MethodImpl(MethodImplOptions.AggressiveInlining)]
42     protected override TLink GetBasePartValue(TLink link) =>
43         ↪ GetLinkDataPartReference(link).Target;
44
45     [MethodImpl(MethodImplOptions.AggressiveInlining)]
46     protected override bool FirstIsToLeftOfSecond(TLink firstSource, TLink firstTarget,
47         ↪ TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
48         ↪ AreEqual(firstTarget, secondTarget) && LessThan(firstSource, secondSource);
49
50     [MethodImpl(MethodImplOptions.AggressiveInlining)]
51     protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
52         ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
53         ↪ AreEqual(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource);
54
55     [MethodImpl(MethodImplOptions.AggressiveInlining)]
56     protected override void ClearNode(TLink node)
57     {
58         ref var link = ref GetLinkIndexPartReference(node);
59         link.LeftAsTarget = Zero;
60         link.RightAsTarget = Zero;
61         link.SizeAsTarget = Zero;
62     }
63 }

```

1.31 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/InternalLinksSizeBalancedTreeMethodsBase.cs

```

1  using System;
2  using System.Text;
3  using System.Collections.Generic;
4  using System.Runtime.CompilerServices;
5  using Platform.Collections.Methods.Trees;
6  using Platform.Converters;
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.Memory.Split.Generic
12 {
13     public unsafe abstract class InternalLinksSizeBalancedTreeMethodsBase<TLink> :
14         ↪ SizeBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
15     {
16         private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
17             ↪ UncheckedConverter<TLink, long>.Default;
18
19         protected readonly TLink Break;
20         protected readonly TLink Continue;
21         protected readonly byte* LinksDataParts;
22         protected readonly byte* LinksIndexParts;
23         protected readonly byte* Header;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected InternalLinksSizeBalancedTreeMethodsBase(LinksConstants<TLink> constants,
27             ↪ byte* linksDataParts, byte* linksIndexParts, byte* header)
28         {
29             LinksDataParts = linksDataParts;
30             LinksIndexParts = linksIndexParts;
31             Header = header;
32             Break = constants.Break;
33             Continue = constants.Continue;
34         }
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected abstract TLink GetTreeRoot(TLink link);
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected abstract TLink GetBasePartValue(TLink link);
41
42         [MethodImpl(MethodImplOptions.AggressiveInlining)]
43         protected abstract TLink GetKeyPartValue(TLink link);
44
45     }
46 }

```

```

42 [MethodImpl(MethodImplOptions.AggressiveInlining)]
43 protected virtual ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) => ref
    ↳ AsRef<RawLinkDataPart<TLink>>(LinksDataParts + RawLinkDataPart<TLink>.SizeInBytes *
    ↳ _addressToInt64Converter.Convert(link));
44
45 [MethodImpl(MethodImplOptions.AggressiveInlining)]
46 protected virtual ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink link) =>
    ↳ ref AsRef<RawLinkIndexPart<TLink>>(LinksIndexParts +
    ↳ RawLinkIndexPart<TLink>.SizeInBytes * _addressToInt64Converter.Convert(link));
47
48 [MethodImpl(MethodImplOptions.AggressiveInlining)]
49 protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second) =>
    ↳ LessThan(GetKeyPartValue(first), GetKeyPartValue(second));
50
51 [MethodImpl(MethodImplOptions.AggressiveInlining)]
52 protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second) =>
    ↳ GreaterThan(GetKeyPartValue(first), GetKeyPartValue(second));
53
54 [MethodImpl(MethodImplOptions.AggressiveInlining)]
55 protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
56 {
57     ref var link = ref GetLinkDataPartReference(linkIndex);
58     return new Link<TLink>(linkIndex, link.Source, link.Target);
59 }
60
61 public TLink this[TLink link, TLink index]
62 {
63     [MethodImpl(MethodImplOptions.AggressiveInlining)]
64     get
65     {
66         var root = GetTreeRoot(link);
67         if (GreaterOrEqualThan(index, GetSize(root)))
68         {
69             return Zero;
70         }
71         while (!EqualToZero(root))
72         {
73             var left = GetLeftOrDefault(root);
74             var leftSize = GetSizeOrZero(left);
75             if (LessThan(index, leftSize))
76             {
77                 root = left;
78                 continue;
79             }
80             if (AreEqual(index, leftSize))
81             {
82                 return root;
83             }
84             root = GetRightOrDefault(root);
85             index = Subtract(index, Increment(leftSize));
86         }
87         return Zero; // TODO: Impossible situation exception (only if tree structure
            ↳ broken)
88     }
89 }
90
91 /// <summary>
92 /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
    ↳ (концом).
93 /// </summary>
94 /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
95 /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
96 /// <returns>Индекс искомой связи.</returns>
97 [MethodImpl(MethodImplOptions.AggressiveInlining)]
98 public abstract TLink Search(TLink source, TLink target);
99
100 [MethodImpl(MethodImplOptions.AggressiveInlining)]
101 protected TLink SearchCore(TLink root, TLink key)
102 {
103     while (!EqualToZero(root))
104     {
105         var rootKey = GetKeyPartValue(root);
106         if (LessThan(key, rootKey)) // node.Key < root.Key
107         {
108             root = GetLeftOrDefault(root);
109         }
110         else if (GreaterThan(key, rootKey)) // node.Key > root.Key
111         {

```

```

112         root = GetRightOrDefault(root);
113     }
114     else // node.Key == root.Key
115     {
116         return root;
117     }
118 }
119 return Zero;
120 }
121
122 // TODO: Return indices range instead of references count
123 [MethodImpl(MethodImplOptions.AggressiveInlining)]
124 public TLink CountUsages(TLink link) => GetSizeOrZero(GetTreeRoot(link));
125
126 [MethodImpl(MethodImplOptions.AggressiveInlining)]
127 public TLink EachUsage(TLink @base, Func<IList<TLink>, TLink> handler) =>
128     ↳ EachUsageCore(@base, GetTreeRoot(@base), handler);
129
130 // TODO: 1. Move target, handler to separate object. 2. Use stack or walker 3. Use
131 ↳ low-level MSIL stack.
132 [MethodImpl(MethodImplOptions.AggressiveInlining)]
133 private TLink EachUsageCore(TLink @base, TLink link, Func<IList<TLink>, TLink> handler)
134 {
135     var @continue = Continue;
136     if (EqualToZero(link))
137     {
138         return @continue;
139     }
140     var @break = Break;
141     if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
142     {
143         return @break;
144     }
145     if (AreEqual(handler(GetLinkValues(link)), @break))
146     {
147         return @break;
148     }
149     if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
150     {
151         return @break;
152     }
153     return @continue;
154 }
155
156 [MethodImpl(MethodImplOptions.AggressiveInlining)]
157 protected override void PrintNodeValue(TLink node, StringBuilder sb)
158 {
159     ref var link = ref GetLinkDataPartReference(node);
160     sb.Append(' ');
161     sb.Append(link.Source);
162     sb.Append('-');
163     sb.Append('>');
164     sb.Append(link.Target);
165 }
166 }

```

1.32 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/InternalLinksSourcesSizeBalancedTreeMethods.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.Memory.Split.Generic
6 {
7     public unsafe class InternalLinksSourcesSizeBalancedTreeMethods<TLink> :
8     ↳ InternalLinksSizeBalancedTreeMethodsBase<TLink>
9     {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public InternalLinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink> constants,
12     ↳ byte* linksDataParts, byte* linksIndexParts, byte* header) : base(constants,
13     ↳ linksDataParts, linksIndexParts, header) { }
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         protected override ref TLink GetLeftReference(TLink node) => ref
17     ↳ GetLinkIndexPartReference(node).LeftAsSource;
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         protected override ref TLink GetRightReference(TLink node) => ref
21     ↳ GetLinkIndexPartReference(node).RightAsSource;

```

```

17     [MethodImpl(MethodImplOptions.AggressiveInlining)]
18     protected override TLink GetLeft(TLink node) =>
19         ↪ GetLinkIndexPartReference(node).LeftAsSource;
20
21     [MethodImpl(MethodImplOptions.AggressiveInlining)]
22     protected override TLink GetRight(TLink node) =>
23         ↪ GetLinkIndexPartReference(node).RightAsSource;
24
25     [MethodImpl(MethodImplOptions.AggressiveInlining)]
26     protected override void SetLeft(TLink node, TLink left) =>
27         ↪ GetLinkIndexPartReference(node).LeftAsSource = left;
28
29     [MethodImpl(MethodImplOptions.AggressiveInlining)]
30     protected override void SetRight(TLink node, TLink right) =>
31         ↪ GetLinkIndexPartReference(node).RightAsSource = right;
32
33     [MethodImpl(MethodImplOptions.AggressiveInlining)]
34     protected override TLink GetSize(TLink node) =>
35         ↪ GetLinkIndexPartReference(node).SizeAsSource;
36
37     [MethodImpl(MethodImplOptions.AggressiveInlining)]
38     protected override void SetSize(TLink node, TLink size) =>
39         ↪ GetLinkIndexPartReference(node).SizeAsSource = size;
40
41     [MethodImpl(MethodImplOptions.AggressiveInlining)]
42     protected override TLink GetTreeRoot(TLink link) =>
43         ↪ GetLinkIndexPartReference(link).RootAsSource;
44
45     [MethodImpl(MethodImplOptions.AggressiveInlining)]
46     protected override TLink GetBasePartValue(TLink link) =>
47         ↪ GetLinkDataPartReference(link).Source;
48
49     [MethodImpl(MethodImplOptions.AggressiveInlining)]
50     protected override TLink GetKeyPartValue(TLink link) =>
51         ↪ GetLinkDataPartReference(link).Target;
52
53     [MethodImpl(MethodImplOptions.AggressiveInlining)]
54     protected override void ClearNode(TLink node)
55     {
56         ref var link = ref GetLinkIndexPartReference(node);
57         link.LeftAsSource = Zero;
58         link.RightAsSource = Zero;
59         link.SizeAsSource = Zero;
60     }
61
62     public override TLink Search(TLink source, TLink target) =>
63         ↪ SearchCore(GetTreeRoot(source), target);
64 }

```

1.33 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/InternalLinksTargetsSizeBalancedTreeMethods.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.Memory.Split.Generic
6 {
7     public unsafe class InternalLinksTargetsSizeBalancedTreeMethods<TLink> :
8         ↪ InternalLinksSizeBalancedTreeMethodsBase<TLink>
9     {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public InternalLinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink> constants,
12             ↪ byte* linksDataParts, byte* linksIndexParts, byte* header) : base(constants,
13             ↪ linksDataParts, linksIndexParts, header) { }
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         protected override ref TLink GetLeftReference(TLink node) => ref
17             ↪ GetLinkIndexPartReference(node).LeftAsTarget;
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         protected override ref TLink GetRightReference(TLink node) => ref
21             ↪ GetLinkIndexPartReference(node).RightAsTarget;
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected override TLink GetLeft(TLink node) =>
25             ↪ GetLinkIndexPartReference(node).LeftAsTarget;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected override TLink GetRight(TLink node) =>
29             ↪ GetLinkIndexPartReference(node).RightAsTarget;
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected override void SetLeft(TLink node, TLink left) =>
33             ↪ GetLinkIndexPartReference(node).LeftAsTarget = left;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override void SetRight(TLink node, TLink right) =>
37             ↪ GetLinkIndexPartReference(node).RightAsTarget = right;
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override void SetSize(TLink node, TLink size) =>
41             ↪ GetLinkIndexPartReference(node).SizeAsTarget = size;
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         protected override void ClearNode(TLink node)
45         {
46             ref var link = ref GetLinkIndexPartReference(node);
47             link.LeftAsTarget = Zero;
48             link.RightAsTarget = Zero;
49             link.SizeAsTarget = Zero;
50         }
51
52         public override TLink Search(TLink source, TLink target) =>
53             ↪ SearchCore(GetTreeRoot(source), target);
54     }
55 }

```

```

21 [MethodImpl(MethodImplOptions.AggressiveInlining)]
22 protected override TLink GetRight(TLink node) =>
    ↳ GetLinkIndexPartReference(node).RightAsTarget;
23
24 [MethodImpl(MethodImplOptions.AggressiveInlining)]
25 protected override void SetLeft(TLink node, TLink left) =>
    ↳ GetLinkIndexPartReference(node).LeftAsTarget = left;
26
27 [MethodImpl(MethodImplOptions.AggressiveInlining)]
28 protected override void SetRight(TLink node, TLink right) =>
    ↳ GetLinkIndexPartReference(node).RightAsTarget = right;
29
30 [MethodImpl(MethodImplOptions.AggressiveInlining)]
31 protected override TLink GetSize(TLink node) =>
    ↳ GetLinkIndexPartReference(node).SizeAsTarget;
32
33 [MethodImpl(MethodImplOptions.AggressiveInlining)]
34 protected override void SetSize(TLink node, TLink size) =>
    ↳ GetLinkIndexPartReference(node).SizeAsTarget = size;
35
36 [MethodImpl(MethodImplOptions.AggressiveInlining)]
37 protected override TLink GetTreeRoot(TLink link) =>
    ↳ GetLinkIndexPartReference(link).RootAsTarget;
38
39 [MethodImpl(MethodImplOptions.AggressiveInlining)]
40 protected override TLink GetBasePartValue(TLink link) =>
    ↳ GetLinkDataPartReference(link).Target;
41
42 [MethodImpl(MethodImplOptions.AggressiveInlining)]
43 protected override TLink GetKeyPartValue(TLink link) =>
    ↳ GetLinkDataPartReference(link).Source;
44
45 [MethodImpl(MethodImplOptions.AggressiveInlining)]
46 protected override void ClearNode(TLink node)
47 {
48     ref var link = ref GetLinkIndexPartReference(node);
49     link.LeftAsTarget = Zero;
50     link.RightAsTarget = Zero;
51     link.SizeAsTarget = Zero;
52 }
53
54 public override TLink Search(TLink source, TLink target) =>
    ↳ SearchCore(GetTreeRoot(target), source);
55 }
56 }

```

1.34 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/SplitMemoryLinks.cs

```

1 using System;
2 using System.Runtime.CompilerServices;
3 using Platform.Singletons;
4 using Platform.Memory;
5 using static System.Runtime.CompilerServices.Unsafe;
6
7 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9 namespace Platform.Data.Doublets.Memory.Split.Generic
10 {
11     public unsafe class SplitMemoryLinks<TLink> : SplitMemoryLinksBase<TLink>
12     {
13         private readonly Func<ILinksTreeMethods<TLink>> _createInternalSourceTreeMethods;
14         private readonly Func<ILinksTreeMethods<TLink>> _createExternalSourceTreeMethods;
15         private readonly Func<ILinksTreeMethods<TLink>> _createInternalTargetTreeMethods;
16         private readonly Func<ILinksTreeMethods<TLink>> _createExternalTargetTreeMethods;
17         private byte* _header;
18         private byte* _linksDataParts;
19         private byte* _linksIndexParts;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
            ↳ indexMemory) : this(dataMemory, indexMemory, DefaultLinksSizeStep) { }
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         public SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
            ↳ indexMemory, long memoryReservationStep) : this(dataMemory, indexMemory,
            ↳ memoryReservationStep, Default<LinksConstants<TLink>>.Instance) { }
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```



```

28 public SplitMemoryLinks(IResizableDirectMemory dataMemory, IResizableDirectMemory
    ↪ indexMemory, long memoryReservationStep, LinksConstants<TLink> constants) :
    ↪ base(dataMemory, indexMemory, memoryReservationStep, constants)
29 {
30     _createInternalSourceTreeMethods = () => new
        ↪ InternalLinksSourcesSizeBalancedTreeMethods<TLink>(Constants, _linksDataParts,
        ↪ _linksIndexParts, _header);
31     _createExternalSourceTreeMethods = () => new
        ↪ ExternalLinksSourcesSizeBalancedTreeMethods<TLink>(Constants, _linksDataParts,
        ↪ _linksIndexParts, _header);
32     _createInternalTargetTreeMethods = () => new
        ↪ InternalLinksTargetsSizeBalancedTreeMethods<TLink>(Constants, _linksDataParts,
        ↪ _linksIndexParts, _header);
33     _createExternalTargetTreeMethods = () => new
        ↪ ExternalLinksTargetsSizeBalancedTreeMethods<TLink>(Constants, _linksDataParts,
        ↪ _linksIndexParts, _header);
34     Init(dataMemory, indexMemory, memoryReservationStep);
35 }
36
37 [MethodImpl(MethodImplOptions.AggressiveInlining)]
38 protected override void SetPointers(IResizableDirectMemory dataMemory,
    ↪ IResizableDirectMemory indexMemory)
39 {
40     _linksDataParts = (byte*)dataMemory.Pointer;
41     _linksIndexParts = (byte*)indexMemory.Pointer;
42     _header = _linksIndexParts;
43     InternalSourcesTreeMethods = _createInternalSourceTreeMethods();
44     ExternalSourcesTreeMethods = _createExternalSourceTreeMethods();
45     InternalTargetsTreeMethods = _createInternalTargetTreeMethods();
46     ExternalTargetsTreeMethods = _createExternalTargetTreeMethods();
47     UnusedLinksListMethods = new UnusedLinksListMethods<TLink>(_linksDataParts, _header);
48 }
49
50 [MethodImpl(MethodImplOptions.AggressiveInlining)]
51 protected override void ResetPointers()
52 {
53     base.ResetPointers();
54     _linksDataParts = null;
55     _linksIndexParts = null;
56     _header = null;
57 }
58
59 [MethodImpl(MethodImplOptions.AggressiveInlining)]
60 protected override ref LinksHeader<TLink> GetHeaderReference() => ref
    ↪ AsRef<LinksHeader<TLink>>(_header);
61
62 [MethodImpl(MethodImplOptions.AggressiveInlining)]
63 protected override ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink linkIndex)
    ↪ => ref AsRef<RawLinkDataPart<TLink>>(_linksDataParts + LinkDataPartSizeInBytes *
    ↪ ConvertToInt64(linkIndex));
64
65 [MethodImpl(MethodImplOptions.AggressiveInlining)]
66 protected override ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink
    ↪ linkIndex) => ref AsRef<RawLinkIndexPart<TLink>>(_linksIndexParts +
    ↪ LinkIndexPartSizeInBytes * ConvertToInt64(linkIndex));
67 }
68 }

```

1.35 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/SplitMemoryLinksBase.cs

```

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

```

```

19 private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
    ↳ UncheckedConverter<TLink, long>.Default;
20 private static readonly UncheckedConverter<long, TLink> _int64ToAddressConverter =
    ↳ UncheckedConverter<long, TLink>.Default;
21
22 private static readonly TLink _zero = default;
23 private static readonly TLink _one = Arithmetic.Increment(_zero);
24
25 /// <summary>Возвращает размер одной связи в байтах.</summary>
26 /// <remarks>
27 /// Используется только во вне класса, не рекомендуется использовать внутри.
28 /// Так как во вне не обязательно будет доступен unsafe C#.
29 /// </remarks>
30 public static readonly long LinkDataPartSizeInBytes = RawLinkDataPart<TLink>.SizeInBytes;
31
32 public static readonly long LinkIndexPartSizeInBytes =
    ↳ RawLinkIndexPart<TLink>.SizeInBytes;
33
34 public static readonly long LinkHeaderSizeInBytes = LinksHeader<TLink>.SizeInBytes;
35
36 public static readonly long DefaultLinksSizeStep = 1 * 1024 * 1024;
37
38 protected readonly IResizableDirectMemory _dataMemory;
39 protected readonly IResizableDirectMemory _indexMemory;
40 protected readonly long _dataMemoryReservationStepInBytes;
41 protected readonly long _indexMemoryReservationStepInBytes;
42
43 protected ILinksTreeMethods<TLink> InternalSourcesTreeMethods;
44 protected ILinksTreeMethods<TLink> ExternalSourcesTreeMethods;
45 protected ILinksTreeMethods<TLink> InternalTargetsTreeMethods;
46 protected ILinksTreeMethods<TLink> ExternalTargetsTreeMethods;
47 // TODO: Возможно чтобы гарантированно проверять на то, является ли связь удалённой,
    ↳ нужно использовать не список а дерево, так как так можно быстрее проверить на
    ↳ наличие связи внутри
48 protected ILinksListMethods<TLink> UnusedLinksListMethods;
49
50 /// <summary>
51 /// Возвращает общее число связей находящихся в хранилище.
52 /// </summary>
53 protected virtual TLink Total
54 {
55     [MethodImpl(MethodImplOptions.AggressiveInlining)]
56     get
57     {
58         ref var header = ref GetHeaderReference();
59         return Subtract(header.AllocatedLinks, header.FreeLinks);
60     }
61 }
62
63 public virtual LinksConstants<TLink> Constants
64 {
65     [MethodImpl(MethodImplOptions.AggressiveInlining)]
66     get;
67 }
68
69 [MethodImpl(MethodImplOptions.AggressiveInlining)]
70 protected SplitMemoryLinksBase(IResizableDirectMemory dataMemory, IResizableDirectMemory
    ↳ indexMemory, long memoryReservationStep, LinksConstants<TLink> constants)
71 {
72     _dataMemory = dataMemory;
73     _indexMemory = indexMemory;
74     _dataMemoryReservationStepInBytes = memoryReservationStep * LinkDataPartSizeInBytes;
75     _indexMemoryReservationStepInBytes = memoryReservationStep *
    ↳ LinkIndexPartSizeInBytes;
76     Constants = constants;
77 }
78
79 [MethodImpl(MethodImplOptions.AggressiveInlining)]
80 protected SplitMemoryLinksBase(IResizableDirectMemory dataMemory, IResizableDirectMemory
    ↳ indexMemory, long memoryReservationStep) : this(dataMemory, indexMemory,
    ↳ memoryReservationStep, Default<LinksConstants<TLink>>.Instance) { }
81
82 [MethodImpl(MethodImplOptions.AggressiveInlining)]
83 protected virtual void Init(IResizableDirectMemory dataMemory, IResizableDirectMemory
    ↳ indexMemory, long memoryReservationStep)
84 {
85     if (dataMemory.ReservedCapacity < memoryReservationStep)
86     {
87         dataMemory.ReservedCapacity = memoryReservationStep;
88     }

```

```

89     if (indexMemory.ReservedCapacity < memoryReservationStep)
90     {
91         indexMemory.ReservedCapacity = memoryReservationStep;
92     }
93     SetPointers(dataMemory, indexMemory);
94     ref var header = ref GetHeaderReference();
95     // Ensure correctness _memory.UsedCapacity over _header->AllocatedLinks
96     // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
97     dataMemory.UsedCapacity = ConvertToInt64(header.AllocatedLinks) *
98     ↪ LinkDataPartSizeInBytes + LinkDataPartSizeInBytes; // First link is read only
99     ↪ zero link.
100     indexMemory.UsedCapacity = ConvertToInt64(header.AllocatedLinks) *
101     ↪ LinkIndexPartSizeInBytes + LinkHeaderSizeInBytes;
102     // Ensure correctness _memory.ReservedLinks over _header->ReservedCapacity
103     // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
104     header.ReservedLinks = ConvertToAddress((dataMemory.ReservedCapacity -
105     ↪ LinkDataPartSizeInBytes) / LinkDataPartSizeInBytes);
106 }
107
108 [MethodImpl(MethodImplOptions.AggressiveInlining)]
109 public virtual TLink Count(ICollection<TLink> restrictions)
110 {
111     // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
112     if (restrictions.Count == 0)
113     {
114         return Total;
115     }
116     var constants = Constants;
117     var any = constants.Any;
118     var index = restrictions[constants.IndexPart];
119     if (restrictions.Count == 1)
120     {
121         if (AreEqual(index, any))
122         {
123             return Total;
124         }
125         return Exists(index) ? GetOne() : GetZero();
126     }
127     if (restrictions.Count == 2)
128     {
129         var value = restrictions[1];
130         if (AreEqual(index, any))
131         {
132             if (AreEqual(value, any))
133             {
134                 return Total; // Any - как отсутствие ограничения
135             }
136             var externalReferencesRange = constants.ExternalReferencesRange;
137             if (externalReferencesRange.HasValue &&
138             ↪ externalReferencesRange.Value.Contains(value))
139             {
140                 return Add(ExternalSourcesTreeMethods.CountUsages(value),
141                 ↪ ExternalTargetsTreeMethods.CountUsages(value));
142             }
143             else
144             {
145                 return Add(InternalSourcesTreeMethods.CountUsages(value),
146                 ↪ InternalTargetsTreeMethods.CountUsages(value));
147             }
148         }
149         else
150         {
151             if (!Exists(index))
152             {
153                 return GetZero();
154             }
155             if (AreEqual(value, any))
156             {
157                 return GetOne();
158             }
159             ref var storedLinkValue = ref GetLinkDataPartReference(index);
160             if (AreEqual(storedLinkValue.Source, value) ||
161             ↪ AreEqual(storedLinkValue.Target, value))
162             {
163                 return GetOne();
164             }
165             return GetZero();
166         }
167     }
168 }

```

```

159 }
160 if (restrictions.Count == 3)
161 {
162     var externalReferencesRange = constants.ExternalReferencesRange;
163     var source = restrictions[constants.SourcePart];
164     var target = restrictions[constants.TargetPart];
165     if (AreEqual(index, any))
166     {
167         if (AreEqual(source, any) && AreEqual(target, any))
168         {
169             return Total;
170         }
171         else if (AreEqual(source, any))
172         {
173             if (externalReferencesRange.HasValue &&
174                 ⇨ externalReferencesRange.Value.Contains(target))
175             {
176                 return ExternalTargetsTreeMethods.CountUsages(target);
177             }
178             else
179             {
180                 return InternalTargetsTreeMethods.CountUsages(target);
181             }
182         }
183         else if (AreEqual(target, any))
184         {
185             if (externalReferencesRange.HasValue &&
186                 ⇨ externalReferencesRange.Value.Contains(source))
187             {
188                 return ExternalSourcesTreeMethods.CountUsages(source);
189             }
190             else
191             {
192                 return InternalSourcesTreeMethods.CountUsages(source);
193             }
194         }
195     }
196     else //if(source != Any && target != Any)
197     {
198         // Эквивалент Exists(source, target) => Count(Any, source, target) > 0
199         TLink link;
200         if (externalReferencesRange.HasValue)
201         {
202             if (externalReferencesRange.Value.Contains(source) &&
203                 ⇨ externalReferencesRange.Value.Contains(target))
204             {
205                 link = ExternalSourcesTreeMethods.Search(source, target);
206             }
207             else if (externalReferencesRange.Value.Contains(source))
208             {
209                 link = InternalTargetsTreeMethods.Search(source, target);
210             }
211             else if (externalReferencesRange.Value.Contains(target))
212             {
213                 link = InternalSourcesTreeMethods.Search(source, target);
214             }
215             else
216             {
217                 if (GreaterThan(InternalSourcesTreeMethods.CountUsages(source),
218                     ⇨ InternalTargetsTreeMethods.CountUsages(target)))
219                 {
220                     link = InternalTargetsTreeMethods.Search(source, target);
221                 }
222                 else
223                 {
224                     link = InternalSourcesTreeMethods.Search(source, target);
225                 }
226             }
227         }
228         else
229         {
230             if (GreaterThan(InternalSourcesTreeMethods.CountUsages(source),
231                 ⇨ InternalTargetsTreeMethods.CountUsages(target)))
232             {
233                 link = InternalTargetsTreeMethods.Search(source, target);
234             }
235             else
236             {
237                 link = InternalSourcesTreeMethods.Search(source, target);
238             }
239         }
240     }
241 }

```

```

232     }
233     }
234     return AreEqual(link, constants.Null) ? GetZero() : GetOne();
235 }
236 }
237 else
238 {
239     if (!Exists(index))
240     {
241         return GetZero();
242     }
243     if (AreEqual(source, any) && AreEqual(target, any))
244     {
245         return GetOne();
246     }
247     ref var storedLinkValue = ref GetLinkDataPartReference(index);
248     if (!AreEqual(source, any) && !AreEqual(target, any))
249     {
250         if (AreEqual(storedLinkValue.Source, source) &&
251             ⇨ AreEqual(storedLinkValue.Target, target))
252         {
253             return GetOne();
254         }
255         return GetZero();
256     }
257     var value = default(TLink);
258     if (AreEqual(source, any))
259     {
260         value = target;
261     }
262     if (AreEqual(target, any))
263     {
264         value = source;
265     }
266     if (AreEqual(storedLinkValue.Source, value) ||
267         ⇨ AreEqual(storedLinkValue.Target, value))
268     {
269         return GetOne();
270     }
271     return GetZero();
272 }
273 }
274
275 [MethodImpl(MethodImplOptions.AggressiveInlining)]
276 public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
277 {
278     var constants = Constants;
279     var @break = constants.Break;
280     if (restrictions.Count == 0)
281     {
282         for (var link = GetOne(); LessOrEqualThan(link,
283             ⇨ GetHeaderReference().AllocatedLinks); link = Increment(link))
284         {
285             if (Exists(link) && AreEqual(handler(GetLinkStruct(link)), @break))
286             {
287                 return @break;
288             }
289         }
290         return @break;
291     }
292     var @continue = constants.Continue;
293     var any = constants.Any;
294     var index = restrictions[constants.IndexPart];
295     if (restrictions.Count == 1)
296     {
297         if (AreEqual(index, any))
298         {
299             return Each(handler, Array.Empty<TLink>());
300         }
301         if (!Exists(index))
302         {
303             return @continue;
304         }
305         return handler(GetLinkStruct(index));
306     }

```

```

306 if (restrictions.Count == 2)
307 {
308     var value = restrictions[1];
309     if (AreEqual(index, any))
310     {
311         if (AreEqual(value, any))
312         {
313             return Each(handler, Array.Empty<TLink>());
314         }
315         if (AreEqual(Each(handler, new Link<TLink>(index, value, any)), @break))
316         {
317             return @break;
318         }
319         return Each(handler, new Link<TLink>(index, any, value));
320     }
321 else
322 {
323     if (!Exists(index))
324     {
325         return @continue;
326     }
327     if (AreEqual(value, any))
328     {
329         return handler(GetLinkStruct(index));
330     }
331     ref var storedLinkValue = ref GetLinkDataPartReference(index);
332     if (AreEqual(storedLinkValue.Source, value) ||
333         AreEqual(storedLinkValue.Target, value))
334     {
335         return handler(GetLinkStruct(index));
336     }
337     return @continue;
338 }
339 }
340 if (restrictions.Count == 3)
341 {
342     var externalReferencesRange = constants.ExternalReferencesRange;
343     var source = restrictions[constants.SourcePart];
344     var target = restrictions[constants.TargetPart];
345     if (AreEqual(index, any))
346     {
347         if (AreEqual(source, any) && AreEqual(target, any))
348         {
349             return Each(handler, Array.Empty<TLink>());
350         }
351         else if (AreEqual(source, any))
352         {
353             if (externalReferencesRange.HasValue &&
354                 ⇨ externalReferencesRange.Value.Contains(target))
355             {
356                 return ExternalTargetsTreeMethods.EachUsage(target, handler);
357             }
358             else
359             {
360                 return InternalTargetsTreeMethods.EachUsage(target, handler);
361             }
362         }
363         else if (AreEqual(target, any))
364         {
365             if (externalReferencesRange.HasValue &&
366                 ⇨ externalReferencesRange.Value.Contains(source))
367             {
368                 return ExternalSourcesTreeMethods.EachUsage(source, handler);
369             }
370             else
371             {
372                 return InternalSourcesTreeMethods.EachUsage(source, handler);
373             }
374         }
375         else //if(source != Any && target != Any)
376         {
377             TLink link;
378             if (externalReferencesRange.HasValue)
379             {
380                 if (externalReferencesRange.Value.Contains(source) &&
381                     ⇨ externalReferencesRange.Value.Contains(target))
382                 {
383                     link = ExternalSourcesTreeMethods.Search(source, target);
384                 }
385             }
386         }
387     }
388 }

```

```

381     }
382     else if (externalReferencesRange.Value.Contains(source))
383     {
384         link = InternalTargetsTreeMethods.Search(source, target);
385     }
386     else if (externalReferencesRange.Value.Contains(target))
387     {
388         link = InternalSourcesTreeMethods.Search(source, target);
389     }
390     else
391     {
392         if (GreaterThan(InternalSourcesTreeMethods.CountUsages(source),
393             ↪ InternalTargetsTreeMethods.CountUsages(target)))
394         {
395             link = InternalTargetsTreeMethods.Search(source, target);
396         }
397         else
398         {
399             link = InternalSourcesTreeMethods.Search(source, target);
400         }
401     }
402     else
403     {
404         if (GreaterThan(InternalSourcesTreeMethods.CountUsages(source),
405             ↪ InternalTargetsTreeMethods.CountUsages(target)))
406         {
407             link = InternalTargetsTreeMethods.Search(source, target);
408         }
409         else
410         {
411             link = InternalSourcesTreeMethods.Search(source, target);
412         }
413     }
414     return AreEqual(link, constants.Null) ? @continue :
415         ↪ handler(GetLinkStruct(link));
416 }
417 else
418 {
419     if (!Exists(index))
420     {
421         return @continue;
422     }
423     if (AreEqual(source, any) && AreEqual(target, any))
424     {
425         return handler(GetLinkStruct(index));
426     }
427     ref var storedLinkValue = ref GetLinkDataPartReference(index);
428     if (!AreEqual(source, any) && !AreEqual(target, any))
429     {
430         if (AreEqual(storedLinkValue.Source, source) &&
431             AreEqual(storedLinkValue.Target, target))
432         {
433             return handler(GetLinkStruct(index));
434         }
435         return @continue;
436     }
437     var value = default(TLink);
438     if (AreEqual(source, any))
439     {
440         value = target;
441     }
442     if (AreEqual(target, any))
443     {
444         value = source;
445     }
446     if (AreEqual(storedLinkValue.Source, value) ||
447         AreEqual(storedLinkValue.Target, value))
448     {
449         return handler(GetLinkStruct(index));
450     }
451     return @continue;
452 }
453 }
454 throw new NotSupportedException("Другие размеры и способы ограничений не
    ↪ поддерживаются.");

```

```

455 /// <remarks>
456 /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
457 ↪ в другом месте (но не в менеджере памяти, а в логике Links)
458 /// </remarks>
459 [MethodImpl(MethodImplOptions.AggressiveInlining)]
460 public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
461 {
462     var constants = Constants;
463     var @null = constants.Null;
464     var externalReferencesRange = constants.ExternalReferencesRange;
465     var linkIndex = restrictions[constants.IndexPart];
466     ref var link = ref GetLinkDataPartReference(linkIndex);
467     var source = link.Source;
468     var target = link.Target;
469     ref var header = ref GetHeaderReference();
470     ref var rootAsSource = ref header.RootAsSource;
471     ref var rootAsTarget = ref header.RootAsTarget;
472     // Будет корректно работать только в том случае, если пространство выделенной связи
473     ↪ предварительно заполнено нулями
474     if (!AreEqual(source, @null))
475     {
476         if (externalReferencesRange.HasValue &&
477             ↪ externalReferencesRange.Value.Contains(source))
478         {
479             ExternalSourcesTreeMethods.Detach(ref rootAsSource, linkIndex);
480         }
481         else
482         {
483             InternalSourcesTreeMethods.Detach(ref
484                 ↪ GetLinkIndexPartReference(source).RootAsSource, linkIndex);
485         }
486     }
487     if (!AreEqual(target, @null))
488     {
489         if (externalReferencesRange.HasValue &&
490             ↪ externalReferencesRange.Value.Contains(target))
491         {
492             ExternalTargetsTreeMethods.Detach(ref rootAsTarget, linkIndex);
493         }
494         else
495         {
496             InternalTargetsTreeMethods.Detach(ref
497                 ↪ GetLinkIndexPartReference(target).RootAsTarget, linkIndex);
498         }
499     }
500     source = link.Source = substitution[constants.SourcePart];
501     target = link.Target = substitution[constants.TargetPart];
502     if (!AreEqual(source, @null))
503     {
504         if (externalReferencesRange.HasValue &&
505             ↪ externalReferencesRange.Value.Contains(source))
506         {
507             ExternalSourcesTreeMethods.Attach(ref rootAsSource, linkIndex);
508         }
509         else
510         {
511             InternalSourcesTreeMethods.Attach(ref
512                 ↪ GetLinkIndexPartReference(source).RootAsSource, linkIndex);
513         }
514     }
515     if (!AreEqual(target, @null))
516     {
517         if (externalReferencesRange.HasValue &&
518             ↪ externalReferencesRange.Value.Contains(target))
519         {
520             ExternalTargetsTreeMethods.Attach(ref rootAsTarget, linkIndex);
521         }
522         else
523         {
524             InternalTargetsTreeMethods.Attach(ref
525                 ↪ GetLinkIndexPartReference(target).RootAsTarget, linkIndex);
526         }
527     }
528     return linkIndex;
529 }
530
531 /// <remarks>

```



```

523  /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
524  → пространство
525  /// </remarks>
526  [MethodImpl(MethodImplOptions.AggressiveInlining)]
527  public virtual TLink Create(IList<TLink> restrictions)
528  {
529      ref var header = ref GetHeaderReference();
530      var freeLink = header.FirstFreeLink;
531      if (!AreEqual(freeLink, Constants.Null))
532      {
533          UnusedLinksListMethods.Detach(freeLink);
534      }
535      else
536      {
537          var maximumPossibleInnerReference = Constants.InternalReferencesRange.Maximum;
538          if (GreaterThan(header.AllocatedLinks, maximumPossibleInnerReference))
539          {
540              throw new LinksLimitReachedException<TLink>(maximumPossibleInnerReference);
541          }
542          if (GreaterOrEqualThan(header.AllocatedLinks, Decrement(header.ReservedLinks)))
543          {
544              _dataMemory.ReservedCapacity += _dataMemory.ReservationStepInBytes;
545              _indexMemory.ReservedCapacity += _indexMemory.ReservationStepInBytes;
546              SetPointers(_dataMemory, _indexMemory);
547              header = ref GetHeaderReference();
548              header.ReservedLinks = ConvertToAddress(_dataMemory.ReservedCapacity /
549                  → LinkDataPartSizeInBytes);
550          }
551          header.AllocatedLinks = Increment(header.AllocatedLinks);
552          _dataMemory.UsedCapacity += LinkDataPartSizeInBytes;
553          _indexMemory.UsedCapacity += LinkIndexPartSizeInBytes;
554          freeLink = header.AllocatedLinks;
555      }
556      return freeLink;
557  }
558  [MethodImpl(MethodImplOptions.AggressiveInlining)]
559  public virtual void Delete(IList<TLink> restrictions)
560  {
561      ref var header = ref GetHeaderReference();
562      var link = restrictions[Constants.IndexPart];
563      if (LessThan(link, header.AllocatedLinks)
564      {
565          UnusedLinksListMethods.AttachAsFirst(link);
566      }
567      else if (AreEqual(link, header.AllocatedLinks))
568      {
569          header.AllocatedLinks = Decrement(header.AllocatedLinks);
570          _dataMemory.UsedCapacity -= LinkDataPartSizeInBytes;
571          _indexMemory.UsedCapacity -= LinkIndexPartSizeInBytes;
572          // Убираем все связи, находящиеся в списке свободных в конце файла, до тех пор,
573          → пока не дойдём до первой существующей связи
574          // Позволяет оптимизировать количество выделенных связей (AllocatedLinks)
575          while (GreaterThan(header.AllocatedLinks, GetZero()) &&
576              → IsUnusedLink(header.AllocatedLinks))
577          {
578              UnusedLinksListMethods.Detach(header.AllocatedLinks);
579              header.AllocatedLinks = Decrement(header.AllocatedLinks);
580              _dataMemory.UsedCapacity -= LinkDataPartSizeInBytes;
581              _indexMemory.UsedCapacity -= LinkIndexPartSizeInBytes;
582          }
583      }
584  }
585  [MethodImpl(MethodImplOptions.AggressiveInlining)]
586  public IList<TLink> GetLinkStruct(TLink linkIndex)
587  {
588      ref var link = ref GetLinkDataPartReference(linkIndex);
589      return new Link<TLink>(linkIndex, link.Source, link.Target);
590  }
591  /// <remarks>
592  /// TODO: Возможно это должно быть событием, вызываемым из IMemory, в том случае, если
593  → адрес реально поменялся
594  ///
595  /// Указатель this.links может быть в том же месте,
596  /// так как 0-я связь не используется и имеет такой же размер как Header,
597  /// поэтому header размещается в том же месте, что и 0-я связь
598  /// </remarks>

```

```

597 [MethodImpl(MethodImplOptions.AggressiveInlining)]
598 protected abstract void SetPointers(IResizableDirectMemory dataMemory,
    ↳ IResizableDirectMemory indexMemory);
599
600 [MethodImpl(MethodImplOptions.AggressiveInlining)]
601 protected virtual void ResetPointers()
602 {
603     InternalSourcesTreeMethods = null;
604     ExternalSourcesTreeMethods = null;
605     InternalTargetsTreeMethods = null;
606     ExternalTargetsTreeMethods = null;
607     UnusedLinksListMethods = null;
608 }
609
610 [MethodImpl(MethodImplOptions.AggressiveInlining)]
611 protected abstract ref LinksHeader<TLink> GetHeaderReference();
612
613 [MethodImpl(MethodImplOptions.AggressiveInlining)]
614 protected abstract ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink linkIndex);
615
616 [MethodImpl(MethodImplOptions.AggressiveInlining)]
617 protected abstract ref RawLinkIndexPart<TLink> GetLinkIndexPartReference(TLink
    ↳ linkIndex);
618
619 [MethodImpl(MethodImplOptions.AggressiveInlining)]
620 protected virtual bool Exists(TLink link)
621     => GreaterOrEqualThan(link, Constants.InternalReferencesRange.Minimum)
622     && LessOrEqualThan(link, GetHeaderReference().AllocatedLinks)
623     && !IsUnusedLink(link);
624
625 [MethodImpl(MethodImplOptions.AggressiveInlining)]
626 protected virtual bool IsUnusedLink(TLink linkIndex)
627 {
628     if (!AreEqual(GetHeaderReference().FirstFreeLink, linkIndex)) // May be this check
        ↳ is not needed
629     {
630         // TODO: Reduce access to memory in different location (should be enough to use
        ↳ just linkIndexPart)
631         ref var linkDataPart = ref GetLinkDataPartReference(linkIndex);
632         ref var linkIndexPart = ref GetLinkIndexPartReference(linkIndex);
633         return AreEqual(linkIndexPart.SizeAsSource, default) &&
        ↳ !AreEqual(linkDataPart.Source, default);
634     }
635     else
636     {
637         return true;
638     }
639 }
640
641 [MethodImpl(MethodImplOptions.AggressiveInlining)]
642 protected virtual TLink GetOne() => _one;
643
644 [MethodImpl(MethodImplOptions.AggressiveInlining)]
645 protected virtual TLink GetZero() => default;
646
647 [MethodImpl(MethodImplOptions.AggressiveInlining)]
648 protected virtual bool AreEqual(TLink first, TLink second) =>
    ↳ _equalityComparer.Equals(first, second);
649
650 [MethodImpl(MethodImplOptions.AggressiveInlining)]
651 protected virtual bool LessThan(TLink first, TLink second) => _comparer.Compare(first,
    ↳ second) < 0;
652
653 [MethodImpl(MethodImplOptions.AggressiveInlining)]
654 protected virtual bool LessOrEqualThan(TLink first, TLink second) =>
    ↳ _comparer.Compare(first, second) <= 0;
655
656 [MethodImpl(MethodImplOptions.AggressiveInlining)]
657 protected virtual bool GreaterThan(TLink first, TLink second) =>
    ↳ _comparer.Compare(first, second) > 0;
658
659 [MethodImpl(MethodImplOptions.AggressiveInlining)]
660 protected virtual bool GreaterOrEqualThan(TLink first, TLink second) =>
    ↳ _comparer.Compare(first, second) >= 0;
661
662 [MethodImpl(MethodImplOptions.AggressiveInlining)]
663 protected virtual long ConvertToInt64(TLink value) =>
    ↳ _addressToInt64Converter.Convert(value);
664

```

```

665 [MethodImpl(MethodImplOptions.AggressiveInlining)]
666 protected virtual TLink ConvertToAddress(long value) =>
    ↳ _int64ToAddressConverter.Convert(value);
667
668 [MethodImpl(MethodImplOptions.AggressiveInlining)]
669 protected virtual TLink Add(TLink first, TLink second) => Arithmetic<TLink>.Add(first,
    ↳ second);
670
671 [MethodImpl(MethodImplOptions.AggressiveInlining)]
672 protected virtual TLink Subtract(TLink first, TLink second) =>
    ↳ Arithmetic<TLink>.Subtract(first, second);
673
674 [MethodImpl(MethodImplOptions.AggressiveInlining)]
675 protected virtual TLink Increment(TLink link) => Arithmetic<TLink>.Increment(link);
676
677 [MethodImpl(MethodImplOptions.AggressiveInlining)]
678 protected virtual TLink Decrement(TLink link) => Arithmetic<TLink>.Decrement(link);
679
680 #region Disposable
681
682 protected override bool AllowMultipleDisposeCalls
683 {
684     [MethodImpl(MethodImplOptions.AggressiveInlining)]
685     get => true;
686 }
687
688 [MethodImpl(MethodImplOptions.AggressiveInlining)]
689 protected override void Dispose(bool manual, bool wasDisposed)
690 {
691     if (!wasDisposed)
692     {
693         ResetPointers();
694         _dataMemory.DisposeIfPossible();
695         _indexMemory.DisposeIfPossible();
696     }
697 }
698
699 #endregion
700 }
701 }

```

1.36 ./csharp/Platform.Data.Doublets/Memory/Split/Generic/UnusedLinksListMethods.cs

```

1 using System.Runtime.CompilerServices;
2 using Platform.Collections.Methods.Lists;
3 using Platform.Converters;
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.Memory.Split.Generic
9 {
10     public unsafe class UnusedLinksListMethods<TLink> : CircularDoublyLinkedListMethods<TLink>,
        ↳ ILinksListMethods<TLink>
11     {
12         private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
            ↳ UncheckedConverter<TLink, long>.Default;
13
14         private readonly byte* _links;
15         private readonly byte* _header;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         public UnusedLinksListMethods(byte* links, byte* header)
19         {
20             _links = links;
21             _header = header;
22         }
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
            ↳ AsRef<LinksHeader<TLink>>(_header);
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected virtual ref RawLinkDataPart<TLink> GetLinkDataPartReference(TLink link) => ref
            ↳ AsRef<RawLinkDataPart<TLink>>(_links + RawLinkDataPart<TLink>.SizeInBytes *
            ↳ _addressToInt64Converter.Convert(link));
29
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]
31         protected override TLink GetFirst() => GetHeaderReference().FirstFreeLink;
32
33         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

34     protected override TLink GetLast() => GetHeaderReference().LastFreeLink;
35
36     [MethodImpl(MethodImplOptions.AggressiveInlining)]
37     protected override TLink GetPrevious(TLink element) =>
38         ↪ GetLinkDataPartReference(element).Source;
39
40     [MethodImpl(MethodImplOptions.AggressiveInlining)]
41     protected override TLink GetNext(TLink element) =>
42         ↪ GetLinkDataPartReference(element).Target;
43
44     [MethodImpl(MethodImplOptions.AggressiveInlining)]
45     protected override TLink GetSize() => GetHeaderReference().FreeLinks;
46
47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     protected override void SetFirst(TLink element) => GetHeaderReference().FirstFreeLink =
49         ↪ element;
50
51     [MethodImpl(MethodImplOptions.AggressiveInlining)]
52     protected override void SetLast(TLink element) => GetHeaderReference().LastFreeLink =
53         ↪ element;
54
55     [MethodImpl(MethodImplOptions.AggressiveInlining)]
56     protected override void SetPrevious(TLink element, TLink previous) =>
57         ↪ GetLinkDataPartReference(element).Source = previous;
58
59     [MethodImpl(MethodImplOptions.AggressiveInlining)]
60     protected override void SetNext(TLink element, TLink next) =>
61         ↪ GetLinkDataPartReference(element).Target = next;
62
63     [MethodImpl(MethodImplOptions.AggressiveInlining)]
64     protected override void SetSize(TLink size) => GetHeaderReference().FreeLinks = size;
65 }

```

1.37 ./csharp/Platform.Data.Doublets/Memory/Split/RawLinkDataPart.cs

```

1  using Platform.Unsafe;
2  using System;
3  using System.Collections.Generic;
4  using System.Runtime.CompilerServices;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Memory.Split
9  {
10     public struct RawLinkDataPart<TLink> : IEquatable<RawLinkDataPart<TLink>>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
13             ↪ EqualityComparer<TLink>.Default;
14
15         public static readonly long SizeInBytes = Structure<RawLinkDataPart<TLink>>.Size;
16
17         public TLink Source;
18         public TLink Target;
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         public override bool Equals(object obj) => obj is RawLinkDataPart<TLink> link ?
22             ↪ Equals(link) : false;
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         public bool Equals(RawLinkDataPart<TLink> other)
26             => _equalityComparer.Equals(Source, other.Source)
27             && _equalityComparer.Equals(Target, other.Target);
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         public override int GetHashCode() => (Source, Target).GetHashCode();
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         public static bool operator ==(RawLinkDataPart<TLink> left, RawLinkDataPart<TLink>
34             ↪ right) => left.Equals(right);
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         public static bool operator !=(RawLinkDataPart<TLink> left, RawLinkDataPart<TLink>
38             ↪ right) => !(left == right);
39     }
40 }

```

1.38 ./csharp/Platform.Data.Doublets/Memory/Split/RawLinkIndexPart.cs

```

1  using Platform.Unsafe;
2  using System;

```

```

3 using System.Collections.Generic;
4 using System.Runtime.CompilerServices;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Memory.Split
9 {
10     public struct RawLinkIndexPart<TLink> : IEquatable<RawLinkIndexPart<TLink>>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
13             ↳ EqualityComparer<TLink>.Default;
14
15         public static readonly long SizeInBytes = Structure<RawLinkIndexPart<TLink>>.Size;
16
17         public TLink RootAsSource;
18         public TLink LeftAsSource;
19         public TLink RightAsSource;
20         public TLink SizeAsSource;
21         public TLink RootAsTarget;
22         public TLink LeftAsTarget;
23         public TLink RightAsTarget;
24         public TLink SizeAsTarget;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         public override bool Equals(object obj) => obj is RawLinkIndexPart<TLink> link ?
28             ↳ Equals(link) : false;
29
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]
31         public bool Equals(RawLinkIndexPart<TLink> other)
32             => _equalityComparer.Equals(RootAsSource, other.RootAsSource)
33             && _equalityComparer.Equals(LeftAsSource, other.LeftAsSource)
34             && _equalityComparer.Equals(RightAsSource, other.RightAsSource)
35             && _equalityComparer.Equals(SizeAsSource, other.SizeAsSource)
36             && _equalityComparer.Equals(RootAsTarget, other.RootAsTarget)
37             && _equalityComparer.Equals(LeftAsTarget, other.LeftAsTarget)
38             && _equalityComparer.Equals(RightAsTarget, other.RightAsTarget)
39             && _equalityComparer.Equals(SizeAsTarget, other.SizeAsTarget);
40
41         [MethodImpl(MethodImplOptions.AggressiveInlining)]
42         public override int GetHashCode() => (RootAsSource, LeftAsSource, RightAsSource,
43             ↳ SizeAsSource, RootAsTarget, LeftAsTarget, RightAsTarget, SizeAsTarget).GetHashCode();
44
45         [MethodImpl(MethodImplOptions.AggressiveInlining)]
46         public static bool operator ==(RawLinkIndexPart<TLink> left, RawLinkIndexPart<TLink>
47             ↳ right) => left.Equals(right);
48
49         [MethodImpl(MethodImplOptions.AggressiveInlining)]
50         public static bool operator !=(RawLinkIndexPart<TLink> left, RawLinkIndexPart<TLink>
51             ↳ right) => !(left == right);
52     }
53 }

```

1.39 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksAvlBalancedTreeMethodsBase.cs

```

1 using System;
2 using System.Text;
3 using System.Collections.Generic;
4 using System.Runtime.CompilerServices;
5 using Platform.Collections.Methods.Trees;
6 using Platform.Converters;
7 using Platform.Numbers;
8 using static System.Runtime.CompilerServices.Unsafe;
9
10 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
11
12 namespace Platform.Data.Doublets.Memory.United.Generic
13 {
14     public unsafe abstract class LinksAvlBalancedTreeMethodsBase<TLink> :
15         ↳ SizedAndThreadedAVLBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
16     {
17         private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
18             ↳ UncheckedConverter<TLink, long>.Default;
19         private static readonly UncheckedConverter<TLink, int> _addressToInt32Converter =
20             ↳ UncheckedConverter<TLink, int>.Default;
21         private static readonly UncheckedConverter<bool, TLink> _boolToAddressConverter =
22             ↳ UncheckedConverter<bool, TLink>.Default;
23         private static readonly UncheckedConverter<TLink, bool> _addressToBoolConverter =
24             ↳ UncheckedConverter<TLink, bool>.Default;
25         private static readonly UncheckedConverter<int, TLink> _int32ToAddressConverter =
26             ↳ UncheckedConverter<int, TLink>.Default;
27
28         protected readonly TLink Break;
29     }
30 }

```

```

23     protected readonly TLink Continue;
24     protected readonly byte* Links;
25     protected readonly byte* Header;
26
27     [MethodImpl(MethodImplOptions.AggressiveInlining)]
28     protected LinksAvlBalancedTreeMethodsBase(LinksConstants<TLink> constants, byte* links,
29     ↪ byte* header)
30     {
31         Links = links;
32         Header = header;
33         Break = constants.Break;
34         Continue = constants.Continue;
35     }
36
37     [MethodImpl(MethodImplOptions.AggressiveInlining)]
38     protected abstract TLink GetTreeRoot();
39
40     [MethodImpl(MethodImplOptions.AggressiveInlining)]
41     protected abstract TLink GetBasePartValue(TLink link);
42
43     [MethodImpl(MethodImplOptions.AggressiveInlining)]
44     protected abstract bool FirstIsToTheRightOfSecond(TLink source, TLink target, TLink
45     ↪ rootSource, TLink rootTarget);
46
47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     protected abstract bool FirstIsToTheLeftOfSecond(TLink source, TLink target, TLink
49     ↪ rootSource, TLink rootTarget);
50
51     [MethodImpl(MethodImplOptions.AggressiveInlining)]
52     protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
53     ↪ AsRef<LinksHeader<TLink>>(Header);
54
55     [MethodImpl(MethodImplOptions.AggressiveInlining)]
56     protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
57     ↪ AsRef<RawLink<TLink>>(Links + RawLink<TLink>.SizeInBytes *
58     ↪ _addressToInt64Converter.Convert(link));
59
60     [MethodImpl(MethodImplOptions.AggressiveInlining)]
61     protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
62     {
63         ref var link = ref GetLinkReference(linkIndex);
64         return new Link<TLink>(linkIndex, link.Source, link.Target);
65     }
66
67     [MethodImpl(MethodImplOptions.AggressiveInlining)]
68     protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
69     {
70         ref var firstLink = ref GetLinkReference(first);
71         ref var secondLink = ref GetLinkReference(second);
72         return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
73         ↪ secondLink.Source, secondLink.Target);
74     }
75
76     [MethodImpl(MethodImplOptions.AggressiveInlining)]
77     protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
78     {
79         ref var firstLink = ref GetLinkReference(first);
80         ref var secondLink = ref GetLinkReference(second);
81         return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
82         ↪ secondLink.Source, secondLink.Target);
83     }
84
85     [MethodImpl(MethodImplOptions.AggressiveInlining)]
86     protected virtual TLink GetSizeValue(TLink value) => Bit<TLink>.PartialRead(value, 5,
87     ↪ -5);
88
89     [MethodImpl(MethodImplOptions.AggressiveInlining)]
90     protected virtual void SetSizeValue(ref TLink storedValue, TLink size) => storedValue =
91     ↪ Bit<TLink>.PartialWrite(storedValue, size, 5, -5);
92
93     [MethodImpl(MethodImplOptions.AggressiveInlining)]
94     protected virtual bool GetLeftIsChildValue(TLink value)
95     {
96         unchecked
97         {
98             return _addressToBoolConverter.Convert(Bit<TLink>.PartialRead(value, 4, 1));
99             //return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 4, 1), default);
100         }
101     }

```

```

91     }
92
93     [MethodImpl(MethodImplOptions.AggressiveInlining)]
94     protected virtual void SetLeftIsChildValue(ref TLink storedValue, bool value)
95     {
96         unchecked
97         {
98             var previousValue = storedValue;
99             var modified = Bit<TLink>.PartialWrite(previousValue,
100                 ↪ _boolToAddressConverter.Convert(value), 4, 1);
101             storedValue = modified;
102         }
103     }
104
105     [MethodImpl(MethodImplOptions.AggressiveInlining)]
106     protected virtual bool GetRightIsChildValue(TLink value)
107     {
108         unchecked
109         {
110             return _addressToBoolConverter.Convert(Bit<TLink>.PartialRead(value, 3, 1));
111             //return !EqualityComparer.Equals(Bit<TLink>.PartialRead(value, 3, 1), default);
112         }
113     }
114
115     [MethodImpl(MethodImplOptions.AggressiveInlining)]
116     protected virtual void SetRightIsChildValue(ref TLink storedValue, bool value)
117     {
118         unchecked
119         {
120             var previousValue = storedValue;
121             var modified = Bit<TLink>.PartialWrite(previousValue,
122                 ↪ _boolToAddressConverter.Convert(value), 3, 1);
123             storedValue = modified;
124         }
125     }
126
127     [MethodImpl(MethodImplOptions.AggressiveInlining)]
128     protected bool IsChild(TLink parent, TLink possibleChild)
129     {
130         var parentSize = GetSize(parent);
131         var childSize = GetSizeOrZero(possibleChild);
132         return GreaterThanZero(childSize) && LessOrEqualThan(childSize, parentSize);
133     }
134
135     [MethodImpl(MethodImplOptions.AggressiveInlining)]
136     protected virtual sbyte GetBalanceValue(TLink storedValue)
137     {
138         unchecked
139         {
140             var value = _addressToInt32Converter.Convert(Bit<TLink>.PartialRead(storedValue,
141                 ↪ 0, 3));
142             value |= 0xF8 * ((value & 4) >> 2); // if negative, then continue ones to the
143                 ↪ end of sbyte
144             return (sbyte)value;
145         }
146     }
147
148     [MethodImpl(MethodImplOptions.AggressiveInlining)]
149     protected virtual void SetBalanceValue(ref TLink storedValue, sbyte value)
150     {
151         unchecked
152         {
153             var packagedValue = _int32ToAddressConverter.Convert((byte)value >> 5 & 4 |
154                 ↪ value & 3);
155             var modified = Bit<TLink>.PartialWrite(storedValue, packagedValue, 0, 3);
156             storedValue = modified;
157         }
158     }
159
160     public TLink this[TLink index]
161     {
162         [MethodImpl(MethodImplOptions.AggressiveInlining)]
163         get
164         {
165             var root = GetTreeRoot();
166             if (GreaterOrEqualThan(index, GetSize(root)))
167             {
168                 return Zero;
169             }
170         }
171     }

```

```

165     while (!EqualToZero(root))
166     {
167         var left = GetLeftOrDefault(root);
168         var leftSize = GetSizeOrZero(left);
169         if (LessThan(index, leftSize))
170         {
171             root = left;
172             continue;
173         }
174         if (AreEqual(index, leftSize))
175         {
176             return root;
177         }
178         root = GetRightOrDefault(root);
179         index = Subtract(index, Increment(leftSize));
180     }
181     return Zero; // TODO: Impossible situation exception (only if tree structure
182                 ↪ broken)
183 }
184
185 /// <summary>
186 /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
187 ↪ (концом).
188 /// </summary>
189 /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
190 /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
191 /// <returns>Индекс искомой связи.</returns>
192 [MethodImpl(MethodImplOptions.AggressiveInlining)]
193 public TLink Search(TLink source, TLink target)
194 {
195     var root = GetTreeRoot();
196     while (!EqualToZero(root))
197     {
198         ref var rootLink = ref GetLinkReference(root);
199         var rootSource = rootLink.Source;
200         var rootTarget = rootLink.Target;
201         if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
202             ↪ node.Key < root.Key
203         {
204             root = GetLeftOrDefault(root);
205         }
206         else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget)) //
207             ↪ node.Key > root.Key
208         {
209             root = GetRightOrDefault(root);
210         }
211         else // node.Key == root.Key
212         {
213             return root;
214         }
215     }
216     return Zero;
217 }
218
219 // TODO: Return indices range instead of references count
220 [MethodImpl(MethodImplOptions.AggressiveInlining)]
221 public TLink CountUsages(TLink link)
222 {
223     var root = GetTreeRoot();
224     var total = GetSize(root);
225     var totalRightIgnore = Zero;
226     while (!EqualToZero(root))
227     {
228         var @base = GetBasePartValue(root);
229         if (LessOrEqualThan(@base, link))
230         {
231             root = GetRightOrDefault(root);
232         }
233         else
234         {
235             totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
236             root = GetLeftOrDefault(root);
237         }
238     }
239     root = GetTreeRoot();
240     var totalLeftIgnore = Zero;
241     while (!EqualToZero(root))

```



```

239     {
240         var @base = GetBasePartValue(root);
241         if (GreaterOrEqualThan(@base, link))
242         {
243             root = GetLeftOrDefault(root);
244         }
245         else
246         {
247             totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
248             root = GetRightOrDefault(root);
249         }
250     }
251     }
252     return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
253 }
254
255 [MethodImpl(MethodImplOptions.AggressiveInlining)]
256 public TLink EachUsage(TLink link, Func<IList<TLink>, TLink> handler)
257 {
258     var root = GetTreeRoot();
259     if (EqualToZero(root))
260     {
261         return Continue;
262     }
263     TLink first = Zero, current = root;
264     while (!EqualToZero(current))
265     {
266         var @base = GetBasePartValue(current);
267         if (GreaterOrEqualThan(@base, link))
268         {
269             if (AreEqual(@base, link))
270             {
271                 first = current;
272             }
273             current = GetLeftOrDefault(current);
274         }
275         else
276         {
277             current = GetRightOrDefault(current);
278         }
279     }
280     if (!EqualToZero(first))
281     {
282         current = first;
283         while (true)
284         {
285             if (AreEqual(handler(GetLinkValues(current)), Break))
286             {
287                 return Break;
288             }
289             current = GetNext(current);
290             if (EqualToZero(current) || !AreEqual(GetBasePartValue(current), link))
291             {
292                 break;
293             }
294         }
295     }
296     return Continue;
297 }
298
299 [MethodImpl(MethodImplOptions.AggressiveInlining)]
300 protected override void PrintNodeValue(TLink node, StringBuilder sb)
301 {
302     ref var link = ref GetLinkReference(node);
303     sb.Append(' ');
304     sb.Append(link.Source);
305     sb.Append('-');
306     sb.Append('>');
307     sb.Append(link.Target);
308 }
309 }
310 }

```

1.40 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksSizeBalancedTreeMethodsBase.cs

```

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

```

```

6  using Platform.Converters;
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.Memory.United.Generic
12 {
13     public unsafe abstract class LinksSizeBalancedTreeMethodsBase<TLink> :
14         ↳ SizeBalancedTreeMethods<TLink>, ILinksTreeMethods<TLink>
15     {
16         private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
17             ↳ UncheckedConverter<TLink, long>.Default;
18
19         protected readonly TLink Break;
20         protected readonly TLink Continue;
21         protected readonly byte* Links;
22         protected readonly byte* Header;
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected LinksSizeBalancedTreeMethodsBase(LinksConstants<TLink> constants, byte* links,
26             ↳ byte* header)
27         {
28             Links = links;
29             Header = header;
30             Break = constants.Break;
31             Continue = constants.Continue;
32         }
33
34         [MethodImpl(MethodImplOptions.AggressiveInlining)]
35         protected abstract TLink GetTreeRoot();
36
37         [MethodImpl(MethodImplOptions.AggressiveInlining)]
38         protected abstract TLink GetBasePartValue(TLink link);
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         protected abstract bool FirstIsToTheRightOfSecond(TLink source, TLink target, TLink
42             ↳ rootSource, TLink rootTarget);
43
44         [MethodImpl(MethodImplOptions.AggressiveInlining)]
45         protected abstract bool FirstIsToTheLeftOfSecond(TLink source, TLink target, TLink
46             ↳ rootSource, TLink rootTarget);
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
50             ↳ AsRef<LinksHeader<TLink>>(Header);
51
52         [MethodImpl(MethodImplOptions.AggressiveInlining)]
53         protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
54             ↳ AsRef<RawLink<TLink>>(Links + RawLink<TLink>.SizeInBytes *
55             ↳ _addressToInt64Converter.Convert(link));
56
57         [MethodImpl(MethodImplOptions.AggressiveInlining)]
58         protected virtual IList<TLink> GetLinkValues(TLink linkIndex)
59         {
60             ref var link = ref GetLinkReference(linkIndex);
61             return new Link<TLink>(linkIndex, link.Source, link.Target);
62         }
63
64         [MethodImpl(MethodImplOptions.AggressiveInlining)]
65         protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
66         {
67             ref var firstLink = ref GetLinkReference(first);
68             ref var secondLink = ref GetLinkReference(second);
69             return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
70                 ↳ secondLink.Source, secondLink.Target);
71         }
72
73         [MethodImpl(MethodImplOptions.AggressiveInlining)]
74         protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
75         {
76             ref var firstLink = ref GetLinkReference(first);
77             ref var secondLink = ref GetLinkReference(second);
78             return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
79                 ↳ secondLink.Source, secondLink.Target);
80         }
81
82         public TLink this[TLink index]
83         {
84             [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

75     get
76     {
77         var root = GetTreeRoot();
78         if (GreaterOrEqualThan(index, GetSize(root)))
79         {
80             return Zero;
81         }
82         while (!EqualToZero(root))
83         {
84             var left = GetLeftOrDefault(root);
85             var leftSize = GetSizeOrZero(left);
86             if (LessThan(index, leftSize))
87             {
88                 root = left;
89                 continue;
90             }
91             if (AreEqual(index, leftSize))
92             {
93                 return root;
94             }
95             root = GetRightOrDefault(root);
96             index = Subtract(index, Increment(leftSize));
97         }
98         return Zero; // TODO: Impossible situation exception (only if tree structure
99         ↪ broken)
100     }
101 }
102
103 /// <summary>
104 /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
105 ↪ (концом).
106 /// </summary>
107 /// <param name="source">Индекс связи, которая является началом на искомой связи.</param>
108 /// <param name="target">Индекс связи, которая является концом на искомой связи.</param>
109 /// <returns>Индекс искомой связи.</returns>
110 [MethodImpl(MethodImplOptions.AggressiveInlining)]
111 public TLink Search(TLink source, TLink target)
112 {
113     var root = GetTreeRoot();
114     while (!EqualToZero(root))
115     {
116         ref var rootLink = ref GetLinkReference(root);
117         var rootSource = rootLink.Source;
118         var rootTarget = rootLink.Target;
119         if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
120             ↪ node.Key < root.Key
121         {
122             root = GetLeftOrDefault(root);
123         }
124         else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget)) //
125             ↪ node.Key > root.Key
126         {
127             root = GetRightOrDefault(root);
128         }
129         else // node.Key == root.Key
130         {
131             return root;
132         }
133     }
134     return Zero;
135 }
136
137 // TODO: Return indices range instead of references count
138 [MethodImpl(MethodImplOptions.AggressiveInlining)]
139 public TLink CountUsages(TLink link)
140 {
141     var root = GetTreeRoot();
142     var total = GetSize(root);
143     var totalRightIgnore = Zero;
144     while (!EqualToZero(root))
145     {
146         var @base = GetBasePartValue(root);
147         if (LessOrEqualThan(@base, link))
148         {
149             root = GetRightOrDefault(root);
150         }
151         else
152         {
153             // ...
154         }
155     }
156 }

```

```

149         totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
150         root = GetLeftOrDefault(root);
151     }
152 }
153 root = GetTreeRoot();
154 var totalLeftIgnore = Zero;
155 while (!EqualToZero(root))
156 {
157     var @base = GetBasePartValue(root);
158     if (GreaterOrEqualThan(@base, link))
159     {
160         root = GetLeftOrDefault(root);
161     }
162     else
163     {
164         totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
165         root = GetRightOrDefault(root);
166     }
167 }
168 return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
169 }
170
171 [MethodImpl(MethodImplOptions.AggressiveInlining)]
172 public TLink EachUsage(TLink @base, Func<IList<TLink>, TLink> handler) =>
173     ↳ EachUsageCore(@base, GetTreeRoot(), handler);
174
175 // TODO: 1. Move target, handler to separate object. 2. Use stack or walker 3. Use
176 ↳ low-level MSIL stack.
177 [MethodImpl(MethodImplOptions.AggressiveInlining)]
178 private TLink EachUsageCore(TLink @base, TLink link, Func<IList<TLink>, TLink> handler)
179 {
180     var @continue = Continue;
181     if (EqualToZero(link))
182     {
183         return @continue;
184     }
185     var linkBasePart = GetBasePartValue(link);
186     var @break = Break;
187     if (GreaterThan(linkBasePart, @base))
188     {
189         if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
190         {
191             return @break;
192         }
193     }
194     else if (LessThan(linkBasePart, @base))
195     {
196         if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
197         {
198             return @break;
199         }
200     }
201     else //if (linkBasePart == @base)
202     {
203         if (AreEqual(handler(GetLinkValues(link)), @break))
204         {
205             return @break;
206         }
207         if (AreEqual(EachUsageCore(@base, GetLeftOrDefault(link), handler), @break))
208         {
209             return @break;
210         }
211         if (AreEqual(EachUsageCore(@base, GetRightOrDefault(link), handler), @break))
212         {
213             return @break;
214         }
215     }
216     return @continue;
217 }
218
219 [MethodImpl(MethodImplOptions.AggressiveInlining)]
220 protected override void PrintNodeValue(TLink node, StringBuilder sb)
221 {
222     ref var link = ref GetLinkReference(node);
223     sb.Append(' ');
224     sb.Append(link.Source);
225     sb.Append('-');
226     sb.Append('>');
227     sb.Append(link.Target);

```

```

226     }
227 }
228 }

```

1.41 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksSourcesAvlBalancedTreeMethods.cs

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Memory.United.Generic
6  {
7      public unsafe class LinksSourcesAvlBalancedTreeMethods<TLink> :
8          ↳ LinksAvlBalancedTreeMethodsBase<TLink>
9      {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public LinksSourcesAvlBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
12             ↳ byte* header) : base(constants, links, header) { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected override ref TLink GetLeftReference(TLink node) => ref
16             ↳ GetLinkReference(node).LeftAsSource;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected 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().RootAsSource;
70
71         [MethodImpl(MethodImplOptions.AggressiveInlining)]
72         protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Source;
73
74     }
75 }

```

```

60     [MethodImpl(MethodImplOptions.AggressiveInlining)]
61     protected override bool FirstIsToLeftOfSecond(TLink firstSource, TLink firstTarget,
        ↪ TLink secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) ||
        ↪ AreEqual(firstSource, secondSource) && LessThan(firstTarget, secondTarget);
62
63     [MethodImpl(MethodImplOptions.AggressiveInlining)]
64     protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
        ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) ||
        ↪ AreEqual(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget);
65
66     [MethodImpl(MethodImplOptions.AggressiveInlining)]
67     protected override void ClearNode(TLink node)
68     {
69         ref var link = ref GetLinkReference(node);
70         link.LeftAsSource = Zero;
71         link.RightAsSource = Zero;
72         link.SizeAsSource = Zero;
73     }
74 }
75 }

```

1.42 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksSourcesSizeBalancedTreeMethods.cs

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Memory.United.Generic
6  {
7      public unsafe class LinksSourcesSizeBalancedTreeMethods<TLink> :
        ↪ LinksSizeBalancedTreeMethodsBase<TLink>
8      {
9          [MethodImpl(MethodImplOptions.AggressiveInlining)]
10         public LinksSourcesSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
            ↪ byte* header) : base(constants, links, header) { }
11
12         [MethodImpl(MethodImplOptions.AggressiveInlining)]
13         protected override ref TLink GetLeftReference(TLink node) => ref
            ↪ GetLinkReference(node).LeftAsSource;
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         protected override ref TLink GetRightReference(TLink node) => ref
            ↪ GetLinkReference(node).RightAsSource;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsSource;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsSource;
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected override void SetLeft(TLink node, TLink left) =>
            ↪ GetLinkReference(node).LeftAsSource = left;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected override void SetRight(TLink node, TLink right) =>
            ↪ GetLinkReference(node).RightAsSource = right;
29
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]
31         protected override TLink GetSize(TLink node) => GetLinkReference(node).SizeAsSource;
32
33         [MethodImpl(MethodImplOptions.AggressiveInlining)]
34         protected override void SetSize(TLink node, TLink size) =>
            ↪ GetLinkReference(node).SizeAsSource = size;
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected override TLink GetTreeRoot() => GetHeaderReference().RootAsSource;
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Source;
41
42         [MethodImpl(MethodImplOptions.AggressiveInlining)]
43         protected override bool FirstIsToLeftOfSecond(TLink firstSource, TLink firstTarget,
            ↪ TLink secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) ||
            ↪ AreEqual(firstSource, secondSource) && LessThan(firstTarget, secondTarget);
44
45         [MethodImpl(MethodImplOptions.AggressiveInlining)]
46         protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
            ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) ||
            ↪ AreEqual(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget);

```

```

47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     protected override void ClearNode(TLink node)
49     {
50         ref var link = ref GetLinkReference(node);
51         link.LeftAsSource = Zero;
52         link.RightAsSource = Zero;
53         link.SizeAsSource = Zero;
54     }
55 }
56 }
57 }

```

1.43 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksTargetsAvlBalancedTreeMethods.cs

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Memory.United.Generic
6  {
7      public unsafe class LinksTargetsAvlBalancedTreeMethods<TLink> :
8          ↳ LinksAvlBalancedTreeMethodsBase<TLink>
9      {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public LinksTargetsAvlBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
12             ↳ byte* header) : base(constants, links, header) { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected override ref TLink GetLeftReference(TLink node) => ref
16             ↳ GetLinkReference(node).LeftAsTarget;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override ref TLink GetRightReference(TLink node) => ref
20             ↳ GetLinkReference(node).RightAsTarget;
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsTarget;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsTarget;
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected override void SetLeft(TLink node, TLink left) =>
30             ↳ GetLinkReference(node).LeftAsTarget = left;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override void SetRight(TLink node, TLink right) =>
34             ↳ GetLinkReference(node).RightAsTarget = right;
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected override TLink GetSize(TLink node) =>
38             ↳ GetSizeValue(GetLinkReference(node).SizeAsTarget);
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         protected override void SetSize(TLink node, TLink size) => SetSizeValue(ref
42             ↳ GetLinkReference(node).SizeAsTarget, size);
43
44         [MethodImpl(MethodImplOptions.AggressiveInlining)]
45         protected override bool GetLeftIsChild(TLink node) =>
46             ↳ GetLeftIsChildValue(GetLinkReference(node).SizeAsTarget);
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         protected override void SetLeftIsChild(TLink node, bool value) =>
50             ↳ SetLeftIsChildValue(ref GetLinkReference(node).SizeAsTarget, value);
51
52         [MethodImpl(MethodImplOptions.AggressiveInlining)]
53         protected override bool GetRightIsChild(TLink node) =>
54             ↳ GetRightIsChildValue(GetLinkReference(node).SizeAsTarget);
55
56         [MethodImpl(MethodImplOptions.AggressiveInlining)]
57         protected override void SetRightIsChild(TLink node, bool value) =>
58             ↳ SetRightIsChildValue(ref GetLinkReference(node).SizeAsTarget, value);
59
60         [MethodImpl(MethodImplOptions.AggressiveInlining)]
61         protected override sbyte GetBalance(TLink node) =>
62             ↳ GetBalanceValue(GetLinkReference(node).SizeAsTarget);
63
64         [MethodImpl(MethodImplOptions.AggressiveInlining)]
65         protected override void SetBalance(TLink node, sbyte value) => SetBalanceValue(ref
66             ↳ GetLinkReference(node).SizeAsTarget, value);
67     }
68 }

```

```

53     [MethodImpl(MethodImplOptions.AggressiveInlining)]
54     protected override TLink GetTreeRoot() => GetHeaderReference().RootAsTarget;
55
56     [MethodImpl(MethodImplOptions.AggressiveInlining)]
57     protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Target;
58
59     [MethodImpl(MethodImplOptions.AggressiveInlining)]
60     protected override bool FirstIsToLeftOfSecond(TLink firstSource, TLink firstTarget,
61     ↪ TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
62     ↪ AreEqual(firstTarget, secondTarget) && LessThan(firstSource, secondSource);
63
64     [MethodImpl(MethodImplOptions.AggressiveInlining)]
65     protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
66     ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
67     ↪ AreEqual(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource);
68
69     [MethodImpl(MethodImplOptions.AggressiveInlining)]
70     protected override void ClearNode(TLink node)
71     {
72         ref var link = ref GetLinkReference(node);
73         link.LeftAsTarget = Zero;
74         link.RightAsTarget = Zero;
75         link.SizeAsTarget = Zero;
76     }
77 }

```

1.44 ./csharp/Platform.Data.Doublets/Memory/United/Generic/LinksTargetsSizeBalancedTreeMethods.cs

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Memory.United.Generic
6  {
7      public unsafe class LinksTargetsSizeBalancedTreeMethods<TLink> :
8      ↪ LinksSizeBalancedTreeMethodsBase<TLink>
9      {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public LinksTargetsSizeBalancedTreeMethods(LinksConstants<TLink> constants, byte* links,
12         ↪ byte* header) : base(constants, links, header) { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected override ref TLink GetLeftReference(TLink node) => ref
16         ↪ GetLinkReference(node).LeftAsTarget;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override ref TLink GetRightReference(TLink node) => ref
20         ↪ GetLinkReference(node).RightAsTarget;
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected override TLink GetLeft(TLink node) => GetLinkReference(node).LeftAsTarget;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected override TLink GetRight(TLink node) => GetLinkReference(node).RightAsTarget;
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected override void SetLeft(TLink node, TLink left) =>
30         ↪ GetLinkReference(node).LeftAsTarget = left;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override void SetRight(TLink node, TLink right) =>
34         ↪ GetLinkReference(node).RightAsTarget = right;
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected override TLink GetSize(TLink node) => GetLinkReference(node).SizeAsTarget;
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override void SetSize(TLink node, TLink size) =>
41         ↪ GetLinkReference(node).SizeAsTarget = size;
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         protected override TLink GetTreeRoot() => GetHeaderReference().RootAsTarget;
45
46         [MethodImpl(MethodImplOptions.AggressiveInlining)]
47         protected override TLink GetBasePartValue(TLink link) => GetLinkReference(link).Target;
48
49         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```



```

43     protected override bool FirstIsToLeftOfSecond(TLink firstSource, TLink firstTarget,
44         ↪ TLink secondSource, TLink secondTarget) => LessThan(firstTarget, secondTarget) ||
45         ↪ AreEqual(firstTarget, secondTarget) && LessThan(firstSource, secondSource);
46
47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     protected override bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget,
49         ↪ TLink secondSource, TLink secondTarget) => GreaterThan(firstTarget, secondTarget) ||
50         ↪ AreEqual(firstTarget, secondTarget) && GreaterThan(firstSource, secondSource);
51
52     [MethodImpl(MethodImplOptions.AggressiveInlining)]
53     protected override void ClearNode(TLink node)
54     {
55         ref var link = ref GetLinkReference(node);
56         link.LeftAsTarget = Zero;
57         link.RightAsTarget = Zero;
58         link.SizeAsTarget = Zero;
59     }
60 }

```

1.45 ./csharp/Platform.Data.Doublets/Memory/United/Generic/UnitedMemoryLinks.cs

```

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

```

```

46         _createTargetTreeMethods = () => new
47         ↪ LinksTargetsSizeBalancedTreeMethods<TLink>(Constants, _links, _header);
48     }
49     Init(memory, memoryReservationStep);
50 }
51 [MethodImpl(MethodImplOptions.AggressiveInlining)]
52 protected override void SetPointers(IResizableDirectMemory memory)
53 {
54     _links = (byte*)memory.Pointer;
55     _header = _links;
56     SourcesTreeMethods = _createSourceTreeMethods();
57     TargetsTreeMethods = _createTargetTreeMethods();
58     UnusedLinksListMethods = new UnusedLinksListMethods<TLink>(_links, _header);
59 }
60
61 [MethodImpl(MethodImplOptions.AggressiveInlining)]
62 protected override void ResetPointers()
63 {
64     base.ResetPointers();
65     _links = null;
66     _header = null;
67 }
68
69 [MethodImpl(MethodImplOptions.AggressiveInlining)]
70 protected override ref LinksHeader<TLink> GetHeaderReference() => ref
71     ↪ AsRef<LinksHeader<TLink>>(_header);
72
73 [MethodImpl(MethodImplOptions.AggressiveInlining)]
74 protected override ref RawLink<TLink> GetLinkReference(TLink linkIndex) => ref
75     ↪ AsRef<RawLink<TLink>>(_links + LinkSizeInBytes * ConvertToInt64(linkIndex));

```

1.46 ./csharp/Platform.Data.Doublets/Memory/United/Generic/UnitedMemoryLinksBase.cs

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Disposables;
5  using Platform.Singletons;
6  using Platform.Converters;
7  using Platform.Numbers;
8  using Platform.Memory;
9  using Platform.Data.Exceptions;
10
11 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
12
13 namespace Platform.Data.Doublets.Memory.United.Generic
14 {
15     public abstract class UnitedMemoryLinksBase<TLink> : DisposableBase, ILinks<TLink>
16     {
17         private static readonly EqualityComparer<TLink> _equalityComparer =
18             ↪ EqualityComparer<TLink>.Default;
19         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
20         private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
21             ↪ UncheckedConverter<TLink, long>.Default;
22         private static readonly UncheckedConverter<long, TLink> _int64ToAddressConverter =
23             ↪ UncheckedConverter<long, TLink>.Default;
24
25         private static readonly TLink _zero = default;
26         private static readonly TLink _one = Arithmetic.Increment(_zero);
27
28         /// <summary>Возвращает размер одной связи в байтах.</summary>
29         /// <remarks>
30         ///     Используется только во вне класса, не рекомендуется использовать внутри.
31         ///     Так как во вне не обязательно будет доступен unsafe C#.
32         /// </remarks>
33         public static readonly long LinkSizeInBytes = RawLink<TLink>.SizeInBytes;
34
35         public static readonly long LinkHeaderSizeInBytes = LinksHeader<TLink>.SizeInBytes;
36
37         public static readonly long DefaultLinksSizeStep = LinkSizeInBytes * 1024 * 1024;
38
39         protected readonly IResizableDirectMemory _memory;
40         protected readonly long _memoryReservationStep;
41
42         protected ILinksTreeMethods<TLink> TargetsTreeMethods;
43         protected ILinksTreeMethods<TLink> SourcesTreeMethods;
44         // TODO: Возможно чтобы гарантированно проверять на то, является ли связь удалённой,
45         ↪ нужно использовать не список а дерево, так как так можно быстрее проверить на
46         ↪ наличие связи внутри

```

```

42     protected ILinksListMethods<TLink> UnusedLinksListMethods;
43
44     /// <summary>
45     /// Возвращает общее число связей находящихся в хранилище.
46     /// </summary>
47     protected virtual TLink Total
48     {
49         [MethodImpl(MethodImplOptions.AggressiveInlining)]
50         get
51         {
52             ref var header = ref GetHeaderReference();
53             return Subtract(header.AllocatedLinks, header.FreeLinks);
54         }
55     }
56
57     public virtual LinksConstants<TLink> Constants
58     {
59         [MethodImpl(MethodImplOptions.AggressiveInlining)]
60         get;
61     }
62
63     [MethodImpl(MethodImplOptions.AggressiveInlining)]
64     protected UnitedMemoryLinksBase(IResizableDirectMemory memory, long
65     ↪ memoryReservationStep, LinksConstants<TLink> constants)
66     {
67         _memory = memory;
68         _memoryReservationStep = memoryReservationStep;
69         Constants = constants;
70     }
71
72     [MethodImpl(MethodImplOptions.AggressiveInlining)]
73     protected UnitedMemoryLinksBase(IResizableDirectMemory memory, long
74     ↪ memoryReservationStep) : this(memory, memoryReservationStep,
75     ↪ Default<LinksConstants<TLink>>.Instance) { }
76
77     [MethodImpl(MethodImplOptions.AggressiveInlining)]
78     protected virtual void Init(IResizableDirectMemory memory, long memoryReservationStep)
79     {
80         if (memory.ReservedCapacity < memoryReservationStep)
81         {
82             memory.ReservedCapacity = memoryReservationStep;
83         }
84         SetPointers(memory);
85         ref var header = ref GetHeaderReference();
86         // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
87         memory.UsedCapacity = ConvertToInt64(header.AllocatedLinks) * LinkSizeInBytes +
88         ↪ LinkHeaderSizeInBytes;
89         // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
90         header.ReservedLinks = ConvertToAddress((memory.ReservedCapacity -
91         ↪ LinkHeaderSizeInBytes) / LinkSizeInBytes);
92     }
93
94     [MethodImpl(MethodImplOptions.AggressiveInlining)]
95     public virtual TLink Count(IList<TLink> restrictions)
96     {
97         // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
98         if (restrictions.Count == 0)
99         {
100             return Total;
101         }
102         var constants = Constants;
103         var any = constants.Any;
104         var index = restrictions[constants.IndexPart];
105         if (restrictions.Count == 1)
106         {
107             if (AreEqual(index, any))
108             {
109                 return Total;
110             }
111             return Exists(index) ? GetOne() : GetZero();
112         }
113         if (restrictions.Count == 2)
114         {
115             var value = restrictions[1];
116             if (AreEqual(index, any))
117             {
118                 if (AreEqual(value, any))
119                 {
120                     return Total; // Any - как отсутствие ограничения
121                 }
122             }
123         }
124     }

```

```

116     }
117     return Add(SourcesTreeMethods.CountUsages(value),
118               ↪ TargetsTreeMethods.CountUsages(value));
119 }
120 else
121 {
122     if (!Exists(index))
123     {
124         return GetZero();
125     }
126     if (AreEqual(value, any))
127     {
128         return GetOne();
129     }
130     ref var storedLinkValue = ref GetLinkReference(index);
131     if (AreEqual(storedLinkValue.Source, value) ||
132         ↪ AreEqual(storedLinkValue.Target, value))
133     {
134         return GetOne();
135     }
136     return GetZero();
137 }
138 if (restrictions.Count == 3)
139 {
140     var source = restrictions[constants.SourcePart];
141     var target = restrictions[constants.TargetPart];
142     if (AreEqual(index, any))
143     {
144         if (AreEqual(source, any) && AreEqual(target, any))
145         {
146             return Total;
147         }
148         else if (AreEqual(source, any))
149         {
150             return TargetsTreeMethods.CountUsages(target);
151         }
152         else if (AreEqual(target, any))
153         {
154             return SourcesTreeMethods.CountUsages(source);
155         }
156         else //if(source != Any && target != Any)
157         {
158             // Эквивалент Exists(source, target) => Count(Any, source, target) > 0
159             var link = SourcesTreeMethods.Search(source, target);
160             return AreEqual(link, constants.Null) ? GetZero() : GetOne();
161         }
162     }
163     else
164     {
165         if (!Exists(index))
166         {
167             return GetZero();
168         }
169         if (AreEqual(source, any) && AreEqual(target, any))
170         {
171             return GetOne();
172         }
173         ref var storedLinkValue = ref GetLinkReference(index);
174         if (!AreEqual(source, any) && !AreEqual(target, any))
175         {
176             if (AreEqual(storedLinkValue.Source, source) &&
177                 ↪ AreEqual(storedLinkValue.Target, target))
178             {
179                 return GetOne();
180             }
181             return GetZero();
182         }
183         var value = default(TLink);
184         if (AreEqual(source, any))
185         {
186             value = target;
187         }
188         if (AreEqual(target, any))
189         {
190             value = source;
191         }

```

```

190         if (AreEqual(storedLinkValue.Source, value) ||
191             ↪ AreEqual(storedLinkValue.Target, value))
192         {
193             return GetOne();
194         }
195         return GetZero();
196     }
197     throw new NotSupportedException("Другие размеры и способы ограничений не
198     ↪ поддерживаются.");
199 }
200 [MethodImpl(MethodImplOptions.AggressiveInlining)]
201 public virtual TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
202 {
203     var constants = Constants;
204     var @break = constants.Break;
205     if (restrictions.Count == 0)
206     {
207         for (var link = GetOne(); LessOrEqualThan(link,
208             ↪ GetHeaderReference().AllocatedLinks); link = Increment(link))
209         {
210             if (Exists(link) && AreEqual(handler(GetLinkStruct(link)), @break))
211             {
212                 return @break;
213             }
214         }
215         return @break;
216     }
217     var @continue = constants.Continue;
218     var any = constants.Any;
219     var index = restrictions[constants.IndexPart];
220     if (restrictions.Count == 1)
221     {
222         if (AreEqual(index, any))
223         {
224             return Each(handler, Array.Empty<TLink>());
225         }
226         if (!Exists(index))
227         {
228             return @continue;
229         }
230         return handler(GetLinkStruct(index));
231     }
232     if (restrictions.Count == 2)
233     {
234         var value = restrictions[1];
235         if (AreEqual(index, any))
236         {
237             if (AreEqual(value, any))
238             {
239                 return Each(handler, Array.Empty<TLink>());
240             }
241             if (AreEqual(Each(handler, new Link<TLink>(index, value, any)), @break))
242             {
243                 return @break;
244             }
245             return Each(handler, new Link<TLink>(index, any, value));
246         }
247         else
248         {
249             if (!Exists(index))
250             {
251                 return @continue;
252             }
253             if (AreEqual(value, any))
254             {
255                 return handler(GetLinkStruct(index));
256             }
257             ref var storedLinkValue = ref GetLinkReference(index);
258             if (AreEqual(storedLinkValue.Source, value) ||
259                 AreEqual(storedLinkValue.Target, value))
260             {
261                 return handler(GetLinkStruct(index));
262             }
263             return @continue;
264         }
265     }
266 }

```

```

265 if (restrictions.Count == 3)
266 {
267     var source = restrictions[constants.SourcePart];
268     var target = restrictions[constants.TargetPart];
269     if (AreEqual(index, any))
270     {
271         if (AreEqual(source, any) && AreEqual(target, any))
272         {
273             return Each(handler, Array.Empty<TLink>());
274         }
275         else if (AreEqual(source, any))
276         {
277             return TargetsTreeMethods.EachUsage(target, handler);
278         }
279         else if (AreEqual(target, any))
280         {
281             return SourcesTreeMethods.EachUsage(source, handler);
282         }
283         else //if(source != Any && target != Any)
284         {
285             var link = SourcesTreeMethods.Search(source, target);
286             return AreEqual(link, constants.Null) ? @continue :
                ↪ handler(GetLinkStruct(link));
287         }
288     }
289     else
290     {
291         if (!Exists(index))
292         {
293             return @continue;
294         }
295         if (AreEqual(source, any) && AreEqual(target, any))
296         {
297             return handler(GetLinkStruct(index));
298         }
299         ref var storedLinkValue = ref GetLinkReference(index);
300         if (!AreEqual(source, any) && !AreEqual(target, any))
301         {
302             if (AreEqual(storedLinkValue.Source, source) &&
303                 AreEqual(storedLinkValue.Target, target))
304             {
305                 return handler(GetLinkStruct(index));
306             }
307             return @continue;
308         }
309         var value = default(TLink);
310         if (AreEqual(source, any))
311         {
312             value = target;
313         }
314         if (AreEqual(target, any))
315         {
316             value = source;
317         }
318         if (AreEqual(storedLinkValue.Source, value) ||
319             AreEqual(storedLinkValue.Target, value))
320         {
321             return handler(GetLinkStruct(index));
322         }
323         return @continue;
324     }
325 }
326 throw new NotSupportedException("Другие размеры и способы ограничений не
    ↪ поддерживаются.");
327 }
328
329 /// <remarks>
330 /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
    ↪ в другом месте (но не в менеджере памяти, а в логике Links)
331 /// </remarks>
332 [MethodImpl(MethodImplOptions.AggressiveInlining)]
333 public virtual TLink Update(IList<TLink> restrictions, IList<TLink> substitution)
334 {
335     var constants = Constants;
336     var @null = constants.Null;
337     var linkIndex = restrictions[constants.IndexPart];
338     ref var link = ref GetLinkReference(linkIndex);
339     ref var header = ref GetHeaderReference();

```

```

340     ref var firstAsSource = ref header.RootAsSource;
341     ref var firstAsTarget = ref header.RootAsTarget;
342     // Будет корректно работать только в том случае, если пространство выделенной связи
    ↪ предварительно заполнено нулями
343     if (!AreEqual(link.Source, @null))
344     {
345         SourcesTreeMethods.Detach(ref firstAsSource, linkIndex);
346     }
347     if (!AreEqual(link.Target, @null))
348     {
349         TargetsTreeMethods.Detach(ref firstAsTarget, linkIndex);
350     }
351     link.Source = substitution[constants.SourcePart];
352     link.Target = substitution[constants.TargetPart];
353     if (!AreEqual(link.Source, @null))
354     {
355         SourcesTreeMethods.Attach(ref firstAsSource, linkIndex);
356     }
357     if (!AreEqual(link.Target, @null))
358     {
359         TargetsTreeMethods.Attach(ref firstAsTarget, linkIndex);
360     }
361     return linkIndex;
362 }
363
364 /// <remarks>
365 /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
    ↪ пространство
366 /// </remarks>
367 [MethodImpl(MethodImplOptions.AggressiveInlining)]
368 public virtual TLink Create(ICollection<TLink> restrictions)
369 {
370     ref var header = ref GetHeaderReference();
371     var freeLink = header.FirstFreeLink;
372     if (!AreEqual(freeLink, Constants.Null))
373     {
374         UnusedLinksListMethods.Detach(freeLink);
375     }
376     else
377     {
378         var maximumPossibleInnerReference = Constants.InternalReferencesRange.Maximum;
379         if (GreaterThan(header.AllocatedLinks, maximumPossibleInnerReference))
380         {
381             throw new LinksLimitReachedException<TLink>(maximumPossibleInnerReference);
382         }
383         if (GreaterOrEqualThan(header.AllocatedLinks, Decrement(header.ReservedLinks)))
384         {
385             _memory.ReservedCapacity += _memory.ReservationStep;
386             SetPointers(_memory);
387             header = ref GetHeaderReference();
388             header.ReservedLinks = ConvertToAddress(_memory.ReservedCapacity /
    ↪ LinkSizeInBytes);
389         }
390         header.AllocatedLinks = Increment(header.AllocatedLinks);
391         _memory.UsedCapacity += LinkSizeInBytes;
392         freeLink = header.AllocatedLinks;
393     }
394     return freeLink;
395 }
396
397 [MethodImpl(MethodImplOptions.AggressiveInlining)]
398 public virtual void Delete(ICollection<TLink> restrictions)
399 {
400     ref var header = ref GetHeaderReference();
401     var link = restrictions[Constants.IndexPart];
402     if (LessThan(link, header.AllocatedLinks))
403     {
404         UnusedLinksListMethods.AttachAsFirst(link);
405     }
406     else if (AreEqual(link, header.AllocatedLinks))
407     {
408         header.AllocatedLinks = Decrement(header.AllocatedLinks);
409         _memory.UsedCapacity -= LinkSizeInBytes;
410         // Убираем все связи, находящиеся в списке свободных в конце файла, до тех пор,
    ↪ пока не дойдём до первой существующей связи
411         // Позволяет оптимизировать количество выделенных связей (AllocatedLinks)
412         while (GreaterThan(header.AllocatedLinks, GetZero()) &&
    ↪ IsUnusedLink(header.AllocatedLinks))
413         {

```

```

414         UnusedLinksListMethods.Detach(header.AllocatedLinks);
415         header.AllocatedLinks = Decrement(header.AllocatedLinks);
416         _memory.UsedCapacity -= LinkSizeInBytes;
417     }
418 }
419 }
420
421 [MethodImpl(MethodImplOptions.AggressiveInlining)]
422 public IList<TLink> GetLinkStruct(TLink linkIndex)
423 {
424     ref var link = ref GetLinkReference(linkIndex);
425     return new Link<TLink>(linkIndex, link.Source, link.Target);
426 }
427
428 /// <remarks>
429 /// TODO: Возможно это должно быть событием, вызываемым из IMemory, в том случае, если
430   ↪ адрес реально поменялся
431 ///
432 /// Указатель this.links может быть в том же месте,
433 /// так как 0-я связь не используется и имеет такой же размер как Header,
434 /// поэтому header размещается в том же месте, что и 0-я связь
435 /// </remarks>
436 [MethodImpl(MethodImplOptions.AggressiveInlining)]
437 protected abstract void SetPointers(IResizableDirectMemory memory);
438
439 [MethodImpl(MethodImplOptions.AggressiveInlining)]
440 protected virtual void ResetPointers()
441 {
442     SourcesTreeMethods = null;
443     TargetsTreeMethods = null;
444     UnusedLinksListMethods = null;
445 }
446
447 [MethodImpl(MethodImplOptions.AggressiveInlining)]
448 protected abstract ref LinksHeader<TLink> GetHeaderReference();
449
450 [MethodImpl(MethodImplOptions.AggressiveInlining)]
451 protected abstract ref RawLink<TLink> GetLinkReference(TLink linkIndex);
452
453 [MethodImpl(MethodImplOptions.AggressiveInlining)]
454 protected virtual bool Exists(TLink link)
455     => GreaterOrEqualThan(link, Constants.InternalReferencesRange.Minimum)
456     && LessOrEqualThan(link, GetHeaderReference().AllocatedLinks)
457     && !IsUnusedLink(link);
458
459 [MethodImpl(MethodImplOptions.AggressiveInlining)]
460 protected virtual bool IsUnusedLink(TLink linkIndex)
461 {
462     if (!AreEqual(GetHeaderReference().FirstFreeLink, linkIndex)) // May be this check
463         ↪ is not needed
464     {
465         ref var link = ref GetLinkReference(linkIndex);
466         return AreEqual(link.SizeAsSource, default) && !AreEqual(link.Source, default);
467     }
468     else
469     {
470         return true;
471     }
472 }
473
474 [MethodImpl(MethodImplOptions.AggressiveInlining)]
475 protected virtual TLink GetOne() => _one;
476
477 [MethodImpl(MethodImplOptions.AggressiveInlining)]
478 protected virtual TLink GetZero() => default;
479
480 [MethodImpl(MethodImplOptions.AggressiveInlining)]
481 protected virtual bool AreEqual(TLink first, TLink second) =>
482     ↪ _equalityComparer.Equals(first, second);
483
484 [MethodImpl(MethodImplOptions.AggressiveInlining)]
485 protected virtual bool LessThan(TLink first, TLink second) => _comparer.Compare(first,
486     ↪ second) < 0;
487
488 [MethodImpl(MethodImplOptions.AggressiveInlining)]
489 protected virtual bool LessOrEqualThan(TLink first, TLink second) =>
490     ↪ _comparer.Compare(first, second) <= 0;
491
492 [MethodImpl(MethodImplOptions.AggressiveInlining)]

```



```

488     protected virtual bool GreaterThan(TLink first, TLink second) =>
489         ↪ _comparer.Compare(first, second) > 0;
490
491     [MethodImpl(MethodImplOptions.AggressiveInlining)]
492     protected virtual bool GreaterOrEqualThan(TLink first, TLink second) =>
493         ↪ _comparer.Compare(first, second) >= 0;
494
495     [MethodImpl(MethodImplOptions.AggressiveInlining)]
496     protected virtual long ConvertToInt64(TLink value) =>
497         ↪ _addressToInt64Converter.Convert(value);
498
499     [MethodImpl(MethodImplOptions.AggressiveInlining)]
500     protected virtual TLink ConvertToAddress(long value) =>
501         ↪ _int64ToAddressConverter.Convert(value);
502
503     [MethodImpl(MethodImplOptions.AggressiveInlining)]
504     protected virtual TLink Add(TLink first, TLink second) => Arithmetic<TLink>.Add(first,
505         ↪ second);
506
507     [MethodImpl(MethodImplOptions.AggressiveInlining)]
508     protected virtual TLink Subtract(TLink first, TLink second) =>
509         ↪ Arithmetic<TLink>.Subtract(first, second);
510
511     [MethodImpl(MethodImplOptions.AggressiveInlining)]
512     protected virtual TLink Increment(TLink link) => Arithmetic<TLink>.Increment(link);
513
514     [MethodImpl(MethodImplOptions.AggressiveInlining)]
515     protected virtual TLink Decrement(TLink link) => Arithmetic<TLink>.Decrement(link);
516
517     #region Disposable
518
519     protected override bool AllowMultipleDisposeCalls
520     {
521         [MethodImpl(MethodImplOptions.AggressiveInlining)]
522         get => true;
523     }
524
525     [MethodImpl(MethodImplOptions.AggressiveInlining)]
526     protected override void Dispose(bool manual, bool wasDisposed)
527     {
528         if (!wasDisposed)
529         {
530             ResetPointers();
531             _memory.DisposeIfPossible();
532         }
533     }
534
535     #endregion
536 }
537
538 }

```

1.47 ./csharp/Platform.Data.Doublets/Memory/United/Generic/UnusedLinksListMethods.cs

```

1  using System.Runtime.CompilerServices;
2  using Platform.Collections.Methods.Lists;
3  using Platform.Converters;
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.Memory.United.Generic
9  {
10     public unsafe class UnusedLinksListMethods<TLink> : CircularDoublyLinkedListMethods<TLink>,
11         ↪ ILinksListMethods<TLink>
12     {
13         private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
14             ↪ UncheckedConverter<TLink, long>.Default;
15
16         private readonly byte* _links;
17         private readonly byte* _header;
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         public UnusedLinksListMethods(byte* links, byte* header)
21         {
22             _links = links;
23             _header = header;
24         }
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         protected virtual ref LinksHeader<TLink> GetHeaderReference() => ref
28             ↪ AsRef<LinksHeader<TLink>>(_header);
29     }
30 }

```

```

26     [MethodImpl(MethodImplOptions.AggressiveInlining)]
27     protected virtual ref RawLink<TLink> GetLinkReference(TLink link) => ref
28     ↪ AsRef<RawLink<TLink>>(_links + RawLink<TLink>.SizeInBytes *
    ↪ _addressToInt64Converter.Convert(link));
29
30     [MethodImpl(MethodImplOptions.AggressiveInlining)]
31     protected override TLink GetFirst() => GetHeaderReference().FirstFreeLink;
32
33     [MethodImpl(MethodImplOptions.AggressiveInlining)]
34     protected override TLink GetLast() => GetHeaderReference().LastFreeLink;
35
36     [MethodImpl(MethodImplOptions.AggressiveInlining)]
37     protected override TLink GetPrevious(TLink element) => GetLinkReference(element).Source;
38
39     [MethodImpl(MethodImplOptions.AggressiveInlining)]
40     protected override TLink GetNext(TLink element) => GetLinkReference(element).Target;
41
42     [MethodImpl(MethodImplOptions.AggressiveInlining)]
43     protected override TLink GetSize() => GetHeaderReference().FreeLinks;
44
45     [MethodImpl(MethodImplOptions.AggressiveInlining)]
46     protected override void SetFirst(TLink element) => GetHeaderReference().FirstFreeLink =
    ↪ element;
47
48     [MethodImpl(MethodImplOptions.AggressiveInlining)]
49     protected override void SetLast(TLink element) => GetHeaderReference().LastFreeLink =
    ↪ element;
50
51     [MethodImpl(MethodImplOptions.AggressiveInlining)]
52     protected override void SetPrevious(TLink element, TLink previous) =>
    ↪ GetLinkReference(element).Source = previous;
53
54     [MethodImpl(MethodImplOptions.AggressiveInlining)]
55     protected override void SetNext(TLink element, TLink next) =>
    ↪ GetLinkReference(element).Target = next;
56
57     [MethodImpl(MethodImplOptions.AggressiveInlining)]
58     protected override void SetSize(TLink size) => GetHeaderReference().FreeLinks = size;
59 }
60 }

```

1.48 ./csharp/Platform.Data.Doublets/Memory/United/RawLink.cs

```

1  using Platform.Unsafe;
2  using System;
3  using System.Collections.Generic;
4  using System.Runtime.CompilerServices;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Memory.United
9  {
10     public struct RawLink<TLink> : IEquatable<RawLink<TLink>>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
    ↪ EqualityComparer<TLink>.Default;
13
14         public static readonly long SizeInBytes = Structure<RawLink<TLink>>.Size;
15
16         public TLink Source;
17         public TLink Target;
18         public TLink LeftAsSource;
19         public TLink RightAsSource;
20         public TLink SizeAsSource;
21         public TLink LeftAsTarget;
22         public TLink RightAsTarget;
23         public TLink SizeAsTarget;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         public override bool Equals(object obj) => obj is RawLink<TLink> link ? Equals(link) :
    ↪ false;
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         public bool Equals(RawLink<TLink> other)
30         => _equalityComparer.Equals(Source, other.Source)
31         && _equalityComparer.Equals(Target, other.Target)
32         && _equalityComparer.Equals(LeftAsSource, other.LeftAsSource)
33         && _equalityComparer.Equals(RightAsSource, other.RightAsSource)
34         && _equalityComparer.Equals(SizeAsSource, other.SizeAsSource)
35         && _equalityComparer.Equals(LeftAsTarget, other.LeftAsTarget)

```

```

36         && _equalityComparer.Equals(RightAsTarget, other.RightAsTarget)
37         && _equalityComparer.Equals(SizeAsTarget, other.SizeAsTarget);
38
39     [MethodImpl(MethodImplOptions.AggressiveInlining)]
40     public override int GetHashCode() => (Source, Target, LeftAsSource, RightAsSource,
41     ↪ SizeAsSource, LeftAsTarget, RightAsTarget, SizeAsTarget).GetHashCode();
42
43     [MethodImpl(MethodImplOptions.AggressiveInlining)]
44     public static bool operator ==(RawLink<TLink> left, RawLink<TLink> right) =>
45     ↪ left.Equals(right);
46
47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     public static bool operator !=(RawLink<TLink> left, RawLink<TLink> right) => !(left ==
49     ↪ right);
50 }
51 }

```

1.49 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksAvlBalancedTreeMethodsBase.cs

```

1  using System.Runtime.CompilerServices;
2  using Platform.Data.Doublets.Memory.United.Generic;
3  using static System.Runtime.CompilerServices.Unsafe;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Memory.United.Specific
8  {
9      public unsafe abstract class UInt64LinksAvlBalancedTreeMethodsBase :
10     ↪ LinksAvlBalancedTreeMethodsBase<ulong>
11     {
12         protected new readonly RawLink<ulong>* Links;
13         protected new readonly LinksHeader<ulong>* Header;
14
15         protected UInt64LinksAvlBalancedTreeMethodsBase(LinksConstants<ulong> constants,
16     ↪ RawLink<ulong>* links, LinksHeader<ulong>* header)
17         : base(constants, (byte*)links, (byte*)header)
18         {
19             Links = links;
20             Header = header;
21         }
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected override ulong GetZero() => OUL;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         protected override bool EqualToZero(ulong value) => value == OUL;
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         protected override bool AreEqual(ulong first, ulong second) => first == second;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override bool GreaterThanZero(ulong value) => value > OUL;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override bool GreaterThan(ulong first, ulong second) => first > second;
37
38         [MethodImpl(MethodImplOptions.AggressiveInlining)]
39         protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
40
41         [MethodImpl(MethodImplOptions.AggressiveInlining)]
42         protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
43     ↪ always true for ulong
44
45         [MethodImpl(MethodImplOptions.AggressiveInlining)]
46         protected override bool LessOrEqualThanZero(ulong value) => value == OUL; // value is
47     ↪ always >= 0 for ulong
48
49         [MethodImpl(MethodImplOptions.AggressiveInlining)]
50         protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
51
52         [MethodImpl(MethodImplOptions.AggressiveInlining)]
53         protected override bool LessThanZero(ulong value) => false; // value < 0 is always false
54     ↪ for ulong
55
56         [MethodImpl(MethodImplOptions.AggressiveInlining)]
57         protected override bool LessThan(ulong first, ulong second) => first < second;
58
59         [MethodImpl(MethodImplOptions.AggressiveInlining)]
60         protected override ulong Increment(ulong value) => ++value;
61
62         [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

58     protected override ulong Decrement(ulong value) => --value;
59
60     [MethodImpl(MethodImplOptions.AggressiveInlining)]
61     protected override ulong Add(ulong first, ulong second) => first + second;
62
63     [MethodImpl(MethodImplOptions.AggressiveInlining)]
64     protected override ulong Subtract(ulong first, ulong second) => first - second;
65
66     [MethodImpl(MethodImplOptions.AggressiveInlining)]
67     protected override bool FirstIsToTheLeftOfSecond(ulong first, ulong second)
68     {
69         ref var firstLink = ref Links[first];
70         ref var secondLink = ref Links[second];
71         return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
72             ↪ secondLink.Source, secondLink.Target);
73     }
74
75     [MethodImpl(MethodImplOptions.AggressiveInlining)]
76     protected override bool FirstIsToTheRightOfSecond(ulong first, ulong second)
77     {
78         ref var firstLink = ref Links[first];
79         ref var secondLink = ref Links[second];
80         return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
81             ↪ secondLink.Source, secondLink.Target);
82     }
83
84     [MethodImpl(MethodImplOptions.AggressiveInlining)]
85     protected override ulong GetSizeValue(ulong value) => (value & 4294967264UL) >> 5;
86
87     [MethodImpl(MethodImplOptions.AggressiveInlining)]
88     protected override void SetSizeValue(ref ulong storedValue, ulong size) => storedValue =
89         ↪ storedValue & 31UL | (size & 134217727UL) << 5;
90
91     [MethodImpl(MethodImplOptions.AggressiveInlining)]
92     protected override bool GetLeftIsChildValue(ulong value) => (value & 16UL) >> 4 == 1UL;
93
94     [MethodImpl(MethodImplOptions.AggressiveInlining)]
95     protected override void SetLeftIsChildValue(ref ulong storedValue, bool value) =>
96         ↪ storedValue = storedValue & 4294967279UL | (As<bool, byte>(ref value) & 1UL) << 4;
97
98     [MethodImpl(MethodImplOptions.AggressiveInlining)]
99     protected override bool GetRightIsChildValue(ulong value) => (value & 8UL) >> 3 == 1UL;
100
101     [MethodImpl(MethodImplOptions.AggressiveInlining)]
102     protected override void SetRightIsChildValue(ref ulong storedValue, bool value) =>
103         ↪ storedValue = storedValue & 4294967287UL | (As<bool, byte>(ref value) & 1UL) << 3;
104
105     [MethodImpl(MethodImplOptions.AggressiveInlining)]
106     protected override sbyte GetBalanceValue(ulong value) => unchecked((sbyte)(value & 7UL |
107         ↪ 0xF8UL * ((value & 4UL) >> 2))); // if negative, then continue ones to the end of
108         ↪ sbyte
109
110     [MethodImpl(MethodImplOptions.AggressiveInlining)]
111     protected override void SetBalanceValue(ref ulong storedValue, sbyte value) =>
112         ↪ storedValue = unchecked(storedValue & 4294967288UL | (ulong)((byte)value >> 5 & 4 |
113         ↪ value & 3) & 7UL);
114
115     [MethodImpl(MethodImplOptions.AggressiveInlining)]
116     protected override ref LinksHeader<ulong> GetHeaderReference() => ref *Header;
117
118     [MethodImpl(MethodImplOptions.AggressiveInlining)]
119     protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref Links[link];
120 }

```

1.50 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksSizeBalancedTreeMethodsBase.cs

```

1  using System.Runtime.CompilerServices;
2  using Platform.Data.Doublets.Memory.United.Generic;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Memory.United.Specific
7  {
8      public unsafe abstract class UInt64LinksSizeBalancedTreeMethodsBase :
9          ↪ LinksSizeBalancedTreeMethodsBase<ulong>
10      {
11          protected new readonly RawLink<ulong>* Links;
12          protected new readonly LinksHeader<ulong>* Header;

```

```

13     protected UInt64LinksSizeBalancedTreeMethodsBase(LinksConstants<ulong> constants,
14         ↳ RawLink<ulong>* links, LinksHeader<ulong>* header)
15         : base(constants, (byte*)links, (byte*)header)
16     {
17         Links = links;
18         Header = header;
19     }
20
21     [MethodImpl(MethodImplOptions.AggressiveInlining)]
22     protected override ulong GetZero() => OUL;
23
24     [MethodImpl(MethodImplOptions.AggressiveInlining)]
25     protected override bool EqualToZero(ulong value) => value == OUL;
26
27     [MethodImpl(MethodImplOptions.AggressiveInlining)]
28     protected override bool AreEqual(ulong first, ulong second) => first == second;
29
30     [MethodImpl(MethodImplOptions.AggressiveInlining)]
31     protected override bool GreaterThanZero(ulong value) => value > OUL;
32
33     [MethodImpl(MethodImplOptions.AggressiveInlining)]
34     protected override bool GreaterThan(ulong first, ulong second) => first > second;
35
36     [MethodImpl(MethodImplOptions.AggressiveInlining)]
37     protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
38
39     [MethodImpl(MethodImplOptions.AggressiveInlining)]
40     protected override bool GreaterOrEqualThanZero(ulong value) => true; // value >= 0 is
41     ↳ always true for ulong
42
43     [MethodImpl(MethodImplOptions.AggressiveInlining)]
44     protected override bool LessOrEqualThanZero(ulong value) => value == OUL; // value is
45     ↳ always >= 0 for ulong
46
47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
49
50     [MethodImpl(MethodImplOptions.AggressiveInlining)]
51     protected override bool LessThanZero(ulong value) => false; // value < 0 is always false
52     ↳ for ulong
53
54     [MethodImpl(MethodImplOptions.AggressiveInlining)]
55     protected override bool LessThan(ulong first, ulong second) => first < second;
56
57     [MethodImpl(MethodImplOptions.AggressiveInlining)]
58     protected override ulong Increment(ulong value) => ++value;
59
60     [MethodImpl(MethodImplOptions.AggressiveInlining)]
61     protected override ulong Decrement(ulong value) => --value;
62
63     [MethodImpl(MethodImplOptions.AggressiveInlining)]
64     protected override ulong Add(ulong first, ulong second) => first + second;
65
66     [MethodImpl(MethodImplOptions.AggressiveInlining)]
67     protected override ulong Subtract(ulong first, ulong second) => first - second;
68
69     [MethodImpl(MethodImplOptions.AggressiveInlining)]
70     protected override bool FirstIsToTheLeftOfSecond(ulong first, ulong second)
71     {
72         ref var firstLink = ref Links[first];
73         ref var secondLink = ref Links[second];
74         return FirstIsToTheLeftOfSecond(firstLink.Source, firstLink.Target,
75             ↳ secondLink.Source, secondLink.Target);
76     }
77
78     [MethodImpl(MethodImplOptions.AggressiveInlining)]
79     protected override bool FirstIsToTheRightOfSecond(ulong first, ulong second)
80     {
81         ref var firstLink = ref Links[first];
82         ref var secondLink = ref Links[second];
83         return FirstIsToTheRightOfSecond(firstLink.Source, firstLink.Target,
84             ↳ secondLink.Source, secondLink.Target);
85     }
86
87     [MethodImpl(MethodImplOptions.AggressiveInlining)]
88     protected override ref LinksHeader<ulong> GetHeaderReference() => ref *Header;
89
90     [MethodImpl(MethodImplOptions.AggressiveInlining)]
91     protected override ref RawLink<ulong> GetLinkReference(ulong link) => ref Links[link];

```

```
86     }
87 }
```

1.51 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksSourcesAvlBalancedTreeMethods.cs

```
1 using System.Runtime.CompilerServices;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Data.Doublets.Memory.United.Specific
6 {
7     public unsafe class UInt64LinksSourcesAvlBalancedTreeMethods :
8     ↪ UInt64LinksAvlBalancedTreeMethodsBase
9     {
10         public UInt64LinksSourcesAvlBalancedTreeMethods(LinksConstants<ulong> constants,
11         ↪ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
12         ↪ { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected override ref ulong GetLeftReference(ulong node) => ref
16         ↪ Links[node].LeftAsSource;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override ref ulong GetRightReference(ulong node) => ref
20         ↪ Links[node].RightAsSource;
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected override ulong GetLeft(ulong node) => Links[node].LeftAsSource;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected override ulong GetRight(ulong node) => Links[node].RightAsSource;
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsSource =
30         ↪ left;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override void SetRight(ulong node, ulong right) => Links[node].RightAsSource =
34         ↪ right;
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected override ulong GetSize(ulong node) => GetSizeValue(Links[node].SizeAsSource);
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override void SetSize(ulong node, ulong size) => SetSizeValue(ref
41         ↪ Links[node].SizeAsSource, size);
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         protected override bool GetLeftIsChild(ulong node) =>
45         ↪ GetLeftIsChildValue(Links[node].SizeAsSource);
46
47         //[MethodImpl(MethodImplOptions.AggressiveInlining)]
48         //protected override bool GetLeftIsChild(ulong node) => IsChild(node, GetLeft(node));
49
50         [MethodImpl(MethodImplOptions.AggressiveInlining)]
51         protected override void SetLeftIsChild(ulong node, bool value) =>
52         ↪ SetLeftIsChildValue(ref Links[node].SizeAsSource, value);
53
54         [MethodImpl(MethodImplOptions.AggressiveInlining)]
55         protected override bool GetRightIsChild(ulong node) =>
56         ↪ GetRightIsChildValue(Links[node].SizeAsSource);
57
58         //[MethodImpl(MethodImplOptions.AggressiveInlining)]
59         //protected override bool GetRightIsChild(ulong node) => IsChild(node, GetRight(node));
60
61         [MethodImpl(MethodImplOptions.AggressiveInlining)]
62         protected override void SetRightIsChild(ulong node, bool value) =>
63         ↪ SetRightIsChildValue(ref Links[node].SizeAsSource, value);
64
65         [MethodImpl(MethodImplOptions.AggressiveInlining)]
66         protected override sbyte GetBalance(ulong node) =>
67         ↪ GetBalanceValue(Links[node].SizeAsSource);
68
69         [MethodImpl(MethodImplOptions.AggressiveInlining)]
70         protected override void SetBalance(ulong node, sbyte value) => SetBalanceValue(ref
71         ↪ Links[node].SizeAsSource, value);
72
73         [MethodImpl(MethodImplOptions.AggressiveInlining)]
74         protected override ulong GetTreeRoot() => Header->RootAsSource;
```

```

62     [MethodImpl(MethodImplOptions.AggressiveInlining)]
63     protected override ulong GetBasePartValue(ulong link) => Links[link].Source;
64
65     [MethodImpl(MethodImplOptions.AggressiveInlining)]
66     protected override bool FirstIsToTheLeftOfSecond(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 bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
73     ↪     ulong secondSource, ulong secondTarget)
74     => firstSource > secondSource || firstSource == secondSource && firstTarget >
75     ↪     secondTarget;
76
77     [MethodImpl(MethodImplOptions.AggressiveInlining)]
78     protected override void ClearNode(ulong node)
79     {
80         ref var link = ref Links[node];
81         link.LeftAsSource = OUL;
82         link.RightAsSource = OUL;
83         link.SizeAsSource = OUL;
84     }
85 }

```

1.52 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksSourcesSizeBalancedTreeMethods.cs

```

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

```

```

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

```

1.53 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksTargetsAvlBalancedTreeMethods.cs

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Memory.United.Specific
6  {
7      public unsafe class UInt64LinksTargetsAvlBalancedTreeMethods :
        ↳ UInt64LinksAvlBalancedTreeMethodsBase
8      {
9          public UInt64LinksTargetsAvlBalancedTreeMethods(LinksConstants<ulong> constants,
        ↳ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
        ↳ { }
10
11         [MethodImpl(MethodImplOptions.AggressiveInlining)]
12         protected override ref ulong GetLeftReference(ulong node) => ref
        ↳ Links[node].LeftAsTarget;
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected override ref ulong GetRightReference(ulong node) => ref
        ↳ Links[node].RightAsTarget;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         protected override ulong GetLeft(ulong node) => Links[node].LeftAsTarget;
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         protected override ulong GetRight(ulong node) => Links[node].RightAsTarget;
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsTarget =
        ↳ left;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         protected override void SetRight(ulong node, ulong right) => Links[node].RightAsTarget =
        ↳ right;
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         protected override ulong GetSize(ulong node) => GetSizeValue(Links[node].SizeAsTarget);
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override void SetSize(ulong node, ulong size) => SetSizeValue(ref
        ↳ Links[node].SizeAsTarget, size);
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected override bool GetLeftIsChild(ulong node) =>
        ↳ GetLeftIsChildValue(Links[node].SizeAsTarget);
37
38         [MethodImpl(MethodImplOptions.AggressiveInlining)]
39         protected override void SetLeftIsChild(ulong node, bool value) =>
        ↳ SetLeftIsChildValue(ref Links[node].SizeAsTarget, value);
40
41         [MethodImpl(MethodImplOptions.AggressiveInlining)]
42         protected override bool GetRightIsChild(ulong node) =>
        ↳ GetRightIsChildValue(Links[node].SizeAsTarget);
43
44         [MethodImpl(MethodImplOptions.AggressiveInlining)]
45         protected override void SetRightIsChild(ulong node, bool value) =>
        ↳ SetRightIsChildValue(ref Links[node].SizeAsTarget, value);
46

```



```

47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     protected override sbyte GetBalance(ulong node) =>
49         ↪ GetBalanceValue(Links[node].SizeAsTarget);
50
51     [MethodImpl(MethodImplOptions.AggressiveInlining)]
52     protected override void SetBalance(ulong node, sbyte value) => SetBalanceValue(ref
53         ↪ Links[node].SizeAsTarget, value);
54
55     [MethodImpl(MethodImplOptions.AggressiveInlining)]
56     protected override ulong GetTreeRoot() => Header->RootAsTarget;
57
58     [MethodImpl(MethodImplOptions.AggressiveInlining)]
59     protected override ulong GetBasePartValue(ulong link) => Links[link].Target;
60
61     [MethodImpl(MethodImplOptions.AggressiveInlining)]
62     protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
63         ↪ ulong secondSource, ulong secondTarget)
64         => firstTarget < secondTarget || firstTarget == secondTarget && firstSource <
65         ↪ secondSource;
66
67     [MethodImpl(MethodImplOptions.AggressiveInlining)]
68     protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
69         ↪ ulong secondSource, ulong secondTarget)
70         => firstTarget > secondTarget || firstTarget == secondTarget && firstSource >
71         ↪ secondSource;
72
73     [MethodImpl(MethodImplOptions.AggressiveInlining)]
74     protected override void ClearNode(ulong node)
75     {
76         ref var link = ref Links[node];
77         link.LeftAsTarget = OUL;
78         link.RightAsTarget = OUL;
79         link.SizeAsTarget = OUL;
80     }
81 }

```

1.54 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64LinksTargetsSizeBalancedTreeMethods.cs

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Data.Doublets.Memory.United.Specific
6  {
7      public unsafe class UInt64LinksTargetsSizeBalancedTreeMethods :
8          ↪ UInt64LinksSizeBalancedTreeMethodsBase
9      {
10         public UInt64LinksTargetsSizeBalancedTreeMethods(LinksConstants<ulong> constants,
11             ↪ RawLink<ulong>* links, LinksHeader<ulong>* header) : base(constants, links, header)
12             ↪ { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected override ref ulong GetLeftReference(ulong node) => ref
16             ↪ Links[node].LeftAsTarget;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected override ref ulong GetRightReference(ulong node) => ref
20             ↪ Links[node].RightAsTarget;
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected override ulong GetLeft(ulong node) => Links[node].LeftAsTarget;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected override ulong GetRight(ulong node) => Links[node].RightAsTarget;
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected override void SetLeft(ulong node, ulong left) => Links[node].LeftAsTarget =
30             ↪ left;
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected override void SetRight(ulong node, ulong right) => Links[node].RightAsTarget =
34             ↪ right;
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected override ulong GetSize(ulong node) => Links[node].SizeAsTarget;
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override void SetSize(ulong node, ulong size) => Links[node].SizeAsTarget =
41             ↪ size;
42     }
43 }

```

```

34     [MethodImpl(MethodImplOptions.AggressiveInlining)]
35     protected override ulong GetTreeRoot() => Header->RootAsTarget;
36
37     [MethodImpl(MethodImplOptions.AggressiveInlining)]
38     protected override ulong GetBasePartValue(ulong link) => Links[link].Target;
39
40     [MethodImpl(MethodImplOptions.AggressiveInlining)]
41     protected override bool FirstIsToTheLeftOfSecond(ulong firstSource, ulong firstTarget,
42         ↪ ulong secondSource, ulong secondTarget)
43         => firstTarget < secondTarget || firstTarget == secondTarget && firstSource <
44         ↪ secondSource;
45
46     [MethodImpl(MethodImplOptions.AggressiveInlining)]
47     protected override bool FirstIsToTheRightOfSecond(ulong firstSource, ulong firstTarget,
48         ↪ ulong secondSource, ulong secondTarget)
49         => firstTarget > secondTarget || firstTarget == secondTarget && firstSource >
50         ↪ secondSource;
51
52     [MethodImpl(MethodImplOptions.AggressiveInlining)]
53     protected override void ClearNode(ulong node)
54     {
55         ref var link = ref Links[node];
56         link.LeftAsTarget = OUL;
57         link.RightAsTarget = OUL;
58         link.SizeAsTarget = OUL;
59     }
60 }

```

1.55 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64UnitedMemoryLinks.cs

```

1  using System;
2  using System.Runtime.CompilerServices;
3  using Platform.Memory;
4  using Platform.Singletons;
5  using Platform.Data.Doublets.Memory.United.Generic;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets.Memory.United.Specific
10 {
11     /// <summary>
12     /// <para>Represents a low-level implementation of direct access to resizable memory, for
13     ↪ organizing the storage of links with addresses represented as <see cref="ulong"
14     ↪ />.</para>
15     /// <para>Представляет низкоуровневую реализация прямого доступа к памяти с переменным
16     ↪ размером, для организации хранения связей с адресами представленными в виде <see
17     ↪ cref="ulong"/>.</para>
18     /// </summary>
19     public unsafe class UInt64UnitedMemoryLinks : UnitedMemoryLinksBase<ulong>
20     {
21         private readonly Func<ILinksTreeMethods<ulong>> _createSourceTreeMethods;
22         private readonly Func<ILinksTreeMethods<ulong>> _createTargetTreeMethods;
23         private LinksHeader<ulong>* _header;
24         private RawLink<ulong>* _links;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         public UInt64UnitedMemoryLinks(string address) : this(address, DefaultLinksSizeStep) { }
28
29         /// <summary>
30         /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
31         ↪ минимальным шагом расширения базы данных.
32         /// </summary>
33         /// <param name="address">Полный путь к файлу базы данных.</param>
34         /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
35         ↪ байтах.</param>
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         public UInt64UnitedMemoryLinks(string address, long memoryReservationStep) : this(new
38         ↪ FileMappedResizableDirectMemory(address, memoryReservationStep),
39         ↪ memoryReservationStep) { }
40
41         [MethodImpl(MethodImplOptions.AggressiveInlining)]
42         public UInt64UnitedMemoryLinks(IResizableDirectMemory memory) : this(memory,
43         ↪ DefaultLinksSizeStep) { }
44
45         [MethodImpl(MethodImplOptions.AggressiveInlining)]
46         public UInt64UnitedMemoryLinks(IResizableDirectMemory memory, long
47         ↪ memoryReservationStep) : this(memory, memoryReservationStep,
48         ↪ Default<LinksConstants<ulong>>.Instance, true) { }
49     }
50 }

```

```

38 [MethodImpl(MethodImplOptions.AggressiveInlining)]
39 public UInt64UnitedMemoryLinks(IResizableDirectMemory memory, long
40     ↪ memoryReservationStep, LinksConstants<ulong> constants, bool useAvlBasedIndex) :
41     ↪ base(memory, memoryReservationStep, constants)
42 {
43     if (useAvlBasedIndex)
44     {
45         _createSourceTreeMethods = () => new
46             ↪ UInt64LinksSourcesAvlBalancedTreeMethods(Constants, _links, _header);
47         _createTargetTreeMethods = () => new
48             ↪ UInt64LinksTargetsAvlBalancedTreeMethods(Constants, _links, _header);
49     }
50     else
51     {
52         _createSourceTreeMethods = () => new
53             ↪ UInt64LinksSourcesSizeBalancedTreeMethods(Constants, _links, _header);
54         _createTargetTreeMethods = () => new
55             ↪ UInt64LinksTargetsSizeBalancedTreeMethods(Constants, _links, _header);
56     }
57     Init(memory, memoryReservationStep);
58 }
59
60 [MethodImpl(MethodImplOptions.AggressiveInlining)]
61 protected override void SetPointers(IResizableDirectMemory memory)
62 {
63     _header = (LinksHeader<ulong>*)memory.Pointer;
64     _links = (RawLink<ulong>*)memory.Pointer;
65     SourcesTreeMethods = _createSourceTreeMethods();
66     TargetsTreeMethods = _createTargetTreeMethods();
67     UnusedLinksListMethods = new UInt64UnusedLinksListMethods(_links, _header);
68 }
69
70 [MethodImpl(MethodImplOptions.AggressiveInlining)]
71 protected override void ResetPointers()
72 {
73     base.ResetPointers();
74     _links = null;
75     _header = null;
76 }
77
78 [MethodImpl(MethodImplOptions.AggressiveInlining)]
79 protected override ref LinksHeader<ulong> GetHeaderReference() => ref *_header;
80
81 [MethodImpl(MethodImplOptions.AggressiveInlining)]
82 protected override ref RawLink<ulong> GetLinkReference(ulong linkIndex) => ref
83     ↪ _links[linkIndex];
84
85 [MethodImpl(MethodImplOptions.AggressiveInlining)]
86 protected override bool AreEqual(ulong first, ulong second) => first == second;
87
88 [MethodImpl(MethodImplOptions.AggressiveInlining)]
89 protected override bool LessThan(ulong first, ulong second) => first < second;
90
91 [MethodImpl(MethodImplOptions.AggressiveInlining)]
92 protected override bool LessOrEqualThan(ulong first, ulong second) => first <= second;
93
94 [MethodImpl(MethodImplOptions.AggressiveInlining)]
95 protected override bool GreaterThan(ulong first, ulong second) => first > second;
96
97 [MethodImpl(MethodImplOptions.AggressiveInlining)]
98 protected override bool GreaterOrEqualThan(ulong first, ulong second) => first >= second;
99
100 [MethodImpl(MethodImplOptions.AggressiveInlining)]
101 protected override ulong GetZero() => 0UL;
102
103 [MethodImpl(MethodImplOptions.AggressiveInlining)]
104 protected override ulong GetOne() => 1UL;
105
106 [MethodImpl(MethodImplOptions.AggressiveInlining)]
107 protected override long ConvertToInt64(ulong value) => (long)value;
108
109 [MethodImpl(MethodImplOptions.AggressiveInlining)]
110 protected override ulong ConvertToAddress(long value) => (ulong)value;
111
112 [MethodImpl(MethodImplOptions.AggressiveInlining)]
113 protected override ulong Add(ulong first, ulong second) => first + second;
114
115 [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

110         protected override ulong Subtract(ulong first, ulong second) => first - second;
111
112         [MethodImpl(MethodImplOptions.AggressiveInlining)]
113         protected override ulong Increment(ulong link) => ++link;
114
115         [MethodImpl(MethodImplOptions.AggressiveInlining)]
116         protected override ulong Decrement(ulong link) => --link;
117     }
118 }

```

1.56 ./csharp/Platform.Data.Doublets/Memory/United/Specific/UInt64UnusedLinksListMethods.cs

```

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

```

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

```

1 using System.Collections.Generic;
2 using Platform.Reflection;
3 using Platform.Converters;
4 using Platform.Numbers;
5 using System.Runtime.CompilerServices;
6
7 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9 namespace Platform.Data.Doublets.Numbers.Unary
10 {
11     public class AddressToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
12         ↪ IConverter<TLink>
13     {
14         private static readonly EqualityComparer<TLink> _equalityComparer =
15             ↪ EqualityComparer<TLink>.Default;
16         private static readonly TLink _zero = default;
17         private static readonly TLink _one = Arithmetic.Increment(_zero);
18
19         private readonly IConverter<int, TLink> _powerOf2ToUnaryNumberConverter;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public AddressToUnaryNumberConverter(ILinks<TLink> links, IConverter<int, TLink>
23             ↪ powerOf2ToUnaryNumberConverter) : base(links) => _powerOf2ToUnaryNumberConverter =
24             ↪ powerOf2ToUnaryNumberConverter;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         public TLink Convert(TLink number)
28         {
29             var links = _links;
30             var nullConstant = links.Constants.Null;
31             var target = nullConstant;
32             for (var i = 0; !_equalityComparer.Equals(number, _zero) && i <
33                 ↪ NumericType<TLink>.BitsSize; i++)
34             {
35                 if (_equalityComparer.Equals(Bit.And(number, _one), _one))
36                 {
37                     target = _equalityComparer.Equals(target, nullConstant)
38                         ? _powerOf2ToUnaryNumberConverter.Convert(i)
39                         : links.GetOrCreate(_powerOf2ToUnaryNumberConverter.Convert(i), target);
40                 }
41             }
42         }
43     }
44 }

```

```

36         number = Bit.ShiftRight(number, 1);
37     }
38     return target;
39 }
40 }
41 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Interfaces;
4  using Platform.Converters;
5  using System.Runtime.CompilerServices;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets.Numbers.Unary
10 {
11     public class LinkToItsFrequencyNumberConveter<TLink> : LinksOperatorBase<TLink>,
12         ⇨ IConverter<Doublet<TLink>, TLink>
13     {
14         private static readonly EqualityComparer<TLink> _equalityComparer =
15             ⇨ EqualityComparer<TLink>.Default;
16
17         private readonly IProperty<TLink, TLink> _frequencyPropertyOperator;
18         private readonly IConverter<TLink> _unaryNumberToAddressConverter;
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         public LinkToItsFrequencyNumberConveter(
22             ILinks<TLink> links,
23             IProperty<TLink, TLink> frequencyPropertyOperator,
24             IConverter<TLink> unaryNumberToAddressConverter)
25             : base(links)
26         {
27             _frequencyPropertyOperator = frequencyPropertyOperator;
28             _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
29         }
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         public TLink Convert(Doublet<TLink> doublet)
33         {
34             var links = _links;
35             var link = links.SearchOrDefault(doublet.Source, doublet.Target);
36             if (_equalityComparer.Equals(link, default))
37             {
38                 throw new ArgumentException($"Link ({doublet}) not found.", nameof(doublet));
39             }
40             var frequency = _frequencyPropertyOperator.Get(link);
41             if (_equalityComparer.Equals(frequency, default))
42             {
43                 return default;
44             }
45             var frequencyNumber = links.GetSource(frequency);
46             return _unaryNumberToAddressConverter.Convert(frequencyNumber);
47         }
48     }
49 }

```

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

```

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

```

```

20     _unaryNumberPowersOf2 = new TLink[64];
21     _unaryNumberPowersOf2[0] = one;
22 }
23
24 [MethodImpl(MethodImplOptions.AggressiveInlining)]
25 public TLink Convert(int power)
26 {
27     Ensure.Always.ArgumentInRange(power, new Range<int>(0, _unaryNumberPowersOf2.Length
    ↪ - 1), nameof(power));
28     if (!_equalityComparer.Equals(_unaryNumberPowersOf2[power], default))
29     {
30         return _unaryNumberPowersOf2[power];
31     }
32     var previousPowerOf2 = Convert(power - 1);
33     var powerOf2 = _links.GetOrCreate(previousPowerOf2, previousPowerOf2);
34     _unaryNumberPowersOf2[power] = powerOf2;
35     return powerOf2;
36 }
37 }
38 }

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3 using Platform.Converters;
4 using Platform.Numbers;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Numbers.Unary
9 {
10     public class UnaryNumberToAddressAddOperationConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
    ↪ EqualityComparer<TLink>.Default;
13         private static readonly UncheckedConverter<TLink, ulong> _addressToUInt64Converter =
    ↪ UncheckedConverter<TLink, ulong>.Default;
14         private static readonly UncheckedConverter<ulong, TLink> _uint64ToAddressConverter =
    ↪ UncheckedConverter<ulong, TLink>.Default;
15         private static readonly TLink _zero = default;
16         private static readonly TLink _one = Arithmetic.Increment(_zero);
17
18         private readonly Dictionary<TLink, TLink> _unaryToUInt64;
19         private readonly TLink _unaryOne;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public UnaryNumberToAddressAddOperationConverter(ILinks<TLink> links, TLink unaryOne)
23             : base(links)
24         {
25             _unaryOne = unaryOne;
26             _unaryToUInt64 = CreateUnaryToUInt64Dictionary(links, unaryOne);
27         }
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         public TLink Convert(TLink unaryNumber)
31         {
32             if (_equalityComparer.Equals(unaryNumber, default))
33             {
34                 return default;
35             }
36             if (_equalityComparer.Equals(unaryNumber, _unaryOne))
37             {
38                 return _one;
39             }
40             var links = _links;
41             var source = links.GetSource(unaryNumber);
42             var target = links.GetTarget(unaryNumber);
43             if (_equalityComparer.Equals(source, target))
44             {
45                 return _unaryToUInt64[unaryNumber];
46             }
47             else
48             {
49                 var result = _unaryToUInt64[source];
50                 TLink lastValue;
51                 while (!_unaryToUInt64.TryGetValue(target, out lastValue))
52                 {
53                     source = links.GetSource(target);
54                     result = Arithmetic<TLink>.Add(result, _unaryToUInt64[source]);

```

```

55         target = links.GetTarget(target);
56     }
57     result = Arithmetic<TLink>.Add(result, lastValue);
58     return result;
59 }
60 }
61
62 [MethodImpl(MethodImplOptions.AggressiveInlining)]
63 private static Dictionary<TLink, TLink> CreateUnaryToUInt64Dictionary(ILinks<TLink>
    ↪ links, TLink unaryOne)
64 {
65     var unaryToUInt64 = new Dictionary<TLink, TLink>
66     {
67         { unaryOne, _one }
68     };
69     var unary = unaryOne;
70     var number = _one;
71     for (var i = 1; i < 64; i++)
72     {
73         unary = links.GetOrCreate(unary, unary);
74         number = Double(number);
75         unaryToUInt64.Add(unary, number);
76     }
77     return unaryToUInt64;
78 }
79
80 [MethodImpl(MethodImplOptions.AggressiveInlining)]
81 private static TLink Double(TLink number) =>
    ↪ _uInt64ToAddressConverter.Convert(_addressToUInt64Converter.Convert(number) * 2UL);
82 }
83 }

```

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

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Reflection;
4  using Platform.Converters;
5  using Platform.Numbers;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets.Numbers.Unary
10 {
11     public class UnaryNumberToAddressOrOperationConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<TLink>
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
    ↪ EqualityComparer<TLink>.Default;
14         private static readonly TLink _zero = default;
15         private static readonly TLink _one = Arithmetic.Increment(_zero);
16
17         private readonly IDictionary<TLink, int> _unaryNumberPowerOf2Indicies;
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         public UnaryNumberToAddressOrOperationConverter(ILinks<TLink> links, IConverter<int>,
    ↪ TLink> powerOf2ToUnaryNumberConverter) : base(links) => _unaryNumberPowerOf2Indicies
    ↪ = CreateUnaryNumberPowerOf2IndiciesDictionary(powerOf2ToUnaryNumberConverter);
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         public TLink Convert(TLink sourceNumber)
24         {
25             var links = _links;
26             var nullConstant = links.Constants.Null;
27             var source = sourceNumber;
28             var target = nullConstant;
29             if (!_equalityComparer.Equals(source, nullConstant))
30             {
31                 while (true)
32                 {
33                     if (_unaryNumberPowerOf2Indicies.TryGetValue(source, out int powerOf2Index))
34                     {
35                         SetBit(ref target, powerOf2Index);
36                         break;
37                     }
38                     else
39                     {
40                         powerOf2Index = _unaryNumberPowerOf2Indicies[links.GetSource(source)];
41                         SetBit(ref target, powerOf2Index);
42                         source = links.GetTarget(source);
43                     }

```

```

44     }
45 }
46 return target;
47 }
48
49 [MethodImpl(MethodImplOptions.AggressiveInlining)]
50 private static Dictionary<TLink, int>
    ↪ CreateUnaryNumberPowerOf2IndicesDictionary(IConverter<int, TLink>
    ↪ powerOf2ToUnaryNumberConverter)
51 {
52     var unaryNumberPowerOf2Indices = new Dictionary<TLink, int>();
53     for (int i = 0; i < NumericType<TLink>.BitsSize; i++)
54     {
55         unaryNumberPowerOf2Indices.Add(powerOf2ToUnaryNumberConverter.Convert(i), i);
56     }
57     return unaryNumberPowerOf2Indices;
58 }
59
60 [MethodImpl(MethodImplOptions.AggressiveInlining)]
61 private static void SetBit(ref TLink target, int powerOf2Index) => target =
    ↪ Bit.Or(target, Bit.ShiftLeft(_one, powerOf2Index));
62 }
63 }

```

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

```

1 using System.Linq;
2 using System.Collections.Generic;
3 using System.Runtime.CompilerServices;
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.PropertyOperators
9 {
10     public class PropertiesOperator<TLink> : LinksOperatorBase<TLink>, IProperties<TLink, TLink,
    ↪ TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
    ↪ EqualityComparer<TLink>.Default;
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         public PropertiesOperator(ILinks<TLink> links) : base(links) { }
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         public TLink GetValue(TLink @object, TLink property)
19         {
20             var links = _links;
21             var objectProperty = links.SearchOrDefault(@object, property);
22             if (_equalityComparer.Equals(objectProperty, default))
23             {
24                 return default;
25             }
26             var constants = links.Constants;
27             var valueLink = links.All(constants.Any, objectProperty).SingleOrDefault();
28             if (valueLink == null)
29             {
30                 return default;
31             }
32             return links.GetTarget(valueLink[constants.IndexPart]);
33         }
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         public void SetValue(TLink @object, TLink property, TLink value)
37         {
38             var links = _links;
39             var objectProperty = links.GetOrCreate(@object, property);
40             links.DeleteMany(links.AllIndices(links.Constants.Any, objectProperty));
41             links.GetOrCreate(objectProperty, value);
42         }
43     }
44 }

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
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 PropertyOperator<TLink> : LinksOperatorBase<TLink>, IProperty<TLink, TLink>
10    {
11        private static readonly EqualityComparer<TLink> _equalityComparer =
12            ↳ EqualityComparer<TLink>.Default;
13
14        private readonly TLink _propertyMarker;
15        private readonly TLink _propertyValueMarker;
16
17        [MethodImpl(MethodImplOptions.AggressiveInlining)]
18        public PropertyOperator(ILinks<TLink> links, TLink propertyMarker, TLink
19            ↳ propertyValueMarker) : base(links)
20        {
21            _propertyMarker = propertyMarker;
22            _propertyValueMarker = propertyValueMarker;
23        }
24
25        [MethodImpl(MethodImplOptions.AggressiveInlining)]
26        public TLink Get(TLink link)
27        {
28            var property = _links.SearchOrDefault(link, _propertyMarker);
29            return GetValue(GetContainer(property));
30        }
31
32        [MethodImpl(MethodImplOptions.AggressiveInlining)]
33        private TLink GetContainer(TLink property)
34        {
35            var valueContainer = default(TLink);
36            if (_equalityComparer.Equals(property, default))
37            {
38                return valueContainer;
39            }
40            var links = _links;
41            var constants = links.Constants;
42            var countinueConstant = constants.Continue;
43            var breakConstant = constants.Break;
44            var anyConstant = constants.Any;
45            var query = new Link<TLink>(anyConstant, property, anyConstant);
46            links.Each(candidate =>
47            {
48                var candidateTarget = links.GetTarget(candidate);
49                var valueTarget = links.GetTarget(candidateTarget);
50                if (_equalityComparer.Equals(valueTarget, _propertyValueMarker))
51                {
52                    valueContainer = links.GetIndex(candidate);
53                    return breakConstant;
54                }
55                return countinueConstant;
56            }, query);
57            return valueContainer;
58        }
59
60        [MethodImpl(MethodImplOptions.AggressiveInlining)]
61        private TLink GetValue(TLink container) => _equalityComparer.Equals(container, default)
62            ↳ ? default : _links.GetTarget(container);
63
64        [MethodImpl(MethodImplOptions.AggressiveInlining)]
65        public void Set(TLink link, TLink value)
66        {
67            var links = _links;
68            var property = links.GetOrCreate(link, _propertyMarker);
69            var container = GetContainer(property);
70            if (_equalityComparer.Equals(container, default))
71            {
72                links.GetOrCreate(property, value);
73            }
74            else
75            {
76                links.Update(container, property, value);
77            }
78        }
79    }
80 }

```

1.64 ./csharp/Platform.Data.Doublets/Sequences/Converters/BalancedVariantConverter.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.Converters
7 {
8     public class BalancedVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
9     {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public BalancedVariantConverter(ILinks<TLink> links) : base(links) { }
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public override TLink Convert(ICollection<TLink> sequence)
15         {
16             var length = sequence.Count;
17             if (length < 1)
18             {
19                 return default;
20             }
21             if (length == 1)
22             {
23                 return sequence[0];
24             }
25             // Make copy of next layer
26             if (length > 2)
27             {
28                 // TODO: Try to use stackalloc (which at the moment is not working with
29                 //      ↪ generics) but will be possible with Sigil
30                 var halvedSequence = new TLink[(length / 2) + (length % 2)];
31                 HalveSequence(halvedSequence, sequence, length);
32                 sequence = halvedSequence;
33                 length = halvedSequence.Length;
34             }
35             // Keep creating layer after layer
36             while (length > 2)
37             {
38                 HalveSequence(sequence, sequence, length);
39                 length = (length / 2) + (length % 2);
40             }
41             return _links.GetOrCreate(sequence[0], sequence[1]);
42         }
43
44         [MethodImpl(MethodImplOptions.AggressiveInlining)]
45         private void HalveSequence(ICollection<TLink> destination, ICollection<TLink> source, int length)
46         {
47             var loopedLength = length - (length % 2);
48             for (var i = 0; i < loopedLength; i += 2)
49             {
50                 destination[i / 2] = _links.GetOrCreate(source[i], source[i + 1]);
51             }
52             if (length > loopedLength)
53             {
54                 destination[length / 2] = source[length - 1];
55             }
56         }
57     }
58 }

```

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

```

1 using System;
2 using System.Collections.Generic;
3 using System.Runtime.CompilerServices;
4 using Platform.Collections;
5 using Platform.Converters;
6 using Platform.Singletons;
7 using Platform.Numbers;
8 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
9
10 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
11
12 namespace Platform.Data.Doublets.Sequences.Converters
13 {
14     /// <remarks>
15     /// TODO: Возможно будет лучше если алгоритм будет выполняться полностью изолированно от
16     ///      ↪ Links на этапе сжатия.
17     ///      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
25     }
26 }

```

```

21 private static readonly LinksConstants<TLink> _constants =
    ↳ Default<LinksConstants<TLink>>.Instance;
22 private static readonly EqualityComparer<TLink> _equalityComparer =
    ↳ EqualityComparer<TLink>.Default;
23 private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
24
25 private static readonly TLink _zero = default;
26 private static readonly TLink _one = Arithmetic.Increment(_zero);
27
28 private readonly IConverter<IList<TLink>, TLink> _baseConverter;
29 private readonly LinkFrequenciesCache<TLink> _doubletFrequenciesCache;
30 private readonly TLink _minFrequencyToCompress;
31 private readonly bool _doInitialFrequenciesIncrement;
32 private Doublet<TLink> _maxDoublet;
33 private LinkFrequency<TLink> _maxDoubletData;
34
35 private struct HalfDoublet
36 {
37     public TLink Element;
38     public LinkFrequency<TLink> DoubletData;
39
40     [MethodImpl(MethodImplOptions.AggressiveInlining)]
41     public HalfDoublet(TLink element, LinkFrequency<TLink> doubletData)
42     {
43         Element = element;
44         DoubletData = doubletData;
45     }
46
47     public override string ToString() => $"{Element}: ({DoubletData})";
48 }
49
50 [MethodImpl(MethodImplOptions.AggressiveInlining)]
51 public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
    ↳ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache)
    : this(links, baseConverter, doubletFrequenciesCache, _one, true) { }
52
53 [MethodImpl(MethodImplOptions.AggressiveInlining)]
54 public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
    ↳ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, bool
    ↳ doInitialFrequenciesIncrement)
    : this(links, baseConverter, doubletFrequenciesCache, _one,
    ↳ doInitialFrequenciesIncrement) { }
55
56 [MethodImpl(MethodImplOptions.AggressiveInlining)]
57 public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
    ↳ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, TLink
    ↳ minFrequencyToCompress, bool doInitialFrequenciesIncrement)
    : base(links)
58 {
59     _baseConverter = baseConverter;
60     _doubletFrequenciesCache = doubletFrequenciesCache;
61     if (_comparer.Compare(minFrequencyToCompress, _one) < 0)
62     {
63         minFrequencyToCompress = _one;
64     }
65     _minFrequencyToCompress = minFrequencyToCompress;
66     _doInitialFrequenciesIncrement = doInitialFrequenciesIncrement;
67     ResetMaxDoublet();
68 }
69
70 [MethodImpl(MethodImplOptions.AggressiveInlining)]
71 public override TLink Convert(IList<TLink> source) =>
    ↳ _baseConverter.Convert(Compress(source));
72
73 /// <remarks>
74 /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte\_pair\_encoding .
75 /// Faster version (doublets' frequencies dictionary is not recreated).
76 /// </remarks>
77 [MethodImpl(MethodImplOptions.AggressiveInlining)]
78 private IList<TLink> Compress(IList<TLink> sequence)
79 {
80     if (sequence.IsNullOrEmpty())
81     {
82         return null;
83     }
84     if (sequence.Count == 1)
85     {
86         return sequence;
87     }
88     if (sequence.Count == 2)

```

```

92     {
93         return new[] { _links.GetOrCreate(sequence[0], sequence[1]) };
94     }
95     // TODO: arraypool with min size (to improve cache locality) or stackalloc with Sigil
96     var copy = new HalfDoublet[sequence.Count];
97     Doublet<TLink> doublet = default;
98     for (var i = 1; i < sequence.Count; i++)
99     {
100         doublet.Source = sequence[i - 1];
101         doublet.Target = sequence[i];
102         LinkFrequency<TLink> data;
103         if (_doInitialFrequenciesIncrement)
104         {
105             data = _doubletFrequenciesCache.IncrementFrequency(ref doublet);
106         }
107         else
108         {
109             data = _doubletFrequenciesCache.GetFrequency(ref doublet);
110             if (data == null)
111             {
112                 throw new NotSupportedException("If you ask not to increment
113                     ↪ frequencies, it is expected that all frequencies for the sequence
114                     ↪ are prepared.");
115             }
116         }
117         copy[i - 1].Element = sequence[i - 1];
118         copy[i - 1].DoubletData = data;
119         UpdateMaxDoublet(ref doublet, data);
120     }
121     copy[sequence.Count - 1].Element = sequence[sequence.Count - 1];
122     copy[sequence.Count - 1].DoubletData = new LinkFrequency<TLink>();
123     if (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
124     {
125         var newLength = ReplaceDoublets(copy);
126         sequence = new TLink[newLength];
127         for (int i = 0; i < newLength; i++)
128         {
129             sequence[i] = copy[i].Element;
130         }
131     }
132     return sequence;
133 }
134
135 /// <remarks>
136 /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte\_pair\_encoding
137 /// </remarks>
138 [MethodImpl(MethodImplOptions.AggressiveInlining)]
139 private int ReplaceDoublets(HalfDoublet[] copy)
140 {
141     var oldLength = copy.Length;
142     var newLength = copy.Length;
143     while (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
144     {
145         var maxDoubletSource = _maxDoublet.Source;
146         var maxDoubletTarget = _maxDoublet.Target;
147         if (_equalityComparer.Equals(_maxDoubletData.Link, _constants.Null))
148         {
149             _maxDoubletData.Link = _links.GetOrCreate(maxDoubletSource,
150                 ↪ maxDoubletTarget);
151         }
152         var maxDoubletReplacementLink = _maxDoubletData.Link;
153         oldLength--;
154         var oldLengthMinusTwo = oldLength - 1;
155         // Substitute all usages
156         int w = 0, r = 0; // (r == read, w == write)
157         for (; r < oldLength; r++)
158         {
159             if (_equalityComparer.Equals(copy[r].Element, maxDoubletSource) &&
160                 ↪ _equalityComparer.Equals(copy[r + 1].Element, maxDoubletTarget))
161             {
162                 if (r > 0)
163                 {
164                     var previous = copy[w - 1].Element;
165                     copy[w - 1].DoubletData.DecrementFrequency();
166                     copy[w - 1].DoubletData =
167                         ↪ _doubletFrequenciesCache.IncrementFrequency(previous,
168                             ↪ maxDoubletReplacementLink);
169                 }

```

```

164         if (r < oldLengthMinusTwo)
165         {
166             var next = copy[r + 2].Element;
167             copy[r + 1].DoubletData.DecrementFrequency();
168             copy[w].DoubletData = _doubletFrequenciesCache.IncrementFrequency(maxDoubletReplacementLink,
169                                     ↪ xDoubletReplacementLink,
170                                     ↪ next);
171         }
172         copy[w++].Element = maxDoubletReplacementLink;
173         r++;
174         newLength--;
175     }
176     else
177     {
178         copy[w++] = copy[r];
179     }
180 }
181 if (w < newLength)
182 {
183     copy[w] = copy[r];
184 }
185 oldLength = newLength;
186 ResetMaxDoublet();
187 UpdateMaxDoublet(copy, newLength);
188 }
189 return newLength;
190 }
191 [MethodImpl(MethodImplOptions.AggressiveInlining)]
192 private void ResetMaxDoublet()
193 {
194     _maxDoublet = new Doublet<TLink>();
195     _maxDoubletData = new LinkFrequency<TLink>();
196 }
197 [MethodImpl(MethodImplOptions.AggressiveInlining)]
198 private void UpdateMaxDoublet(HalfDoublet[] copy, int length)
199 {
200     Doublet<TLink> doublet = default;
201     for (var i = 1; i < length; i++)
202     {
203         doublet.Source = copy[i - 1].Element;
204         doublet.Target = copy[i].Element;
205         UpdateMaxDoublet(ref doublet, copy[i - 1].DoubletData);
206     }
207 }
208 [MethodImpl(MethodImplOptions.AggressiveInlining)]
209 private void UpdateMaxDoublet(ref Doublet<TLink> doublet, LinkFrequency<TLink> data)
210 {
211     var frequency = data.Frequency;
212     var maxFrequency = _maxDoubletData.Frequency;
213     //if (frequency > _minFrequencyToCompress && (maxFrequency < frequency ||
214     ↪ (maxFrequency == frequency && doublet.Source + doublet.Target < /* gives better
215     ↪ compression string data (and gives collisions quickly) */ _maxDoublet.Source +
216     ↪ _maxDoublet.Target)))
217     if (_comparer.Compare(frequency, _minFrequencyToCompress) > 0 &&
218         (_comparer.Compare(maxFrequency, frequency) < 0 ||
219         ↪ (_equalityComparer.Equals(maxFrequency, frequency) &&
220         ↪ _comparer.Compare(Arithmetic.Add(doublet.Source, doublet.Target),
221         ↪ Arithmetic.Add(_maxDoublet.Source, _maxDoublet.Target)) > 0))) /* gives
222         ↪ better stability and better compression on sequent data and even on random
223         ↪ numbers data (but gives collisions anyway) */
224     {
225         _maxDoublet = doublet;
226         _maxDoubletData = data;
227     }
228 }
229 }

```

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

```

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

```

```

8 {
9     public abstract class LinksListToSequenceConverterBase<TLink> : LinksOperatorBase<TLink>,
        ↳ IConverter<IList<TLink>, TLink>
10     {
11         [MethodImpl(MethodImplOptions.AggressiveInlining)]
12         protected LinksListToSequenceConverterBase(ILinks<TLink> links) : base(links) { }
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         public abstract TLink Convert(IList<TLink> source);
16     }
17 }

```

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

```

1 using System.Collections.Generic;
2 using System.Linq;
3 using System.Runtime.CompilerServices;
4 using Platform.Converters;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Sequences.Converters
9 {
10     public class OptimalVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
            ↳ EqualityComparer<TLink>.Default;
13         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
14
15         private readonly IConverter<IList<TLink>> _sequenceToItsLocalElementLevelsConverter;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         public OptimalVariantConverter(ILinks<TLink> links, IConverter<IList<TLink>>
            ↳ sequenceToItsLocalElementLevelsConverter) : base(links)
19         => _sequenceToItsLocalElementLevelsConverter =
            ↳ sequenceToItsLocalElementLevelsConverter;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public override TLink Convert(IList<TLink> sequence)
23         {
24             var length = sequence.Count;
25             if (length == 1)
26             {
27                 return sequence[0];
28             }
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                     }
65                     else if (i == length - 1)

```

```

63         {
64             sequence[w] = sequence[i];
65             levels[w] = levels[i];
66             w++;
67         }
68     }
69     else
70     {
71         currentLevel = levels[i];
72         levelRepeat = 1;
73         if (skipOnce)
74         {
75             skipOnce = false;
76         }
77         else
78         {
79             sequence[w] = sequence[i - 1];
80             levels[w] = levels[i - 1];
81             previousLevel = levels[w];
82             w++;
83         }
84         if (i == length - 1)
85         {
86             sequence[w] = sequence[i];
87             levels[w] = levels[i];
88             w++;
89         }
90     }
91     }
92     length = w;
93 }
94 return _links.GetOrCreate(sequence[0], sequence[1]);
95 }
96
97 [MethodImpl(MethodImplOptions.AggressiveInlining)]
98 private static TLink GetGreatestNeighbourLowerThanCurrentOrCurrent(TLink previous, TLink
↪ current, TLink next)
99 {
100     return _comparer.Compare(previous, next) > 0
101         ? _comparer.Compare(previous, current) < 0 ? previous : current
102         : _comparer.Compare(next, current) < 0 ? next : current;
103 }
104
105 [MethodImpl(MethodImplOptions.AggressiveInlining)]
106 private static TLink GetNextLowerThanCurrentOrCurrent(TLink current, TLink next) =>
↪ _comparer.Compare(next, current) < 0 ? next : current;
107
108 [MethodImpl(MethodImplOptions.AggressiveInlining)]
109 private static TLink GetPreviousLowerThanCurrentOrCurrent(TLink previous, TLink current)
↪ => _comparer.Compare(previous, current) < 0 ? previous : current;
110 }
111 }

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3 using Platform.Converters;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Data.Doublets.Sequences.Converters
8 {
9     public class SequenceToItsLocalElementLevelsConverter<TLink> : LinksOperatorBase<TLink>,
↪ IConverter<IList<TLink>>
10     {
11         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
12
13         private readonly IConverter<Doublet<TLink>, TLink> _linkToItsFrequencyToNumberConveter;
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         public SequenceToItsLocalElementLevelsConverter(ILinks<TLink> links,
↪ IConverter<Doublet<TLink>, TLink> linkToItsFrequencyToNumberConveter) : base(links)
↪ => _linkToItsFrequencyToNumberConveter = linkToItsFrequencyToNumberConveter;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         public IList<TLink> Convert(IList<TLink> sequence)
20         {
21             var levels = new TLink[sequence.Count];
22             levels[0] = GetFrequencyNumber(sequence[0], sequence[1]);

```

```

23     for (var i = 1; i < sequence.Count - 1; i++)
24     {
25         var previous = GetFrequencyNumber(sequence[i - 1], sequence[i]);
26         var next = GetFrequencyNumber(sequence[i], sequence[i + 1]);
27         levels[i] = _comparer.Compare(previous, next) > 0 ? previous : next;
28     }
29     levels[levels.Length - 1] = GetFrequencyNumber(sequence[sequence.Count - 2],
30     ↪ sequence[sequence.Count - 1]);
31     return levels;
32 }
33 [MethodImpl(MethodImplOptions.AggressiveInlining)]
34 public TLink GetFrequencyNumber(TLink source, TLink target) =>
35     ↪ _linkToItsFrequencyToNumberConveter.Convert(new Doublet<TLink>(source, target));
36 }

```

1.69 ./csharp/Platform.Data.Doublets/Sequences/CriterionMatchers/DefaultSequenceElementCriterionMatcher.cs

```

1 using System.Runtime.CompilerServices;
2 using Platform.Interfaces;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences.CriterionMatchers
7 {
8     public class DefaultSequenceElementCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
9     ↪ ICriterionMatcher<TLink>
10    {
11        [MethodImpl(MethodImplOptions.AggressiveInlining)]
12        public DefaultSequenceElementCriterionMatcher(ILinks<TLink> links) : base(links) { }
13
14        [MethodImpl(MethodImplOptions.AggressiveInlining)]
15        public bool IsMatched(TLink argument) => _links.IsPartialPoint(argument);
16    }

```

1.70 ./csharp/Platform.Data.Doublets/Sequences/CriterionMatchers/MarkedSequenceCriterionMatcher.cs

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
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.CriterionMatchers
8 {
9     public class MarkedSequenceCriterionMatcher<TLink> : ICriterionMatcher<TLink>
10    {
11        private static readonly EqualityComparer<TLink> _equalityComparer =
12        ↪ EqualityComparer<TLink>.Default;
13
14        private readonly ILinks<TLink> _links;
15        private readonly TLink _sequenceMarkerLink;
16
17        [MethodImpl(MethodImplOptions.AggressiveInlining)]
18        public MarkedSequenceCriterionMatcher(ILinks<TLink> links, TLink sequenceMarkerLink)
19        {
20            _links = links;
21            _sequenceMarkerLink = sequenceMarkerLink;
22        }
23
24        [MethodImpl(MethodImplOptions.AggressiveInlining)]
25        public bool IsMatched(TLink sequenceCandidate)
26        => _equalityComparer.Equals(_links.GetSource(sequenceCandidate), _sequenceMarkerLink)
27        || !_equalityComparer.Equals(_links.SearchOrDefault(_sequenceMarkerLink,
28        ↪ sequenceCandidate), _links.Constants.Null);
29    }

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3 using Platform.Collections.Stacks;
4 using Platform.Data.Doublets.Sequences.HeightProviders;
5 using Platform.Data.Sequences;
6
7 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9 namespace Platform.Data.Doublets.Sequences
10 {

```



```

11 public class DefaultSequenceAppender<TLink> : LinksOperatorBase<TLink>,
    ↳ ISequenceAppender<TLink>
12 {
13     private static readonly EqualityComparer<TLink> _equalityComparer =
        ↳ EqualityComparer<TLink>.Default;
14
15     private readonly IStack<TLink> _stack;
16     private readonly ISequenceHeightProvider<TLink> _heightProvider;
17
18     [MethodImpl(MethodImplOptions.AggressiveInlining)]
19     public DefaultSequenceAppender(ILinks<TLink> links, IStack<TLink> stack,
        ↳ ISequenceHeightProvider<TLink> heightProvider)
        : base(links)
20     {
21     }
22     _stack = stack;
23     _heightProvider = heightProvider;
24 }
25
26 [MethodImpl(MethodImplOptions.AggressiveInlining)]
27 public TLink Append(TLink sequence, TLink appendant)
28 {
29     var cursor = sequence;
30     var links = _links;
31     while (!_equalityComparer.Equals(_heightProvider.Get(cursor), default))
32     {
33         var source = links.GetSource(cursor);
34         var target = links.GetTarget(cursor);
35         if (_equalityComparer.Equals(_heightProvider.Get(source),
            ↳ _heightProvider.Get(target)))
36         {
37             break;
38         }
39         else
40         {
41             _stack.Push(source);
42             cursor = target;
43         }
44     }
45     var left = cursor;
46     var right = appendant;
47     while (!_equalityComparer.Equals(cursor = _stack.Pop(), links.Constants.Null))
48     {
49         right = links.GetOrCreate(left, right);
50         left = cursor;
51     }
52     return links.GetOrCreate(left, right);
53 }
54 }
55 }

```

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

```

1 using System.Collections.Generic;
2 using System.Linq;
3 using System.Runtime.CompilerServices;
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.Sequences
9 {
10     public class DuplicateSegmentsCounter<TLink> : ICounter<int>
11     {
12         private readonly IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
            ↳ _duplicateFragmentsProvider;
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         public DuplicateSegmentsCounter(IProvider<IList<KeyValuePair<IList<TLink>,
            ↳ IList<TLink>>>> duplicateFragmentsProvider) => _duplicateFragmentsProvider =
            ↳ duplicateFragmentsProvider;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         public int Count() => _duplicateFragmentsProvider.Get().Sum(x => x.Value.Count);
19     }
20 }

```

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

```

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

```

```

5 using Platform.Interfaces;
6 using Platform.Collections;
7 using Platform.Collections.Lists;
8 using Platform.Collections.Segments;
9 using Platform.Collections.Segments.Walkers;
10 using Platform.Singletons;
11 using Platform.Converters;
12 using Platform.Data.Doublets.Unicode;
13
14 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
15
16 namespace Platform.Data.Doublets.Sequences
17 {
18     public class DuplicateSegmentsProvider<TLink> :
19         ↳ DictionaryBasedDuplicateSegmentsWalkerBase<TLink>,
20         ↳ IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
21     {
22         private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
23             ↳ UncheckedConverter<TLink, long>.Default;
24         private static readonly UncheckedConverter<TLink, ulong> _addressToUInt64Converter =
25             ↳ UncheckedConverter<TLink, ulong>.Default;
26         private static readonly UncheckedConverter<ulong, TLink> _uInt64ToAddressConverter =
27             ↳ UncheckedConverter<ulong, TLink>.Default;
28
29         private readonly ILinks<TLink> _links;
30         private readonly ILinks<TLink> _sequences;
31         private HashSet<KeyValuePair<IList<TLink>, IList<TLink>>> _groups;
32         private BitString _visited;
33
34         private class ItemEquilityComparer : IEqualityComparer<KeyValuePair<IList<TLink>,
35             ↳ IList<TLink>>>
36         {
37             private readonly IListEqualityComparer<TLink> _listComparer;
38
39             public ItemEquilityComparer() => _listComparer =
40                 ↳ Default<IListEqualityComparer<TLink>>.Instance;
41
42             [MethodImpl(MethodImplOptions.AggressiveInlining)]
43             public bool Equals(KeyValuePair<IList<TLink>, IList<TLink>> left,
44                 ↳ KeyValuePair<IList<TLink>, IList<TLink>> right) =>
45                 ↳ _listComparer.Equals(left.Key, right.Key) && _listComparer.Equals(left.Value,
46                 ↳ right.Value);
47
48             [MethodImpl(MethodImplOptions.AggressiveInlining)]
49             public int GetHashCode(KeyValuePair<IList<TLink>, IList<TLink>> pair) =>
50                 ↳ (_listComparer.GetHashCode(pair.Key),
51                 ↳ _listComparer.GetHashCode(pair.Value)).GetHashCode();
52         }
53
54         private class ItemComparer : IComparer<KeyValuePair<IList<TLink>, IList<TLink>>>
55         {
56             private readonly IListComparer<TLink> _listComparer;
57
58             [MethodImpl(MethodImplOptions.AggressiveInlining)]
59             public ItemComparer() => _listComparer = Default<IListComparer<TLink>>.Instance;
60
61             [MethodImpl(MethodImplOptions.AggressiveInlining)]
62             public int Compare(KeyValuePair<IList<TLink>, IList<TLink>> left,
63                 ↳ KeyValuePair<IList<TLink>, IList<TLink>> right)
64             {
65                 var intermediateResult = _listComparer.Compare(left.Key, right.Key);
66                 if (intermediateResult == 0)
67                 {
68                     intermediateResult = _listComparer.Compare(left.Value, right.Value);
69                 }
70                 return intermediateResult;
71             }
72         }
73
74         [MethodImpl(MethodImplOptions.AggressiveInlining)]
75         public DuplicateSegmentsProvider(ILinks<TLink> links, ILinks<TLink> sequences)
76             : base(minimumStringSegmentLength: 2)
77         {
78             _links = links;
79             _sequences = sequences;
80         }
81
82         [MethodImpl(MethodImplOptions.AggressiveInlining)]
83         public IList<KeyValuePair<IList<TLink>, IList<TLink>>> Get()
84         {

```

```

72     _groups = new HashSet<KeyValuePair<IList<TLink>,
73         ↳ IList<TLink>>>(Default<ItemEqualityComparer>.Instance);
74     var links = _links;
75     var count = links.Count();
76     _visited = new BitString(_addressToInt64Converter.Convert(count) + 1L);
77     links.Each(link =>
78     {
79         var linkIndex = links.GetIndex(link);
80         var linkBitIndex = _addressToInt64Converter.Convert(linkIndex);
81         var constants = links.Constants;
82         if (!_visited.Get(linkBitIndex))
83         {
84             var sequenceElements = new List<TLink>();
85             var filler = new ListFiller<TLink, TLink>(sequenceElements, constants.Break);
86             _sequences.Each(filler.AddSkipFirstAndReturnConstant, new
87                 ↳ LinkAddress<TLink>(linkIndex));
88             if (sequenceElements.Count > 2)
89             {
90                 WalkAll(sequenceElements);
91             }
92             return constants.Continue;
93         });
94     var resultList = _groups.ToList();
95     var comparer = Default<ItemComparer>.Instance;
96     resultList.Sort(comparer);
97     #if DEBUG
98     foreach (var item in resultList)
99     {
100         PrintDuplicates(item);
101     }
102     #endif
103     return resultList;
104 }
105 [MethodImpl(MethodImplOptions.AggressiveInlining)]
106 protected override Segment<TLink> CreateSegment(IList<TLink> elements, int offset, int
107     ↳ length) => new Segment<TLink>(elements, offset, length);
108 [MethodImpl(MethodImplOptions.AggressiveInlining)]
109 protected override void OnDuplicateFound(Segment<TLink> segment)
110 {
111     var duplicates = CollectDuplicatesForSegment(segment);
112     if (duplicates.Count > 1)
113     {
114         _groups.Add(new KeyValuePair<IList<TLink>, IList<TLink>>(segment.ToArray(),
115             ↳ duplicates));
116     }
117 }
118 [MethodImpl(MethodImplOptions.AggressiveInlining)]
119 private List<TLink> CollectDuplicatesForSegment(Segment<TLink> segment)
120 {
121     var duplicates = new List<TLink>();
122     var readAsElement = new HashSet<TLink>();
123     var restrictions = segment.ShiftRight();
124     var constants = _links.Constants;
125     restrictions[0] = constants.Any;
126     _sequences.Each(sequence =>
127     {
128         var sequenceIndex = sequence[constants.IndexPart];
129         duplicates.Add(sequenceIndex);
130         readAsElement.Add(sequenceIndex);
131         return constants.Continue;
132     }, restrictions);
133     if (duplicates.Any(x => _visited.Get(_addressToInt64Converter.Convert(x))))
134     {
135         return new List<TLink>();
136     }
137     foreach (var duplicate in duplicates)
138     {
139         var duplicateBitIndex = _addressToInt64Converter.Convert(duplicate);
140         _visited.Set(duplicateBitIndex);
141     }
142     if (_sequences is Sequences sequencesExperiments)
143     {

```

```

144         var partiallyMatched = sequencesExperiments.GetAllPartiallyMatchingSequences4((H
            ↪ ashSet<ulong>)(object)readAsElement,
            ↪ (IList<ulong>)segment);
145     foreach (var partiallyMatchedSequence in partiallyMatched)
146     {
147         var sequenceIndex =
            ↪ _uInt64ToAddressConverter.Convert(partiallyMatchedSequence);
            duplicates.Add(sequenceIndex);
148     }
149 }
150 }
151 duplicates.Sort();
152 return duplicates;
153 }
154
155 [MethodImpl(MethodImplOptions.AggressiveInlining)]
156 private void PrintDuplicates(KeyValuePair<IList<TLink>, IList<TLink>> duplicatesItem)
157 {
158     if (!(_links is ILinks<ulong> ulongLinks))
159     {
160         return;
161     }
162     var duplicatesKey = duplicatesItem.Key;
163     var keyString = UnicodeMap.FromLinksToString((IList<ulong>)duplicatesKey);
164     Console.WriteLine($"{keyString} ({string.Join(", ", duplicatesKey)}");
165     var duplicatesList = duplicatesItem.Value;
166     for (int i = 0; i < duplicatesList.Count; i++)
167     {
168         var sequenceIndex = _addressToUInt64Converter.Convert(duplicatesList[i]);
169         var formattedSequenceStructure = ulongLinks.FormatStructure(sequenceIndex, x =>
            ↪ Point<ulong>.IsPartialPoint(x), (sb, link) => _ =
            ↪ UnicodeMap.IsCharLink(link.Index) ?
            ↪ sb.Append(UnicodeMap.FromLinkToChar(link.Index)) : sb.Append(link.Index));
170         Console.WriteLine(formattedSequenceStructure);
171         var sequenceString = UnicodeMap.FromSequenceLinkToString(sequenceIndex,
            ↪ ulongLinks);
172         Console.WriteLine(sequenceString);
173     }
174     Console.WriteLine();
175 }
176 }
177 }

```

1.74 ./csharp/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 =
            ↪ EqualityComparer<TLink>.Default;
19         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
20
21         private static readonly TLink _zero = default;
22         private static readonly TLink _one = Arithmetic.Increment(_zero);
23
24         private readonly Dictionary<Doublet<TLink>, LinkFrequency<TLink>> _doubletsCache;
25         private readonly ICounter<TLink, TLink> _frequencyCounter;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         public LinkFrequenciesCache(ILinks<TLink> links, ICounter<TLink, TLink> frequencyCounter)
29             : base(links)
30         {
31             _doubletsCache = new Dictionary<Doublet<TLink>, LinkFrequency<TLink>>(4096,
32             ↪ DoubletComparer<TLink>.Default);
33             _frequencyCounter = frequencyCounter;
34         }
35     }
36 }

```

```

34 [MethodImpl(MethodImplOptions.AggressiveInlining)]
35 public LinkFrequency<TLink> GetFrequency(TLink source, TLink target)
36 {
37     var doublet = new Doublet<TLink>(source, target);
38     return GetFrequency(ref doublet);
39 }
40
41 [MethodImpl(MethodImplOptions.AggressiveInlining)]
42 public LinkFrequency<TLink> GetFrequency(ref Doublet<TLink> doublet)
43 {
44     _doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data);
45     return data;
46 }
47
48 [MethodImpl(MethodImplOptions.AggressiveInlining)]
49 public void IncrementFrequencies(IList<TLink> sequence)
50 {
51     for (var i = 1; i < sequence.Count; i++)
52     {
53         IncrementFrequency(sequence[i - 1], sequence[i]);
54     }
55 }
56
57 [MethodImpl(MethodImplOptions.AggressiveInlining)]
58 public LinkFrequency<TLink> IncrementFrequency(TLink source, TLink target)
59 {
60     var doublet = new Doublet<TLink>(source, target);
61     return IncrementFrequency(ref doublet);
62 }
63
64 [MethodImpl(MethodImplOptions.AggressiveInlining)]
65 public void PrintFrequencies(IList<TLink> sequence)
66 {
67     for (var i = 1; i < sequence.Count; i++)
68     {
69         PrintFrequency(sequence[i - 1], sequence[i]);
70     }
71 }
72
73 [MethodImpl(MethodImplOptions.AggressiveInlining)]
74 public void PrintFrequency(TLink source, TLink target)
75 {
76     var number = GetFrequency(source, target).Frequency;
77     Console.WriteLine("{0},{1} - {2}", source, target, number);
78 }
79
80 [MethodImpl(MethodImplOptions.AggressiveInlining)]
81 public LinkFrequency<TLink> IncrementFrequency(ref Doublet<TLink> doublet)
82 {
83     if (_doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data))
84     {
85         data.IncrementFrequency();
86     }
87     else
88     {
89         var link = _links.SearchOrDefault(doublet.Source, doublet.Target);
90         data = new LinkFrequency<TLink>(_one, link);
91         if (!_equalityComparer.Equals(link, default))
92         {
93             data.Frequency = Arithmetic.Add(data.Frequency,
94                 ↪ _frequencyCounter.Count(link));
95         }
96         _doubletsCache.Add(doublet, data);
97     }
98     return data;
99 }
100
101 [MethodImpl(MethodImplOptions.AggressiveInlining)]
102 public void ValidateFrequencies()
103 {
104     foreach (var entry in _doubletsCache)
105     {
106         var value = entry.Value;
107         var linkIndex = value.Link;
108         if (!_equalityComparer.Equals(linkIndex, default))
109         {
110             var frequency = value.Frequency;
111             var count = _frequencyCounter.Count(linkIndex);
112             // TODO: Why `frequency` always greater than `count` by 1?

```

```

112         if (((_comparer.Compare(frequency, count) > 0) &&
113             ↪ (_comparer.Compare(Arithmetic.Subtract(frequency, count), _one) > 0))
114             || ((_comparer.Compare(count, frequency) > 0) &&
115                 ↪ (_comparer.Compare(Arithmetic.Subtract(count, frequency), _one) > 0)))
116         {
117             throw new InvalidOperationException("Frequencies validation failed.");
118         }
119     //else
120     //{
121     //    if (value.Frequency > 0)
122     //    {
123     //        var frequency = value.Frequency;
124     //        linkIndex = _createLink(entry.Key.Source, entry.Key.Target);
125     //        var count = _countLinkFrequency(linkIndex);
126     //        if ((frequency > count && frequency - count > 1) || (count > frequency
127     ↪ && count - frequency > 1))
128     //            throw new InvalidOperationException("Frequencies validation
129     ↪ failed.");
130     //    }
131     //}
132 }
133 }

```

1.75 ./csharp/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         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public LinkFrequency(TLink frequency, TLink link)
15         {
16             Frequency = frequency;
17             Link = link;
18         }
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         public LinkFrequency() { }
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         public void IncrementFrequency() => Frequency = Arithmetic<TLink>.Increment(Frequency);
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         public void DecrementFrequency() => Frequency = Arithmetic<TLink>.Decrement(Frequency);
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         public override string ToString() => $"F: {Frequency}, L: {Link}";
31     }
32 }

```

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

```

1 using System.Runtime.CompilerServices;
2 using Platform.Converters;
3
4 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6 namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
7 {
8     public class FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<TLink> :
9     ↪ IConverter<Doublet<TLink>, TLink>
10     {
11         private readonly LinkFrequenciesCache<TLink> _cache;
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public
15         ↪ FrequenciesCacheBasedLinkToItsFrequencyNumberConverter(LinkFrequenciesCache<TLink>
16         ↪ cache) => _cache = cache;
17     }
18 }

```

```

15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         public TLink Convert(Doublet<TLink> source) => _cache.GetFrequency(ref source).Frequency;
17     }
18 }

```

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

```

1 using System.Runtime.CompilerServices;
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.Frequencies.Counters
7 {
8     public class MarkedSequenceSymbolFrequencyOneOffCounter<TLink> :
9         ↳ SequenceSymbolFrequencyOneOffCounter<TLink>
10     {
11         private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public MarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
15             ↳ ICriterionMatcher<TLink> markedSequenceMatcher, TLink sequenceLink, TLink symbol)
16             : base(links, sequenceLink, symbol)
17             => _markedSequenceMatcher = markedSequenceMatcher;
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         public override TLink Count()
21         {
22             if (!_markedSequenceMatcher.IsMatched(_sequenceLink))
23             {
24                 return default;
25             }
26             return base.Count();
27         }
28     }
29 }

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3 using Platform.Interfaces;
4 using Platform.Numbers;
5 using Platform.Data.Sequences;
6
7 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
10 {
11     public class SequenceSymbolFrequencyOneOffCounter<TLink> : ICounter<TLink>
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
14             ↳ EqualityComparer<TLink>.Default;
15         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
16
17         protected readonly ILinks<TLink> _links;
18         protected readonly TLink _sequenceLink;
19         protected readonly TLink _symbol;
20         protected TLink _total;
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         public SequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink sequenceLink,
24             ↳ TLink symbol)
25         {
26             _links = links;
27             _sequenceLink = sequenceLink;
28             _symbol = symbol;
29             _total = default;
30         }
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         public virtual TLink Count()
34         {
35             if (_comparer.Compare(_total, default) > 0)
36             {
37                 return _total;
38             }
39             StopableSequenceWalker.WalkRight(_sequenceLink, _links.GetSource, _links.GetTarget,
40                 ↳ IsElement, VisitElement);
41             return _total;
42         }
43     }
44 }

```

```

41     [MethodImpl(MethodImplOptions.AggressiveInlining)]
42     private bool IsElement(TLink x) => _equalityComparer.Equals(x, _symbol) ||
    ↪ _links.IsPartialPoint(x); // TODO: Use SequenceElementCriteriaMatcher instead of
    ↪ IsPartialPoint
43
44     [MethodImpl(MethodImplOptions.AggressiveInlining)]
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 }

```

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

```

1  using System.Runtime.CompilerServices;
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.Frequencies.Counters
7  {
8      public class TotalMarkedSequenceSymbolFrequencyCounter<TLink> : ICounter<TLink, TLink>
9      {
10         private readonly ILinks<TLink> _links;
11         private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public TotalMarkedSequenceSymbolFrequencyCounter(ILinks<TLink> links,
    ↪ ICriterionMatcher<TLink> markedSequenceMatcher)
15         {
16             _links = links;
17             _markedSequenceMatcher = markedSequenceMatcher;
18         }
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         public TLink Count(TLink argument) => new
    ↪ TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
    ↪ _markedSequenceMatcher, argument).Count();
22     }
23 }

```

1.80 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalMarkedSequenceSymbolFrequencyOneOffCounter.cs

```

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

```

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

```

1  using System.Runtime.CompilerServices;
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.Frequencies.Counters
7 {
8     public class TotalSequenceSymbolFrequencyCounter<TLink> : ICounter<TLink, TLink>
9     {
10         private readonly ILinks<TLink> _links;
11
12         [MethodImpl(MethodImplOptions.AggressiveInlining)]
13         public TotalSequenceSymbolFrequencyCounter(ILinks<TLink> links) => _links = links;
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         public TLink Count(TLink symbol) => new
17             ↪ TotalSequenceSymbolFrequencyOneOffCounter<TLink>(_links, symbol).Count();
18     }
19 }

```

1.82 ./csharp/Platform.Data.Doublets/Sequences/Frequencies/Counters/TotalSequenceSymbolFrequencyOneOffCounter.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.Sequences.Frequencies.Counters
9 {
10     public class TotalSequenceSymbolFrequencyOneOffCounter<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 _symbol;
18         protected readonly HashSet<TLink> _visits;
19         protected TLink _total;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public TotalSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink symbol)
23         {
24             _links = links;
25             _symbol = symbol;
26             _visits = new HashSet<TLink>();
27             _total = default;
28         }
29
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]
31         public TLink Count()
32         {
33             if (_comparer.Compare(_total, default) > 0 || _visits.Count > 0)
34             {
35                 return _total;
36             }
37             CountCore(_symbol);
38             return _total;
39         }
40
41         [MethodImpl(MethodImplOptions.AggressiveInlining)]
42         private void CountCore(TLink link)
43         {
44             var any = _links.Constants.Any;
45             if (_equalityComparer.Equals(_links.Count(any, link), default))
46             {
47                 CountSequenceSymbolFrequency(link);
48             }
49             else
50             {
51                 _links.Each(EachElementHandler, any, link);
52             }
53         }
54
55         [MethodImpl(MethodImplOptions.AggressiveInlining)]
56         protected virtual void CountSequenceSymbolFrequency(TLink link)
57         {
58             var symbolFrequencyCounter = new SequenceSymbolFrequencyOneOffCounter<TLink>(_links,
59                 ↪ link, _symbol);
60             _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
61         }
62     }
63 }

```

```

60
61     [MethodImpl(MethodImplOptions.AggressiveInlining)]
62     private TLink EachElementHandler(IList<TLink> doublet)
63     {
64         var constants = _links.Constants;
65         var doubletIndex = doublet[constants.IndexPart];
66         if (_visits.Add(doubletIndex))
67         {
68             CountCore(doubletIndex);
69         }
70         return constants.Continue;
71     }
72 }
73 }

```

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

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Interfaces;
4  using Platform.Converters;
5
6  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8  namespace Platform.Data.Doublets.Sequences.HeightProviders
9  {
10     public class CachedSequenceHeightProvider<TLink> : ISequenceHeightProvider<TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
13             ⇨ EqualityComparer<TLink>.Default;
14
15         private readonly TLink _heightPropertyMarker;
16         private readonly ISequenceHeightProvider<TLink> _baseHeightProvider;
17         private readonly IConverter<TLink> _addressToUnaryNumberConverter;
18         private readonly IConverter<TLink> _unaryNumberToAddressConverter;
19         private readonly IProperties<TLink, TLink, TLink> _propertyOperator;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public CachedSequenceHeightProvider(
23             ISequenceHeightProvider<TLink> baseHeightProvider,
24             IConverter<TLink> addressToUnaryNumberConverter,
25             IConverter<TLink> unaryNumberToAddressConverter,
26             TLink heightPropertyMarker,
27             IProperties<TLink, TLink, TLink> propertyOperator)
28         {
29             _heightPropertyMarker = heightPropertyMarker;
30             _baseHeightProvider = baseHeightProvider;
31             _addressToUnaryNumberConverter = addressToUnaryNumberConverter;
32             _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
33             _propertyOperator = propertyOperator;
34
35             [MethodImpl(MethodImplOptions.AggressiveInlining)]
36             public TLink Get(TLink sequence)
37             {
38                 TLink height;
39                 var heightValue = _propertyOperator.GetValue(sequence, _heightPropertyMarker);
40                 if (_equalityComparer.Equals(heightValue, default))
41                 {
42                     height = _baseHeightProvider.Get(sequence);
43                     heightValue = _addressToUnaryNumberConverter.Convert(height);
44                     _propertyOperator.SetValue(sequence, _heightPropertyMarker, heightValue);
45                 }
46                 else
47                 {
48                     height = _unaryNumberToAddressConverter.Convert(heightValue);
49                 }
50                 return height;
51             }
52         }
53     }

```

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

```

1  using System.Runtime.CompilerServices;
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.HeightProviders
8  {

```

```

9     public class DefaultSequenceRightHeightProvider<TLink> : LinksOperatorBase<TLink>,
    ↪ ISequenceHeightProvider<TLink>
10     {
11         private readonly ICriterionMatcher<TLink> _elementMatcher;
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public DefaultSequenceRightHeightProvider(ILinks<TLink> links, ICriterionMatcher<TLink>
    ↪ elementMatcher) : base(links) => _elementMatcher = elementMatcher;
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         public TLink Get(TLink sequence)
18         {
19             var height = default(TLink);
20             var pairOrElement = sequence;
21             while (!_elementMatcher.IsMatched(pairOrElement))
22             {
23                 pairOrElement = _links.GetTarget(pairOrElement);
24                 height = Arithmetic.Increment(height);
25             }
26             return height;
27         }
28     }
29 }

```

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

```

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

```

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

```

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

```

```

40         if (indexed)
41         {
42             _cache.IncrementFrequency(source, target);
43         }
44         return indexed;
45     }
46
47     [MethodImpl(MethodImplOptions.AggressiveInlining)]
48     public bool MightContain(ICollection<TLink> sequence)
49     {
50         var indexed = true;
51         var i = sequence.Count;
52         while (--i >= 1 && (indexed = IsIndexed(sequence[i - 1], sequence[i]))) { }
53         return indexed;
54     }
55
56     [MethodImpl(MethodImplOptions.AggressiveInlining)]
57     private bool IsIndexed(TLink source, TLink target)
58     {
59         var frequency = _cache.GetFrequency(source, target);
60         if (frequency == null)
61         {
62             return false;
63         }
64         return !_equalityComparer.Equals(frequency.Frequency, default);
65     }
66 }
67 }

```

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

```

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

```

```

47         return indexed;
48     }
49
50     [MethodImpl(MethodImplOptions.AggressiveInlining)]
51     private void Increment(TLink link)
52     {
53         var previousFrequency = _frequencyPropertyOperator.Get(link);
54         var frequency = _frequencyIncrementer.Increment(previousFrequency);
55         _frequencyPropertyOperator.Set(link, frequency);
56     }
57 }
58 }

```

1.88 ./csharp/Platform.Data.Doublets/Sequences/Indexes/ISequenceIndex.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.Indexes
7  {
8      public interface ISequenceIndex<TLink>
9      {
10         /// <summary>
11         /// Индексирует последовательность глобально, и возвращает значение,
12         /// определяющие была ли запрошенная последовательность проиндексирована ранее.
13         /// </summary>
14         /// <param name="sequence">Последовательность для индексации.</param>
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         bool Add(IList<TLink> sequence);
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         bool MightContain(IList<TLink> sequence);
20     }
21 }

```

1.89 ./csharp/Platform.Data.Doublets/Sequences/Indexes/SequenceIndex.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.Indexes
7  {
8      public class SequenceIndex<TLink> : LinksOperatorBase<TLink>, ISequenceIndex<TLink>
9      {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11             ↳ EqualityComparer<TLink>.Default;
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public SequenceIndex(ILinks<TLink> links) : base(links) { }
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         public virtual bool Add(IList<TLink> sequence)
18         {
19             var indexed = true;
20             var i = sequence.Count;
21             while (--i >= 1 && (indexed =
22                 ↳ !_equalityComparer.Equals(_links.SearchOrDefault(sequence[i - 1], sequence[i]),
23                 ↳ default))) { }
24             for (; i >= 1; i--)
25             {
26                 _links.GetOrCreate(sequence[i - 1], sequence[i]);
27             }
28             return indexed;
29         }
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         public virtual bool MightContain(IList<TLink> sequence)
33         {
34             var indexed = true;
35             var i = sequence.Count;
36             while (--i >= 1 && (indexed =
37                 ↳ !_equalityComparer.Equals(_links.SearchOrDefault(sequence[i - 1], sequence[i]),
38                 ↳ default))) { }
39             return indexed;
40         }
41     }
42 }

```

1.90 ./csharp/Platform.Data.Doublets/Sequences/Indexes/SynchronizedSequenceIndex.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.Indexes
7  {
8      public class SynchronizedSequenceIndex<TLink> : ISequenceIndex<TLink>
9      {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11             ↳ EqualityComparer<TLink>.Default;
12
13         private readonly ISynchronizedLinks<TLink> _links;
14
15         [MethodImpl(MethodImplOptions.AggressiveInlining)]
16         public SynchronizedSequenceIndex(ISynchronizedLinks<TLink> links) => _links = links;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         public bool Add(IList<TLink> sequence)
20         {
21             var indexed = true;
22             var i = sequence.Count;
23             var links = _links.Unsync;
24             _links.SyncRoot.ExecuteReadOperation(() =>
25             {
26                 while (--i >= 1 && (indexed =
27                     ↳ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
28                     ↳ sequence[i]), default))) { }
29             });
30             if (!indexed)
31             {
32                 _links.SyncRoot.ExecuteWriteOperation(() =>
33                 {
34                     for (; i >= 1; i--)
35                     {
36                         links.GetOrCreate(sequence[i - 1], sequence[i]);
37                     }
38                 });
39             }
40             return indexed;
41         }
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         public bool MightContain(IList<TLink> sequence)
45         {
46             var links = _links.Unsync;
47             return _links.SyncRoot.ExecuteReadOperation(() =>
48             {
49                 var indexed = true;
50                 var i = sequence.Count;
51                 while (--i >= 1 && (indexed =
52                     ↳ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
53                     ↳ sequence[i]), default))) { }
54                 return indexed;
55             });
56         }
57     }
58 }

```

1.91 ./csharp/Platform.Data.Doublets/Sequences/Indexes/Unindex.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.Indexes
7  {
8      public class Unindex<TLink> : ISequenceIndex<TLink>
9      {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         public virtual bool Add(IList<TLink> sequence) => false;
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         public virtual bool MightContain(IList<TLink> sequence) => true;
15     }
16 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using System.Linq;
5  using System.Text;
6  using Platform.Collections;
7  using Platform.Collections.Sets;
8  using Platform.Collections.Stacks;
9  using Platform.Data.Exceptions;
10 using Platform.Data.Sequences;
11 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
12 using Platform.Data.Doublets.Sequences.Walkers;
13 using LinkIndex = System.UInt64;
14 using Stack = System.Collections.Generic.Stack<ulong>;
15
16 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
17
18 namespace Platform.Data.Doublets.Sequences
19 {
20     partial class Sequences
21     {
22         #region Create All Variants (Not Practical)
23
24         /// <remarks>
25         /// Number of links that is needed to generate all variants for
26         /// sequence of length N corresponds to https://oeis.org/A014143/list sequence.
27         /// </remarks>
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         public ulong[] CreateAllVariants2(ulong[] sequence)
30         {
31             return _sync.ExecuteWriteOperation(() =>
32             {
33                 if (sequence.IsNullOrEmpty())
34                 {
35                     return Array.Empty<ulong>();
36                 }
37                 Links.EnsureLinkExists(sequence);
38                 if (sequence.Length == 1)
39                 {
40                     return sequence;
41                 }
42                 return CreateAllVariants2Core(sequence, 0, sequence.Length - 1);
43             });
44         }
45
46         [MethodImpl(MethodImplOptions.AggressiveInlining)]
47         private ulong[] CreateAllVariants2Core(ulong[] sequence, long startAt, long stopAt)
48         {
49             #if DEBUG
50                 if ((stopAt - startAt) < 0)
51                 {
52                     throw new ArgumentOutOfRangeException(nameof(startAt), "startAt должен быть
53                     ↪ меньше или равен stopAt");
54                 }
55                 #endif
56                 if ((stopAt - startAt) == 0)
57                 {
58                     return new[] { sequence[startAt] };
59                 }
60                 if ((stopAt - startAt) == 1)
61                 {
62                     return new[] { Links.Unsync.GetOrCreate(sequence[startAt], sequence[stopAt]) };
63                 }
64                 var variants = new ulong[(ulong)Platform.Numbers.Math.Catalan(stopAt - startAt)];
65                 var last = 0;
66                 for (var splitter = startAt; splitter < stopAt; splitter++)
67                 {
68                     var left = CreateAllVariants2Core(sequence, startAt, splitter);
69                     var right = CreateAllVariants2Core(sequence, splitter + 1, stopAt);
70                     for (var i = 0; i < left.Length; i++)
71                     {
72                         for (var j = 0; j < right.Length; j++)
73                         {
74                             var variant = Links.Unsync.GetOrCreate(left[i], right[j]);
75                             if (variant == Constants.Null)
76                             {
77                                 throw new NotImplementedException("Creation cancellation is not
78                                 ↪ implemented.");
79                             }
80                         }
81                     }
82                     last++;
83                 }
84                 return variants;
85             }
86         }
87     }
88 }

```

```

77         }
78         variants[last++] = variant;
79     }
80 }
81 }
82 return variants;
83 }
84
85 [MethodImpl(MethodImplOptions.AggressiveInlining)]
86 public List<ulong> CreateAllVariants1(params ulong[] sequence)
87 {
88     return _sync.ExecuteWriteOperation(() =>
89     {
90         if (sequence.IsNullOrEmpty())
91         {
92             return new List<ulong>();
93         }
94         Links.Unsync.EnsureLinkExists(sequence);
95         if (sequence.Length == 1)
96         {
97             return new List<ulong> { sequence[0] };
98         }
99         var results = new
100             ↳ List<ulong>((int)Platform.Numbers.Math.Catalan(sequence.Length));
101         return CreateAllVariants1Core(sequence, results);
102     });
103 }
104
105 [MethodImpl(MethodImplOptions.AggressiveInlining)]
106 private List<ulong> CreateAllVariants1Core(ulong[] sequence, List<ulong> results)
107 {
108     if (sequence.Length == 2)
109     {
110         var link = Links.Unsync.GetOrCreate(sequence[0], sequence[1]);
111         if (link == Constants.Null)
112         {
113             throw new NotImplementedException("Creation cancellation is not
114                 ↳ implemented.");
115         }
116         results.Add(link);
117         return results;
118     }
119     var innerSequenceLength = sequence.Length - 1;
120     var innerSequence = new ulong[innerSequenceLength];
121     for (var li = 0; li < innerSequenceLength; li++)
122     {
123         var link = Links.Unsync.GetOrCreate(sequence[li], sequence[li + 1]);
124         if (link == Constants.Null)
125         {
126             throw new NotImplementedException("Creation cancellation is not
127                 ↳ implemented.");
128         }
129         for (var isi = 0; isi < li; isi++)
130         {
131             innerSequence[isi] = sequence[isi];
132         }
133         innerSequence[li] = link;
134         for (var isi = li + 1; isi < innerSequenceLength; isi++)
135         {
136             innerSequence[isi] = sequence[isi + 1];
137         }
138         CreateAllVariants1Core(innerSequence, results);
139     }
140     return results;
141 }
142
143 #endregion
144
145 [MethodImpl(MethodImplOptions.AggressiveInlining)]
146 public HashSet<ulong> Each1(params ulong[] sequence)
147 {
148     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
149     Each1(link =>
150     {
151         if (!visitedLinks.Contains(link))
152         {
153             visitedLinks.Add(link); // изучить почему случаются повторы
154         }
155     });
156 }

```



```

152         return true;
153     }, sequence);
154     return visitedLinks;
155 }
156
157 [MethodImpl(MethodImplOptions.AggressiveInlining)]
158 private void Each1(Func<ulong, bool> handler, params ulong[] sequence)
159 {
160     if (sequence.Length == 2)
161     {
162         Links.Unsync.Each(sequence[0], sequence[1], handler);
163     }
164     else
165     {
166         var innerSequenceLength = sequence.Length - 1;
167         for (var li = 0; li < innerSequenceLength; li++)
168         {
169             var left = sequence[li];
170             var right = sequence[li + 1];
171             if (left == 0 && right == 0)
172             {
173                 continue;
174             }
175             var linkIndex = li;
176             ulong[] innerSequence = null;
177             Links.Unsync.Each(doublet =>
178             {
179                 if (innerSequence == null)
180                 {
181                     innerSequence = new ulong[innerSequenceLength];
182                     for (var isi = 0; isi < linkIndex; isi++)
183                     {
184                         innerSequence[isi] = sequence[isi];
185                     }
186                     for (var isi = linkIndex + 1; isi < innerSequenceLength; isi++)
187                     {
188                         innerSequence[isi] = sequence[isi + 1];
189                     }
190                 }
191                 innerSequence[linkIndex] = doublet[Constants.IndexPart];
192                 Each1(handler, innerSequence);
193                 return Constants.Continue;
194             }, Constants.Any, left, right);
195         }
196     }
197 }
198
199 [MethodImpl(MethodImplOptions.AggressiveInlining)]
200 public HashSet<ulong> EachPart(params ulong[] sequence)
201 {
202     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
203     EachPartCore(link =>
204     {
205         var linkIndex = link[Constants.IndexPart];
206         if (!visitedLinks.Contains(linkIndex))
207         {
208             visitedLinks.Add(linkIndex); // изучить почему случаются повторы
209         }
210         return Constants.Continue;
211     }, sequence);
212     return visitedLinks;
213 }
214
215 [MethodImpl(MethodImplOptions.AggressiveInlining)]
216 public void EachPart(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[] sequence)
217 {
218     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
219     EachPartCore(link =>
220     {
221         var linkIndex = link[Constants.IndexPart];
222         if (!visitedLinks.Contains(linkIndex))
223         {
224             visitedLinks.Add(linkIndex); // изучить почему случаются повторы
225             return handler(new LinkAddress<LinkIndex>(linkIndex));
226         }
227         return Constants.Continue;
228     }, sequence);
229 }
230

```

```

231 [MethodImpl(MethodImplOptions.AggressiveInlining)]
232 private void EachPartCore(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[]
    ↳ sequence)
233 {
234     if (sequence.IsNullOrEmpty())
235     {
236         return;
237     }
238     Links.EnsureLinkIsAnyOrExists(sequence);
239     if (sequence.Length == 1)
240     {
241         var link = sequence[0];
242         if (link > 0)
243         {
244             handler(new LinkAddress<LinkIndex>(link));
245         }
246         else
247         {
248             Links.Each(Constants.Any, Constants.Any, handler);
249         }
250     }
251     else if (sequence.Length == 2)
252     {
253         // _links.Each(sequence[0], sequence[1], handler);
254         //   o_|      x_o ...
255         // x_|      |__|
256         Links.Each(sequence[1], Constants.Any, doublet =>
257         {
258             var match = Links.SearchOrDefault(sequence[0], doublet);
259             if (match != Constants.Null)
260             {
261                 handler(new LinkAddress<LinkIndex>(match));
262             }
263             return true;
264         });
265         // |_x      ... x_o
266         // |_o      |__|
267         Links.Each(Constants.Any, sequence[0], doublet =>
268         {
269             var match = Links.SearchOrDefault(doublet, sequence[1]);
270             if (match != 0)
271             {
272                 handler(new LinkAddress<LinkIndex>(match));
273             }
274             return true;
275         });
276         //           .x o_.
277         //           |__|
278         PartialStepRight(x => handler(x), sequence[0], sequence[1]);
279     }
280     else
281     {
282         throw new NotImplementedException();
283     }
284 }
285
286 [MethodImpl(MethodImplOptions.AggressiveInlining)]
287 private void PartialStepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
288 {
289     Links.Unsync.Each(Constants.Any, left, doublet =>
290     {
291         StepRight(handler, doublet, right);
292         if (left != doublet)
293         {
294             PartialStepRight(handler, doublet, right);
295         }
296         return true;
297     });
298 }
299
300 [MethodImpl(MethodImplOptions.AggressiveInlining)]
301 private void StepRight(Action<IList<LinkIndex>> handler, ulong left, ulong right)
302 {
303     Links.Unsync.Each(left, Constants.Any, rightStep =>
304     {
305         TryStepRightUp(handler, right, rightStep);
306         return true;
307     });

```

```

308     }
309
310     [MethodImpl(MethodImplOptions.AggressiveInlining)]
311     private void TryStepRightUp(Action<IList<LinkIndex>> handler, ulong right, ulong
    ↪ stepFrom)
312     {
313         var upStep = stepFrom;
314         var firstSource = Links.Unsync.GetTarget(upStep);
315         while (firstSource != right && firstSource != upStep)
316         {
317             upStep = firstSource;
318             firstSource = Links.Unsync.GetSource(upStep);
319         }
320         if (firstSource == right)
321         {
322             handler(new LinkAddress<LinkIndex>(stepFrom));
323         }
324     }
325
326     // TODO: Test
327     [MethodImpl(MethodImplOptions.AggressiveInlining)]
328     private void PartialStepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
329     {
330         Links.Unsync.Each(right, Constants.Any, doublet =>
331         {
332             StepLeft(handler, left, doublet);
333             if (right != doublet)
334             {
335                 PartialStepLeft(handler, left, doublet);
336             }
337             return true;
338         });
339     }
340
341     [MethodImpl(MethodImplOptions.AggressiveInlining)]
342     private void StepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
343     {
344         Links.Unsync.Each(Constants.Any, right, leftStep =>
345         {
346             TryStepLeftUp(handler, left, leftStep);
347             return true;
348         });
349     }
350
351     [MethodImpl(MethodImplOptions.AggressiveInlining)]
352     private void TryStepLeftUp(Action<IList<LinkIndex>> handler, ulong left, ulong stepFrom)
353     {
354         var upStep = stepFrom;
355         var firstTarget = Links.Unsync.GetSource(upStep);
356         while (firstTarget != left && firstTarget != upStep)
357         {
358             upStep = firstTarget;
359             firstTarget = Links.Unsync.GetTarget(upStep);
360         }
361         if (firstTarget == left)
362         {
363             handler(new LinkAddress<LinkIndex>(stepFrom));
364         }
365     }
366
367     [MethodImpl(MethodImplOptions.AggressiveInlining)]
368     private bool StartsWith(ulong sequence, ulong link)
369     {
370         var upStep = sequence;
371         var firstSource = Links.Unsync.GetSource(upStep);
372         while (firstSource != link && firstSource != upStep)
373         {
374             upStep = firstSource;
375             firstSource = Links.Unsync.GetSource(upStep);
376         }
377         return firstSource == link;
378     }
379
380     [MethodImpl(MethodImplOptions.AggressiveInlining)]
381     private bool EndsWith(ulong sequence, ulong link)
382     {
383         var upStep = sequence;
384         var lastTarget = Links.Unsync.GetTarget(upStep);
385         while (lastTarget != link && lastTarget != upStep)

```

```

386     {
387         upStep = lastTarget;
388         lastTarget = Links.Unsync.GetTarget(upStep);
389     }
390     return lastTarget == link;
391 }
392
393 [MethodImpl(MethodImplOptions.AggressiveInlining)]
394 public List<ulong> GetAllMatchingSequences0(params ulong[] sequence)
395 {
396     return _sync.ExecuteReadOperation(() =>
397     {
398         var results = new List<ulong>();
399         if (sequence.Length > 0)
400         {
401             Links.EnsureLinkExists(sequence);
402             var firstElement = sequence[0];
403             if (sequence.Length == 1)
404             {
405                 results.Add(firstElement);
406                 return results;
407             }
408             if (sequence.Length == 2)
409             {
410                 var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
411                 if (doublet != Constants.Null)
412                 {
413                     results.Add(doublet);
414                 }
415                 return results;
416             }
417             var linksInSequence = new HashSet<ulong>(sequence);
418             void handler(IList<LinkIndex> result)
419             {
420                 var resultIndex = result[Links.Constants.IndexPart];
421                 var filterPosition = 0;
422                 StopableSequenceWalker.WalkRight(resultIndex, Links.Unsync.GetSource,
423                     ↪ Links.Unsync.GetTarget,
424                     ↪ x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
425                     ↪ x =>
426                     {
427                         if (filterPosition == sequence.Length)
428                         {
429                             filterPosition = -2; // Длиннее чем нужно
430                             return false;
431                         }
432                         if (x != sequence[filterPosition])
433                         {
434                             filterPosition = -1;
435                             return false; // Начинается иначе
436                         }
437                         filterPosition++;
438                     }
439                     return true;
440                 });
441                 if (filterPosition == sequence.Length)
442                 {
443                     results.Add(resultIndex);
444                 }
445             }
446             if (sequence.Length >= 2)
447             {
448                 StepRight(handler, sequence[0], sequence[1]);
449             }
450             var last = sequence.Length - 2;
451             for (var i = 1; i < last; i++)
452             {
453                 PartialStepRight(handler, sequence[i], sequence[i + 1]);
454             }
455             if (sequence.Length >= 3)
456             {
457                 StepLeft(handler, sequence[sequence.Length - 2],
458                     ↪ sequence[sequence.Length - 1]);
459             }
460         }
461         return results;
462     });
463 }

```

```

462 [MethodImpl(MethodImplOptions.AggressiveInlining)]
463 public HashSet<ulong> GetAllMatchingSequences1(params ulong[] sequence)
464 {
465     return _sync.ExecuteReadOperation(() =>
466     {
467         var results = new HashSet<ulong>();
468         if (sequence.Length > 0)
469         {
470             Links.EnsureLinkExists(sequence);
471             var firstElement = sequence[0];
472             if (sequence.Length == 1)
473             {
474                 results.Add(firstElement);
475                 return results;
476             }
477             if (sequence.Length == 2)
478             {
479                 var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
480                 if (doublet != Constants.Null)
481                 {
482                     results.Add(doublet);
483                 }
484                 return results;
485             }
486             var matcher = new Matcher(this, sequence, results, null);
487             if (sequence.Length >= 2)
488             {
489                 StepRight(matcher.AddFullMatchedToResults, sequence[0], sequence[1]);
490             }
491             var last = sequence.Length - 2;
492             for (var i = 1; i < last; i++)
493             {
494                 PartialStepRight(matcher.AddFullMatchedToResults, sequence[i],
495                     ↪ sequence[i + 1]);
496             }
497             if (sequence.Length >= 3)
498             {
499                 StepLeft(matcher.AddFullMatchedToResults, sequence[sequence.Length - 2],
500                     ↪ sequence[sequence.Length - 1]);
501             }
502             return results;
503         });
504     }
505
506     public const int MaxSequenceFormatSize = 200;
507
508     [MethodImpl(MethodImplOptions.AggressiveInlining)]
509     public string FormatSequence(LinkIndex sequenceLink, params LinkIndex[] knownElements)
510     ↪ => FormatSequence(sequenceLink, (sb, x) => sb.Append(x), true, knownElements);
511
512     [MethodImpl(MethodImplOptions.AggressiveInlining)]
513     public string FormatSequence(LinkIndex sequenceLink, Action<StringBuilder, LinkIndex>
514     ↪ elementToString, bool insertComma, params LinkIndex[] knownElements) =>
515     ↪ Links.SyncRoot.ExecuteReadOperation(() => FormatSequence(Links.Unsync, sequenceLink,
516     ↪ elementToString, insertComma, knownElements));
517
518     [MethodImpl(MethodImplOptions.AggressiveInlining)]
519     private string FormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
520     ↪ Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
521     ↪ LinkIndex[] knownElements)
522     {
523         var linksInSequence = new HashSet<ulong>(knownElements);
524         //var entered = new HashSet<ulong>();
525         var sb = new StringBuilder();
526         sb.Append('{');
527         if (links.Exists(sequenceLink))
528         {
529             StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
530                 x => linksInSequence.Contains(x) || links.IsPartialPoint(x), element => //
531                 ↪ entered.AddAndReturnVoid, x => { }, entered.DoNotContains
532             {
533                 if (insertComma && sb.Length > 1)
534                 {
535                     sb.Append(',');
536                 }
537                 //if (entered.Contains(element))
538                 //{

```

```

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

```

```

601     var results = new HashSet<ulong>();
602     for (var i = 0; i < sequence.Length; i++)
603     {
604         AllUsagesCore(sequence[i], results);
605     }
606     var filteredResults = new List<ulong>();
607     var linksInSequence = new HashSet<ulong>(sequence);
608     foreach (var result in results)
609     {
610         var filterPosition = -1;
611         StopableSequenceWalker.WalkRight(result, Links.Unsync.GetSource,
        ↪ Links.Unsync.GetTarget,
612         x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
        ↪ x =>
        {
613             if (filterPosition == (sequence.Length - 1))
614             {
615                 return false;
616             }
617             if (filterPosition >= 0)
618             {
619                 if (x == sequence[filterPosition + 1])
620                 {
621                     filterPosition++;
622                 }
623                 else
624                 {
625                     return false;
626                 }
627             }
628             if (filterPosition < 0)
629             {
630                 if (x == sequence[0])
631                 {
632                     filterPosition = 0;
633                 }
634             }
635             return true;
636         }
637     });
638     if (filterPosition == (sequence.Length - 1))
639     {
640         filteredResults.Add(result);
641     }
642     return filteredResults;
643 }
644 return new List<ulong>();
645 });
646 }
647
648 [MethodImpl(MethodImplOptions.AggressiveInlining)]
649 public HashSet<ulong> GetAllPartiallyMatchingSequences1(params ulong[] sequence)
650 {
651     return _sync.ExecuteReadOperation(() =>
652     {
653         if (sequence.Length > 0)
654         {
655             Links.EnsureLinkExists(sequence);
656             var results = new HashSet<ulong>();
657             for (var i = 0; i < sequence.Length; i++)
658             {
659                 AllUsagesCore(sequence[i], results);
660             }
661             var filteredResults = new HashSet<ulong>();
662             var matcher = new Matcher(this, sequence, filteredResults, null);
663             matcher.AddAllPartialMatchedToResults(results);
664             return filteredResults;
665         }
666         return new HashSet<ulong>();
667     });
668 }
669
670 [MethodImpl(MethodImplOptions.AggressiveInlining)]
671 public bool GetAllPartiallyMatchingSequences2(Func<IList<LinkIndex>, LinkIndex> handler,
672 ↪ params ulong[] sequence)
673 {
674     return _sync.ExecuteReadOperation(() =>
675     {

```

```

676         if (sequence.Length > 0)
677         {
678             Links.EnsureLinkExists(sequence);
679
680             var results = new HashSet<ulong>();
681             var filteredResults = new HashSet<ulong>();
682             var matcher = new Matcher(this, sequence, filteredResults, handler);
683             for (var i = 0; i < sequence.Length; i++)
684             {
685                 if (!AllUsagesCore1(sequence[i], results, matcher.HandlePartialMatched))
686                 {
687                     return false;
688                 }
689             }
690             return true;
691         }
692         return true;
693     });
694 }
695
696 //public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
697 //{
698 //    return Sync.ExecuteReadOperation(() =>
699 //    {
700 //        if (sequence.Length > 0)
701 //        {
702 //            _links.EnsureEachLinkIsAnyOrExists(sequence);
703
704 //            var firstResults = new HashSet<ulong>();
705 //            var lastResults = new HashSet<ulong>();
706
707 //            var first = sequence.First(x => x != LinksConstants.Any);
708 //            var last = sequence.Last(x => x != LinksConstants.Any);
709
710 //            AllUsagesCore(first, firstResults);
711 //            AllUsagesCore(last, lastResults);
712
713 //            firstResults.IntersectWith(lastResults);
714
715 //            //for (var i = 0; i < sequence.Length; i++)
716 //            //    AllUsagesCore(sequence[i], results);
717
718 //            var filteredResults = new HashSet<ulong>();
719 //            var matcher = new Matcher(this, sequence, filteredResults, null);
720 //            matcher.AddAllPartialMatchedToResults(firstResults);
721 //            return filteredResults;
722 //        }
723
724 //        return new HashSet<ulong>();
725 //    });
726 //}
727
728 [MethodImpl(MethodImplOptions.AggressiveInlining)]
729 public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
730 {
731     return _sync.ExecuteReadOperation((Func<HashSet<ulong>>)(() =>
732     {
733         if (sequence.Length > 0)
734         {
735             ILinksExtensions.EnsureLinkIsAnyOrExists<ulong>(Links,
736                 ↪ (IList<ulong>)sequence);
737             var firstResults = new HashSet<ulong>();
738             var lastResults = new HashSet<ulong>();
739             var first = sequence.First(x => x != Constants.Any);
740             var last = sequence.Last(x => x != Constants.Any);
741             AllUsagesCore(first, firstResults);
742             AllUsagesCore(last, lastResults);
743             firstResults.IntersectWith(lastResults);
744             //for (var i = 0; i < sequence.Length; i++)
745             //    AllUsagesCore(sequence[i], results);
746             var filteredResults = new HashSet<ulong>();
747             var matcher = new Matcher(this, sequence, filteredResults, null);
748             matcher.AddAllPartialMatchedToResults(firstResults);
749             return filteredResults;
750         }
751         return new HashSet<ulong>();
752     }));
753 }

```



```

754 [MethodImpl(MethodImplOptions.AggressiveInlining)]
755 public HashSet<ulong> GetAllPartiallyMatchingSequences4(HashSet<ulong> readAsElements,
756     ↳ IList<ulong> sequence)
757 {
758     return _sync.ExecuteReadOperation(() =>
759     {
760         if (sequence.Count > 0)
761         {
762             Links.EnsureLinkExists(sequence);
763             var results = new HashSet<LinkIndex>();
764             //var nextResults = new HashSet<ulong>();
765             //for (var i = 0; i < sequence.Length; i++)
766             //{
767                 AllUsagesCore(sequence[i], nextResults);
768                 if (results.IsNullOrEmpty())
769                 {
770                     results = nextResults;
771                     nextResults = new HashSet<ulong>();
772                 }
773                 else
774                 {
775                     results.IntersectWith(nextResults);
776                     nextResults.Clear();
777                 }
778             }
779             var collector1 = new AllUsagesCollector1(Links.Unsync, results);
780             collector1.Collect(Links.Unsync.GetLink(sequence[0]));
781             var next = new HashSet<ulong>();
782             for (var i = 1; i < sequence.Count; i++)
783             {
784                 var collector = new AllUsagesCollector1(Links.Unsync, next);
785                 collector.Collect(Links.Unsync.GetLink(sequence[i]));
786
787                 results.IntersectWith(next);
788                 next.Clear();
789             }
790             var filteredResults = new HashSet<ulong>();
791             var matcher = new Matcher(this, sequence, filteredResults, null,
792                 ↳ readAsElements);
793             matcher.AddAllPartialMatchedToResultsAndReadAsElements(results.OrderBy(x =>
794                 ↳ x)); // OrderBy is a Hack
795             return filteredResults;
796         }
797         return new HashSet<ulong>();
798     });
799 }
800
801 // Does not work
802 //public HashSet<ulong> GetAllPartiallyMatchingSequences5(HashSet<ulong> readAsElements,
803 //    ↳ params ulong[] sequence)
804 //{
805 //    var visited = new HashSet<ulong>();
806 //    var results = new HashSet<ulong>();
807 //    var matcher = new Matcher(this, sequence, visited, x => { results.Add(x); return
808 //        ↳ true; }, readAsElements);
809 //    var last = sequence.Length - 1;
810 //    for (var i = 0; i < last; i++)
811 //    {
812 //        PartialStepRight(matcher.PartialMatch, sequence[i], sequence[i + 1]);
813 //    }
814 //    return results;
815 //}
816
817 [MethodImpl(MethodImplOptions.AggressiveInlining)]
818 public List<ulong> GetAllPartiallyMatchingSequences(params ulong[] sequence)
819 {
820     return _sync.ExecuteReadOperation(() =>
821     {
822         if (sequence.Length > 0)
823         {
824             Links.EnsureLinkExists(sequence);
825             //var firstElement = sequence[0];
826             //if (sequence.Length == 1)
827             //{
828                 //results.Add(firstElement);
829                 return results;
830             }
831             //}
832         }
833     });
834 }

```

```

826 //if (sequence.Length == 2)
827 //{
828 //    //var doublet = _links.SearchCore(firstElement, sequence[1]);
829 //    //if (doublet != Doublets.Links.Null)
830 //        results.Add(doublet);
831 //    return results;
832 //}
833 //var lastElement = sequence[sequence.Length - 1];
834 //Func<ulong, bool> handler = x =>
835 //{
836 //    if (StartsWith(x, firstElement) && EndsWith(x, lastElement))
837 //        results.Add(x);
838 //    return true;
839 //};
840 //if (sequence.Length >= 2)
841 //    StepRight(handler, sequence[0], sequence[1]);
842 //var last = sequence.Length - 2;
843 //for (var i = 1; i < last; i++)
844 //    PartialStepRight(handler, sequence[i], sequence[i + 1]);
845 //if (sequence.Length >= 3)
846 //    StepLeft(handler, sequence[sequence.Length - 2],
847 //        sequence[sequence.Length - 1]);
848 //if (sequence.Length == 1)
849 //    throw new NotImplementedException(); // all sequences, containing
850 //    this element?
851 //if (sequence.Length == 2)
852 //{
853 //    var results = new List<ulong>();
854 //    PartialStepRight(results.Add, sequence[0], sequence[1]);
855 //    return results;
856 //}
857 //var matches = new List<List<ulong>>();
858 //var last = sequence.Length - 1;
859 //for (var i = 0; i < last; i++)
860 //{
861 //    var results = new List<ulong>();
862 //    //StepRight(results.Add, sequence[i], sequence[i + 1]);
863 //    PartialStepRight(results.Add, sequence[i], sequence[i + 1]);
864 //    if (results.Count > 0)
865 //        matches.Add(results);
866 //    else
867 //        return results;
868 //    if (matches.Count == 2)
869 //    {
870 //        var merged = new List<ulong>();
871 //        for (var j = 0; j < matches[0].Count; j++)
872 //            for (var k = 0; k < matches[1].Count; k++)
873 //                CloseInnerConnections(merged.Add, matches[0][j],
874 //                    matches[1][k]);
875 //        if (merged.Count > 0)
876 //            matches = new List<List<ulong>> { merged };
877 //        else
878 //            return new List<ulong>();
879 //    }
880 //}
881 //if (matches.Count > 0)
882 //{
883 //    var usages = new HashSet<ulong>();
884 //    for (int i = 0; i < sequence.Length; i++)
885 //    {
886 //        AllUsagesCore(sequence[i], usages);
887 //    }
888 //    //for (int i = 0; i < matches[0].Count; i++)
889 //    //    AllUsagesCore(matches[0][i], usages);
890 //    //usages.UnionWith(matches[0]);
891 //    return usages.ToList();
892 //}
893 var firstLinkUsages = new HashSet<ulong>();
894 AllUsagesCore(sequence[0], firstLinkUsages);
895 firstLinkUsages.Add(sequence[0]);
896 //var previousMatchings = firstLinkUsages.ToList(); //new List<ulong>() {
897 //    sequence[0] }; // or all sequences, containing this element?
898 //return GetAllPartiallyMatchingSequencesCore(sequence, firstLinkUsages,
899 //    1).ToList();
900 var results = new HashSet<ulong>();

```

```

897         foreach (var match in GetAllPartiallyMatchingSequencesCore(sequence,
898             ↪ firstLinkUsages, 1))
899         {
900             AllUsagesCore(match, results);
901         }
902         return results.ToList();
903     }
904     return new List<ulong>();
905 });
906 }
907
908 /// <remarks>
909 /// TODO: Может потребоваться ограничение на уровень глубины рекурсии
910 /// </remarks>
911 [MethodImpl(MethodImplOptions.AggressiveInlining)]
912 public HashSet<ulong> AllUsages(ulong link)
913 {
914     return _sync.ExecuteReadOperation(() =>
915     {
916         var usages = new HashSet<ulong>();
917         AllUsagesCore(link, usages);
918         return usages;
919     });
920 }
921
922 // При сборе всех использований (последовательностей) можно сохранять обратный путь к
923 ↪ той связи с которой начинался поиск (STTTSSSTT),
924 // причём достаточно одного бита для хранения перехода влево или вправо
925 [MethodImpl(MethodImplOptions.AggressiveInlining)]
926 private void AllUsagesCore(ulong link, HashSet<ulong> usages)
927 {
928     bool handler(ulong doublet)
929     {
930         if (usages.Add(doublet))
931         {
932             AllUsagesCore(doublet, usages);
933         }
934         return true;
935     }
936     Links.Unsync.Each(link, Constants.Any, handler);
937     Links.Unsync.Each(Constants.Any, link, handler);
938 }
939
940 [MethodImpl(MethodImplOptions.AggressiveInlining)]
941 public HashSet<ulong> AllBottomUsages(ulong link)
942 {
943     return _sync.ExecuteReadOperation(() =>
944     {
945         var visits = new HashSet<ulong>();
946         var usages = new HashSet<ulong>();
947         AllBottomUsagesCore(link, visits, usages);
948         return usages;
949     });
950 }
951
952 [MethodImpl(MethodImplOptions.AggressiveInlining)]
953 private void AllBottomUsagesCore(ulong link, HashSet<ulong> visits, HashSet<ulong>
954 ↪ usages)
955 {
956     bool handler(ulong doublet)
957     {
958         if (visits.Add(doublet))
959         {
960             AllBottomUsagesCore(doublet, visits, usages);
961         }
962         return true;
963     }
964     if (Links.Unsync.Count(Constants.Any, link) == 0)
965     {
966         usages.Add(link);
967     }
968     else
969     {
970         Links.Unsync.Each(link, Constants.Any, handler);
971         Links.Unsync.Each(Constants.Any, link, handler);
972     }
973 }

```

```

972 [MethodImpl(MethodImplOptions.AggressiveInlining)]
973 public ulong CalculateTotalSymbolFrequencyCore(ulong symbol)
974 {
975     if (Options.UseSequenceMarker)
976     {
977         var counter = new TotalMarkedSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
978             ↪ Options.MarkedSequenceMatcher, symbol);
979         return counter.Count();
980     }
981     else
982     {
983         var counter = new TotalSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
984             ↪ symbol);
985         return counter.Count();
986     }
987 }
988 [MethodImpl(MethodImplOptions.AggressiveInlining)]
989 private bool AllUsagesCore1(ulong link, HashSet<ulong> usages, Func<IList<LinkIndex>,
990     ↪ LinkIndex> outerHandler)
991 {
992     bool handler(ulong doublet)
993     {
994         if (usages.Add(doublet))
995         {
996             if (outerHandler(new LinkAddress<LinkIndex>(doublet)) != Constants.Continue)
997             {
998                 return false;
999             }
1000             if (!AllUsagesCore1(doublet, usages, outerHandler))
1001             {
1002                 return false;
1003             }
1004         }
1005         return true;
1006     }
1007     return Links.Unsync.Each(link, Constants.Any, handler)
1008         && Links.Unsync.Each(Constants.Any, link, handler);
1009 }
1010 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1011 public void CalculateAllUsages(ulong[] totals)
1012 {
1013     var calculator = new AllUsagesCalculator(Links, totals);
1014     calculator.Calculate();
1015 }
1016 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1017 public void CalculateAllUsages2(ulong[] totals)
1018 {
1019     var calculator = new AllUsagesCalculator2(Links, totals);
1020     calculator.Calculate();
1021 }
1022 private class AllUsagesCalculator
1023 {
1024     private readonly SynchronizedLinks<ulong> _links;
1025     private readonly ulong[] _totals;
1026
1027     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1028     public AllUsagesCalculator(SynchronizedLinks<ulong> links, ulong[] totals)
1029     {
1030         _links = links;
1031         _totals = totals;
1032     }
1033
1034     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1035     public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
1036         ↪ CalculateCore);
1037
1038     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1039     private bool CalculateCore(ulong link)
1040     {
1041         if (_totals[link] == 0)
1042         {
1043             var total = 1UL;
1044             _totals[link] = total;
1045             var visitedChildren = new HashSet<ulong>();
1046             bool linkCalculator(ulong child)

```

```

1047         {
1048             if (link != child && visitedChildren.Add(child))
1049             {
1050                 total += _totals[child] == 0 ? 1 : _totals[child];
1051             }
1052             return true;
1053         }
1054         _links.Unsync.Each(link, _links.Constants.Any, linkCalculator);
1055         _links.Unsync.Each(_links.Constants.Any, link, linkCalculator);
1056         _totals[link] = total;
1057     }
1058     return true;
1059 }
1060
1061 private class AllUsagesCalculator2
1062 {
1063     private readonly SynchronizedLinks<ulong> _links;
1064     private readonly ulong[] _totals;
1065
1066     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1067     public AllUsagesCalculator2(SynchronizedLinks<ulong> links, ulong[] totals)
1068     {
1069         _links = links;
1070         _totals = totals;
1071     }
1072
1073     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1074     public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
1075         ↪ CalculateCore);
1076
1077     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1078     private bool IsElement(ulong link)
1079     {
1080         // _linksInSequence.Contains(link) ||
1081         return _links.Unsync.GetTarget(link) == link || _links.Unsync.GetSource(link) ==
1082             ↪ link;
1083     }
1084
1085     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1086     private bool CalculateCore(ulong link)
1087     {
1088         // TODO: Проработать защиту от заикливания
1089         // Основано на SequenceWalker.WalkLeft
1090         Func<ulong, ulong> getSource = _links.Unsync.GetSource;
1091         Func<ulong, ulong> getTarget = _links.Unsync.GetTarget;
1092         Func<ulong, bool> isElement = IsElement;
1093         void visitLeaf(ulong parent)
1094         {
1095             if (link != parent)
1096             {
1097                 _totals[parent]++;
1098             }
1099         }
1100         void visitNode(ulong parent)
1101         {
1102             if (link != parent)
1103             {
1104                 _totals[parent]++;
1105             }
1106         }
1107         var stack = new Stack();
1108         var element = link;
1109         if (isElement(element))
1110         {
1111             visitLeaf(element);
1112         }
1113         else
1114         {
1115             while (true)
1116             {
1117                 if (isElement(element))
1118                 {
1119                     if (stack.Count == 0)
1120                     {
1121                         break;
1122                     }
1123                     element = stack.Pop();
1124                     var source = getSource(element);

```

```

1124         var target = getTarget(element);
1125         // 06pa6oрка элемеHта
1126         if (isElement(target))
1127         {
1128             visitLeaf(target);
1129         }
1130         if (isElement(source))
1131         {
1132             visitLeaf(source);
1133         }
1134         element = source;
1135     }
1136     else
1137     {
1138         stack.Push(element);
1139         visitNode(element);
1140         element = getTarget(element);
1141     }
1142 }
1143 }
1144 _totals[link]++;
1145 return true;
1146 }
1147 }
1148
1149 private class AllUsagesCollector
1150 {
1151     private readonly ILinks<ulong> _links;
1152     private readonly HashSet<ulong> _usages;
1153
1154     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1155     public AllUsagesCollector(ILinks<ulong> links, HashSet<ulong> usages)
1156     {
1157         _links = links;
1158         _usages = usages;
1159     }
1160
1161     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1162     public bool Collect(ulong link)
1163     {
1164         if (_usages.Add(link))
1165         {
1166             _links.Each(link, _links.Constants.Any, Collect);
1167             _links.Each(_links.Constants.Any, link, Collect);
1168         }
1169         return true;
1170     }
1171 }
1172
1173 private class AllUsagesCollector1
1174 {
1175     private readonly ILinks<ulong> _links;
1176     private readonly HashSet<ulong> _usages;
1177     private readonly ulong _continue;
1178
1179     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1180     public AllUsagesCollector1(ILinks<ulong> links, HashSet<ulong> usages)
1181     {
1182         _links = links;
1183         _usages = usages;
1184         _continue = _links.Constants.Continue;
1185     }
1186
1187     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1188     public ulong Collect(ICollection<ulong> link)
1189     {
1190         var linkIndex = _links.GetIndex(link);
1191         if (_usages.Add(linkIndex))
1192         {
1193             _links.Each(Collect, _links.Constants.Any, linkIndex);
1194         }
1195         return _continue;
1196     }
1197 }
1198
1199 private class AllUsagesCollector2
1200 {
1201     private readonly ILinks<ulong> _links;
1202     private readonly BitString _usages;
1203

```

```

1204 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1205 public AllUsagesCollector2(ILinks<ulong> links, BitString usages)
1206 {
1207     _links = links;
1208     _usages = usages;
1209 }
1210
1211 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1212 public bool Collect(ulong link)
1213 {
1214     if (_usages.Add((long)link))
1215     {
1216         _links.Each(link, _links.Constants.Any, Collect);
1217         _links.Each(_links.Constants.Any, link, Collect);
1218     }
1219     return true;
1220 }
1221 }
1222
1223 private class AllUsagesIntersectingCollector
1224 {
1225     private readonly SynchronizedLinks<ulong> _links;
1226     private readonly HashSet<ulong> _intersectWith;
1227     private readonly HashSet<ulong> _usages;
1228     private readonly HashSet<ulong> _enter;
1229
1230     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1231     public AllUsagesIntersectingCollector(SynchronizedLinks<ulong> links, HashSet<ulong>
↪ intersectWith, HashSet<ulong> usages)
1232     {
1233         _links = links;
1234         _intersectWith = intersectWith;
1235         _usages = usages;
1236         _enter = new HashSet<ulong>(); // защита от зацикливания
1237     }
1238
1239     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1240     public bool Collect(ulong link)
1241     {
1242         if (_enter.Add(link))
1243         {
1244             if (_intersectWith.Contains(link))
1245             {
1246                 _usages.Add(link);
1247             }
1248             _links.Unsync.Each(link, _links.Constants.Any, Collect);
1249             _links.Unsync.Each(_links.Constants.Any, link, Collect);
1250         }
1251         return true;
1252     }
1253 }
1254
1255 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1256 private void CloseInnerConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
↪ right)
1257 {
1258     TryStepLeftUp(handler, left, right);
1259     TryStepRightUp(handler, right, left);
1260 }
1261
1262 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1263 private void AllCloseConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
↪ right)
1264 {
1265     // Direct
1266     if (left == right)
1267     {
1268         handler(new LinkAddress<LinkIndex>(left));
1269     }
1270     var doublet = Links.Unsync.SearchOrDefault(left, right);
1271     if (doublet != Constants.Null)
1272     {
1273         handler(new LinkAddress<LinkIndex>(doublet));
1274     }
1275     // Inner
1276     CloseInnerConnections(handler, left, right);
1277     // Outer
1278     StepLeft(handler, left, right);
1279     StepRight(handler, left, right);

```



```

1346         uniqueSequenceElements.Add(patternSequence[i]);
1347     }
1348 }
1349 var results = new HashSet<ulong>();
1350 foreach (var uniqueSequenceElement in uniqueSequenceElements)
1351 {
1352     AllUsagesCore(uniqueSequenceElement, results);
1353 }
1354 var filteredResults = new HashSet<ulong>();
1355 var matcher = new PatternMatcher(this, patternSequence, filteredResults);
1356 matcher.AddAllPatternMatchedToResults(results);
1357 return filteredResults;
1358 }
1359 return new HashSet<ulong>();
1360 });
1361 }
1362
1363 // Найти все возможные связи между указанным списком связей.
1364 // Находит связи между всеми указанными связями в любом порядке.
1365 // TODO: решить что делать с повторами (когда одни и те же элементы встречаются
1366 // ↳ несколько раз в последовательности)
1367 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1368 public HashSet<ulong> GetAllConnections(params ulong[] linksToConnect)
1369 {
1370     return _sync.ExecuteReadOperation(() =>
1371     {
1372         var results = new HashSet<ulong>();
1373         if (linksToConnect.Length > 0)
1374         {
1375             Links.EnsureLinkExists(linksToConnect);
1376             AllUsagesCore(linksToConnect[0], results);
1377             for (var i = 1; i < linksToConnect.Length; i++)
1378             {
1379                 var next = new HashSet<ulong>();
1380                 AllUsagesCore(linksToConnect[i], next);
1381                 results.IntersectWith(next);
1382             }
1383             return results;
1384         }
1385     });
1386 }
1387 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1388 public HashSet<ulong> GetAllConnections1(params ulong[] linksToConnect)
1389 {
1390     return _sync.ExecuteReadOperation(() =>
1391     {
1392         var results = new HashSet<ulong>();
1393         if (linksToConnect.Length > 0)
1394         {
1395             Links.EnsureLinkExists(linksToConnect);
1396             var collector1 = new AllUsagesCollector(Links.Unsync, results);
1397             collector1.Collect(linksToConnect[0]);
1398             var next = new HashSet<ulong>();
1399             for (var i = 1; i < linksToConnect.Length; i++)
1400             {
1401                 var collector = new AllUsagesCollector(Links.Unsync, next);
1402                 collector.Collect(linksToConnect[i]);
1403                 results.IntersectWith(next);
1404                 next.Clear();
1405             }
1406             return results;
1407         }
1408     });
1409 }
1410
1411 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1412 public HashSet<ulong> GetAllConnections2(params ulong[] linksToConnect)
1413 {
1414     return _sync.ExecuteReadOperation(() =>
1415     {
1416         var results = new HashSet<ulong>();
1417         if (linksToConnect.Length > 0)
1418         {
1419             Links.EnsureLinkExists(linksToConnect);
1420             var collector1 = new AllUsagesCollector(Links, results);
1421             collector1.Collect(linksToConnect[0]);
1422             //AllUsagesCore(linksToConnect[0], results);

```

```

1423         for (var i = 1; i < linksToConnect.Length; i++)
1424         {
1425             var next = new HashSet<ulong>();
1426             var collector = new AllUsagesIntersectingCollector(Links, results, next);
1427             collector.Collect(linksToConnect[i]);
1428             //AllUsagesCore(linksToConnect[i], next);
1429             //results.IntersectWith(next);
1430             results = next;
1431         }
1432     }
1433     return results;
1434 });
1435 }
1436
1437 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1438 public List<ulong> GetAllConnections3(params ulong[] linksToConnect)
1439 {
1440     return _sync.ExecuteReadOperation(() =>
1441     {
1442         var results = new BitString((long)Links.Unsync.Count() + 1); // new
1443         ↪ BitArray((int)_links.Total + 1);
1444         if (linksToConnect.Length > 0)
1445         {
1446             Links.EnsureLinkExists(linksToConnect);
1447             var collector1 = new AllUsagesCollector2(Links.Unsync, results);
1448             collector1.Collect(linksToConnect[0]);
1449             for (var i = 1; i < linksToConnect.Length; i++)
1450             {
1451                 var next = new BitString((long)Links.Unsync.Count() + 1); //new
1452                 ↪ BitArray((int)_links.Total + 1);
1453                 var collector = new AllUsagesCollector2(Links.Unsync, next);
1454                 collector.Collect(linksToConnect[i]);
1455                 results = results.And(next);
1456             }
1457         }
1458         return results.GetSetUInt64Indices();
1459     });
1460 }
1461
1462 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1463 private static ulong[] Simplify(ulong[] sequence)
1464 {
1465     // Считаем новый размер последовательности
1466     long newLength = 0;
1467     var zeroOrManyStepped = false;
1468     for (var i = 0; i < sequence.Length; i++)
1469     {
1470         if (sequence[i] == ZeroOrMany)
1471         {
1472             if (zeroOrManyStepped)
1473             {
1474                 continue;
1475             }
1476             zeroOrManyStepped = true;
1477         }
1478         else
1479         {
1480             //if (zeroOrManyStepped) Is it efficient?
1481             zeroOrManyStepped = false;
1482         }
1483         newLength++;
1484     }
1485     // Строим новую последовательность
1486     zeroOrManyStepped = false;
1487     var newSequence = new ulong[newLength];
1488     long j = 0;
1489     for (var i = 0; i < sequence.Length; i++)
1490     {
1491         //var current = zeroOrManyStepped;
1492         //zeroOrManyStepped = patternSequence[i] == zeroOrMany;
1493         //if (current && zeroOrManyStepped)
1494         //    continue;
1495         //var newZeroOrManyStepped = patternSequence[i] == zeroOrMany;
1496         //if (zeroOrManyStepped && newZeroOrManyStepped)
1497         //    continue;
1498         //zeroOrManyStepped = newZeroOrManyStepped;
1499         if (sequence[i] == ZeroOrMany)
1500         {

```

```

1499         if (zeroOrManyStepped)
1500         {
1501             continue;
1502         }
1503         zeroOrManyStepped = true;
1504     }
1505     else
1506     {
1507         //if (zeroOrManyStepped) Is it efficient?
1508         zeroOrManyStepped = false;
1509     }
1510     newSequence[j++] = sequence[i];
1511 }
1512 return newSequence;
1513 }
1514
1515 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1516 public static void TestSimplify()
1517 {
1518     var sequence = new ulong[] { ZeroOrMany, ZeroOrMany, 2, 3, 4, ZeroOrMany,
1519         ↪ ZeroOrMany, ZeroOrMany, 4, ZeroOrMany, ZeroOrMany, ZeroOrMany };
1520     var simplifiedSequence = Simplify(sequence);
1521 }
1522
1523 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1524 public List<ulong> GetSimilarSequences() => new List<ulong>();
1525
1526 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1527 public void Prediction()
1528 {
1529     //_links
1530     //_sequences
1531 }
1532
1533 #region From Triplets
1534
1535 //public static void DeleteSequence(Link sequence)
1536 //{
1537 //}
1538
1539 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1540 public List<ulong> CollectMatchingSequences(ulong[] links)
1541 {
1542     if (links.Length == 1)
1543     {
1544         throw new InvalidOperationException("Подпоследовательности с одним элементом не
1545             ↪ поддерживаются.");
1546     }
1547     var leftBound = 0;
1548     var rightBound = links.Length - 1;
1549     var left = links[leftBound++];
1550     var right = links[rightBound--];
1551     var results = new List<ulong>();
1552     CollectMatchingSequences(left, leftBound, links, right, rightBound, ref results);
1553     return results;
1554 }
1555
1556 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1557 private void CollectMatchingSequences(ulong leftLink, int leftBound, ulong[]
1558     ↪ middleLinks, ulong rightLink, int rightBound, ref List<ulong> results)
1559 {
1560     var leftLinkTotalReferers = Links.Unsync.Count(leftLink);
1561     var rightLinkTotalReferers = Links.Unsync.Count(rightLink);
1562     if (leftLinkTotalReferers <= rightLinkTotalReferers)
1563     {
1564         var nextLeftLink = middleLinks[leftBound];
1565         var elements = GetRightElements(leftLink, nextLeftLink);
1566         if (leftBound <= rightBound)
1567         {
1568             for (var i = elements.Length - 1; i >= 0; i--)
1569             {
1570                 var element = elements[i];
1571                 if (element != 0)
1572                 {
1573                     CollectMatchingSequences(element, leftBound + 1, middleLinks,
1574                         ↪ rightLink, rightBound, ref results);
1575                 }
1576             }
1577         }
1578     }
1579 }

```

```

1574     else
1575     {
1576         for (var i = elements.Length - 1; i >= 0; i--)
1577         {
1578             var element = elements[i];
1579             if (element != 0)
1580             {
1581                 results.Add(element);
1582             }
1583         }
1584     }
1585 }
1586 else
1587 {
1588     var nextRightLink = middleLinks[rightBound];
1589     var elements = GetLeftElements(rightLink, nextRightLink);
1590     if (leftBound <= rightBound)
1591     {
1592         for (var i = elements.Length - 1; i >= 0; i--)
1593         {
1594             var element = elements[i];
1595             if (element != 0)
1596             {
1597                 CollectMatchingSequences(leftLink, leftBound, middleLinks,
1598                                         ↪ elements[i], rightBound - 1, ref results);
1599             }
1600         }
1601     }
1602     else
1603     {
1604         for (var i = elements.Length - 1; i >= 0; i--)
1605         {
1606             var element = elements[i];
1607             if (element != 0)
1608             {
1609                 results.Add(element);
1610             }
1611         }
1612     }
1613 }
1614
1615 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1616 public ulong[] GetRightElements(ulong startLink, ulong rightLink)
1617 {
1618     var result = new ulong[5];
1619     TryStepRight(startLink, rightLink, result, 0);
1620     Links.Each(Constants.Any, startLink, couple =>
1621     {
1622         if (couple != startLink)
1623         {
1624             if (TryStepRight(couple, rightLink, result, 2))
1625             {
1626                 return false;
1627             }
1628         }
1629         return true;
1630     });
1631     if (Links.GetTarget(Links.GetTarget(startLink)) == rightLink)
1632     {
1633         result[4] = startLink;
1634     }
1635     return result;
1636 }
1637
1638 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1639 public bool TryStepRight(ulong startLink, ulong rightLink, ulong[] result, int offset)
1640 {
1641     var added = 0;
1642     Links.Each(startLink, Constants.Any, couple =>
1643     {
1644         if (couple != startLink)
1645         {
1646             var coupleTarget = Links.GetTarget(couple);
1647             if (coupleTarget == rightLink)
1648             {
1649                 result[offset] = couple;
1650                 if (++added == 2)

```

```

1651         {
1652             return false;
1653         }
1654     }
1655     else if (Links.GetSource(coupleTarget) == rightLink) // coupleTarget.Linker
1656         ↪ == Net.And &&
1657     {
1658         result[offset + 1] = couple;
1659         if (++added == 2)
1660         {
1661             return false;
1662         }
1663     }
1664     return true;
1665 });
1666 return added > 0;
1667 }
1668
1669 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1670 public ulong[] GetLeftElements(ulong startLink, ulong leftLink)
1671 {
1672     var result = new ulong[5];
1673     TryStepLeft(startLink, leftLink, result, 0);
1674     Links.Each(startLink, Constants.Any, couple =>
1675     {
1676         if (couple != startLink)
1677         {
1678             if (TryStepLeft(couple, leftLink, result, 2))
1679             {
1680                 return false;
1681             }
1682         }
1683         return true;
1684     });
1685     if (Links.GetSource(Links.GetSource(leftLink)) == startLink)
1686     {
1687         result[4] = leftLink;
1688     }
1689     return result;
1690 }
1691
1692 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1693 public bool TryStepLeft(ulong startLink, ulong leftLink, ulong[] result, int offset)
1694 {
1695     var added = 0;
1696     Links.Each(Constants.Any, startLink, couple =>
1697     {
1698         if (couple != startLink)
1699         {
1700             var coupleSource = Links.GetSource(couple);
1701             if (coupleSource == leftLink)
1702             {
1703                 result[offset] = couple;
1704                 if (++added == 2)
1705                 {
1706                     return false;
1707                 }
1708             }
1709             else if (Links.GetTarget(coupleSource) == leftLink) // coupleSource.Linker
1710                 ↪ == Net.And &&
1711             {
1712                 result[offset + 1] = couple;
1713                 if (++added == 2)
1714                 {
1715                     return false;
1716                 }
1717             }
1718             return true;
1719         });
1720     return added > 0;
1721 }
1722
1723 #endregion
1724
1725 #region Walkers
1726
1727 public class PatternMatcher : RightSequenceWalker<ulong>

```

```

1728 {
1729     private readonly Sequences _sequences;
1730     private readonly ulong[] _patternSequence;
1731     private readonly HashSet<LinkIndex> _linksInSequence;
1732     private readonly HashSet<LinkIndex> _results;
1733
1734     #region Pattern Match
1735
1736     enum PatternBlockType
1737     {
1738         Undefined,
1739         Gap,
1740         Elements
1741     }
1742
1743     struct PatternBlock
1744     {
1745         public PatternBlockType Type;
1746         public long Start;
1747         public long Stop;
1748     }
1749
1750     private readonly List<PatternBlock> _pattern;
1751     private int _patternPosition;
1752     private long _sequencePosition;
1753
1754     #endregion
1755
1756     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1757     public PatternMatcher(Sequences sequences, LinkIndex[] patternSequence,
1758         ↳ HashSet<LinkIndex> results)
1759         : base(sequences.Links.Unsync, new DefaultStack<ulong>())
1760     {
1761         _sequences = sequences;
1762         _patternSequence = patternSequence;
1763         _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
1764             ↳ _sequences.Constants.Any && x != ZeroOrMany));
1765         _results = results;
1766         _pattern = CreateDetailedPattern();
1767     }
1768
1769     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1770     protected override bool IsElement(ulong link) => _linksInSequence.Contains(link) ||
1771         ↳ base.IsElement(link);
1772
1773     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1774     public bool PatternMatch(LinkIndex sequenceToMatch)
1775     {
1776         _patternPosition = 0;
1777         _sequencePosition = 0;
1778         foreach (var part in Walk(sequenceToMatch))
1779         {
1780             if (!PatternMatchCore(part))
1781             {
1782                 break;
1783             }
1784         }
1785         return _patternPosition == _pattern.Count || (_patternPosition == _pattern.Count
1786             ↳ - 1 && _pattern[_patternPosition].Start == 0);
1787     }
1788
1789     [MethodImpl(MethodImplOptions.AggressiveInlining)]
1790     private List<PatternBlock> CreateDetailedPattern()
1791     {
1792         var pattern = new List<PatternBlock>();
1793         var patternBlock = new PatternBlock();
1794         for (var i = 0; i < _patternSequence.Length; i++)
1795         {
1796             if (patternBlock.Type == PatternBlockType.Undefined)
1797             {
1798                 if (_patternSequence[i] == _sequences.Constants.Any)
1799                 {
1800                     patternBlock.Type = PatternBlockType.Gap;
1801                     patternBlock.Start = 1;
1802                     patternBlock.Stop = 1;
1803                 }
1804                 else if (_patternSequence[i] == ZeroOrMany)
1805                 {
1806                     patternBlock.Type = PatternBlockType.Gap;
1807                     patternBlock.Start = 0;
1808                 }
1809             }
1810             else
1811             {
1812                 patternBlock.Type = PatternBlockType.Elements;
1813                 patternBlock.Start = 1;
1814                 patternBlock.Stop = 1;
1815             }
1816             pattern.Add(patternBlock);
1817             patternBlock = new PatternBlock();
1818         }
1819         return pattern;
1820     }
1821 }

```

```

1804         patternBlock.Stop = long.MaxValue;
1805     }
1806     else
1807     {
1808         patternBlock.Type = PatternBlockType.Elements;
1809         patternBlock.Start = i;
1810         patternBlock.Stop = i;
1811     }
1812 }
1813 else if (patternBlock.Type == PatternBlockType.Elements)
1814 {
1815     if (_patternSequence[i] == _sequences.Constants.Any)
1816     {
1817         pattern.Add(patternBlock);
1818         patternBlock = new PatternBlock
1819         {
1820             Type = PatternBlockType.Gap,
1821             Start = 1,
1822             Stop = 1
1823         };
1824     }
1825     else if (_patternSequence[i] == ZeroOrMany)
1826     {
1827         pattern.Add(patternBlock);
1828         patternBlock = new PatternBlock
1829         {
1830             Type = PatternBlockType.Gap,
1831             Start = 0,
1832             Stop = long.MaxValue
1833         };
1834     }
1835     else
1836     {
1837         patternBlock.Stop = i;
1838     }
1839 }
1840 else // patternBlock.Type == PatternBlockType.Gap
1841 {
1842     if (_patternSequence[i] == _sequences.Constants.Any)
1843     {
1844         patternBlock.Start++;
1845         if (patternBlock.Stop < patternBlock.Start)
1846         {
1847             patternBlock.Stop = patternBlock.Start;
1848         }
1849     }
1850     else if (_patternSequence[i] == ZeroOrMany)
1851     {
1852         patternBlock.Stop = long.MaxValue;
1853     }
1854     else
1855     {
1856         pattern.Add(patternBlock);
1857         patternBlock = new PatternBlock
1858         {
1859             Type = PatternBlockType.Elements,
1860             Start = i,
1861             Stop = i
1862         };
1863     }
1864 }
1865 }
1866 if (patternBlock.Type != PatternBlockType.Undefined)
1867 {
1868     pattern.Add(patternBlock);
1869 }
1870 return pattern;
1871 }
1872
1873 // match: search for regexp anywhere in text
1874 //int match(char* regexp, char* text)
1875 //{
1876 //    do
1877 //    {
1878 //        } while (*text++ != '\0');
1879 //    return 0;
1880 //}
1881
1882 // matchhere: search for regexp at beginning of text
1883 //int matchhere(char* regexp, char* text)

```

```

1884 // {
1885 //     if (regex[0] == '\0')
1886 //         return 1;
1887 //     if (regex[1] == '*')
1888 //         return matchstar(regex[0], regex + 2, text);
1889 //     if (regex[0] == '$' && regex[1] == '\0')
1890 //         return *text == '\0';
1891 //     if (*text != '\0' && (regex[0] == '.' || regex[0] == *text))
1892 //         return matchhere(regex + 1, text + 1);
1893 //     return 0;
1894 // }
1895
1896 // matchstar: search for c*regex at beginning of text
1897 // int matchstar(int c, char* regex, char* text)
1898 // {
1899 //     do
1900 //     {
1901 //         /* a * matches zero or more instances */
1902 //         if (matchhere(regex, text))
1903 //             return 1;
1904 //     } while (*text != '\0' && (*text++ == c || c == '.'));
1905 //     return 0;
1906 // }
1907
1908 // private void GetNextPatternElement(out LinkIndex element, out long mininumGap, out
1909 //     ↪ long maximumGap)
1910 // {
1911 //     mininumGap = 0;
1912 //     maximumGap = 0;
1913 //     element = 0;
1914 //     for (; _patternPosition < _patternSequence.Length; _patternPosition++)
1915 //     {
1916 //         if (_patternSequence[_patternPosition] == Doublets.Links.Null)
1917 //             mininumGap++;
1918 //         else if (_patternSequence[_patternPosition] == ZeroOrMany)
1919 //             maximumGap = long.MaxValue;
1920 //         else
1921 //             break;
1922 //     }
1923
1924 //     if (maximumGap < mininumGap)
1925 //         maximumGap = mininumGap;
1926 // }
1927
1928 [MethodImpl(MethodImplOptions.AggressiveInlining)]
1929 private bool PatternMatchCore(LinkIndex element)
1930 {
1931     if (_patternPosition >= _pattern.Count)
1932     {
1933         _patternPosition = -2;
1934         return false;
1935     }
1936     var currentPatternBlock = _pattern[_patternPosition];
1937     if (currentPatternBlock.Type == PatternBlockType.Gap)
1938     {
1939         // var currentMatchingBlockLength = (_sequencePosition -
1940         //     ↪ _lastMatchedBlockPosition);
1941         if (_sequencePosition < currentPatternBlock.Start)
1942         {
1943             _sequencePosition++;
1944             return true; // Двигаемся дальше
1945         }
1946         // Это последний блок
1947         if (_pattern.Count == _patternPosition + 1)
1948         {
1949             _patternPosition++;
1950             _sequencePosition = 0;
1951             return false; // Полное соответствие
1952         }
1953         else
1954         {
1955             if (_sequencePosition > currentPatternBlock.Stop)
1956             {
1957                 return false; // Соответствие невозможно
1958             }
1959             var nextPatternBlock = _pattern[_patternPosition + 1];
1960             if (_patternSequence[nextPatternBlock.Start] == element)
1961             {
1962                 if (nextPatternBlock.Start < nextPatternBlock.Stop)

```



```

1960         {
1961             _patternPosition++;
1962             _sequencePosition = 1;
1963         }
1964         else
1965         {
1966             _patternPosition += 2;
1967             _sequencePosition = 0;
1968         }
1969     }
1970 }
1971 }
1972 else // currentPatternBlock.Type == PatternBlockType.Elements
1973 {
1974     var patternElementPosition = currentPatternBlock.Start + _sequencePosition;
1975     if (_patternSequence[patternElementPosition] != element)
1976     {
1977         return false; // Соответствие невозможно
1978     }
1979     if (patternElementPosition == currentPatternBlock.Stop)
1980     {
1981         _patternPosition++;
1982         _sequencePosition = 0;
1983     }
1984     else
1985     {
1986         _sequencePosition++;
1987     }
1988 }
1989 return true;
1990 //if (_patternSequence[_patternPosition] != element)
1991 //    return false;
1992 //else
1993 //{
1994 //    _sequencePosition++;
1995 //    _patternPosition++;
1996 //    return true;
1997 //}
1998 //if (_filterPosition == _patternSequence.Length)
1999 //{
2000 //    _filterPosition = -2; // Длиннее чем нужно
2001 //    return false;
2002 //}
2003 //if (element != _patternSequence[_filterPosition])
2004 //{
2005 //    _filterPosition = -1;
2006 //    return false; // Начинается иначе
2007 //}
2008 //_filterPosition++;
2009 //if (_filterPosition == (_patternSequence.Length - 1))
2010 //    return false;
2011 //if (_filterPosition >= 0)
2012 //{
2013 //    if (element == _patternSequence[_filterPosition + 1])
2014 //        _filterPosition++;
2015 //    else
2016 //        return false;
2017 //}
2018 //if (_filterPosition < 0)
2019 //{
2020 //    if (element == _patternSequence[0])
2021 //        _filterPosition = 0;
2022 //}
2023 }
2024 }
2025
2026 [MethodImpl(MethodImplOptions.AggressiveInlining)]
2027 public void AddAllPatternMatchedToResults(IEnumerable<ulong> sequencesToMatch)
2028 {
2029     foreach (var sequenceToMatch in sequencesToMatch)
2030     {
2031         if (PatternMatch(sequenceToMatch))
2032         {
2033             _results.Add(sequenceToMatch);
2034         }
2035     }
2036 }
2037 }
2038

```

```
2039     #endregion
2040 }
2041 }
```

1.93 ./csharp/Platform.Data.Doublets/Sequences/Sequences.cs

```
1  using System;
2  using System.Collections.Generic;
3  using System.Linq;
4  using System.Runtime.CompilerServices;
5  using Platform.Collections;
6  using Platform.Collections.Lists;
7  using Platform.Collections.Stacks;
8  using Platform.Threading.Synchronization;
9  using Platform.Data.Doublets.Sequences.Walkers;
10 using LinkIndex = System.UInt64;
11
12 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
13
14 namespace Platform.Data.Doublets.Sequences
15 {
16     /// <summary>
17     /// Представляет коллекцию последовательностей связей.
18     /// </summary>
19     /// <remarks>
20     /// Обязательно реализовать атомарность каждого публичного метода.
21     ///
22     /// TODO:
23     ///
24     /// !!! Повышение вероятности повторного использования групп (подпоследовательностей),
25     /// через естественную группировку по unicode типам, все whitespace вместе, все символы
26     /// ↪ вместе, все числа вместе и т.п.
27     /// + использовать ровно сбалансированный вариант, чтобы уменьшать вложенность (глубину
28     /// ↪ графа)
29     ///
30     /// х*у - найти все связи между, в последовательностях любой формы, если не стоит
31     /// ↪ ограничитель на то, что является последовательностью, а что нет,
32     /// то находятся любые структуры связей, которые содержат эти элементы именно в таком
33     /// ↪ порядке.
34     ///
35     /// Рост последовательности слева и справа.
36     /// Поиск со звёздочкой.
37     /// URL, PURL - реестр используемых во вне ссылок на ресурсы,
38     /// так же проблема может быть решена при реализации дистанционных триггеров.
39     /// Нужны ли уникальные указатели вообще?
40     /// Что если обращение к информации будет происходить через содержимое всегда?
41     ///
42     /// Писать тесты.
43     ///
44     ///
45     /// Можно убрать зависимость от конкретной реализации Links,
46     /// на зависимость от абстрактного элемента, который может быть представлен несколькими
47     /// ↪ способами.
48     ///
49     /// Можно ли как-то сделать один общий интерфейс
50     ///
51     ///
52     /// Блокчейн и/или гит для распределённой записи транзакций.
53     ///
54     /// </remarks>
55     public partial class Sequences : ILinks<LinkIndex> // IList<string>, IList<LinkIndex[]>
56     ↪ (после завершения реализации Sequences)
57     {
58         /// <summary>Возвращает значение LinkIndex, обозначающее любое количество
59         ↪ связей.</summary>
60         public const LinkIndex ZeroOrMany = LinkIndex.MaxValue;
61
62         public SequencesOptions<LinkIndex> Options { get; }
63         public SynchronizedLinks<LinkIndex> Links { get; }
64         private readonly ISynchronization _sync;
65
66         public LinksConstants<LinkIndex> Constants { get; }
67
68         [MethodImpl(MethodImplOptions.AggressiveInlining)]
69         public Sequences(SynchronizedLinks<LinkIndex> links, SequencesOptions<LinkIndex> options)
70         {
71             Links = links;
72             _sync = links.SyncRoot;
73             Options = options;
74             Options.ValidateOptions();
75         }
76     }
77 }
```

```

68     Options.InitOptions(Links);
69     Constants = links.Constants;
70 }
71
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 public Sequences(SynchronizedLinks<LinkIndex> links) : this(links, new
↪ SequencesOptions<LinkIndex>()) { }
74
75 [MethodImpl(MethodImplOptions.AggressiveInlining)]
76 public bool IsSequence(LinkIndex sequence)
77 {
78     return _sync.ExecuteReadOperation(() =>
79     {
80         if (Options.UseSequenceMarker)
81         {
82             return Options.MarkedSequenceMatcher.IsMatched(sequence);
83         }
84         return !Links.Unsync.IsPartialPoint(sequence);
85     });
86 }
87
88 [MethodImpl(MethodImplOptions.AggressiveInlining)]
89 private LinkIndex GetSequenceByElements(LinkIndex sequence)
90 {
91     if (Options.UseSequenceMarker)
92     {
93         return Links.SearchOrDefault(Options.SequenceMarkerLink, sequence);
94     }
95     return sequence;
96 }
97
98 [MethodImpl(MethodImplOptions.AggressiveInlining)]
99 private LinkIndex GetSequenceElements(LinkIndex sequence)
100 {
101     if (Options.UseSequenceMarker)
102     {
103         var linkContents = new Link<ulong>(Links.GetLink(sequence));
104         if (linkContents.Source == Options.SequenceMarkerLink)
105         {
106             return linkContents.Target;
107         }
108         if (linkContents.Target == Options.SequenceMarkerLink)
109         {
110             return linkContents.Source;
111         }
112     }
113     return sequence;
114 }
115
116 #region Count
117
118 [MethodImpl(MethodImplOptions.AggressiveInlining)]
119 public LinkIndex Count(ICollection<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 [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

146 private LinkIndex CountUsages(params LinkIndex[] restrictions)
147 {
148     if (restrictions.Length == 0)
149     {
150         return 0;
151     }
152     if (restrictions.Length == 1) // Первая связь это адрес
153     {
154         if (restrictions[0] == Constants.Null)
155         {
156             return 0;
157         }
158         var any = Constants.Any;
159         if (Options.UseSequenceMarker)
160         {
161             var elementsLink = GetSequenceElements(restrictions[0]);
162             var sequenceLink = GetSequenceByElements(elementsLink);
163             if (sequenceLink != Constants.Null)
164             {
165                 return Links.Count(any, sequenceLink) + Links.Count(any, elementsLink) -
166                     ↪ 1;
167             }
168             return Links.Count(any, elementsLink);
169         }
170         return Links.Count(any, restrictions[0]);
171     }
172     throw new NotImplementedException();
173 }
174 #endregion
175 #region Create
176 [MethodImpl(MethodImplOptions.AggressiveInlining)]
177 public LinkIndex Create(ICollection<LinkIndex> restrictions)
178 {
179     return _sync.ExecuteWriteOperation(() =>
180     {
181         if (restrictions.IsNullOrEmpty())
182         {
183             return Constants.Null;
184         }
185         Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
186         return CreateCore(restrictions);
187     });
188 }
189
190 [MethodImpl(MethodImplOptions.AggressiveInlining)]
191 private LinkIndex CreateCore(ICollection<LinkIndex> restrictions)
192 {
193     LinkIndex[] sequence = restrictions.SkipFirst();
194     if (Options.UseIndex)
195     {
196         Options.Index.Add(sequence);
197     }
198     var sequenceRoot = default(LinkIndex);
199     if (Options.EnforceSingleSequenceVersionOnWriteBasedOnExisting)
200     {
201         var matches = Each(restrictions);
202         if (matches.Count > 0)
203         {
204             sequenceRoot = matches[0];
205         }
206     }
207     else if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew)
208     {
209         return CompactCore(sequence);
210     }
211     if (sequenceRoot == default)
212     {
213         sequenceRoot = Options.LinksToSequenceConverter.Convert(sequence);
214     }
215     if (Options.UseSequenceMarker)
216     {
217         return Links.Unsync.GetOrCreate(Options.SequenceMarkerLink, sequenceRoot);
218     }
219     return sequenceRoot; // Возвращаем корень последовательности (т.е. сами элементы)
220 }
221
222

```

```

223 #endregion
224
225 #region Each
226
227 [MethodImpl(MethodImplOptions.AggressiveInlining)]
228 public List<LinkIndex> Each(IList<LinkIndex> sequence)
229 {
230     var results = new List<LinkIndex>();
231     var filler = new ListFiller<LinkIndex, LinkIndex>(results, Constants.Continue);
232     Each(filler.AddFirstAndReturnConstant, sequence);
233     return results;
234 }
235
236 [MethodImpl(MethodImplOptions.AggressiveInlining)]
237 public LinkIndex Each(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
238     ↪ restrictions)
239 {
240     return _sync.ExecuteReadOperation(() =>
241     {
242         if (restrictions.IsNullOrEmpty())
243         {
244             return Constants.Continue;
245         }
246         Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
247         if (restrictions.Count == 1)
248         {
249             var link = restrictions[0];
250             var any = Constants.Any;
251             if (link == any)
252             {
253                 if (Options.UseSequenceMarker)
254                 {
255                     return Links.Unsync.Each(handler, new Link<LinkIndex>(any,
256                         ↪ Options.SequenceMarkerLink, any));
257                 }
258                 else
259                 {
260                     return Links.Unsync.Each(handler, new Link<LinkIndex>(any, any,
261                         ↪ any));
262                 }
263             }
264             if (Options.UseSequenceMarker)
265             {
266                 var sequenceLinkValues = Links.Unsync.GetLink(link);
267                 if (sequenceLinkValues[Constants.SourcePart] ==
268                     ↪ Options.SequenceMarkerLink)
269                 {
270                     link = sequenceLinkValues[Constants.TargetPart];
271                 }
272             }
273             var sequence = Options.Walker.Walk(link).ToArray().ShiftRight();
274             sequence[0] = link;
275             return handler(sequence);
276         }
277         else if (restrictions.Count == 2)
278         {
279             throw new NotImplementedException();
280         }
281         else if (restrictions.Count == 3)
282         {
283             return Links.Unsync.Each(handler, restrictions);
284         }
285         else
286         {
287             var sequence = restrictions.SkipFirst();
288             if (Options.UseIndex && !Options.Index.MightContain(sequence))
289             {
290                 return Constants.Break;
291             }
292             return EachCore(handler, sequence);
293         }
294     });
295 }
296
297 [MethodImpl(MethodImplOptions.AggressiveInlining)]
298 private LinkIndex EachCore(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
299     ↪ values)

```

```

296 {
297     var matcher = new Matcher(this, values, new HashSet<LinkIndex>(), handler);
298     // TODO: Find out why matcher.HandleFullMatched executed twice for the same sequence
299     ↪ Id.
300     Func<IList<LinkIndex>, LinkIndex> innerHandler = Options.UseSequenceMarker ?
301     ↪ (Func<IList<LinkIndex>, LinkIndex>)matcher.HandleFullMatchedSequence :
302     ↪ matcher.HandleFullMatched;
303     //if (sequence.Length >= 2)
304     if (StepRight(innerHandler, values[0], values[1]) != Constants.Continue)
305     {
306         return Constants.Break;
307     }
308     var last = values.Count - 2;
309     for (var i = 1; i < last; i++)
310     {
311         if (PartialStepRight(innerHandler, values[i], values[i + 1]) !=
312         ↪ Constants.Continue)
313         {
314             return Constants.Break;
315         }
316     }
317     if (values.Count >= 3)
318     {
319         if (StepLeft(innerHandler, values[values.Count - 2], values[values.Count - 1])
320         ↪ != Constants.Continue)
321         {
322             return Constants.Break;
323         }
324     }
325     return Constants.Continue;
326 }
327
328 [MethodImpl(MethodImplOptions.AggressiveInlining)]
329 private LinkIndex PartialStepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
330 ↪ left, LinkIndex right)
331 {
332     return Links.Unsync.Each(doublet =>
333     {
334         var doubletIndex = doublet[Constants.IndexPart];
335         if (StepRight(handler, doubletIndex, right) != Constants.Continue)
336         {
337             return Constants.Break;
338         }
339         if (left != doubletIndex)
340         {
341             return PartialStepRight(handler, doubletIndex, right);
342         }
343         return Constants.Continue;
344     }, new Link<LinkIndex>(Constants.Any, Constants.Any, left));
345 }
346
347 [MethodImpl(MethodImplOptions.AggressiveInlining)]
348 private LinkIndex StepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex left,
349 ↪ LinkIndex right) => Links.Unsync.Each(rightStep => TryStepRightUp(handler, right,
350 ↪ rightStep[Constants.IndexPart]), new Link<LinkIndex>(Constants.Any, left,
351 ↪ Constants.Any));
352
353 [MethodImpl(MethodImplOptions.AggressiveInlining)]
354 private LinkIndex TryStepRightUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
355 ↪ right, LinkIndex stepFrom)
356 {
357     var upStep = stepFrom;
358     var firstSource = Links.Unsync.GetTarget(upStep);
359     while (firstSource != right && firstSource != upStep)
360     {
361         upStep = firstSource;
362         firstSource = Links.Unsync.GetSource(upStep);
363     }
364     if (firstSource == right)
365     {
366         return handler(new LinkAddress<LinkIndex>(stepFrom));
367     }
368     return Constants.Continue;
369 }
370
371 [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

362 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));
363
364 [MethodImpl(MethodImplOptions.AggressiveInlining)]
365 private LinkIndex TryStepLeftUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
    ↳ left, LinkIndex stepFrom)
366 {
367     var upStep = stepFrom;
368     var firstTarget = Links.Unsync.GetSource(upStep);
369     while (firstTarget != left && firstTarget != upStep)
370     {
371         upStep = firstTarget;
372         firstTarget = Links.Unsync.GetTarget(upStep);
373     }
374     if (firstTarget == left)
375     {
376         return handler(new LinkAddress<LinkIndex>(stepFrom));
377     }
378     return Constants.Continue;
379 }
380
381 #endregion
382
383 #region Update
384
385 [MethodImpl(MethodImplOptions.AggressiveInlining)]
386 public LinkIndex Update(IList<LinkIndex> restrictions, IList<LinkIndex> substitution)
387 {
388     var sequence = restrictions.SkipFirst();
389     var newSequence = substitution.SkipFirst();
390     if (sequence.IsNullOrEmpty() && newSequence.IsNullOrEmpty())
391     {
392         return Constants.Null;
393     }
394     if (sequence.IsNullOrEmpty())
395     {
396         return Create(substitution);
397     }
398     if (newSequence.IsNullOrEmpty())
399     {
400         Delete(restrictions);
401         return Constants.Null;
402     }
403     return _sync.ExecuteWriteOperation((Func<ulong>)(() =>
404     {
405         ILinksExtensions.EnsureLinkIsAnyOrExists<ulong>(Links, (IList<ulong>)sequence);
406         Links.EnsureLinkExists(newSequence);
407         return UpdateCore(sequence, newSequence);
408     })));
409 }
410
411 [MethodImpl(MethodImplOptions.AggressiveInlining)]
412 private LinkIndex UpdateCore(IList<LinkIndex> sequence, IList<LinkIndex> newSequence)
413 {
414     LinkIndex bestVariant;
415     if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew &&
    ↳ !sequence.EqualTo(newSequence))
416     {
417         bestVariant = CompactCore(newSequence);
418     }
419     else
420     {
421         bestVariant = CreateCore(newSequence);
422     }
423     // TODO: Check all options only ones before loop execution
424     // Возможно нужно две версии Each, возвращающий фактические последовательности и с
    ↳ маркером,
425     // или возможно даже возвращать и тот и тот вариант. С другой стороны все варианты
    ↳ можно получить имея только фактические последовательности.
426     foreach (var variant in Each(sequence))
427     {
428         if (variant != bestVariant)
429         {
430             UpdateOneCore(variant, bestVariant);
431         }
432     }
433     return bestVariant;

```

```

434 }
435
436 [MethodImpl(MethodImplOptions.AggressiveInlining)]
437 private void UpdateOneCore(LinkIndex sequence, LinkIndex newSequence)
438 {
439     if (Options.UseGarbageCollection)
440     {
441         var sequenceElements = GetSequenceElements(sequence);
442         var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
443         var sequenceLink = GetSequenceByElements(sequenceElements);
444         var newSequenceElements = GetSequenceElements(newSequence);
445         var newSequenceLink = GetSequenceByElements(newSequenceElements);
446         if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
447         {
448             if (sequenceLink != Constants.Null)
449             {
450                 Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
451             }
452             Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
453         }
454         ClearGarbage(sequenceElementsContents.Source);
455         ClearGarbage(sequenceElementsContents.Target);
456     }
457     else
458     {
459         if (Options.UseSequenceMarker)
460         {
461             var sequenceElements = GetSequenceElements(sequence);
462             var sequenceLink = GetSequenceByElements(sequenceElements);
463             var newSequenceElements = GetSequenceElements(newSequence);
464             var newSequenceLink = GetSequenceByElements(newSequenceElements);
465             if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
466             {
467                 if (sequenceLink != Constants.Null)
468                 {
469                     Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
470                 }
471                 Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
472             }
473         }
474         else
475         {
476             if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
477             {
478                 Links.Unsync.MergeAndDelete(sequence, newSequence);
479             }
480         }
481     }
482 }
483
484 #endregion
485
486 #region Delete
487
488 [MethodImpl(MethodImplOptions.AggressiveInlining)]
489 public void Delete(IList<LinkIndex> restrictions)
490 {
491     _sync.ExecuteWriteOperation(() =>
492     {
493         var sequence = restrictions.SkipFirst();
494         // TODO: Check all options only ones before loop execution
495         foreach (var linkToDelete in Each(sequence))
496         {
497             DeleteOneCore(linkToDelete);
498         }
499     });
500 }
501
502 [MethodImpl(MethodImplOptions.AggressiveInlining)]
503 private void DeleteOneCore(LinkIndex link)
504 {
505     if (Options.UseGarbageCollection)
506     {
507         var sequenceElements = GetSequenceElements(link);
508         var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
509         var sequenceLink = GetSequenceByElements(sequenceElements);
510         if (Options.UseCascadeDelete || CountUsages(link) == 0)
511         {

```



```

512         if (sequenceLink != Constants.Null)
513         {
514             Links.Unsync.Delete(sequenceLink);
515         }
516         Links.Unsync.Delete(link);
517     }
518     ClearGarbage(sequenceElementsContents.Source);
519     ClearGarbage(sequenceElementsContents.Target);
520 }
521 else
522 {
523     if (Options.UseSequenceMarker)
524     {
525         var sequenceElements = GetSequenceElements(link);
526         var sequenceLink = GetSequenceByElements(sequenceElements);
527         if (Options.UseCascadeDelete || CountUsages(link) == 0)
528         {
529             if (sequenceLink != Constants.Null)
530             {
531                 Links.Unsync.Delete(sequenceLink);
532             }
533             Links.Unsync.Delete(link);
534         }
535     }
536     else
537     {
538         if (Options.UseCascadeDelete || CountUsages(link) == 0)
539         {
540             Links.Unsync.Delete(link);
541         }
542     }
543 }
544 }
545
546 #endregion
547
548 #region Compactification
549
550 [MethodImpl(MethodImplOptions.AggressiveInlining)]
551 public void CompactAll()
552 {
553     _sync.ExecuteWriteOperation(() =>
554     {
555         var sequences = Each((LinkAddress<LinkIndex>)Constants.Any);
556         for (int i = 0; i < sequences.Count; i++)
557         {
558             var sequence = this.ToList(sequences[i]);
559             Compact(sequence.ShiftRight());
560         }
561     });
562 }
563
564 /// <remarks>
565 /// bestVariant можно выбирать по максимальному числу использований,
566 /// но балансированный позволяет гарантировать уникальность (если есть возможность,
567 /// гарантировать его использование в других местах).
568 ///
569 /// Получается этот метод должен игнорировать Options.EnforceSingleSequenceVersionOnWrite
570 /// </remarks>
571 [MethodImpl(MethodImplOptions.AggressiveInlining)]
572 public LinkIndex Compact(ICollection<LinkIndex> sequence)
573 {
574     return _sync.ExecuteWriteOperation(() =>
575     {
576         if (sequence.IsNullOrEmpty())
577         {
578             return Constants.Null;
579         }
580         Links.EnsureInnerReferenceExists(sequence, nameof(sequence));
581         return CompactCore(sequence);
582     });
583 }
584
585 [MethodImpl(MethodImplOptions.AggressiveInlining)]
586 private LinkIndex CompactCore(ICollection<LinkIndex> sequence) => UpdateCore(sequence,
587     ↪ sequence);
588
589 #endregion

```

```

590 #region Garbage Collection
591
592 /// <remarks>
593 /// TODO: Добавить дополнительный обработчик / событие CanBeDeleted которое можно
594   ↳ определить извне или в унаследованном классе
595 /// </remarks>
596 [MethodImpl(MethodImplOptions.AggressiveInlining)]
597 private bool IsGarbage(LinkIndex link) => link != Options.SequenceMarkerLink &&
598   ↳ !Links.Unsync.IsPartialPoint(link) && Links.Count(Constants.Any, link) == 0;
599
600 [MethodImpl(MethodImplOptions.AggressiveInlining)]
601 private void ClearGarbage(LinkIndex link)
602 {
603     if (IsGarbage(link))
604     {
605         var contents = new Link<ulong>(Links.GetLink(link));
606         Links.Unsync.Delete(link);
607         ClearGarbage(contents.Source);
608         ClearGarbage(contents.Target);
609     }
610 }
611
612 #endregion
613
614 #region Walkers
615
616 [MethodImpl(MethodImplOptions.AggressiveInlining)]
617 public bool EachPart(Func<LinkIndex, bool> handler, LinkIndex sequence)
618 {
619     return _sync.ExecuteReadOperation(() =>
620     {
621         var links = Links.Unsync;
622         foreach (var part in Options.Walker.Walk(sequence))
623         {
624             if (!handler(part))
625             {
626                 return false;
627             }
628         }
629         return true;
630     });
631 }
632
633 public class Matcher : RightSequenceWalker<LinkIndex>
634 {
635     private readonly Sequences _sequences;
636     private readonly IList<LinkIndex> _patternSequence;
637     private readonly HashSet<LinkIndex> _linksInSequence;
638     private readonly HashSet<LinkIndex> _results;
639     private readonly Func<IList<LinkIndex>, LinkIndex> _stopableHandler;
640     private readonly HashSet<LinkIndex> _readAsElements;
641     private int _filterPosition;
642
643     [MethodImpl(MethodImplOptions.AggressiveInlining)]
644     public Matcher(Sequences sequences, IList<LinkIndex> patternSequence,
645         ↳ HashSet<LinkIndex> results, Func<IList<LinkIndex>, LinkIndex> stopableHandler,
646         ↳ HashSet<LinkIndex> readAsElements = null)
647         : base(sequences.Links.Unsync, new DefaultStack<LinkIndex>())
648     {
649         _sequences = sequences;
650         _patternSequence = patternSequence;
651         _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
652             ↳ _links.Constants.Any && x != ZeroOrMany));
653         _results = results;
654         _stopableHandler = stopableHandler;
655         _readAsElements = readAsElements;
656     }
657
658     [MethodImpl(MethodImplOptions.AggressiveInlining)]
659     protected override bool IsElement(LinkIndex link) => base.IsElement(link) ||
660     ↳ (_readAsElements != null && _readAsElements.Contains(link)) ||
661     ↳ _linksInSequence.Contains(link);
662
663     [MethodImpl(MethodImplOptions.AggressiveInlining)]
664     public bool FullMatch(LinkIndex sequenceToMatch)
665     {
666         _filterPosition = 0;
667         foreach (var part in Walk(sequenceToMatch))
668         {
669             if (!FullMatchCore(part))
670             {
671                 return false;
672             }
673         }
674         return true;
675     }
676
677     private bool FullMatchCore(LinkIndex part)
678     {
679         if (_filterPosition == 0)
680         {
681             _filterPosition = 1;
682             return true;
683         }
684         if (_filterPosition == 1)
685         {
686             _filterPosition = 2;
687             return true;
688         }
689         if (_filterPosition == 2)
690         {
691             _filterPosition = 3;
692             return true;
693         }
694         if (_filterPosition == 3)
695         {
696             _filterPosition = 4;
697             return true;
698         }
699         if (_filterPosition == 4)
700         {
701             _filterPosition = 5;
702             return true;
703         }
704         if (_filterPosition == 5)
705         {
706             _filterPosition = 6;
707             return true;
708         }
709         if (_filterPosition == 6)
710         {
711             _filterPosition = 7;
712             return true;
713         }
714         if (_filterPosition == 7)
715         {
716             _filterPosition = 8;
717             return true;
718         }
719         if (_filterPosition == 8)
720         {
721             _filterPosition = 9;
722             return true;
723         }
724         if (_filterPosition == 9)
725         {
726             _filterPosition = 10;
727             return true;
728         }
729         if (_filterPosition == 10)
730         {
731             _filterPosition = 11;
732             return true;
733         }
734         if (_filterPosition == 11)
735         {
736             _filterPosition = 12;
737             return true;
738         }
739         if (_filterPosition == 12)
740         {
741             _filterPosition = 13;
742             return true;
743         }
744         if (_filterPosition == 13)
745         {
746             _filterPosition = 14;
747             return true;
748         }
749         if (_filterPosition == 14)
750         {
751             _filterPosition = 15;
752             return true;
753         }
754         if (_filterPosition == 15)
755         {
756             _filterPosition = 16;
757             return true;
758         }
759         if (_filterPosition == 16)
760         {
761             _filterPosition = 17;
762             return true;
763         }
764         if (_filterPosition == 17)
765         {
766             _filterPosition = 18;
767             return true;
768         }
769         if (_filterPosition == 18)
770         {
771             _filterPosition = 19;
772             return true;
773         }
774         if (_filterPosition == 19)
775         {
776             _filterPosition = 20;
777             return true;
778         }
779         if (_filterPosition == 20)
780         {
781             _filterPosition = 21;
782             return true;
783         }
784         if (_filterPosition == 21)
785         {
786             _filterPosition = 22;
787             return true;
788         }
789         if (_filterPosition == 22)
790         {
791             _filterPosition = 23;
792             return true;
793         }
794         if (_filterPosition == 23)
795         {
796             _filterPosition = 24;
797             return true;
798         }
799         if (_filterPosition == 24)
800         {
801             _filterPosition = 25;
802             return true;
803         }
804         if (_filterPosition == 25)
805         {
806             _filterPosition = 26;
807             return true;
808         }
809         if (_filterPosition == 26)
810         {
811             _filterPosition = 27;
812             return true;
813         }
814         if (_filterPosition == 27)
815         {
816             _filterPosition = 28;
817             return true;
818         }
819         if (_filterPosition == 28)
820         {
821             _filterPosition = 29;
822             return true;
823         }
824         if (_filterPosition == 29)
825         {
826             _filterPosition = 30;
827             return true;
828         }
829         if (_filterPosition == 30)
830         {
831             _filterPosition = 31;
832             return true;
833         }
834         if (_filterPosition == 31)
835         {
836             _filterPosition = 32;
837             return true;
838         }
839         if (_filterPosition == 32)
840         {
841             _filterPosition = 33;
842             return true;
843         }
844         if (_filterPosition == 33)
845         {
846             _filterPosition = 34;
847             return true;
848         }
849         if (_filterPosition == 34)
850         {
851             _filterPosition = 35;
852             return true;
853         }
854         if (_filterPosition == 35)
855         {
856             _filterPosition = 36;
857             return true;
858         }
859         if (_filterPosition == 36)
860         {
861             _filterPosition = 37;
862             return true;
863         }
864         if (_filterPosition == 37)
865         {
866             _filterPosition = 38;
867             return true;
868         }
869         if (_filterPosition == 38)
870         {
871             _filterPosition = 39;
872             return true;
873         }
874         if (_filterPosition == 39)
875         {
876             _filterPosition = 40;
877             return true;
878         }
879         if (_filterPosition == 40)
880         {
881             _filterPosition = 41;
882             return true;
883         }
884         if (_filterPosition == 41)
885         {
886             _filterPosition = 42;
887             return true;
888         }
889         if (_filterPosition == 42)
890         {
891             _filterPosition = 43;
892             return true;
893         }
894         if (_filterPosition == 43)
895         {
896             _filterPosition = 44;
897             return true;
898         }
899         if (_filterPosition == 44)
900         {
901             _filterPosition = 45;
902             return true;
903         }
904         if (_filterPosition == 45)
905         {
906             _filterPosition = 46;
907             return true;
908         }
909         if (_filterPosition == 46)
910         {
911             _filterPosition = 47;
912             return true;
913         }
914         if (_filterPosition == 47)
915         {
916             _filterPosition = 48;
917             return true;
918         }
919         if (_filterPosition == 48)
920         {
921             _filterPosition = 49;
922             return true;
923         }
924         if (_filterPosition == 49)
925         {
926             _filterPosition = 50;
927             return true;
928         }
929         if (_filterPosition == 50)
930         {
931             _filterPosition = 51;
932             return true;
933         }
934         if (_filterPosition == 51)
935         {
936             _filterPosition = 52;
937             return true;
938         }
939         if (_filterPosition == 52)
940         {
941             _filterPosition = 53;
942             return true;
943         }
944         if (_filterPosition == 53)
945         {
946             _filterPosition = 54;
947             return true;
948         }
949         if (_filterPosition == 54)
950         {
951             _filterPosition = 55;
952             return true;
953         }
954         if (_filterPosition == 55)
955         {
956             _filterPosition = 56;
957             return true;
958         }
959         if (_filterPosition == 56)
960         {
961             _filterPosition = 57;
962             return true;
963         }
964         if (_filterPosition == 57)
965         {
966             _filterPosition = 58;
967             return true;
968         }
969         if (_filterPosition == 58)
970         {
971             _filterPosition = 59;
972             return true;
973         }
974         if (_filterPosition == 59)
975         {
976             _filterPosition = 60;
977             return true;
978         }
979         if (_filterPosition == 60)
980         {
981             _filterPosition = 61;
982             return true;
983         }
984         if (_filterPosition == 61)
985         {
986             _filterPosition = 62;
987             return true;
988         }
989         if (_filterPosition == 62)
990         {
991             _filterPosition = 63;
992             return true;
993         }
994         if (_filterPosition == 63)
995         {
996             _filterPosition = 64;
997             return true;
998         }
999         if (_filterPosition == 64)
1000         {
1001             _filterPosition = 65;
1002             return true;
1003         }
1004         if (_filterPosition == 65)
1005         {
1006             _filterPosition = 66;
1007             return true;
1008         }
1009         if (_filterPosition == 66)
1010         {
1011             _filterPosition = 67;
1012             return true;
1013         }
1014         if (_filterPosition == 67)
1015         {
1016             _filterPosition = 68;
1017             return true;
1018         }
1019         if (_filterPosition == 68)
1020         {
1021             _filterPosition = 69;
1022             return true;
1023         }
1024         if (_filterPosition == 69)
1025         {
1026             _filterPosition = 70;
1027             return true;
1028         }
1029         if (_filterPosition == 70)
1030         {
1031             _filterPosition = 71;
1032             return true;
1033         }
1034         if (_filterPosition == 71)
1035         {
1036             _filterPosition = 72;
1037             return true;
1038         }
1039         if (_filterPosition == 72)
1040         {
1041             _filterPosition = 73;
1042             return true;
1043         }
1044         if (_filterPosition == 73)
1045         {
1046             _filterPosition = 74;
1047             return true;
1048         }
1049         if (_filterPosition == 74)
1050         {
1051             _filterPosition = 75;
1052             return true;
1053         }
1054         if (_filterPosition == 75)
1055         {
1056             _filterPosition = 76;
1057             return true;
1058         }
1059         if (_filterPosition == 76)
1060         {
1061             _filterPosition = 77;
1062             return true;
1063         }
1064         if (_filterPosition == 77)
1065         {
1066             _filterPosition = 78;
1067             return true;
1068         }
1069         if (_filterPosition == 78)
1070         {
1071             _filterPosition = 79;
1072             return true;
1073         }
1074         if (_filterPosition == 79)
1075         {
1076             _filterPosition = 80;
1077             return true;
1078         }
1079         if (_filterPosition == 80)
1080         {
1081             _filterPosition = 81;
1082             return true;
1083         }
1084         if (_filterPosition == 81)
1085         {
1086             _filterPosition = 82;
1087             return true;
1088         }
1089         if (_filterPosition == 82)
1090         {
1091             _filterPosition = 83;
1092             return true;
1093         }
1094         if (_filterPosition == 83)
1095         {
1096             _filterPosition = 84;
1097             return true;
1098         }
1099         if (_filterPosition == 84)
1100         {
1101             _filterPosition = 85;
1102             return true;
1103         }
1104         if (_filterPosition == 85)
1105         {
1106             _filterPosition = 86;
1107             return true;
1108         }
1109         if (_filterPosition == 86)
1110         {
1111             _filterPosition = 87;
1112             return true;
1113         }
1114         if (_filterPosition == 87)
1115         {
1116             _filterPosition = 88;
1117             return true;
1118         }
1119         if (_filterPosition == 88)
1120         {
1121             _filterPosition = 89;
1122             return true;
1123         }
1124         if (_filterPosition == 89)
1125         {
1126             _filterPosition = 90;
1127             return true;
1128         }
1129         if (_filterPosition == 90)
1130         {
1131             _filterPosition = 91;
1132             return true;
1133         }
1134         if (_filterPosition == 91)
1135         {
1136             _filterPosition = 92;
1137             return true;
1138         }
1139         if (_filterPosition == 92)
1140         {
1141             _filterPosition = 93;
1142             return true;
1143         }
1144         if (_filterPosition == 93)
1145         {
1146             _filterPosition = 94;
1147             return true;
1148         }
1149         if (_filterPosition == 94)
1150         {
1151             _filterPosition = 95;
1152             return true;
1153         }
1154         if (_filterPosition == 95)
1155         {
1156             _filterPosition = 96;
1157             return true;
1158         }
1159         if (_filterPosition == 96)
1160         {
1161             _filterPosition = 97;
1162             return true;
1163         }
1164         if (_filterPosition == 97)
1165         {
1166             _filterPosition = 98;
1167             return true;
1168         }
1169         if (_filterPosition == 98)
1170         {
1171             _filterPosition = 99;
1172             return true;
1173         }
1174         if (_filterPosition == 99)
1175         {
1176             _filterPosition = 100;
1177             return true;
1178         }
1179         if (_filterPosition == 100)
1180         {
1181             _filterPosition = 101;
1182             return true;
1183         }
1184         if (_filterPosition == 101)
1185         {
1186             _filterPosition = 102;
1187             return true;
1188         }
1189         if (_filterPosition == 102)
1190         {
1191             _filterPosition = 103;
1192             return true;
1193         }
1194         if (_filterPosition == 103)
1195         {
1196             _filterPosition = 104;
1197             return true;
1198         }
1199         if (_filterPosition == 104)
1200         {
1201             _filterPosition = 105;
1202             return true;
1203         }
1204         if (_filterPosition == 105)
1205         {
1206             _filterPosition = 106;
1207             return true;
1208         }
1209         if (_filterPosition == 106)
1210         {
1211             _filterPosition = 107;
1212             return true;
1213         }
1214         if (_filterPosition == 107)
1215         {
1216             _filterPosition = 108;
1217             return true;
1218         }
1219         if (_filterPosition == 108)
1220         {
1221             _filterPosition = 109;
1222             return true;
1223         }
1224         if (_filterPosition == 109)
1225         {
1226             _filterPosition = 110;
1227             return true;
1228         }
1229         if (_filterPosition == 110)
1230         {
1231             _filterPosition = 111;
1232             return true;
1233         }
1234         if (_filterPosition == 111)
1235         {
1236             _filterPosition = 112;
1237             return true;
1238         }
1239         if (_filterPosition == 112)
1240         {
1241             _filterPosition = 113;
1242             return true;
1243         }
1244         if (_filterPosition == 113)
1245         {
1246             _filterPosition = 114;
1247             return true;
1248         }
1249         if (_filterPosition == 114)
1250         {
1251             _filterPosition = 115;
1252             return true;
1253         }
1254         if (_filterPosition == 115)
1255         {
1256             _filterPosition = 116;
1257             return true;
1258         }
1259         if (_filterPosition == 116)
1260         {
1261             _filterPosition = 117;
1262             return true;
1263         }
1264         if (_filterPosition == 117)
1265         {
1266             _filterPosition = 118;
1267             return true;
1268         }
1269         if (_filterPosition == 118)
1270         {
1271             _filterPosition = 119;
1272             return true;
1273         }
1274         if (_filterPosition == 119)
1275         {
1276             _filterPosition = 120;
1277             return true;
1278         }
1279         if (_filterPosition == 120)
1280         {
1281             _filterPosition = 121;
1282             return true;
1283         }
1284         if (_filterPosition == 121)
1285         {
1286             _filterPosition = 122;
1287             return true;
1288         }
1289         if (_filterPosition == 122)
1290         {
1291             _filterPosition = 123;
1292             return true;
1293         }
1294         if (_filterPosition == 123)
1295         {
1296             _filterPosition = 124;
1297             return true;
1298         }
1299         if (_filterPosition == 124)
1300         {
1301             _filterPosition = 125;
1302             return true;
1303         }
1304         if (_filterPosition == 125)
1305         {
1306             _filterPosition = 126;
1307             return true;
1308         }
1309         if (_filterPosition == 126)
1310         {
1311             _filterPosition = 127;
1312             return true;
1313         }
1314         if (_filterPosition == 127)
1315         {
1316             _filterPosition = 128;
1317             return true;
1318         }
1319         if (_filterPosition == 128)
1320         {
1321             _filterPosition = 129;
1322             return true;
1323         }
1324         if (_filterPosition == 129)
1325         {
1326             _filterPosition = 130;
1327             return true;
1328         }
1329         if (_filterPosition == 130)
1330         {
1331             _filterPosition = 131;
1332             return true;
1333         }
1334         if (_filterPosition == 131)
1335         {
1336             _filterPosition = 132;
1337             return true;
1338         }
1339         if (_filterPosition == 132)
1340         {
1341             _filterPosition = 133;
1342             return true;
1343         }
1344         if (_filterPosition == 133)
1345         {
1346             _filterPosition = 134;
1347             return true;
1348         }
1349         if (_filterPosition == 134)
1350         {
1351             _filterPosition = 135;
1352             return true;
1353         }
1354         if (_filterPosition == 135)
1355         {
1356             _filterPosition = 136;
1357             return true;
1358         }
1359         if (_filterPosition == 136)
1360         {
1361             _filterPosition = 137;
1362             return true;
1363         }
1364         if (_filterPosition == 137)
1365         {
1366             _filterPosition = 138;
1367             return true;
1368         }
1369         if (_filterPosition == 138)
1370         {
1371             _filterPosition = 139;
1372             return true;
1373         }
1374         if (_filterPosition == 139)
1375         {
1376             _filterPosition = 140;
1377             return true;
1378         }
1379         if (_filterPosition == 140)
1380         {
1381             _filterPosition = 141;
1382             return true;
1383         }
1384         if (_filterPosition == 141)
1385         {
1386             _filterPosition = 142;
1387             return true;
1388         }
1389         if (_filterPosition == 142)
1390         {
1391             _filterPosition = 143;
1392             return true;
1393         }
1394         if (_filterPosition == 143)
1395         {
1396             _filterPosition = 144;
1397             return true;
1398         }
1399         if (_filterPosition == 144)
1400         {
1401             _filterPosition = 145;
1402             return true;
1403         }
1404         if (_filterPosition == 145)
1405         {
1406             _filterPosition = 146;
1407             return true;
1408         }
1409         if (_filterPosition == 146)
1410         {
1411             _filterPosition = 147;
1412             return true;
1413         }
1414         if (_filterPosition == 147)
1415         {
1416             _filterPosition = 148;
1417             return true;
1418         }
1419         if (_filterPosition == 148)
1420         {
1421             _filterPosition = 149;
1422             return true;
1423         }
1424         if (_filterPosition == 149)
1425         {
1426             _filterPosition = 150;
1427             return true;
1428         }
1429         if (_filterPosition == 150)
1430         {
1431             _filterPosition = 151;
1432             return true;
1433         }
1434         if (_filterPosition == 151)
1435         {
1436             _filterPosition = 152;
1437             return true;
1438         }
1439         if (_filterPosition == 152)
1440         {
1441             _filterPosition = 153;
1442             return true;
1443         }
1444         if (_filterPosition == 153)
1445         {
1446             _filterPosition = 154;
1447             return true;
1448         }
1449         if (_filterPosition == 154)
1450         {
1451             _filterPosition = 155;
1452             return true;
1453         }
1454         if (_filterPosition == 155)
1455         {
1456             _filterPosition = 156;
1457             return true;
1458         }
1459         if (_filterPosition == 156)
1460         {
1461             _filterPosition = 157;
1462             return true;
1463         }
1464         if (_filterPosition == 157)
1465         {
1466             _filterPosition = 158;
1467             return true;
1468         }
1469         if (_filterPosition == 158)
1470         {
1471             _filterPosition = 159;
1472             return true;
1473         }
1474         if (_filterPosition == 159)
1475         {
1476             _filterPosition = 160;
1477             return true;
1478         }
1479         if (_filterPosition == 160)
1480         {
1481             _filterPosition = 161;
1482             return true;
1483         }
1484         if (_filterPosition == 161)
1485         {
1486             _filterPosition = 162;
1487             return true;
1488         }
1489         if (_filterPosition == 162)
1490         {
1491             _filterPosition = 163;
1492             return true;
1493         }
1494         if (_filterPosition == 163)
1495         {
1496             _filterPosition = 164;
1497             return true;
1498         }
1499         if (_filterPosition == 164)
1500         {
1501             _filterPosition = 165;
1502             return true;
1503         }
1504         if (_filterPosition == 165)
1505         {
1506             _filterPosition = 166;
1507             return true;
1508         }
1509         if (_filterPosition == 166)
1510         {
1511             _filterPosition = 167;
1512             return true;
1513         }
1514         if (_filterPosition == 167)
1515         {
1516             _filterPosition = 168;
1517             return true;
1518         }
1519         if (_filterPosition == 168)
1520         {
1521             _filterPosition = 169;
1522             return true;
1523         }
1524         if (_filterPosition == 169)
1525         {
1526             _filterPosition = 170;
1527             return true;
1528         }
1529         if (_filterPosition == 170)
1530         {
1531             _filterPosition = 171;
1532             return true;
1533         }
1534         if (_filterPosition == 171)
1535         {
1536             _filterPosition = 172;
1537             return true;
1538         }
1539         if (_filterPosition == 172)
1540         {
1541             _filterPosition = 173;
1542             return true;
1543         }
1544         if (_filterPosition == 173)
1545         {
1546             _filterPosition = 174;
1547             return true;
1548         }
1549         if (_filterPosition == 174)
1550         {
1551             _filterPosition = 175;
1552             return true;
1553         }
1554         if (_filterPosition == 175)
1555         {
1556             _filterPosition = 176;
1557             return true;
1558         }
1559         if (_filterPosition == 176)
1560         {
1561             _filterPosition = 177;
1562             return true;
1563         }
1564         if (_filterPosition == 177)
1565         {
1566             _filterPosition = 178;
1567             return true;
1568         }
1569         if (_filterPosition == 178)
1570         {
1571             _filterPosition = 179;
1572             return true;
1573         }
1574         if (_filterPosition == 179)
1575         {
1576             _filterPosition = 180;
1577             return true;
1578         }
1579         if (_filterPosition == 180)
1580         {
1581             _filterPosition = 181;
1582             return true;
1583         }
1584         if (_filterPosition == 181)
1585         {
1586             _filterPosition = 182;
1587             return true;
1588         }
1589         if (_filterPosition == 182)
1590         {
1591             _filterPosition = 183;
1592             return true;
1593         }
1594         if (_filterPosition == 183)
1595         {
1596             _filterPosition = 184;
1597             return true;
1598         }
1599         if (_filterPosition == 184)
1600         {
1601             _filterPosition = 185;
1602             return true;
1603         }
1604         if (_filterPosition == 185)
1605         {
1606             _filterPosition = 186;
1607             return true;
1608         }
1609         if (_filterPosition == 186)
1610         {
1611             _filterPosition = 187;
1612             return true;
1613         }
1614         if (_filterPosition == 187)
1615         {
1616             _filterPosition = 188;
1617             return true;
1618         }
1619         if (_filterPosition == 188)
1620         {
1621             _filterPosition = 189;
1622             return true;
1623         }
1624         if (_filterPosition == 189)
1625         {
1626             _filterPosition = 190;
1627             return true;
1628         }
1629         if (_filterPosition == 190)
1630         {
1631             _filterPosition = 191;
1632             return true;
1633         }
1634         if (_filterPosition == 191)
1635         {
1636             _filterPosition = 192;
1637             return true;
1638         }
1639         if (_filterPosition == 192)
1640         {
1641             _filterPosition = 193;
1642             return true;
1643         }
1644         if (_filterPosition == 193)
1645         {
1646             _filterPosition = 194;
1647             return true;
1648         }
1649         if (_filterPosition == 194)
1650         {
1651             _filterPosition = 195;
1652             return true;
1653         }
1654         if (_filterPosition == 195)
1655         {
1656             _filterPosition = 196;
1657             return true;
1658         }
1659         if (_filterPosition == 196)
1660         {
1661             _filterPosition = 197;
1662             return true;
1663         }
1664         if (_filterPosition == 197)
1665         {
1666             _filterPosition = 198;
1667             return true;
1668         }
1669         if (_filterPosition == 198)
1670         {
1671             _filterPosition = 199;
1672             return true;
1673         }
1674         if (_filterPosition == 199)
1675         {
1676             _filterPosition = 200;
1677             return true;
1678         }
1679         if (_filterPosition == 200)
1680         {
1681             _filterPosition = 201;
1682             return true;
1683         }
1684         if (_filterPosition == 201)
1685         {
1686             _filterPosition = 202;
1687             return true;
1688         }
1689         if (_filterPosition == 202)
1690         {
1691             _filterPosition = 203;
1692             return true;
1693         }
1694         if (_filterPosition == 203)
1695         {
1696             _filterPosition = 204;
1697             return true;
1698         }
1699         if (_filterPosition == 204)
1700         {
1701             _filterPosition = 205;
1702             return true;
1703         }
1704         if (_filterPosition == 205)
1705         {
1706             _filterPosition = 206;
1707             return true;
1708         }
1709         if (_filterPosition == 206)
1710         {
1711             _filterPosition = 207;
1712             return true;
1713         }
1714         if (_filterPosition == 207)
1715         {
1716             _filterPosition = 208;
1717             return true;
1718         }
1719         if (_filterPosition == 208)
1720         {
1721             _filterPosition = 209;
1722             return true;
1723         }
1724         if (_filterPosition == 209)
1725         {
1726             _filterPosition = 210;
1727             return true;
1728         }
1729         if (_filterPosition == 210)
1730         {
1731             _filterPosition = 211;
1732             return true;
1733         }
1734         if (_filterPosition == 211)
1735         {
1736             _filterPosition = 212;
1737             return true;
1738         }
1739         if (_filterPosition == 212)
1740         {
1741             _filterPosition = 213;
1742             return true;
1743         }
1744         if (_filterPosition == 213)
1745         {
1746             _filterPosition = 214;
1747             return true;
1748         }
1749         if (_filterPosition == 214)
1750         {
1751             _filterPosition = 215;
1752             return true;
1753         }
1754         if (_filterPosition == 215)
1755         {
1756             _filterPosition = 216;
1757             return true;
1758         }
1759         if (_filterPosition == 216)
1760         {
1761             _filterPosition = 217;
1762             return true;
1763         }
1764         if (_filterPosition == 217)
1765         {
1766             _filterPosition = 218;
1767             return true;
1768         }
1769         if (_filterPosition == 218)
1770         {
1771             _filterPosition = 219;
1772             return true;
1773         }
1774         if (_filterPosition == 219)
1775         {
1776             _filterPosition = 220
```

```

663         {
664             break;
665         }
666     }
667     return _filterPosition == _patternSequence.Count;
668 }
669
670 [MethodImpl(MethodImplOptions.AggressiveInlining)]
671 private bool FullMatchCore(LinkIndex element)
672 {
673     if (_filterPosition == _patternSequence.Count)
674     {
675         _filterPosition = -2; // Длиннее чем нужно
676         return false;
677     }
678     if (_patternSequence[_filterPosition] != _links.Constants.Any
679         && element != _patternSequence[_filterPosition])
680     {
681         _filterPosition = -1;
682         return false; // Начинается/Продолжается иначе
683     }
684     _filterPosition++;
685     return true;
686 }
687
688 [MethodImpl(MethodImplOptions.AggressiveInlining)]
689 public void AddFullMatchedToResults(ICollection<LinkIndex> restrictions)
690 {
691     var sequenceToMatch = restrictions[_links.Constants.IndexPart];
692     if (FullMatch(sequenceToMatch))
693     {
694         _results.Add(sequenceToMatch);
695     }
696 }
697
698 [MethodImpl(MethodImplOptions.AggressiveInlining)]
699 public LinkIndex HandleFullMatched(ICollection<LinkIndex> restrictions)
700 {
701     var sequenceToMatch = restrictions[_links.Constants.IndexPart];
702     if (FullMatch(sequenceToMatch) && _results.Add(sequenceToMatch))
703     {
704         return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
705     }
706     return _links.Constants.Continue;
707 }
708
709 [MethodImpl(MethodImplOptions.AggressiveInlining)]
710 public LinkIndex HandleFullMatchedSequence(ICollection<LinkIndex> restrictions)
711 {
712     var sequenceToMatch = restrictions[_links.Constants.IndexPart];
713     var sequence = _sequences.GetSequenceByElements(sequenceToMatch);
714     if (sequence != _links.Constants.Null && FullMatch(sequenceToMatch) &&
715         ↪ _results.Add(sequenceToMatch))
716     {
717         return _stopableHandler(new LinkAddress<LinkIndex>(sequence));
718     }
719     return _links.Constants.Continue;
720 }
721
722 /// <remarks>
723 /// TODO: Add support for LinksConstants.Any
724 /// </remarks>
725 [MethodImpl(MethodImplOptions.AggressiveInlining)]
726 public bool PartialMatch(LinkIndex sequenceToMatch)
727 {
728     _filterPosition = -1;
729     foreach (var part in Walk(sequenceToMatch))
730     {
731         if (!PartialMatchCore(part))
732         {
733             break;
734         }
735     }
736     return _filterPosition == _patternSequence.Count - 1;
737 }
738
739 [MethodImpl(MethodImplOptions.AggressiveInlining)]
740 private bool PartialMatchCore(LinkIndex element)
741 {

```

```

741     if (_filterPosition == (_patternSequence.Count - 1))
742     {
743         return false; // Нашлось
744     }
745     if (_filterPosition >= 0)
746     {
747         if (element == _patternSequence[_filterPosition + 1])
748         {
749             _filterPosition++;
750         }
751         else
752         {
753             _filterPosition = -1;
754         }
755     }
756     if (_filterPosition < 0)
757     {
758         if (element == _patternSequence[0])
759         {
760             _filterPosition = 0;
761         }
762     }
763     return true; // Ищем дальше
764 }
765
766 [MethodImpl(MethodImplOptions.AggressiveInlining)]
767 public void AddPartialMatchedToResults(LinkIndex sequenceToMatch)
768 {
769     if (PartialMatch(sequenceToMatch))
770     {
771         _results.Add(sequenceToMatch);
772     }
773 }
774
775 [MethodImpl(MethodImplOptions.AggressiveInlining)]
776 public LinkIndex HandlePartialMatched(IList<LinkIndex> restrictions)
777 {
778     var sequenceToMatch = restrictions[_links.Constants.IndexPart];
779     if (PartialMatch(sequenceToMatch))
780     {
781         return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
782     }
783     return _links.Constants.Continue;
784 }
785
786 [MethodImpl(MethodImplOptions.AggressiveInlining)]
787 public void AddAllPartialMatchedToResults(IEnumerable<LinkIndex> sequencesToMatch)
788 {
789     foreach (var sequenceToMatch in sequencesToMatch)
790     {
791         if (PartialMatch(sequenceToMatch))
792         {
793             _results.Add(sequenceToMatch);
794         }
795     }
796 }
797
798 [MethodImpl(MethodImplOptions.AggressiveInlining)]
799 public void AddAllPartialMatchedToResultsAndReadAsElements(IEnumerable<LinkIndex>
↵ sequencesToMatch)
800 {
801     foreach (var sequenceToMatch in sequencesToMatch)
802     {
803         if (PartialMatch(sequenceToMatch))
804         {
805             _readAsElements.Add(sequenceToMatch);
806             _results.Add(sequenceToMatch);
807         }
808     }
809 }
810 }
811
812 #endregion
813 }
814 }

```

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

```

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

```

```

3 using Platform.Collections.Lists;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Data.Doublets.Sequences
8 {
9     public static class SequencesExtensions
10    {
11        [MethodImpl(MethodImplOptions.AggressiveInlining)]
12        public static TLink Create<TLink>(this ILinks<TLink> sequences, IList<TLink[]>
13        ↪ groupedSequence)
14        {
15            var finalSequence = new TLink[groupedSequence.Count];
16            for (var i = 0; i < finalSequence.Length; i++)
17            {
18                var part = groupedSequence[i];
19                finalSequence[i] = part.Length == 1 ? part[0] :
20                ↪ sequences.Create(part.ShiftRight());
21            }
22            return sequences.Create(finalSequence.ShiftRight());
23        }
24
25        [MethodImpl(MethodImplOptions.AggressiveInlining)]
26        public static IList<TLink> ToList<TLink>(this ILinks<TLink> sequences, TLink sequence)
27        {
28            var list = new List<TLink>();
29            var filler = new ListFiller<TLink, TLink>(list, sequences.Constants.Break);
30            sequences.Each(filler.AddSkipFirstAndReturnConstant, new
31            ↪ LinkAddress<TLink>(sequence));
32            return list;
33        }
34    }
35 }

```

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

```

1 using System;
2 using System.Collections.Generic;
3 using Platform.Interfaces;
4 using Platform.Collections.Stacks;
5 using Platform.Converters;
6 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
7 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
8 using Platform.Data.Doublets.Sequences.Converters;
9 using Platform.Data.Doublets.Sequences.Walkers;
10 using Platform.Data.Doublets.Sequences.Indexes;
11 using Platform.Data.Doublets.Sequences.CriterionMatchers;
12 using System.Runtime.CompilerServices;
13
14 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
15
16 namespace Platform.Data.Doublets.Sequences
17 {
18     public class SequencesOptions<TLink> // TODO: To use type parameter <TLink> the
19     ↪ ILinks<TLink> must contain GetConstants function.
20    {
21        private static readonly EqualityComparer<TLink> _equalityComparer =
22        ↪ EqualityComparer<TLink>.Default;
23
24        public TLink SequenceMarkerLink
25        {
26            [MethodImpl(MethodImplOptions.AggressiveInlining)]
27            get;
28            [MethodImpl(MethodImplOptions.AggressiveInlining)]
29            set;
30        }
31
32        public bool UseCascadeUpdate
33        {
34            [MethodImpl(MethodImplOptions.AggressiveInlining)]
35            get;
36            [MethodImpl(MethodImplOptions.AggressiveInlining)]
37            set;
38        }
39
40        public bool UseCascadeDelete
41        {
42            [MethodImpl(MethodImplOptions.AggressiveInlining)]
43            get;
44            [MethodImpl(MethodImplOptions.AggressiveInlining)]
45            set;
46        }
47    }
48 }

```

```

44     }
45
46     public bool UseIndex
47     {
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         get;
50         [MethodImpl(MethodImplOptions.AggressiveInlining)]
51         set;
52     } // TODO: Update Index on sequence update/delete.
53
54     public bool UseSequenceMarker
55     {
56         [MethodImpl(MethodImplOptions.AggressiveInlining)]
57         get;
58         [MethodImpl(MethodImplOptions.AggressiveInlining)]
59         set;
60     }
61
62     public bool UseCompression
63     {
64         [MethodImpl(MethodImplOptions.AggressiveInlining)]
65         get;
66         [MethodImpl(MethodImplOptions.AggressiveInlining)]
67         set;
68     }
69
70     public bool UseGarbageCollection
71     {
72         [MethodImpl(MethodImplOptions.AggressiveInlining)]
73         get;
74         [MethodImpl(MethodImplOptions.AggressiveInlining)]
75         set;
76     }
77
78     public bool EnforceSingleSequenceVersionOnWriteBasedOnExisting
79     {
80         [MethodImpl(MethodImplOptions.AggressiveInlining)]
81         get;
82         [MethodImpl(MethodImplOptions.AggressiveInlining)]
83         set;
84     }
85
86     public bool EnforceSingleSequenceVersionOnWriteBasedOnNew
87     {
88         [MethodImpl(MethodImplOptions.AggressiveInlining)]
89         get;
90         [MethodImpl(MethodImplOptions.AggressiveInlining)]
91         set;
92     }
93
94     public MarkedSequenceCriterionMatcher<TLink> MarkedSequenceMatcher
95     {
96         [MethodImpl(MethodImplOptions.AggressiveInlining)]
97         get;
98         [MethodImpl(MethodImplOptions.AggressiveInlining)]
99         set;
100     }
101
102     public IConverter<IList<TLink>, TLink> LinksToSequenceConverter
103     {
104         [MethodImpl(MethodImplOptions.AggressiveInlining)]
105         get;
106         [MethodImpl(MethodImplOptions.AggressiveInlining)]
107         set;
108     }
109
110     public ISequenceIndex<TLink> Index
111     {
112         [MethodImpl(MethodImplOptions.AggressiveInlining)]
113         get;
114         [MethodImpl(MethodImplOptions.AggressiveInlining)]
115         set;
116     }
117
118     public ISequenceWalker<TLink> Walker
119     {
120         [MethodImpl(MethodImplOptions.AggressiveInlining)]
121         get;
122         [MethodImpl(MethodImplOptions.AggressiveInlining)]
123         set;
124     }

```

```

125
126 public bool ReadFullSequence
127 {
128     [MethodImpl(MethodImplOptions.AggressiveInlining)]
129     get;
130     [MethodImpl(MethodImplOptions.AggressiveInlining)]
131     set;
132 }
133
134 // TODO: Реализовать компактификацию при чтении
135 //public bool EnforceSingleSequenceVersionOnRead { get; set; }
136 //public bool UseRequestMarker { get; set; }
137 //public bool StoreRequestResults { get; set; }
138
139 [MethodImpl(MethodImplOptions.AggressiveInlining)]
140 public void InitOptions(ISynchronizedLinks<TLink> links)
141 {
142     if (UseSequenceMarker)
143     {
144         if (_equalityComparer.Equals(SequenceMarkerLink, links.Constants.Null))
145         {
146             SequenceMarkerLink = links.CreatePoint();
147         }
148         else
149         {
150             if (!links.Exists(SequenceMarkerLink))
151             {
152                 var link = links.CreatePoint();
153                 if (!_equalityComparer.Equals(link, SequenceMarkerLink))
154                 {
155                     throw new InvalidOperationException("Cannot recreate sequence marker
156                                     ↪ link.");
157                 }
158             }
159             if (MarkedSequenceMatcher == null)
160             {
161                 MarkedSequenceMatcher = new MarkedSequenceCriterionMatcher<TLink>(links,
162                                     ↪ SequenceMarkerLink);
163             }
164             var balancedVariantConverter = new BalancedVariantConverter<TLink>(links);
165             if (UseCompression)
166             {
167                 if (LinksToSequenceConverter == null)
168                 {
169                     ICounter<TLink, TLink> totalSequenceSymbolFrequencyCounter;
170                     if (UseSequenceMarker)
171                     {
172                         totalSequenceSymbolFrequencyCounter = new
173                             ↪ TotalMarkedSequenceSymbolFrequencyCounter<TLink>(links,
174                             ↪ MarkedSequenceMatcher);
175                     }
176                     else
177                     {
178                         totalSequenceSymbolFrequencyCounter = new
179                             ↪ TotalSequenceSymbolFrequencyCounter<TLink>(links);
180                     }
181                     var doubletFrequenciesCache = new LinkFrequenciesCache<TLink>(links,
182                             ↪ totalSequenceSymbolFrequencyCounter);
183                     var compressingConverter = new CompressingConverter<TLink>(links,
184                             ↪ balancedVariantConverter, doubletFrequenciesCache);
185                     LinksToSequenceConverter = compressingConverter;
186                 }
187             }
188             else
189             {
190                 if (LinksToSequenceConverter == null)
191                 {
192                     LinksToSequenceConverter = balancedVariantConverter;
193                 }
194             }
195             if (UseIndex && Index == null)
196             {
197                 Index = new SequenceIndex<TLink>(links);
198             }
199             if (Walker == null)
200             {

```

```

196         Walker = new RightSequenceWalker<TLink>(links, new DefaultStack<TLink>());
197     }
198 }
199
200 [MethodImpl(MethodImplOptions.AggressiveInlining)]
201 public void ValidateOptions()
202 {
203     if (UseGarbageCollection && !UseSequenceMarker)
204     {
205         throw new NotSupportedException("To use garbage collection UseSequenceMarker
206             ↪ option must be on.");
207     }
208 }
209 }

```

1.96 ./csharp/Platform.Data.Doublets/Sequences/Walkers/ISequenceWalker.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.Walkers
7 {
8     public interface ISequenceWalker<TLink>
9     {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         IEnumerable<TLink> Walk(TLink sequence);
12     }
13 }

```

1.97 ./csharp/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         [MethodImpl(MethodImplOptions.AggressiveInlining)]
13         public LeftSequenceWalker(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
14             ↪ isElement) : base(links, stack, isElement) { }
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         public LeftSequenceWalker(ILinks<TLink> links, IStack<TLink> stack) : base(links, stack,
18             ↪ links.IsPartialPoint) { }
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         protected override TLink GetNextElementAfterPop(TLink element) =>
22             ↪ _links.GetSource(element);
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected override TLink GetNextElementAfterPush(TLink element) =>
26             ↪ _links.GetTarget(element);
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected override IEnumerable<TLink> WalkContents(TLink element)
30         {
31             var links = _links;
32             var parts = links.GetLink(element);
33             var start = links.Constants.SourcePart;
34             for (var i = parts.Count - 1; i >= start; i--)
35             {
36                 var part = parts[i];
37                 if (IsElement(part))
38                 {
39                     yield return part;
40                 }
41             }
42         }
43     }
44 }

```


1.98 ./csharp/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         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public LeveledSequenceWalker(ILinks<TLink> links, Func<TLink, bool> isElement) :
23             ↪ base(links) => _isElement = isElement;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         public LeveledSequenceWalker(ILinks<TLink> links) : base(links) => _isElement =
27             ↪ _links.IsPartialPoint;
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         public IEnumerable<TLink> Walk(TLink sequence) => ToArray(sequence);
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         public TLink[] ToArray(TLink sequence)
34         {
35             var length = 1;
36             var array = new TLink[length];
37             array[0] = sequence;
38             if (_isElement(sequence))
39             {
40                 return array;
41             }
42             bool hasElements;
43             do
44             {
45                 length *= 2;
46 #if USEARRAYPOOL
47                 var nextArray = ArrayPool.Allocate<ulong>(length);
48 #else
49                 var nextArray = new TLink[length];
50 #endif
51                 hasElements = false;
52                 for (var i = 0; i < array.Length; i++)
53                 {
54                     var candidate = array[i];
55                     if (_equalityComparer.Equals(array[i], default))
56                     {
57                         continue;
58                     }
59                     var doubletOffset = i * 2;
60                     if (_isElement(candidate))
61                     {
62                         nextArray[doubletOffset] = candidate;
63                     }
64                     else
65                     {
66                         var links = _links;
67                         var link = links.GetLink(candidate);
68                         var linkSource = links.GetSource(link);
69                         var linkTarget = links.GetTarget(link);
70                         nextArray[doubletOffset] = linkSource;
71                         nextArray[doubletOffset + 1] = linkTarget;
72                         if (!hasElements)
73                         {
74                             hasElements = !(_isElement(linkSource) && _isElement(linkTarget));
75                         }
76                     }
77                 }
78             } while (length < array.Length);
79             if (array.Length > 1)

```

```

77         {
78             ArrayPool.Free(array);
79         }
80 #endif
81         array = nextArray;
82     }
83     while (hasElements);
84     var filledElementsCount = CountFilledElements(array);
85     if (filledElementsCount == array.Length)
86     {
87         return array;
88     }
89     else
90     {
91         return CopyFilledElements(array, filledElementsCount);
92     }
93 }
94
95 [MethodImpl(MethodImplOptions.AggressiveInlining)]
96 private static TLink[] CopyFilledElements(TLink[] array, int filledElementsCount)
97 {
98     var finalArray = new TLink[filledElementsCount];
99     for (int i = 0, j = 0; i < array.Length; i++)
100     {
101         if (!_equalityComparer.Equals(array[i], default))
102         {
103             finalArray[j] = array[i];
104             j++;
105         }
106     }
107 #if USEARRAYPOOL
108     ArrayPool.Free(array);
109 #endif
110     return finalArray;
111 }
112
113 [MethodImpl(MethodImplOptions.AggressiveInlining)]
114 private static int CountFilledElements(TLink[] array)
115 {
116     var count = 0;
117     for (var i = 0; i < array.Length; i++)
118     {
119         if (!_equalityComparer.Equals(array[i], default))
120         {
121             count++;
122         }
123     }
124     return count;
125 }
126 }
127 }

```

1.99 ./csharp/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         [MethodImpl(MethodImplOptions.AggressiveInlining)]
13         public RightSequenceWalker(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
14             isElement) : base(links, stack, isElement) { }
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         public RightSequenceWalker(ILinks<TLink> links, IStack<TLink> stack) : base(links,
18             stack, links.IsPartialPoint) { }
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         protected override TLink GetNextElementAfterPop(TLink element) =>
22             _links.GetTarget(element);
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected override TLink GetNextElementAfterPush(TLink element) =>
26             _links.GetSource(element);
27     }
28 }

```

```

24     [MethodImpl(MethodImplOptions.AggressiveInlining)]
25     protected override IEnumerable<TLink> WalkContents(TLink element)
26     {
27         var parts = _links.GetLink(element);
28         for (var i = _links.Constants.SourcePart; i < parts.Count; i++)
29         {
30             var part = parts[i];
31             if (IsElement(part))
32             {
33                 yield return part;
34             }
35         }
36     }
37 }
38 }

```

1.100 ./csharp/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         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
18             ↳ isElement) : base(links)
19         {
20             _stack = stack;
21             _isElement = isElement;
22         }
23
24         [MethodImpl(MethodImplOptions.AggressiveInlining)]
25         protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack) : this(links,
26             ↳ stack, links.IsPartialPoint) { }
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         public IEnumerable<TLink> Walk(TLink sequence)
30         {
31             _stack.Clear();
32             var element = sequence;
33             if (IsElement(element))
34             {
35                 yield return element;
36             }
37             else
38             {
39                 while (true)
40                 {
41                     if (IsElement(element))
42                     {
43                         if (_stack.IsEmpty)
44                         {
45                             break;
46                         }
47                         element = _stack.Pop();
48                         foreach (var output in WalkContents(element))
49                         {
50                             yield return output;
51                         }
52                         element = GetNextElementAfterPop(element);
53                     }
54                     else
55                     {
56                         _stack.Push(element);
57                         element = GetNextElementAfterPush(element);
58                     }
59                 }
60             }
61         }
62     }
63 }

```

```

60     [MethodImpl(MethodImplOptions.AggressiveInlining)]
61     protected virtual bool IsElement(TLink elementLink) => _isElement(elementLink);
62
63     [MethodImpl(MethodImplOptions.AggressiveInlining)]
64     protected abstract TLink GetNextElementAfterPop(TLink element);
65
66     [MethodImpl(MethodImplOptions.AggressiveInlining)]
67     protected abstract TLink GetNextElementAfterPush(TLink element);
68
69     [MethodImpl(MethodImplOptions.AggressiveInlining)]
70     protected abstract IEnumerable<TLink> WalkContents(TLink element);
71 }
72 }

```

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

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Collections.Stacks;
4
5  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7  namespace Platform.Data.Doublets.Stacks
8  {
9      public class Stack<TLink> : LinksOperatorBase<TLink>, IStack<TLink>
10     {
11         private static readonly EqualityComparer<TLink> _equalityComparer =
12             ↪ EqualityComparer<TLink>.Default;
13
14         private readonly TLink _stack;
15
16         public bool IsEmpty
17         {
18             [MethodImpl(MethodImplOptions.AggressiveInlining)]
19             get => _equalityComparer.Equals(Peek(), _stack);
20         }
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         public Stack(ILinks<TLink> links, TLink stack) : base(links) => _stack = stack;
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         private TLink GetStackMarker() => _links.GetSource(_stack);
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         private TLink GetTop() => _links.GetTarget(_stack);
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         public TLink Peek() => _links.GetTarget(GetTop());
33
34         [MethodImpl(MethodImplOptions.AggressiveInlining)]
35         public TLink Pop()
36         {
37             var element = Peek();
38             if (!_equalityComparer.Equals(element, _stack))
39             {
40                 var top = GetTop();
41                 var previousTop = _links.GetSource(top);
42                 _links.Update(_stack, GetStackMarker(), previousTop);
43                 _links.Delete(top);
44             }
45             return element;
46         }
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         public void Push(TLink element) => _links.Update(_stack, GetStackMarker(),
50             ↪ _links.GetOrCreate(GetTop(), element));
51     }
52 }

```

1.102 ./csharp/Platform.Data.Doublets/Stacks/StackExtensions.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.Stacks
6  {
7      public static class StackExtensions
8      {
9          [MethodImpl(MethodImplOptions.AggressiveInlining)]
10         public static TLink CreateStack<TLink>(this ILinks<TLink> links, TLink stackMarker)
11         {

```

```

12         var stackPoint = links.CreatePoint();
13         var stack = links.Update(stackPoint, stackMarker, stackPoint);
14         return stack;
15     }
16 }
17 }

```

1.103 ./csharp/Platform.Data.Doublets/SynchronizedLinks.cs

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Data.Doublets;
5  using Platform.Threading.Synchronization;
6
7  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
8
9  namespace Platform.Data.Doublets
10 {
11     /// <remarks>
12     /// TODO: Autogeneration of synchronized wrapper (decorator).
13     /// TODO: Try to unfold code of each method using IL generation for performance improvements.
14     /// TODO: Or even to unfold multiple layers of implementations.
15     /// </remarks>
16     public class SynchronizedLinks<TLinkAddress> : ISynchronizedLinks<TLinkAddress>
17     {
18         public LinksConstants<TLinkAddress> Constants
19         {
20             [MethodImpl(MethodImplOptions.AggressiveInlining)]
21             get;
22         }
23
24         public ISynchronization SyncRoot
25         {
26             [MethodImpl(MethodImplOptions.AggressiveInlining)]
27             get;
28         }
29
30         public ILinks<TLinkAddress> Sync
31         {
32             [MethodImpl(MethodImplOptions.AggressiveInlining)]
33             get;
34         }
35
36         public ILinks<TLinkAddress> Unsync
37         {
38             [MethodImpl(MethodImplOptions.AggressiveInlining)]
39             get;
40         }
41
42         [MethodImpl(MethodImplOptions.AggressiveInlining)]
43         public SynchronizedLinks(ILinks<TLinkAddress> links) : this(new
            ↳ ReaderWriterLockSynchronization(), links) { }
44
45         [MethodImpl(MethodImplOptions.AggressiveInlining)]
46         public SynchronizedLinks(ISynchronization synchronization, ILinks<TLinkAddress> links)
47         {
48             SyncRoot = synchronization;
49             Sync = this;
50             Unsync = links;
51             Constants = links.Constants;
52         }
53
54         [MethodImpl(MethodImplOptions.AggressiveInlining)]
55         public TLinkAddress Count(IList<TLinkAddress> restriction) =>
            ↳ SyncRoot.ExecuteReadOperation(restriction, Unsync.Count);
56
57         [MethodImpl(MethodImplOptions.AggressiveInlining)]
58         public TLinkAddress Each(Func<IList<TLinkAddress>, TLinkAddress> handler,
            ↳ IList<TLinkAddress> restrictions) => SyncRoot.ExecuteReadOperation(handler,
            ↳ restrictions, (handler1, restrictions1) => Unsync.Each(handler1, restrictions1));
59
60         [MethodImpl(MethodImplOptions.AggressiveInlining)]
61         public TLinkAddress Create(IList<TLinkAddress> restrictions) =>
            ↳ SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Create);
62
63         [MethodImpl(MethodImplOptions.AggressiveInlining)]
64         public TLinkAddress Update(IList<TLinkAddress> restrictions, IList<TLinkAddress>
            ↳ substitution) => SyncRoot.ExecuteWriteOperation(restrictions, substitution,
            ↳ Unsync.Update);
65

```

```

66     [MethodImpl(MethodImplOptions.AggressiveInlining)]
67     public void Delete(IList<TLinkAddress> restrictions) =>
        ↳ SyncRoot.ExecuteWriteOperation(restrictions, Unsync.Delete);
68
69     //public T Trigger(IList<T> restriction, Func<IList<T>, IList<T>, T> matchedHandler,
        ↳ IList<T> substitution, Func<IList<T>, IList<T>, T> substitutedHandler)
70     //{
71     //    if (restriction != null && substitution != null &&
        ↳ !substitution.EqualTo(restriction))
72     //        return SyncRoot.ExecuteWriteOperation(restriction, matchedHandler,
        ↳ substitution, substitutedHandler, Unsync.Trigger);
73
74     //    return SyncRoot.ExecuteReadOperation(restriction, matchedHandler, substitution,
        ↳ substitutedHandler, Unsync.Trigger);
75     //}
76 }
77 }

```

1.104 ./csharp/Platform.Data.Doublets/UInt64LinksExtensions.cs

```

1  using System;
2  using System.Text;
3  using System.Collections.Generic;
4  using System.Runtime.CompilerServices;
5  using Platform.Singletons;
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         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         public static void UseUnicode(this ILinks<ulong> links) => UnicodeMap.InitNew(links);
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         public static bool AnyLinkIsAny(this ILinks<ulong> links, params ulong[] sequence)
21         {
22             if (sequence == null)
23             {
24                 return false;
25             }
26             var constants = links.Constants;
27             for (var i = 0; i < sequence.Length; i++)
28             {
29                 if (sequence[i] == constants.Any)
30                 {
31                     return true;
32                 }
33             }
34             return false;
35         }
36
37         [MethodImpl(MethodImplOptions.AggressiveInlining)]
38         public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
            ↳ Func<Link<ulong>, bool> isElement, bool renderIndex = false, bool renderDebug =
            ↳ false)
39         {
40             var sb = new StringBuilder();
41             var visited = new HashSet<ulong>();
42             links.AppendStructure(sb, visited, linkIndex, isElement, (innerSb, link) =>
                ↳ innerSb.Append(link.Index), renderIndex, renderDebug);
43             return sb.ToString();
44         }
45
46         [MethodImpl(MethodImplOptions.AggressiveInlining)]
47         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)
48         {
49             var sb = new StringBuilder();
50             var visited = new HashSet<ulong>();
51             links.AppendStructure(sb, visited, linkIndex, isElement, appendElement, renderIndex,
                ↳ renderDebug);
52             return sb.ToString();
53         }
54     }
55 }

```

```

54 [MethodImpl(MethodImplOptions.AggressiveInlining)]
55 public static void AppendStructure(this ILinks<ulong> links, StringBuilder sb,
56     ↳ HashSet<ulong> visited, ulong linkIndex, Func<Link<ulong>, bool> isElement,
57     ↳ Action<StringBuilder, Link<ulong>> appendElement, bool renderIndex = false, bool
58     ↳ renderDebug = false)
59 {
60     if (sb == null)
61     {
62         throw new ArgumentNullException(nameof(sb));
63     }
64     if (linkIndex == Constants.Null || linkIndex == Constants.Any || linkIndex ==
65     ↳ Constants.Itself)
66     {
67         return;
68     }
69     if (links.Exists(linkIndex))
70     {
71         if (visited.Add(linkIndex))
72         {
73             sb.Append('(');
74             var link = new Link<ulong>(links.GetLink(linkIndex));
75             if (renderIndex)
76             {
77                 sb.Append(link.Index);
78                 sb.Append(':');
79             }
80             if (link.Source == link.Index)
81             {
82                 sb.Append(link.Index);
83             }
84             else
85             {
86                 var source = new Link<ulong>(links.GetLink(link.Source));
87                 if (isElement(source))
88                 {
89                     appendElement(sb, source);
90                 }
91                 else
92                 {
93                     links.AppendStructure(sb, visited, source.Index, isElement,
94     ↳ appendElement, renderIndex);
95                 }
96             }
97             sb.Append(' ');
98             if (link.Target == link.Index)
99             {
100                 sb.Append(link.Index);
101             }
102             else
103             {
104                 var target = new Link<ulong>(links.GetLink(link.Target));
105                 if (isElement(target))
106                 {
107                     appendElement(sb, target);
108                 }
109                 else
110                 {
111                     links.AppendStructure(sb, visited, target.Index, isElement,
112     ↳ appendElement, renderIndex);
113                 }
114             }
115             sb.Append(')');
116         }
117         else
118         {
119             if (renderDebug)
120             {
121                 sb.Append('*');
122             }
123             sb.Append(linkIndex);
124         }
125     }
126     else
127     {
128         if (renderDebug)
129         {
130             sb.Append('~');
131         }
132     }
133 }

```

```

126     }
127     sb.Append(linkIndex);
128 }
129 }
130 }
131 }

```

1.105 ./csharp/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         /// Или
42         ///
43         /// public struct TransitionHeader
44         /// {
45         ///     public ulong TransactionIdCombined;
46         ///     public ulong TimestampCombined;
47         ///
48         ///     public ulong TransactionId
49         ///     {
50         ///         get
51         ///         {
52         ///             return (ulong) mask & TransactionIdCombined;
53         ///         }
54         ///     }
55         ///
56         ///     public UniqueTimestamp Timestamp
57         ///     {
58         ///         get
59         ///         {
60         ///             return (UniqueTimestamp)mask & TransactionIdCombined;
61         ///         }
62         ///     }
63         ///
64         ///     public TransactionItemType Type
65         ///     {
66         ///         get
67         ///         {
68         ///             // Использовать по одному биту из TransactionId и Timestamp,
69         ///             // для значения в 2 бита, которое представляет тип операции
70         ///             throw new NotImplementedException();
71         ///         }
72         ///     }
73         /// }
74     }
75 }

```



```

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 : IEquatable<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         [MethodImpl(MethodImplOptions.AggressiveInlining)]
95         public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
96         ↪ transactionId, Link<ulong> before, Link<ulong> after)
97         {
98             TransactionId = transactionId;
99             Before = before;
100            After = after;
101            Timestamp = uniqueTimestampFactory.Create();
102        }
103
104         [MethodImpl(MethodImplOptions.AggressiveInlining)]
105         public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
106         ↪ transactionId, Link<ulong> before) : this(uniqueTimestampFactory, transactionId,
107         ↪ before, default) { }
108
109         [MethodImpl(MethodImplOptions.AggressiveInlining)]
110         public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
111         ↪ transactionId) : this(uniqueTimestampFactory, transactionId, default, default) {
112         ↪ }
113
114         [MethodImpl(MethodImplOptions.AggressiveInlining)]
115         public override string ToString() => $"{Timestamp} {TransactionId}: {Before} =>
116         ↪ {After}";
117
118         [MethodImpl(MethodImplOptions.AggressiveInlining)]
119         public override bool Equals(object obj) => obj is Transition transition ?
120         ↪ Equals(transition) : false;
121
122         [MethodImpl(MethodImplOptions.AggressiveInlining)]
123         public override int GetHashCode() => (TransactionId, Before, After,
124         ↪ Timestamp).GetHashCode();
125
126         [MethodImpl(MethodImplOptions.AggressiveInlining)]
127         public bool Equals(Transition other) => TransactionId == other.TransactionId &&
128         ↪ Before == other.Before && After == other.After && Timestamp == other.Timestamp;
129
130         [MethodImpl(MethodImplOptions.AggressiveInlining)]
131         public static bool operator ==(Transition left, Transition right) =>
132         ↪ left.Equals(right);
133
134         [MethodImpl(MethodImplOptions.AggressiveInlining)]
135         public static bool operator !=(Transition left, Transition right) => !(left ==
136         ↪ right);
137     }
138
139     /// <remarks>
140     /// Другие варианты реализации транзакций (атомарности):
141     /// 1. Разделение хранения значения связи ((Source Target) или (Source Linker
142     ↪ Target)) и индексов.
143     /// 2. Хранение трансформаций/операций в отдельном хранилище Links, но дополнительно
144     ↪ потребуется решить вопрос
145     /// со ссылками на внешние идентификаторы, или как-то иначе решить вопрос с
146     ↪ пересечениями идентификаторов.
147     ///
148     /// Где хранить промежуточный список транзакций?
149     ///

```

```

136  /// В оперативной памяти:
137  /// Минусы:
138  /// 1. Может усложнить систему, если она будет функционировать самостоятельно,
139  /// так как нужно отдельно выделять память под список трансформаций.
140  /// 2. Выделенной оперативной памяти может не хватить, в том случае,
141  /// если транзакция использует слишком много трансформаций.
142  /// -> Можно использовать жёсткий диск для слишком длинных транзакций.
143  /// -> Максимальный размер списка трансформаций можно ограничить / задать
    ↳ константой.
144  /// 3. При подтверждении транзакции (Commit) все трансформации записываются разом
    ↳ создавая задержку.
145  ///
146  /// На жёстком диске:
147  /// Минусы:
148  /// 1. Длительный отклик, на запись каждой трансформации.
149  /// 2. Лог транзакций дополнительно наполняется отменёнными транзакциями.
150  /// -> Это может решаться упаковкой/исключением дублирующих операций.
151  /// -> Также это может решаться тем, что короткие транзакции вообще
152  /// не будут записываться в случае отката.
153  /// 3. Перед тем как выполнять отмену операций транзакции нужно дождаться пока все
    ↳ операции (трансформации)
    ↳ будут записаны в лог.
154  ///
155  /// </remarks>
156  public class Transaction : DisposableBase
157  {
158      private readonly Queue<Transition> _transitions;
159      private readonly UInt64LinksTransactionsLayer _layer;
160      public bool IsCommitted { get; private set; }
161      public bool IsReverted { get; private set; }
162
163      [MethodImpl(MethodImplOptions.AggressiveInlining)]
164      public Transaction(UInt64LinksTransactionsLayer layer)
165      {
166          _layer = layer;
167          if (_layer._currentTransactionId != 0)
168          {
169              throw new NotSupportedException("Nested transactions not supported.");
170          }
171          IsCommitted = false;
172          IsReverted = false;
173          _transitions = new Queue<Transition>();
174          SetCurrentTransaction(layer, this);
175      }
176
177      [MethodImpl(MethodImplOptions.AggressiveInlining)]
178      public void Commit()
179      {
180          EnsureTransactionAllowsWriteOperations(this);
181          while (_transitions.Count > 0)
182          {
183              var transition = _transitions.Dequeue();
184              _layer._transitions.Enqueue(transition);
185          }
186          _layer._lastCommittedTransactionId = _layer._currentTransactionId;
187          IsCommitted = true;
188      }
189
190      [MethodImpl(MethodImplOptions.AggressiveInlining)]
191      private void Revert()
192      {
193          EnsureTransactionAllowsWriteOperations(this);
194          var transitionsToRevert = new Transition[_transitions.Count];
195          _transitions.CopyTo(transitionsToRevert, 0);
196          for (var i = transitionsToRevert.Length - 1; i >= 0; i--)
197          {
198              _layer.RevertTransition(transitionsToRevert[i]);
199          }
200          IsReverted = true;
201      }
202
203      [MethodImpl(MethodImplOptions.AggressiveInlining)]
204      public static void SetCurrentTransaction(UInt64LinksTransactionsLayer layer,
205          ↳ Transaction transaction)
206      {
207          layer._currentTransactionId = layer._lastCommittedTransactionId + 1;
208          layer._currentTransactionTransitions = transaction._transitions;
209          layer._currentTransaction = transaction;
210      }

```

```

211 [MethodImpl(MethodImplOptions.AggressiveInlining)]
212 public static void EnsureTransactionAllowsWriteOperations(Transaction transaction)
213 {
214     if (transaction.IsReverted)
215     {
216         throw new InvalidOperationException("Transation is reverted.");
217     }
218     if (transaction.IsCommitted)
219     {
220         throw new InvalidOperationException("Transation is committed.");
221     }
222 }
223
224 [MethodImpl(MethodImplOptions.AggressiveInlining)]
225 protected override void Dispose(bool manual, bool wasDisposed)
226 {
227     if (!wasDisposed && _layer != null && !_layer.Disposable.IsDisposed)
228     {
229         if (!IsCommitted && !IsReverted)
230         {
231             Revert();
232         }
233         _layer.ResetCurrentTransation();
234     }
235 }
236
237 }
238
239 public static readonly TimeSpan DefaultPushDelay = TimeSpan.FromSeconds(0.1);
240
241 private readonly string _logAddress;
242 private readonly FileStream _log;
243 private readonly Queue<Transition> _transitions;
244 private readonly UniqueTimestampFactory _uniqueTimestampFactory;
245 private Task _transitionsPusher;
246 private Transition _lastCommittedTransition;
247 private ulong _currentTransactionId;
248 private Queue<Transition> _currentTransactionTransitions;
249 private Transaction _currentTransaction;
250 private ulong _lastCommittedTransactionId;
251
252 [MethodImpl(MethodImplOptions.AggressiveInlining)]
253 public UInt64LinksTransactionsLayer(ILinks<ulong> links, string logAddress)
254     : base(links)
255 {
256     if (string.IsNullOrEmpty(logAddress))
257     {
258         throw new ArgumentNullException(nameof(logAddress));
259     }
260     // В первой строке файла хранится последняя законченную транзакцию.
261     // При запуске это используется для проверки удачного закрытия файла лога.
262     // In the first line of the file the last committed transaction is stored.
263     // On startup, this is used to check that the log file is successfully closed.
264     var lastCommittedTransition = FileHelpers.ReadFirstOrDefault<Transition>(logAddress);
265     var lastWrittenTransition = FileHelpers.ReadLastOrDefault<Transition>(logAddress);
266     if (!lastCommittedTransition.Equals(lastWrittenTransition))
267     {
268         Dispose();
269         throw new NotSupportedException("Database is damaged, autorecovery is not
270             ↳ supported yet.");
271     }
272     if (lastCommittedTransition == default)
273     {
274         FileHelpers.WriteFirst(logAddress, lastCommittedTransition);
275     }
276     _lastCommittedTransition = lastCommittedTransition;
277     // TODO: Think about a better way to calculate or store this value
278     var allTransitions = FileHelpers.ReadAll<Transition>(logAddress);
279     _lastCommittedTransactionId = allTransitions.Length > 0 ? allTransitions.Max(x =>
280         ↳ x.TransactionId) : 0;
281     _uniqueTimestampFactory = new UniqueTimestampFactory();
282     _logAddress = logAddress;
283     _log = FileHelpers.Append(logAddress);
284     _transitions = new Queue<Transition>();
285     _transitionsPusher = new Task(TransitionsPusher);
286     _transitionsPusher.Start();
287 }
288 [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

288 public IList<ulong> GetLinkValue(ulong link) => _links.GetLink(link);
289
290 [MethodImpl(MethodImplOptions.AggressiveInlining)]
291 public override ulong Create(IList<ulong> restrictions)
292 {
293     var createdLinkIndex = _links.Create();
294     var createdLink = new Link<ulong>(_links.GetLink(createdLinkIndex));
295     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
296         ↪ default, createdLink));
297     return createdLinkIndex;
298 }
299
300 [MethodImpl(MethodImplOptions.AggressiveInlining)]
301 public override ulong Update(IList<ulong> restrictions, IList<ulong> substitution)
302 {
303     var linkIndex = restrictions[_constants.IndexPart];
304     var beforeLink = new Link<ulong>(_links.GetLink(linkIndex));
305     linkIndex = _links.Update(restrictions, substitution);
306     var afterLink = new Link<ulong>(_links.GetLink(linkIndex));
307     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
308         ↪ beforeLink, afterLink));
309     return linkIndex;
310 }
311
312 [MethodImpl(MethodImplOptions.AggressiveInlining)]
313 public override void Delete(IList<ulong> restrictions)
314 {
315     var link = restrictions[_constants.IndexPart];
316     var deletedLink = new Link<ulong>(_links.GetLink(link));
317     _links.Delete(link);
318     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
319         ↪ deletedLink, default));
320 }
321
322 [MethodImpl(MethodImplOptions.AggressiveInlining)]
323 private Queue<Transition> GetCurrentTransitions() => _currentTransactionTransitions ??
324     ↪ _transitions;
325
326 [MethodImpl(MethodImplOptions.AggressiveInlining)]
327 private void CommitTransition(Transition transition)
328 {
329     if (_currentTransaction != null)
330     {
331         Transaction.EnsureTransactionAllowsWriteOperations(_currentTransaction);
332     }
333     var transitions = GetCurrentTransitions();
334     transitions.Enqueue(transition);
335 }
336
337 [MethodImpl(MethodImplOptions.AggressiveInlining)]
338 private void RevertTransition(Transition transition)
339 {
340     if (transition.After.IsNull()) // Revert Deletion with Creation
341     {
342         _links.Create();
343     }
344     else if (transition.Before.IsNull()) // Revert Creation with Deletion
345     {
346         _links.Delete(transition.After.Index);
347     }
348     else // Revert Update
349     {
350         _links.Update(new[] { transition.After.Index, transition.Before.Source,
351             ↪ transition.Before.Target });
352     }
353 }
354
355 [MethodImpl(MethodImplOptions.AggressiveInlining)]
356 private void ResetCurrentTransation()
357 {
358     _currentTransactionId = 0;
359     _currentTransactionTransitions = null;
360     _currentTransaction = null;
361 }
362
363 [MethodImpl(MethodImplOptions.AggressiveInlining)]
364 private void PushTransitions()
365 {

```

```

361     if (_log == null || _transitions == null)
362     {
363         return;
364     }
365     for (var i = 0; i < _transitions.Count; i++)
366     {
367         var transition = _transitions.Dequeue();
368
369         _log.Write(transition);
370         _lastCommittedTransition = transition;
371     }
372 }
373
374 [MethodImpl(MethodImplOptions.AggressiveInlining)]
375 private void TransitionsPusher()
376 {
377     while (!Disposable.IsDisposed && _transitionsPusher != null)
378     {
379         Thread.Sleep(DefaultPushDelay);
380         PushTransitions();
381     }
382 }
383
384 [MethodImpl(MethodImplOptions.AggressiveInlining)]
385 public Transaction BeginTransaction() => new Transaction(this);
386
387 [MethodImpl(MethodImplOptions.AggressiveInlining)]
388 private void DisposeTransitions()
389 {
390     try
391     {
392         var pusher = _transitionsPusher;
393         if (pusher != null)
394         {
395             _transitionsPusher = null;
396             pusher.Wait();
397         }
398         if (_transitions != null)
399         {
400             PushTransitions();
401         }
402         _log.DisposeIfPossible();
403         FileHelpers.WriteFirst(_logAddress, _lastCommittedTransition);
404     }
405     catch (Exception ex)
406     {
407         ex.Ignore();
408     }
409 }
410
411 #region DisposalBase
412
413 [MethodImpl(MethodImplOptions.AggressiveInlining)]
414 protected override void Dispose(bool manual, bool wasDisposed)
415 {
416     if (!wasDisposed)
417     {
418         DisposeTransitions();
419     }
420     base.Dispose(manual, wasDisposed);
421 }
422
423 #endregion
424 }
425 }

```

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

```

1  using System.Runtime.CompilerServices;
2  using Platform.Converters;
3
4  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
5
6  namespace Platform.Data.Doublets.Unicode
7  {
8      public class CharToUnicodeSymbolConverter<TLink> : LinksOperatorBase<TLink>,
9          ⇨ IConverter<char, TLink>
10     {
11         private static readonly UncheckedConverter<char, TLink> _charToAddressConverter =
12             ⇨ UncheckedConverter<char, TLink>.Default;

```

```

12     private readonly IConverter<TLink> _addressToNumberConverter;
13     private readonly TLink _unicodeSymbolMarker;
14
15     [MethodImpl(MethodImplOptions.AggressiveInlining)]
16     public CharToUnicodeSymbolConverter(ILinks<TLink> links, IConverter<TLink>
17     ↪ addressToNumberConverter, TLink unicodeSymbolMarker) : base(links)
18     {
19         _addressToNumberConverter = addressToNumberConverter;
20         _unicodeSymbolMarker = unicodeSymbolMarker;
21     }
22
23     [MethodImpl(MethodImplOptions.AggressiveInlining)]
24     public TLink Convert(char source)
25     {
26         var unaryNumber =
27         ↪ _addressToNumberConverter.Convert(_charToAddressConverter.Convert(source));
28         return _links.GetOrCreate(unaryNumber, _unicodeSymbolMarker);
29     }

```

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

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Converters;
4  using Platform.Data.Doublets.Sequences.Indexes;
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 StringToUnicodeSequenceConverter<TLink> : LinksOperatorBase<TLink>,
11     ↪ IConverter<string, TLink>
12     {
13         private readonly IConverter<char, TLink> _charToUnicodeSymbolConverter;
14         private readonly ISequenceIndex<TLink> _index;
15         private readonly IConverter<IList<TLink>, TLink> _listToSequenceLinkConverter;
16         private readonly TLink _unicodeSequenceMarker;
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<char, TLink>
20         ↪ charToUnicodeSymbolConverter, ISequenceIndex<TLink> index, IConverter<IList<TLink>,
21         ↪ TLink> listToSequenceLinkConverter, TLink unicodeSequenceMarker) : base(links)
22         {
23             _charToUnicodeSymbolConverter = charToUnicodeSymbolConverter;
24             _index = index;
25             _listToSequenceLinkConverter = listToSequenceLinkConverter;
26             _unicodeSequenceMarker = unicodeSequenceMarker;
27         }
28
29         [MethodImpl(MethodImplOptions.AggressiveInlining)]
30         public TLink Convert(string source)
31         {
32             var elements = new TLink[source.Length];
33             for (int i = 0; i < elements.Length; i++)
34             {
35                 elements[i] = _charToUnicodeSymbolConverter.Convert(source[i]);
36             }
37             _index.Add(elements);
38             var sequence = _listToSequenceLinkConverter.Convert(elements);
39             return _links.GetOrCreate(sequence, _unicodeSequenceMarker);
40         }
41     }

```

1.108 ./csharp/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 [MethodImpl(MethodImplOptions.AggressiveInlining)]
22 public UnicodeMap(ILinks<ulong> links) => _links = links;
23
24 [MethodImpl(MethodImplOptions.AggressiveInlining)]
25 public static UnicodeMap InitNew(ILinks<ulong> links)
26 {
27     var map = new UnicodeMap(links);
28     map.Init();
29     return map;
30 }
31
32 [MethodImpl(MethodImplOptions.AggressiveInlining)]
33 public void Init()
34 {
35     if (_initialized)
36     {
37         return;
38     }
39     _initialized = true;
40     var firstLink = _links.CreatePoint();
41     if (firstLink != FirstCharLink)
42     {
43         _links.Delete(firstLink);
44     }
45     else
46     {
47         for (var i = FirstCharLink + 1; i <= LastCharLink; i++)
48         {
49             // From NIL to It (NIL -> Character) transformation meaning, (or infinite
50             // ↳ amount of NIL characters before actual Character)
51             var createdLink = _links.CreatePoint();
52             _links.Update(createdLink, firstLink, createdLink);
53             if (createdLink != i)
54             {
55                 throw new InvalidOperationException("Unable to initialize UTF 16
56                 ↳ table.");
57             }
58         }
59     }
60
61     // 0 - null link
62     // 1 - nil character (0 character)
63     // ...
64     // 65536 (0(1) + 65535 = 65536 possible values)
65
66 [MethodImpl(MethodImplOptions.AggressiveInlining)]
67 public static ulong FromCharToLink(char character) => (ulong)character + 1;
68
69 [MethodImpl(MethodImplOptions.AggressiveInlining)]
70 public static char FromLinkToChar(ulong link) => (char)(link - 1);
71
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 public static bool IsCharLink(ulong link) => link <= MapSize;
74
75 [MethodImpl(MethodImplOptions.AggressiveInlining)]
76 public static string FromLinksToString(IList<ulong> linksList)
77 {
78     var sb = new StringBuilder();
79     for (int i = 0; i < linksList.Count; i++)
80     {
81         sb.Append(FromLinkToChar(linksList[i]));
82     }
83     return sb.ToString();
84 }
85
86 [MethodImpl(MethodImplOptions.AggressiveInlining)]
87 public static string FromSequenceLinkToString(ulong link, ILinks<ulong> links)
88 {
89     var sb = new StringBuilder();
90     if (links.Exists(link))
91     {
92         StopableSequenceWalker.WalkRight(link, links.GetSource, links.GetTarget,

```

```

92         x => x <= MapSize || links.GetSource(x) == x || links.GetTarget(x) == x,
93         ↪ element =>
94     {
95         sb.Append(FromLinkToChar(element));
96         return true;
97     });
98     return sb.ToString();
99 }
100
101 [MethodImpl(MethodImplOptions.AggressiveInlining)]
102 public static ulong[] FromCharsToLinkArray(char[] chars) => FromCharsToLinkArray(chars,
103     ↪ chars.Length);
104
105 [MethodImpl(MethodImplOptions.AggressiveInlining)]
106 public static ulong[] FromCharsToLinkArray(char[] chars, int count)
107 {
108     // char array to ulong array
109     var linksSequence = new ulong[count];
110     for (var i = 0; i < count; i++)
111     {
112         linksSequence[i] = FromCharToLink(chars[i]);
113     }
114     return linksSequence;
115 }
116
117 [MethodImpl(MethodImplOptions.AggressiveInlining)]
118 public static ulong[] FromStringToLinkArray(string sequence)
119 {
120     // char array to ulong array
121     var linksSequence = new ulong[sequence.Length];
122     for (var i = 0; i < sequence.Length; i++)
123     {
124         linksSequence[i] = FromCharToLink(sequence[i]);
125     }
126     return linksSequence;
127 }
128
129 [MethodImpl(MethodImplOptions.AggressiveInlining)]
130 public static List<ulong[]> FromStringToLinkArrayGroups(string sequence)
131 {
132     var result = new List<ulong[]>();
133     var offset = 0;
134     while (offset < sequence.Length)
135     {
136         var currentCategory = CharUnicodeInfo.GetUnicodeCategory(sequence[offset]);
137         var relativeLength = 1;
138         var absoluteLength = offset + relativeLength;
139         while (absoluteLength < sequence.Length &&
140             currentCategory ==
141             ↪ CharUnicodeInfo.GetUnicodeCategory(sequence[absoluteLength]))
142         {
143             relativeLength++;
144             absoluteLength++;
145         }
146         // char array to ulong array
147         var innerSequence = new ulong[relativeLength];
148         var maxLength = offset + relativeLength;
149         for (var i = offset; i < maxLength; i++)
150         {
151             innerSequence[i - offset] = FromCharToLink(sequence[i]);
152         }
153         result.Add(innerSequence);
154         offset += relativeLength;
155     }
156     return result;
157 }
158
159 [MethodImpl(MethodImplOptions.AggressiveInlining)]
160 public static List<ulong[]> FromLinkArrayToLinkArrayGroups(ulong[] array)
161 {
162     var result = new List<ulong[]>();
163     var offset = 0;
164     while (offset < array.Length)
165     {
166         var relativeLength = 1;
167         if (array[offset] <= LastCharLink)
168         {

```



```

167         var currentCategory =
168             ↳ CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(array[offset]));
169         var absoluteLength = offset + relativeLength;
170         while (absoluteLength < array.Length &&
171             array[absoluteLength] <= LastCharLink &&
172             currentCategory == CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(
173                 ↳ array[absoluteLength])))
174         {
175             relativeLength++;
176             absoluteLength++;
177         }
178     }
179     else
180     {
181         var absoluteLength = offset + relativeLength;
182         while (absoluteLength < array.Length && array[absoluteLength] > LastCharLink)
183         {
184             relativeLength++;
185             absoluteLength++;
186         }
187         // copy array
188         var innerSequence = new ulong[relativeLength];
189         var maxLength = offset + relativeLength;
190         for (var i = offset; i < maxLength; i++)
191         {
192             innerSequence[i - offset] = array[i];
193         }
194         result.Add(innerSequence);
195         offset += relativeLength;
196     }
197     return result;
198 }
199 }

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
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.Unicode
8 {
9     public class UnicodeSequenceCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
10         ↳ ICriterionMatcher<TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
13             ↳ EqualityComparer<TLink>.Default;
14
15         private readonly TLink _unicodeSequenceMarker;
16
17         [MethodImpl(MethodImplOptions.AggressiveInlining)]
18         public UnicodeSequenceCriterionMatcher(ILinks<TLink> links, TLink unicodeSequenceMarker)
19             ↳ : base(links) => _unicodeSequenceMarker = unicodeSequenceMarker;
20
21         [MethodImpl(MethodImplOptions.AggressiveInlining)]
22         public bool IsMatched(TLink link) => _equalityComparer.Equals(_links.GetTarget(link),
23             ↳ _unicodeSequenceMarker);
24     }
25 }

```

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

```

1 using System;
2 using System.Linq;
3 using System.Runtime.CompilerServices;
4 using Platform.Interfaces;
5 using Platform.Converters;
6 using Platform.Data.Doublets.Sequences.Walkers;
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 UnicodeSequenceToStringConverter<TLink> : LinksOperatorBase<TLink>,
13         ↳ IConverter<TLink, string>
14     {
15         private readonly ICriterionMatcher<TLink> _unicodeSequenceCriterionMatcher;
16         private readonly ISequenceWalker<TLink> _sequenceWalker;
17     }
18 }

```

```

16     private readonly IConverter<TLink, char> _unicodeSymbolToCharConverter;
17
18     [MethodImpl(MethodImplOptions.AggressiveInlining)]
19     public UnicodeSequenceToStringConverter(ILinks<TLink> links, ICriterionMatcher<TLink>
        ↳ unicodeSequenceCriterionMatcher, ISequenceWalker<TLink> sequenceWalker,
        ↳ IConverter<TLink, char> unicodeSymbolToCharConverter) : base(links)
20     {
21         _unicodeSequenceCriterionMatcher = unicodeSequenceCriterionMatcher;
22         _sequenceWalker = sequenceWalker;
23         _unicodeSymbolToCharConverter = unicodeSymbolToCharConverter;
24     }
25
26     [MethodImpl(MethodImplOptions.AggressiveInlining)]
27     public string Convert(TLink source)
28     {
29         if (!_unicodeSequenceCriterionMatcher.IsMatched(source))
30         {
31             throw new ArgumentOutOfRangeException(nameof(source), source, "Specified link is
        ↳ not a unicode sequence.");
32         }
33         var sequence = _links.GetSource(source);
34         var charArray = _sequenceWalker.Walk(sequence).Select(_unicodeSymbolToCharConverter.
        ↳ Convert).ToArray();
35         return new string(charArray);
36     }
37 }
38 }

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
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.Unicode
8 {
9     public class UnicodeSymbolCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
        ↳ ICriterionMatcher<TLink>
10    {
11        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↳ EqualityComparer<TLink>.Default;
12
13        private readonly TLink _unicodeSymbolMarker;
14
15        [MethodImpl(MethodImplOptions.AggressiveInlining)]
16        public UnicodeSymbolCriterionMatcher(ILinks<TLink> links, TLink unicodeSymbolMarker) :
        ↳ base(links) => _unicodeSymbolMarker = unicodeSymbolMarker;
17
18        [MethodImpl(MethodImplOptions.AggressiveInlining)]
19        public bool IsMatched(TLink link) => _equalityComparer.Equals(_links.GetTarget(link),
        ↳ _unicodeSymbolMarker);
20    }
21 }

```

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

```

1 using System;
2 using System.Runtime.CompilerServices;
3 using Platform.Interfaces;
4 using Platform.Converters;
5
6 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8 namespace Platform.Data.Doublets.Unicode
9 {
10    public class UnicodeSymbolToCharConverter<TLink> : LinksOperatorBase<TLink>,
        ↳ IConverter<TLink, char>
11    {
12        private static readonly UncheckedConverter<TLink, char> _addressToCharConverter =
        ↳ UncheckedConverter<TLink, char>.Default;
13
14        private readonly IConverter<TLink> _numberToAddressConverter;
15        private readonly ICriterionMatcher<TLink> _unicodeSymbolCriterionMatcher;
16
17        [MethodImpl(MethodImplOptions.AggressiveInlining)]
18        public UnicodeSymbolToCharConverter(ILinks<TLink> links, IConverter<TLink>
        ↳ numberToAddressConverter, ICriterionMatcher<TLink> unicodeSymbolCriterionMatcher) :
        ↳ base(links)
19    {

```

```

20     _numberToAddressConverter = numberToAddressConverter;
21     _unicodeSymbolCriterionMatcher = unicodeSymbolCriterionMatcher;
22 }
23
24 [MethodImpl(MethodImplOptions.AggressiveInlining)]
25 public char Convert(TLink source)
26 {
27     if (!_unicodeSymbolCriterionMatcher.IsMatched(source))
28     {
29         throw new ArgumentOutOfRangeException(nameof(source), source, "Specified link is
        ↳ not a unicode symbol.");
30     }
31     return _addressToCharConverter.Convert(_numberToAddressConverter.Convert(_links.GetS
        ↳ ource(source)));
32 }
33 }
34 }

```

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

```

1.114 ./csharp/Platform.Data.Doublets.Tests/ILinksExtensionsTests.cs

```

1  using Xunit;
2
3  namespace Platform.Data.Doublets.Tests
4  {

```

```

5     public class ILinksExtensionsTests
6     {
7         [Fact]
8         public void FormatTest()
9         {
10             using (var scope = new TempLinksTestScope())
11             {
12                 var links = scope.Links;
13                 var link = links.Create();
14                 var linkString = links.Format(link);
15                 Assert.Equal("(1: 1 1)", linkString);
16             }
17         }
18     }
19 }

```

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

```

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

```

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

```

1 using System;
2 using System.Linq;
3 using Xunit;
4 using Platform.Collections.Stacks;
5 using Platform.Collections.Arrays;
6 using Platform.Memory;
7 using Platform.Data.Numbers.Raw;
8 using Platform.Data.Doublets.Sequences;
9 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
10 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
11 using Platform.Data.Doublets.Sequences.Converters;
12 using Platform.Data.Doublets.PropertyOperators;
13 using Platform.Data.Doublets.Incrementers;
14 using Platform.Data.Doublets.Sequences.Walkers;
15 using Platform.Data.Doublets.Sequences.Indexes;
16 using Platform.Data.Doublets.Unicode;
17 using Platform.Data.Doublets.Numbers.Unary;
18 using Platform.Data.Doublets.Decorators;
19 using Platform.Data.Doublets.Memory.United.Specific;
20
21 namespace Platform.Data.Doublets.Tests
22 {
23     public static class OptimalVariantSequenceTests
24     {
25         private static readonly string _sequenceExample = "зеленела зелёная зелень";
26         private static readonly string _loremIpsumExample = @"Lorem ipsum dolor sit amet,
27             ↪ consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore
28             ↪ magna aliqua.
29             Facilisi nullam vehicula ipsum a arcu cursus vitae congue mauris.
30             Et malesuada fames ac turpis egestas sed.
31             Eget velit aliquet sagittis id consectetur purus.
32             Dignissim cras tincidunt lobortis feugiat vivamus.
33             Vitae aliquet nec ullamcorper sit.
34             Lectus quam id leo in vitae.
35             Tortor dignissim convallis aenean et tortor at risus viverra adipiscing.
36             Sed risus ultricies tristique nulla aliquet enim tortor at auctor.
37             Integer eget aliquet nibh praesent tristique.
38             Vitae congue eu consequat ac felis donec et odio.
39             Tristique et egestas quis ipsum suspendisse.
40             Suspendisse potenti nullam ac tortor vitae purus faucibus ornare.
41             Nulla facilisi etiam dignissim diam quis enim lobortis scelerisque.

```

```

40 Imperdiet proin fermentum leo vel orci.
41 In ante metus dictum at tempor commodo.
42 Nisi lacus sed viverra tellus in.
43 Quam vulputate dignissim suspendisse in.
44 Elit scelerisque mauris pellentesque pulvinar pellentesque habitant morbi tristique senectus.
45 Gravida cum sociis natoque penatibus et magnis dis parturient.
46 Risus quis varius quam quisque id diam.
47 Congue nisi vitae suscipit tellus mauris a diam maecenas.
48 Eget nunc scelerisque viverra mauris in aliquam sem fringilla.
49 Pharetra vel turpis nunc eget lorem dolor sed viverra.
50 Mattis pellentesque id nibh tortor id aliquet.
51 Purus non enim praesent elementum facilisis leo vel.
52 Etiam sit amet nisl purus in mollis nunc sed.
53 Tortor at auctor urna nunc id cursus metus aliquam.
54 Volutpat odio facilisis mauris sit amet.
55 Turpis egestas pretium aenean pharetra magna ac placerat.
56 Fermentum dui faucibus in ornare quam viverra orci sagittis eu.
57 Porttitor leo a diam sollicitudin tempor id eu.
58 Volutpat sed cras ornare arcu dui.
59 Ut aliquam purus sit amet luctus venenatis lectus magna.
60 Aliquet risus feugiat in ante metus dictum at.
61 Mattis nunc sed blandit libero.
62 Elit pellentesque habitant morbi tristique senectus et netus.
63 Nibh sit amet commodo nulla facilisi nullam vehicula ipsum a.
64 Enim sit amet venenatis urna cursus eget nunc scelerisque viverra.
65 Amet venenatis urna cursus eget nunc scelerisque viverra mauris in.
66 Diam donec adipiscing tristique risus nec feugiat.
67 Pulvinar mattis nunc sed blandit libero volutpat.
68 Cras fermentum odio eu feugiat pretium nibh ipsum.
69 In nulla posuere sollicitudin aliquam ultrices sagittis orci a.
70 Mauris pellentesque pulvinar pellentesque habitant morbi tristique senectus et.
71 A iaculis at erat pellentesque.
72 Morbi blandit cursus risus at ultrices mi tempus imperdiet nulla.
73 Eget lorem dolor sed viverra ipsum nunc.
74 Leo a diam sollicitudin tempor id eu.
75 Interdum consectetur libero id faucibus nisl tincidunt eget nullam non.";
76
77 [Fact]
78 public static void LinksBasedFrequencyStoredOptimalVariantSequenceTest()
79 {
80     using (var scope = new TempLinksTestScope(useSequences: false))
81     {
82         var links = scope.Links;
83         var constants = links.Constants;
84
85         links.UseUnicode();
86
87         var sequence = UnicodeMap.FromStringToLinkArray(_sequenceExample);
88
89         var meaningRoot = links.CreatePoint();
90         var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
91         var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
92         var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
93             ↳ constants.Itself);
94
95         var unaryNumberToAddressConverter = new
96             ↳ UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
97         var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
98         var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
99             ↳ frequencyMarker, unaryOne, unaryNumberIncrementer);
100         var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
101             ↳ frequencyPropertyMarker, frequencyMarker);
102         var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
103             ↳ frequencyPropertyOperator, frequencyIncrementer);
104         var linkToItsFrequencyNumberConverter = new
105             ↳ LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
106             ↳ unaryNumberToAddressConverter);
107         var sequenceToItsLocalElementLevelsConverter = new
108             ↳ SequenceToItsLocalElementLevelsConverter<ulong>(links,
109             ↳ linkToItsFrequencyNumberConverter);
110         var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
111             ↳ sequenceToItsLocalElementLevelsConverter);
112
113         var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
114             ↳ Walker = new LeveledSequenceWalker<ulong>(links) });
115
116         ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
117             ↳ index, optimalVariantConverter);
118     }
119 }

```

```

109 [Fact]
110 public static void DictionaryBasedFrequencyStoredOptimalVariantSequenceTest()
111 {
112     using (var scope = new TempLinksTestScope(useSequences: false))
113     {
114         var links = scope.Links;
115
116         links.UseUnicode();
117
118         var sequence = UnicodeMap.FromStringToLinkArray(_sequenceExample);
119
120         var totalSequenceSymbolFrequencyCounter = new
121             ↪ TotalSequenceSymbolFrequencyCounter<ulong>(links);
122
123         var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
124             ↪ totalSequenceSymbolFrequencyCounter);
125
126         var index = new
127             ↪ CachedFrequencyIncrementingSequenceIndex<ulong>(linkFrequenciesCache);
128         var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFrequency
129             ↪ ncyNumberConverter<ulong>(linkFrequenciesCache);
130
131         var sequenceToItsLocalElementLevelsConverter = new
132             ↪ SequenceToItsLocalElementLevelsConverter<ulong>(links,
133             ↪ linkToItsFrequencyNumberConverter);
134         var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
135             ↪ sequenceToItsLocalElementLevelsConverter);
136
137         var sequences = new Sequences.Sequences(links, new SequencesOptions<ulong>() {
138             ↪ Walker = new LeveledSequenceWalker<ulong>(links) });
139
140         ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
141             ↪ index, optimalVariantConverter);
142     }
143 }
144
145 private static void ExecuteTest(Sequences.Sequences sequences, ulong[] sequence,
146     ↪ SequenceToItsLocalElementLevelsConverter<ulong>
147     ↪ sequenceToItsLocalElementLevelsConverter, ISequenceIndex<ulong> index,
148     ↪ OptimalVariantConverter<ulong> optimalVariantConverter)
149 {
150     index.Add(sequence);
151
152     var optimalVariant = optimalVariantConverter.Convert(sequence);
153
154     var readSequence1 = sequences.ToList(optimalVariant);
155
156     Assert.True(sequence.SequenceEqual(readSequence1));
157 }
158
159 [Fact]
160 public static void SavedSequencesOptimizationTest()
161 {
162     LinksConstants<ulong> constants = new LinksConstants<ulong>((1, long.MaxValue),
163         ↪ (long.MaxValue + 1UL, ulong.MaxValue));
164
165     using (var memory = new HeapResizableDirectMemory())
166     using (var disposableLinks = new UInt64UnitedMemoryLinks(memory,
167         ↪ UInt64UnitedMemoryLinks.DefaultLinksSizeStep, constants, useAvlBasedIndex:
168         ↪ false))
169     {
170         var links = new UInt64Links(disposableLinks);
171
172         var root = links.CreatePoint();
173
174         //var numberToAddressConverter = new RawNumberToAddressConverter<ulong>();
175         var addressToNumberConverter = new AddressToRawNumberConverter<ulong>();
176
177         var unicodeSymbolMarker = links.GetOrCreate(root,
178             ↪ addressToNumberConverter.Convert(1));
179         var unicodeSequenceMarker = links.GetOrCreate(root,
180             ↪ addressToNumberConverter.Convert(2));
181
182         var totalSequenceSymbolFrequencyCounter = new
183             ↪ TotalSequenceSymbolFrequencyCounter<ulong>(links);
184         var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
185             ↪ totalSequenceSymbolFrequencyCounter);
186         var index = new
187             ↪ CachedFrequencyIncrementingSequenceIndex<ulong>(linkFrequenciesCache);

```

```

168     var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<ulong>(linkFrequenciesCache);
169     var sequenceToItsLocalElementLevelsConverter = new SequenceToItsLocalElementLevelsConverter<ulong>(links,
170     ↪ linkToItsFrequencyNumberConverter);
171     var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
172     ↪ sequenceToItsLocalElementLevelsConverter);
173
174     var walker = new RightSequenceWalker<ulong>(links, new DefaultStack<ulong>(),
175     ↪ (link) => constants.IsExternalReference(link) || links.IsPartialPoint(link));
176
177     var unicodeSequencesOptions = new SequencesOptions<ulong>()
178     {
179         UseSequenceMarker = true,
180         SequenceMarkerLink = unicodeSequenceMarker,
181         UseIndex = true,
182         Index = index,
183         LinksToSequenceConverter = optimalVariantConverter,
184         Walker = walker,
185         UseGarbageCollection = true
186     };
187
188     var unicodeSequences = new Sequences.Sequences(new SynchronizedLinks<ulong>(links), unicodeSequencesOptions);
189
190     // Create some sequences
191     var strings = _loremIpsumExample.Split(new[] { '\n', '\r' },
192     ↪ StringSplitOptions.RemoveEmptyEntries);
193     var arrays = strings.Select(x => x.Select(y =>
194     ↪ addressToNumberConverter.Convert(y)).ToArray()).ToArray();
195     for (int i = 0; i < arrays.Length; i++)
196     {
197         unicodeSequences.Create(arrays[i].ShiftRight());
198     }
199
200     var linksCountAfterCreation = links.Count();
201
202     // get list of sequences links
203     // for each sequence link
204     // create new sequence version
205     // if new sequence is not the same as sequence link
206     // delete sequence link
207     // collect garbage
208     unicodeSequences.CompactAll();
209
210     var linksCountAfterCompactification = links.Count();
211
212     Assert.True(linksCountAfterCompactification < linksCountAfterCreation);
213 }
214 }
215 }

```

1.117 ./csharp/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> {
24                     ↪ Walker = new LeveledSequenceWalker<ulong>(links) });
25
26                 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));
50     Assert.True(sequence.SequenceEqual(readSequence2));
51
52     // Assert.True(sw2.Elapsed < sw3.Elapsed);
53
54     Console.WriteLine($"Stack-based walker: {sw3.Elapsed}, Level-based reader:
55     ↪ {sw2.Elapsed}");
56
57     for (var i = 0; i < sequenceLength; i++)
58     {
59         links.Delete(sequence[i]);
60     }
61 }
62 }
63 }

```

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

```

1  using System.IO;
2  using Xunit;
3  using Platform.Singletons;
4  using Platform.Memory;
5  using Platform.Data.Doublets.Memory.United.Specific;
6
7  namespace Platform.Data.Doublets.Tests
8  {
9      public static class ResizableDirectMemoryLinksTests
10     {
11         private static readonly LinksConstants<ulong> _constants =
12             ↪ Default<LinksConstants<ulong>>.Instance;
13
14         [Fact]
15         public static void BasicFileMappedMemoryTest()
16         {
17             var tempFilename = Path.GetTempFileName();
18             using (var memoryAdapter = new UInt64UnitedMemoryLinks(tempFilename))
19             {
20                 memoryAdapter.TestBasicMemoryOperations();
21             }
22             File.Delete(tempFilename);
23
24             [Fact]
25             public static void BasicHeapMemoryTest()
26             {
27                 using (var memory = new
28                     ↪ HeapResizableDirectMemory(UInt64UnitedMemoryLinks.DefaultLinksSizeStep))
29                 using (var memoryAdapter = new UInt64UnitedMemoryLinks(memory,
30                     ↪ UInt64UnitedMemoryLinks.DefaultLinksSizeStep))
31                 {
32                     memoryAdapter.TestBasicMemoryOperations();
33                 }
34
35                 private static void TestBasicMemoryOperations(this ILinks<ulong> memoryAdapter)
36                 {

```



```

36         var link = memoryAdapter.Create();
37         memoryAdapter.Delete(link);
38     }
39
40     [Fact]
41     public static void NonexistentReferencesHeapMemoryTest()
42     {
43         using (var memory = new
44             ↳ HeapResizableDirectMemory(UInt64UnitedMemoryLinks.DefaultLinksSizeStep))
45         using (var memoryAdapter = new UInt64UnitedMemoryLinks(memory,
46             ↳ UInt64UnitedMemoryLinks.DefaultLinksSizeStep))
47         {
48             memoryAdapter.TestNonexistentReferences();
49         }
50
51         private static void TestNonexistentReferences(this ILinks<ulong> memoryAdapter)
52         {
53             var link = memoryAdapter.Create();
54             memoryAdapter.Update(link, ulong.MaxValue, ulong.MaxValue);
55             var resultLink = _constants.Null;
56             memoryAdapter.Each(foundLink =>
57             {
58                 resultLink = foundLink[_constants.IndexPart];
59                 return _constants.Break;
60             }, _constants.Any, ulong.MaxValue, ulong.MaxValue);
61             Assert.True(resultLink == link);
62             Assert.True(memoryAdapter.Count(ulong.MaxValue) == 0);
63             memoryAdapter.Delete(link);
64         }
65     }

```

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

```

1  using Xunit;
2  using Platform.Scopes;
3  using Platform.Memory;
4  using Platform.Data.Doublets.Decorators;
5  using Platform.Reflection;
6  using Platform.Data.Doublets.Memory.United.Generic;
7  using Platform.Data.Doublets.Memory.United.Specific;
8
9  namespace Platform.Data.Doublets.Tests
10 {
11     public static class ScopeTests
12     {
13         [Fact]
14         public static void SingleDependencyTest()
15         {
16             using (var scope = new Scope())
17             {
18                 scope.IncludeAssemblyOf<IMemory>();
19                 var instance = scope.Use<IDirectMemory>();
20                 Assert.IsType<HeapResizableDirectMemory>(instance);
21             }
22         }
23
24         [Fact]
25         public static void CascadeDependencyTest()
26         {
27             using (var scope = new Scope())
28             {
29                 scope.Include<TemporaryFileMappedResizableDirectMemory>();
30                 scope.Include<UInt64UnitedMemoryLinks>();
31                 var instance = scope.Use<ILinks<ulong>>();
32                 Assert.IsType<UInt64UnitedMemoryLinks>(instance);
33             }
34         }
35
36         [Fact]
37         public static void FullAutoResolutionTest()
38         {
39             using (var scope = new Scope(autoInclude: true, autoExplore: true))
40             {
41                 var instance = scope.Use<UInt64Links>();
42                 Assert.IsType<UInt64Links>(instance);
43             }
44         }
45     }

```

```

46     [Fact]
47     public static void TypeParametersTest()
48     {
49         using (var scope = new Scope<Types<HeapResizableDirectMemory,
50             ↪ UnitedMemoryLinks<ulong>>>())
51         {
52             var links = scope.Use<ILinks<ulong>>>();
53             Assert.IsType<UnitedMemoryLinks<ulong>>>(links);
54         }
55     }
56 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Diagnostics;
4  using System.Linq;
5  using Xunit;
6  using Platform.Collections;
7  using Platform.Collections.Arrays;
8  using Platform.Random;
9  using Platform.IO;
10 using Platform.Singletons;
11 using Platform.Data.Doublets.Sequences;
12 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
13 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
14 using Platform.Data.Doublets.Sequences.Converters;
15 using Platform.Data.Doublets.Unicode;
16
17 namespace Platform.Data.Doublets.Tests
18 {
19     public static class SequencesTests
20     {
21         private static readonly LinksConstants<ulong> _constants =
22             ↪ Default<LinksConstants<ulong>>.Instance;
23
24         static SequencesTests()
25         {
26             // Trigger static constructor to not mess with performance measurements
27             _ = BitString.GetBitMaskFromIndex(1);
28         }
29
30         [Fact]
31         public static void CreateAllVariantsTest()
32         {
33             const long sequenceLength = 8;
34
35             using (var scope = new TempLinksTestScope(useSequences: true))
36             {
37                 var links = scope.Links;
38                 var sequences = scope.Sequences;
39
40                 var sequence = new ulong[sequenceLength];
41                 for (var i = 0; i < sequenceLength; i++)
42                 {
43                     sequence[i] = links.Create();
44                 }
45
46                 var sw1 = Stopwatch.StartNew();
47                 var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
48
49                 var sw2 = Stopwatch.StartNew();
50                 var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();
51
52                 Assert.True(results1.Count > results2.Length);
53                 Assert.True(sw1.Elapsed > sw2.Elapsed);
54
55                 for (var i = 0; i < sequenceLength; i++)
56                 {
57                     links.Delete(sequence[i]);
58                 }
59
60                 Assert.True(links.Count() == 0);
61             }
62
63             //[Fact]
64             //public void CUDTest()
65             //{

```

```

66 // var tempFilename = Path.GetTempFileName();
67
68 // const long sequenceLength = 8;
69
70 // const ulong itself = LinksConstants.Itself;
71
72 // using (var memoryAdapter = new ResizableDirectMemoryLinks(tempFilename,
73 //     ↪ DefaultLinksSizeStep))
74 // using (var links = new Links(memoryAdapter))
75 // {
76 //     var sequence = new ulong[sequenceLength];
77 //     for (var i = 0; i < sequenceLength; i++)
78 //         sequence[i] = links.Create(itself, itself);
79
80 //     SequencesOptions o = new SequencesOptions();
81
82 //     // TODO: Из числа в bool значения o.UseSequenceMarker = ((value & 1) != 0)
83 //     o.
84
85 //     var sequences = new Sequences(links);
86
87 //     var sw1 = Stopwatch.StartNew();
88 //     var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
89
90 //     var sw2 = Stopwatch.StartNew();
91 //     var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();
92
93 //     Assert.True(results1.Count > results2.Length);
94 //     Assert.True(sw1.Elapsed > sw2.Elapsed);
95
96 //     for (var i = 0; i < sequenceLength; i++)
97 //         links.Delete(sequence[i]);
98 // }
99
100 // File.Delete(tempFilename);
101 //}
102
103 [Fact]
104 public static void AllVariantsSearchTest()
105 {
106     const long sequenceLength = 8;
107
108     using (var scope = new TempLinksTestScope(useSequences: true))
109     {
110         var links = scope.Links;
111         var sequences = scope.Sequences;
112
113         var sequence = new ulong[sequenceLength];
114         for (var i = 0; i < sequenceLength; i++)
115         {
116             sequence[i] = links.Create();
117         }
118
119         var createResults = sequences.CreateAllVariants2(sequence).Distinct().ToArray();
120
121         //for (int i = 0; i < createResults.Length; i++)
122         //    sequences.Create(createResults[i]);
123
124         var sw0 = Stopwatch.StartNew();
125         var searchResults0 = sequences.GetAllMatchingSequences0(sequence); sw0.Stop();
126
127         var sw1 = Stopwatch.StartNew();
128         var searchResults1 = sequences.GetAllMatchingSequences1(sequence); sw1.Stop();
129
130         var sw2 = Stopwatch.StartNew();
131         var searchResults2 = sequences.Each1(sequence); sw2.Stop();
132
133         var sw3 = Stopwatch.StartNew();
134         var searchResults3 = sequences.Each(sequence.ShiftRight()); sw3.Stop();
135
136         var intersection0 = createResults.Intersect(searchResults0).ToList();
137         Assert.True(intersection0.Count == searchResults0.Count);
138         Assert.True(intersection0.Count == createResults.Length);
139
140         var intersection1 = createResults.Intersect(searchResults1).ToList();
141         Assert.True(intersection1.Count == searchResults1.Count);
142         Assert.True(intersection1.Count == createResults.Length);
143
144         var intersection2 = createResults.Intersect(searchResults2).ToList();
145         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
202 [Fact]
203 public static void AllPartialVariantsSearchTest()
204 {
205     const long sequenceLength = 8;
206
207     using (var scope = new TempLinksTestScope(useSequences: true))
208     {
209         var links = scope.Links;
210         var sequences = scope.Sequences;
211
212         var sequence = new ulong[sequenceLength];
213         for (var i = 0; i < sequenceLength; i++)
214         {
215             sequence[i] = links.Create();
216         }
217
218         var createResults = sequences.CreateAllVariants2(sequence);
219
220         //var createResultsStrings = createResults.Select(x => x + ": " +
221             ↪ sequences.FormatSequence(x)).ToList();
222         //Global.Trash = createResultsStrings;

```

```

223     var partialSequence = new ulong[sequenceLength - 2];
224
225     Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
226
227     var sw1 = Stopwatch.StartNew();
228     var searchResults1 =
229         ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
230
231     var sw2 = Stopwatch.StartNew();
232     var searchResults2 =
233         ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
234
235     //var sw3 = Stopwatch.StartNew();
236     //var searchResults3 =
237         ↪ sequences.GetAllPartiallyMatchingSequences2(partialSequence); sw3.Stop();
238
239     var sw4 = Stopwatch.StartNew();
240     var searchResults4 =
241         ↪ sequences.GetAllPartiallyMatchingSequences3(partialSequence); sw4.Stop();
242
243     //Global.Trash = searchResults3;
244
245     //var searchResults1Strings = searchResults1.Select(x => x + ": " +
246         ↪ sequences.FormatSequence(x)).ToList();
247     //Global.Trash = searchResults1Strings;
248
249     var intersection1 = createResults.Intersect(searchResults1).ToList();
250     Assert.True(intersection1.Count == createResults.Length);
251
252     var intersection2 = createResults.Intersect(searchResults2).ToList();
253     Assert.True(intersection2.Count == createResults.Length);
254
255     var intersection4 = createResults.Intersect(searchResults4).ToList();
256     Assert.True(intersection4.Count == createResults.Length);
257
258     for (var i = 0; i < sequenceLength; i++)
259     {
260         links.Delete(sequence[i]);
261     }
262 }
263
264 [Fact]
265 public static void BalancedPartialVariantsSearchTest()
266 {
267     const long sequenceLength = 200;
268
269     using (var scope = new TempLinksTestScope(useSequences: true))
270     {
271         var links = scope.Links;
272         var sequences = scope.Sequences;
273
274         var sequence = new ulong[sequenceLength];
275         for (var i = 0; i < sequenceLength; i++)
276         {
277             sequence[i] = links.Create();
278         }
279
280         var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
281
282         var balancedVariant = balancedVariantConverter.Convert(sequence);
283
284         var partialSequence = new ulong[sequenceLength - 2];
285
286         Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
287
288         var sw1 = Stopwatch.StartNew();
289         var searchResults1 =
290             ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
291
292         var sw2 = Stopwatch.StartNew();
293         var searchResults2 =
294             ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
295
296         Assert.True(searchResults1.Count == 1 && balancedVariant == searchResults1[0]);
297
298         Assert.True(searchResults2.Count == 1 && balancedVariant ==
299             ↪ searchResults2.First());
300
301         for (var i = 0; i < sequenceLength; i++)

```

```

295         {
296             links.Delete(sequence[i]);
297         }
298     }
299 }
300
301 [Fact(Skip = "Correct implementation is pending")]
302 public static void PatternMatchTest()
303 {
304     var zeroOrMany = Sequences.Sequences.ZeroOrMany;
305
306     using (var scope = new TempLinksTestScope(useSequences: true))
307     {
308         var links = scope.Links;
309         var sequences = scope.Sequences;
310
311         var e1 = links.Create();
312         var e2 = links.Create();
313
314         var sequence = new[]
315         {
316             e1, e2, e1, e2 // mama / papa
317         };
318
319         var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
320
321         var balancedVariant = balancedVariantConverter.Convert(sequence);
322
323         // 1: [1]
324         // 2: [2]
325         // 3: [1,2]
326         // 4: [1,2,1,2]
327
328         var doublet = links.GetSource(balancedVariant);
329
330         var matchedSequences1 = sequences.MatchPattern(e2, e1, zeroOrMany);
331
332         Assert.True(matchedSequences1.Count == 0);
333
334         var matchedSequences2 = sequences.MatchPattern(zeroOrMany, e2, e1);
335
336         Assert.True(matchedSequences2.Count == 0);
337
338         var matchedSequences3 = sequences.MatchPattern(e1, zeroOrMany, e1);
339
340         Assert.True(matchedSequences3.Count == 0);
341
342         var matchedSequences4 = sequences.MatchPattern(e1, zeroOrMany, e2);
343
344         Assert.Contains(doublet, matchedSequences4);
345         Assert.Contains(balancedVariant, matchedSequences4);
346
347         for (var i = 0; i < sequence.Length; i++)
348         {
349             links.Delete(sequence[i]);
350         }
351     }
352 }
353
354 [Fact]
355 public static void IndexTest()
356 {
357     using (var scope = new TempLinksTestScope(new SequencesOptions<ulong> { UseIndex =
358         ↪ true }, useSequences: true))
359     {
360         var links = scope.Links;
361         var sequences = scope.Sequences;
362         var index = sequences.Options.Index;
363
364         var e1 = links.Create();
365         var e2 = links.Create();
366
367         var sequence = new[]
368         {
369             e1, e2, e1, e2 // mama / papa
370         };
371
372         Assert.False(index.MightContain(sequence));
373
374         index.Add(sequence);

```

```

374         Assert.True(index.MightContain(sequence));
375     }
376 }
377 }
378
379 /// <summary>Imported from https://raw.githubusercontent.com/wiki/Konard/LinksPlatform/%
    ↳ 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
    ↳ %D0%B8%D0%BD%D0%B0%D0%BB%D0%BE%D1%81%D1%8C.md</summary>
380 private static readonly string _exampleText =
381     @"([english
    ↳ version](https://github.com/Konard/LinksPlatform/wiki/About-the-beginning))
382
383 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?
384
385 ![чёрное пространство, белое
    ↳ пространство](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/1.png
    ↳ "чёрное пространство, белое пространство")](https://raw.githubusercontent.com/Konard/Links
    ↳ Platform/master/doc/Intro/1.png)
386
387 Что может быть минимальным рисунком, образом, графикой? Может быть это точка? Это ли простейшая
    ↳ форма? Но есть ли у точки размер? Цвет? Масса? Координаты? Время существования?
388
389 ![чёрное пространство, чёрная
    ↳ точка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/2.png
    ↳ "чёрное пространство, чёрная
    ↳ точка")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/2.png)
390
391 А что если повторить? Сделать копию? Создать дубликат? Из одного сделать два? Может это быть
    ↳ так? Инверсия? Отражение? Сумма?
392
393 ![белая точка, чёрная
    ↳ точка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/3.png "белая
    ↳ точка, чёрная
    ↳ точка")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/3.png)
394
395 А что если мы вообразим движение? Нужно ли время? Каким самым коротким будет путь? Что будет
    ↳ если этот путь зафиксировать? Запомнить след? Как две точки становятся линией? Чертой?
    ↳ Грань? Разделителем? Единицей?
396
397 ![две белые точки, чёрная вертикальная
    ↳ линия](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/4.png "две
    ↳ белые точки, чёрная вертикальная
    ↳ линия")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/4.png)
398
399 Можно ли замкнуть движение? Может ли это быть кругом? Можно ли замкнуть время? Или остаётся
    ↳ только спираль? Но что если замкнуть предел? Создать ограничение, разделение? Получится
    ↳ замкнутая область? Полностью отделённая от всего остального? Но что это всё остальное? Что
    ↳ можно делить? В каком направлении? Ничего или всё? Пустота или полнота? Начало или конец?
    ↳ Или может быть это единица и ноль? Дуальность? Противоположность? А что будет с кругом если
    ↳ у него нет размера? Будет ли круг точкой? Точка состоящая из точек?
400
401 ![белая вертикальная линия, чёрный
    ↳ круг](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/5.png "белая
    ↳ вертикальная линия, чёрный
    ↳ круг")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/5.png)
402
403 Как ещё можно использовать грань, черту, линию? А что если она может что-то соединять, может
    ↳ тогда её нужно повернуть? Почему то, что перпендикулярно вертикальному горизонтально?
    ↳ Горизонт? Инвертирует ли это смысл? Что такое смысл? Из чего состоит смысл? Существует ли
    ↳ элементарная единица смысла?
404
405 ![белый круг, чёрная горизонтальная
    ↳ линия](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/6.png "белый
    ↳ круг, чёрная горизонтальная
    ↳ линия")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/6.png)
406
407 Соединять, допустим, а какой смысл в этом есть ещё? Что если помимо смысла "соединить,
    ↳ связать", есть ещё и смысл направления "от начала к концу"? От предка к потомку? От
    ↳ родителя к ребёнку? От общего к частному?
408
409 ![белая горизонтальная линия, чёрная горизонтальная
    ↳ стрелка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/7.png
    ↳ "белая горизонтальная линия, чёрная горизонтальная
    ↳ стрелка")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/7.png)
410

```

```

411 Шаг назад. Возьмём опять отделённую область, которая лишь та же замкнутая линия, что ещё она
    ↳ может представлять собой? Объект? Но в чём его суть? Разве не в том, что у него есть
    ↳ граница, разделяющая внутреннее и внешнее? Допустим связь, стрелка, линия соединяет два
    ↳ объекта, как бы это выглядело?
412
413 [![белая связь, чёрная направленная
    ↳ связь](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/8.png "белая
    ↳ связь, чёрная направленная
    ↳ связь")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/8.png)
414
415 Допустим у нас есть смысл ""связать"" и смысл ""направления"", много ли это нам даёт? Много ли
    ↳ вариантов интерпретации? А что если уточнить, каким именно образом выполнена связь? Что если
    ↳ можно задать ей чёткий, конкретный смысл? Что это будет? Тип? Глагол? Связка? Действие?
    ↳ Трансформация? Переход из состояния в состояние? Или всё это и есть объект, суть которого в
    ↳ его конечном состоянии, если конечно конец определён направлением?
416
417 [![белая обычная и направленная связи, чёрная типизированная
    ↳ связь](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/9.png "белая
    ↳ обычная и направленная связи, чёрная типизированная
    ↳ связь")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/9.png)
418
419 А что если всё это время, мы смотрели на суть как бы снаружи? Можно ли взглянуть на это изнутри?
    ↳ Что будет внутри объектов? Объекты ли это? Или это связи? Может ли эта структура описать
    ↳ сама себя? Но что тогда получится, разве это не рекурсия? Может это фрактал?
420
421 [![белая обычная и направленная связи с рекурсивной внутренней структурой, чёрная типизированная
    ↳ связь с рекурсивной внутренней
    ↳ структурой](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/10.png
    ↳ ""белая обычная и направленная связи с рекурсивной внутренней структурой, чёрная
    ↳ типизированная связь с рекурсивной внутренней структурой"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/10.png)
422
423 На один уровень внутрь (вниз)? Или на один уровень во вне (вверх)? Или это можно назвать шагом
    ↳ рекурсии или фрактала?
424
425 [![белая обычная и направленная связи с двойной рекурсивной внутренней структурой, чёрная
    ↳ типизированная связь с двойной рекурсивной внутренней
    ↳ структурой](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/11.png
    ↳ ""белая обычная и направленная связи с двойной рекурсивной внутренней структурой, чёрная
    ↳ типизированная связь с двойной рекурсивной внутренней структурой"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/11.png)
426
427 Последовательность? Массив? Список? Множество? Объект? Таблица? Элементы? Цвета? Символы? Буквы?
    ↳ Слово? Цифры? Число? Алфавит? Дерево? Сеть? Граф? Гиперграф?
428
429 [![белая обычная и направленная связи со структурой из 8 цветных элементов последовательности,
    ↳ чёрная типизированная связь со структурой из 8 цветных элементов последовательности](https://
    ↳ raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/12.png "белая обычная и
    ↳ направленная связи со структурой из 8 цветных элементов последовательности, чёрная
    ↳ типизированная связь со структурой из 8 цветных элементов последовательности"")](https://raw
    ↳ .githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/12.png)
430
431 ...
432
433 [![анимация](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro-animat
    ↳ ion-500.gif
    ↳ ""анимация"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro
    ↳ -animation-500.gif)";
434
435     private static readonly string _exampleLoremIpsumText =
436         @"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor
            ↳ incididunt ut labore et dolore magna aliqua.
437 Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo
    ↳ consequat.";
438
439     [Fact]
440     public static void CompressionTest()
441     {
442         using (var scope = new TempLinksTestScope(useSequences: true))
443         {
444             var links = scope.Links;
445             var sequences = scope.Sequences;
446
447             var e1 = links.Create();
448             var e2 = links.Create();
449
450             var sequence = new[]
451             {
452                 e1, e2, e1, e2 // mama / papa / template [(m/p), a] { [1] [2] [1] [2] }

```



```

453     };
454
455     var balancedVariantConverter = new BalancedVariantConverter<ulong>(links.Unsync);
456     var totalSequenceSymbolFrequencyCounter = new
457         ↳ TotalSequenceSymbolFrequencyCounter<ulong>(links.Unsync);
458     var doubletFrequenciesCache = new LinkFrequenciesCache<ulong>(links.Unsync,
459         ↳ totalSequenceSymbolFrequencyCounter);
460     var compressingConverter = new CompressingConverter<ulong>(links.Unsync,
461         ↳ balancedVariantConverter, doubletFrequenciesCache);
462
463     var compressedVariant = compressingConverter.Convert(sequence);
464
465     // 1: [1]          (1->1) point
466     // 2: [2]          (2->2) point
467     // 3: [1,2]        (1->2) doublet
468     // 4: [1,2,1,2]    (3->3) doublet
469
470     Assert.True(links.GetSource(links.GetSource(compressedVariant)) == sequence[0]);
471     Assert.True(links.GetTarget(links.GetSource(compressedVariant)) == sequence[1]);
472     Assert.True(links.GetSource(links.GetTarget(compressedVariant)) == sequence[2]);
473     Assert.True(links.GetTarget(links.GetTarget(compressedVariant)) == sequence[3]);
474
475     var source = _constants.SourcePart;
476     var target = _constants.TargetPart;
477
478     Assert.True(links.GetByKeys(compressedVariant, source, source) == sequence[0]);
479     Assert.True(links.GetByKeys(compressedVariant, source, target) == sequence[1]);
480     Assert.True(links.GetByKeys(compressedVariant, target, source) == sequence[2]);
481     Assert.True(links.GetByKeys(compressedVariant, target, target) == sequence[3]);
482
483     // 4 - length of sequence
484     Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 0)
485         ↳ == sequence[0]);
486     Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 1)
487         ↳ == sequence[1]);
488     Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 2)
489         ↳ == sequence[2]);
490     Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 3)
491         ↳ == sequence[3]);
492 }
493
494 [Fact]
495 public static void CompressionEfficiencyTest()
496 {
497     var strings = _exampleLoremIpsumText.Split(new[] { '\n', '\r' },
498         ↳ StringSplitOptions.RemoveEmptyEntries);
499     var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
500     var totalCharacters = arrays.Select(x => x.Length).Sum();
501
502     using (var scope1 = new TempLinksTestScope(useSequences: true))
503     using (var scope2 = new TempLinksTestScope(useSequences: true))
504     using (var scope3 = new TempLinksTestScope(useSequences: true))
505     {
506         scope1.Links.Unsync.UseUnicode();
507         scope2.Links.Unsync.UseUnicode();
508         scope3.Links.Unsync.UseUnicode();
509
510         var balancedVariantConverter1 = new
511             ↳ BalancedVariantConverter<ulong>(scope1.Links.Unsync);
512         var totalSequenceSymbolFrequencyCounter = new
513             ↳ TotalSequenceSymbolFrequencyCounter<ulong>(scope1.Links.Unsync);
514         var linkFrequenciesCache1 = new LinkFrequenciesCache<ulong>(scope1.Links.Unsync,
515             ↳ totalSequenceSymbolFrequencyCounter);
516         var compressor1 = new CompressingConverter<ulong>(scope1.Links.Unsync,
517             ↳ balancedVariantConverter1, linkFrequenciesCache1,
518             ↳ doInitialFrequenciesIncrement: false);
519
520         //var compressor2 = scope2.Sequences;
521         var compressor3 = scope3.Sequences;
522
523         var constants = Default<LinksConstants<ulong>>.Instance;
524
525         var sequences = compressor3;
526         //var meaningRoot = links.CreatePoint();
527         //var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
528         //var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);

```

```

517 //var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
518     ↳ constants.Itself);
519
520 //var unaryNumberToAddressConverter = new
521     ↳ UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
522 //var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links,
523     ↳ unaryOne);
524 //var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
525     ↳ frequencyMarker, unaryOne, unaryNumberIncrementer);
526 //var frequencyPropertyOperator = new FrequencyPropertyOperator<ulong>(links,
527     ↳ frequencyPropertyMarker, frequencyMarker);
528 //var linkFrequencyIncrementer = new LinkFrequencyIncrementer<ulong>(links,
529     ↳ frequencyPropertyOperator, frequencyIncrementer);
530 //var linkToItsFrequencyNumberConverter = new
531     ↳ LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
532     ↳ unaryNumberToAddressConverter);
533
534 var linkFrequenciesCache3 = new LinkFrequenciesCache<ulong>(scope3.Links.Unsync,
535     ↳ totalSequenceSymbolFrequencyCounter);
536
537 var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFreque_
538     ↳ ncyNumberConverter<ulong>(linkFrequenciesCache3);
539
540 var sequenceToItsLocalElementLevelsConverter = new
541     ↳ SequenceToItsLocalElementLevelsConverter<ulong>(scope3.Links.Unsync,
542     ↳ linkToItsFrequencyNumberConverter);
543 var optimalVariantConverter = new
544     ↳ OptimalVariantConverter<ulong>(scope3.Links.Unsync,
545     ↳ sequenceToItsLocalElementLevelsConverter);
546
547 var compressed1 = new ulong[arrays.Length];
548 var compressed2 = new ulong[arrays.Length];
549 var compressed3 = new ulong[arrays.Length];
550
551 var START = 0;
552 var END = arrays.Length;
553
554 //for (int i = START; i < END; i++)
555 //    linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
556
557 var initialCount1 = scope2.Links.Unsync.Count();
558
559 var sw1 = Stopwatch.StartNew();
560
561 for (int i = START; i < END; i++)
562 {
563     linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
564     compressed1[i] = compressor1.Convert(arrays[i]);
565 }
566
567 var elapsed1 = sw1.Elapsed;
568
569 var balancedVariantConverter2 = new
570     ↳ BalancedVariantConverter<ulong>(scope2.Links.Unsync);
571
572 var initialCount2 = scope2.Links.Unsync.Count();
573
574 var sw2 = Stopwatch.StartNew();
575
576 for (int i = START; i < END; i++)
577 {
578     compressed2[i] = balancedVariantConverter2.Convert(arrays[i]);
579 }
580
581 var elapsed2 = sw2.Elapsed;
582
583 for (int i = START; i < END; i++)
584 {
585     linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
586 }
587
588 var initialCount3 = scope3.Links.Unsync.Count();
589
590 var sw3 = Stopwatch.StartNew();
591
592 for (int i = START; i < END; i++)
593 {
594     //linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
595     compressed3[i] = optimalVariantConverter.Convert(arrays[i]);

```

```

581     }
582
583     var elapsed3 = sw3.Elapsed;
584
585     Console.WriteLine($"Compressor: {elapsed1}, Balanced variant: {elapsed2},
586         ↳ Optimal variant: {elapsed3}");
587
588     // Assert.True(elapsed1 > elapsed2);
589
590     // Checks
591     for (int i = START; i < END; i++)
592     {
593         var sequence1 = compressed1[i];
594         var sequence2 = compressed2[i];
595         var sequence3 = compressed3[i];
596
597         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
598             ↳ scope1.Links.Unsync);
599
600         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
601             ↳ scope2.Links.Unsync);
602
603         var decompress3 = UnicodeMap.FromSequenceLinkToString(sequence3,
604             ↳ scope3.Links.Unsync);
605
606         var structure1 = scope1.Links.Unsync.FormatStructure(sequence1, link =>
607             ↳ link.IsPartialPoint());
608         var structure2 = scope2.Links.Unsync.FormatStructure(sequence2, link =>
609             ↳ link.IsPartialPoint());
610         var structure3 = scope3.Links.Unsync.FormatStructure(sequence3, link =>
611             ↳ link.IsPartialPoint());
612
613         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
614             ↳ arrays[i].Length > 3)
615         //    Assert.False(structure1 == structure2);
616         //if (sequence3 != Constants.Null && sequence2 != Constants.Null &&
617             ↳ arrays[i].Length > 3)
618         //    Assert.False(structure3 == structure2);
619
620         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
621         Assert.True(strings[i] == decompress3 && decompress3 == decompress2);
622     }
623
624     Assert.True((int)(scope1.Links.Unsync.Count() - initialCount1) <
625         ↳ totalCharacters);
626     Assert.True((int)(scope2.Links.Unsync.Count() - initialCount2) <
627         ↳ totalCharacters);
628     Assert.True((int)(scope3.Links.Unsync.Count() - initialCount3) <
629         ↳ totalCharacters);
630
631     Console.WriteLine($"{{(double)(scope1.Links.Unsync.Count() - initialCount1) /
632         ↳ totalCharacters}} | {{(double)(scope2.Links.Unsync.Count() - initialCount2) /
633         ↳ totalCharacters}} | {{(double)(scope3.Links.Unsync.Count() - initialCount3) /
634         ↳ totalCharacters}}");
635
636     Assert.True(scope1.Links.Unsync.Count() - initialCount1 <
637         ↳ scope2.Links.Unsync.Count() - initialCount2);
638     Assert.True(scope3.Links.Unsync.Count() - initialCount3 <
639         ↳ scope2.Links.Unsync.Count() - initialCount2);
640
641     var duplicateProvider1 = new
642         ↳ DuplicateSegmentsProvider<ulong>(scope1.Links.Unsync, scope1.Sequences);
643     var duplicateProvider2 = new
644         ↳ DuplicateSegmentsProvider<ulong>(scope2.Links.Unsync, scope2.Sequences);
645     var duplicateProvider3 = new
646         ↳ DuplicateSegmentsProvider<ulong>(scope3.Links.Unsync, scope3.Sequences);
647
648     var duplicateCounter1 = new DuplicateSegmentsCounter<ulong>(duplicateProvider1);
649     var duplicateCounter2 = new DuplicateSegmentsCounter<ulong>(duplicateProvider2);
650     var duplicateCounter3 = new DuplicateSegmentsCounter<ulong>(duplicateProvider3);
651
652     var duplicates1 = duplicateCounter1.Count();
653
654     ConsoleHelpers.Debug("-----");
655
656     var duplicates2 = duplicateCounter2.Count();
657
658     ConsoleHelpers.Debug("-----");

```

```

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
669         ↪ SequencesOptions<ulong> { UseCompression = true,
670         ↪ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
671     using (var scope2 = new TempLinksTestScope(useSequences: true))
672     {
673         scope1.Links.UseUnicode();
674         scope2.Links.UseUnicode();
675
676         //var compressor1 = new Compressor(scope1.Links.Unsync, scope1.Sequences);
677         var compressor1 = scope1.Sequences;
678         var compressor2 = scope2.Sequences;
679
680         var compressed1 = new ulong[arrays.Length];
681         var compressed2 = new ulong[arrays.Length];
682
683         var sw1 = Stopwatch.StartNew();
684
685         var START = 0;
686         var END = arrays.Length;
687
688         // Collisions proved (cannot be solved by max doublet comparison, no stable rule)
689         // Stability issue starts at 10001 or 11000
690         //for (int i = START; i < END; i++)
691         //{
692         //    var first = compressor1.Compress(arrays[i]);
693         //    var second = compressor1.Compress(arrays[i]);
694
695         //    if (first == second)
696         //        compressed1[i] = first;
697         //    else
698         //    {
699         //        // TODO: Find a solution for this case
700         //    }
701         //}
702
703         for (int i = START; i < END; i++)
704         {
705             var first = compressor1.Create(arrays[i].ShiftRight());
706             var second = compressor1.Create(arrays[i].ShiftRight());
707
708             if (first == second)
709             {
710                 compressed1[i] = first;
711             }
712             else
713             {
714                 // TODO: Find a solution for this case
715             }
716         }
717     }
718 }

```

```

716     var elapsed1 = sw1.Elapsed;
717
718     var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
719
720     var sw2 = Stopwatch.StartNew();
721
722     for (int i = START; i < END; i++)
723     {
724         var first = balancedVariantConverter.Convert(arrays[i]);
725         var second = balancedVariantConverter.Convert(arrays[i]);
726
727         if (first == second)
728         {
729             compressed2[i] = first;
730         }
731     }
732
733     var elapsed2 = sw2.Elapsed;
734
735     Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
736     ↪ {elapsed2}");
737
738     Assert.True(elapsed1 > elapsed2);
739
740     // Checks
741     for (int i = START; i < END; i++)
742     {
743         var sequence1 = compressed1[i];
744         var sequence2 = compressed2[i];
745
746         if (sequence1 != _constants.Null && sequence2 != _constants.Null)
747         {
748             var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
749             ↪ scope1.Links);
750
751             var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
752             ↪ scope2.Links);
753
754             //var structure1 = scope1.Links.FormatStructure(sequence1, link =>
755             ↪ link.IsPartialPoint());
756             //var structure2 = scope2.Links.FormatStructure(sequence2, link =>
757             ↪ link.IsPartialPoint());
758
759             //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
760             ↪ arrays[i].Length > 3)
761             //    Assert.False(structure1 == structure2);
762
763             Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
764         }
765     }
766
767     Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
768     Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
769
770     Debug.WriteLine($"{{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
771     ↪ totalCharacters}} | {{(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
772     ↪ totalCharacters}}");
773
774     Assert.True(scope1.Links.Count() <= scope2.Links.Count());
775
776     //compressor1.ValidateFrequencies();
777 }
778
779 [Fact]
780 public static void RandomNumbersCompressionQualityTest()
781 {
782     const ulong N = 500;
783
784     //const ulong minNumbers = 10000;
785     //const ulong maxNumbers = 20000;
786
787     //var strings = new List<string>();
788
789     //for (ulong i = 0; i < N; i++)
790     //    strings.Add(RandomHelpers.DefaultFactory.NextUInt64(minNumbers,
791     ↪ maxNumbers).ToString());

```

```

786 var strings = new List<string>();
787
788 for (ulong i = 0; i < N; i++)
789 {
790     strings.Add(RandomHelpers.Default.NextUInt64().ToString());
791 }
792
793 strings = strings.Distinct().ToList();
794
795 var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
796 var totalCharacters = arrays.Select(x => x.Length).Sum();
797
798 using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
    ↳ SequencesOptions<ulong> { UseCompression = true,
    ↳ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
    using (var scope2 = new TempLinksTestScope(useSequences: true))
    {
799         scope1.Links.UseUnicode();
800         scope2.Links.UseUnicode();
801
802         var compressor1 = scope1.Sequences;
803         var compressor2 = scope2.Sequences;
804
805         var compressed1 = new ulong[arrays.Length];
806         var compressed2 = new ulong[arrays.Length];
807
808         var sw1 = Stopwatch.StartNew();
809
810         var START = 0;
811         var END = arrays.Length;
812
813         for (int i = START; i < END; i++)
814         {
815             compressed1[i] = compressor1.Create(arrays[i].ShiftRight());
816         }
817
818         var elapsed1 = sw1.Elapsed;
819
820         var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
821
822         var sw2 = Stopwatch.StartNew();
823
824         for (int i = START; i < END; i++)
825         {
826             compressed2[i] = balancedVariantConverter.Convert(arrays[i]);
827         }
828
829         var elapsed2 = sw2.Elapsed;
830
831         Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
832             ↳ {elapsed2}");
833
834         Assert.True(elapsed1 > elapsed2);
835
836         // Checks
837         for (int i = START; i < END; i++)
838         {
839             var sequence1 = compressed1[i];
840             var sequence2 = compressed2[i];
841
842             if (sequence1 != _constants.Null && sequence2 != _constants.Null)
843             {
844                 var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
845                     ↳ scope1.Links);
846
847                 var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
848                     ↳ scope2.Links);
849
850                 Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
851             }
852         }
853
854         Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
855         Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
856
857         Debug.WriteLine($"{{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
    ↳ totalCharacters}} | {{(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
    ↳ totalCharacters}}");

```

```

858         // Can be worse than balanced variant
859         //Assert.True(scope1.Links.Count() <= scope2.Links.Count());
860
861         //compressor1.ValidateFrequencies();
862     }
863 }
864
865 [Fact]
866 public static void AllTreeBreakDownAtSequencesCreationBugTest()
867 {
868     // Made out of AllPossibleConnectionsTest test.
869
870     //const long sequenceLength = 5; //100% bug
871     const long sequenceLength = 4; //100% bug
872     //const long sequenceLength = 3; //100% _no_bug (ok)
873
874     using (var scope = new TempLinksTestScope(useSequences: true))
875     {
876         var links = scope.Links;
877         var sequences = scope.Sequences;
878
879         var sequence = new ulong[sequenceLength];
880         for (var i = 0; i < sequenceLength; i++)
881         {
882             sequence[i] = links.Create();
883         }
884
885         var createResults = sequences.CreateAllVariants2(sequence);
886
887         Global.Trash = createResults;
888
889         for (var i = 0; i < sequenceLength; i++)
890         {
891             links.Delete(sequence[i]);
892         }
893     }
894 }
895
896 [Fact]
897 public static void AllPossibleConnectionsTest()
898 {
899     const long sequenceLength = 5;
900
901     using (var scope = new TempLinksTestScope(useSequences: true))
902     {
903         var links = scope.Links;
904         var sequences = scope.Sequences;
905
906         var sequence = new ulong[sequenceLength];
907         for (var i = 0; i < sequenceLength; i++)
908         {
909             sequence[i] = links.Create();
910         }
911
912         var createResults = sequences.CreateAllVariants2(sequence);
913         var reverseResults = sequences.CreateAllVariants2(sequence.Reverse().ToArray());
914
915         for (var i = 0; i < 1; i++)
916         {
917             var sw1 = Stopwatch.StartNew();
918             var searchResults1 = sequences.GetAllConnections(sequence); sw1.Stop();
919
920             var sw2 = Stopwatch.StartNew();
921             var searchResults2 = sequences.GetAllConnections1(sequence); sw2.Stop();
922
923             var sw3 = Stopwatch.StartNew();
924             var searchResults3 = sequences.GetAllConnections2(sequence); sw3.Stop();
925
926             var sw4 = Stopwatch.StartNew();
927             var searchResults4 = sequences.GetAllConnections3(sequence); sw4.Stop();
928
929             Global.Trash = searchResults3;
930             Global.Trash = searchResults4; //-V3008
931
932             var intersection1 = createResults.Intersect(searchResults1).ToList();
933             Assert.True(intersection1.Count == createResults.Length);
934
935             var intersection2 = reverseResults.Intersect(searchResults1).ToList();
936             Assert.True(intersection2.Count == reverseResults.Length);
937

```

```

938         var intersection0 = searchResults1.Intersect(searchResults2).ToList();
939         Assert.True(intersection0.Count == searchResults2.Count);
940
941         var intersection3 = searchResults2.Intersect(searchResults3).ToList();
942         Assert.True(intersection3.Count == searchResults3.Count);
943
944         var intersection4 = searchResults3.Intersect(searchResults4).ToList();
945         Assert.True(intersection4.Count == searchResults4.Count);
946     }
947
948     for (var i = 0; i < sequenceLength; i++)
949     {
950         links.Delete(sequence[i]);
951     }
952 }
953
954 [Fact(Skip = "Correct implementation is pending")]
955 public static void CalculateAllUsagesTest()
956 {
957     const long sequenceLength = 3;
958
959     using (var scope = new TempLinksTestScope(useSequences: true))
960     {
961         var links = scope.Links;
962         var sequences = scope.Sequences;
963
964         var sequence = new ulong[sequenceLength];
965         for (var i = 0; i < sequenceLength; i++)
966         {
967             sequence[i] = links.Create();
968         }
969
970         var createResults = sequences.CreateAllVariants2(sequence);
971
972         //var reverseResults =
973         ↪ sequences.CreateAllVariants2(sequence.Reverse().ToArray());
974
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 }
996 }

```

1.121 ./csharp/Platform.Data.Doublets.Tests/SplitMemoryGenericLinksTests.cs

```

1  using System;
2  using Xunit;
3  using Platform.Memory;
4  using Platform.Data.Doublets.Memory.Split.Generic;
5
6  namespace Platform.Data.Doublets.Tests
7  {
8      public unsafe static class SplitMemoryGenericLinksTests
9      {
10         [Fact]
11         public static void CRUDTest()
12         {
13             Using<byte>(links => links.TestCRUDOperations());
14             Using<ushort>(links => links.TestCRUDOperations());
15             Using<uint>(links => links.TestCRUDOperations());
16             Using<ulong>(links => links.TestCRUDOperations());
17         }
18     }

```



```

19 [Fact]
20 public static void RawNumbersCRUDTest()
21 {
22     UsingWithExternalReferences<byte>(links => links.TestRawNumbersCRUDOperations());
23     UsingWithExternalReferences<ushort>(links => links.TestRawNumbersCRUDOperations());
24     UsingWithExternalReferences<uint>(links => links.TestRawNumbersCRUDOperations());
25     UsingWithExternalReferences<ulong>(links => links.TestRawNumbersCRUDOperations());
26 }
27
28 [Fact]
29 public static void MultipleRandomCreationsAndDeletionsTest()
30 {
31     Using<byte>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Test
32         ↪ MultipleRandomCreationsAndDeletions(16)); // Cannot use more because current
33         ↪ implementation of tree cuts out 5 bits from the address space.
34     Using<ushort>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Te
35         ↪ stMultipleRandomCreationsAndDeletions(100));
36     Using<uint>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Test
37         ↪ MultipleRandomCreationsAndDeletions(100));
38     Using<ulong>(links => links.DecorateWithAutomaticUniquenessAndUsagesResolution().Tes
39         ↪ tMultipleRandomCreationsAndDeletions(100));
40 }
41
42 private static void Using<TLink>(Action<ILinks<TLink>> action)
43 {
44     using (var dataMemory = new HeapResizableDirectMemory())
45     using (var indexMemory = new HeapResizableDirectMemory())
46     using (var memory = new SplitMemoryLinks<TLink>(dataMemory, indexMemory))
47     {
48         action(memory);
49     }
50 }
51
52 private static void UsingWithExternalReferences<TLink>(Action<ILinks<TLink>> action)
53 {
54     var constants = new LinksConstants<TLink>(enableExternalReferencesSupport: true);
55     using (var dataMemory = new HeapResizableDirectMemory())
56     using (var indexMemory = new HeapResizableDirectMemory())
57     using (var memory = new SplitMemoryLinks<TLink>(dataMemory, indexMemory,
58         ↪ SplitMemoryLinks<TLink>.DefaultLinksSizeStep, constants))
59     {
60         action(memory);
61     }
62 }
63 }
64 }

```

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

```

1  using System.IO;
2  using Platform.Disposables;
3  using Platform.Data.Doublets.Sequences;
4  using Platform.Data.Doublets.Decorators;
5  using Platform.Data.Doublets.Memory.United.Specific;
6
7  namespace Platform.Data.Doublets.Tests
8  {
9      public class TempLinksTestScope : DisposableBase
10     {
11         public ILinks<ulong> MemoryAdapter { get; }
12         public SynchronizedLinks<ulong> Links { get; }
13         public Sequences.Sequences Sequences { get; }
14         public string TempFilename { get; }
15         public string TempTransactionLogFilename { get; }
16         private readonly bool _deleteFiles;
17
18         public TempLinksTestScope(bool deleteFiles = true, bool useSequences = false, bool
19             ↪ useLog = false) : this(new SequencesOptions<ulong>(), deleteFiles, useSequences,
20             ↪ useLog) { }
21
22         public TempLinksTestScope(SequencesOptions<ulong> sequencesOptions, bool deleteFiles =
23             ↪ true, bool useSequences = false, bool useLog = false)
24         {
25             _deleteFiles = deleteFiles;
26             TempFilename = Path.GetTempFileName();
27             TempTransactionLogFilename = Path.GetTempFileName();
28             var coreMemoryAdapter = new UInt64UnitedMemoryLinks(TempFilename);
29             MemoryAdapter = useLog ? (ILinks<ulong>)new
30                 ↪ UInt64LinksTransactionsLayer(coreMemoryAdapter, TempTransactionLogFilename) :
31                 ↪ coreMemoryAdapter;

```

```

27     Links = new SynchronizedLinks<ulong>(new UInt64Links(MemoryAdapter));
28     if (useSequences)
29     {
30         Sequences = new Sequences.Sequences(Links, sequencesOptions);
31     }
32 }
33
34 protected override void Dispose(bool manual, bool wasDisposed)
35 {
36     if (!wasDisposed)
37     {
38         Links.Unsync.DisposeIfPossible();
39         if (_deleteFiles)
40         {
41             DeleteFiles();
42         }
43     }
44 }
45
46 public void DeleteFiles()
47 {
48     File.Delete(TempFilename);
49     File.Delete(TempTransactionLogFilename);
50 }
51 }
52 }

```

1.123 ./csharp/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  using Platform.Converters;
8
9  namespace Platform.Data.Doublets.Tests
10 {
11     public static class TestExtensions
12     {
13         public static void TestCRUDOperations<T>(this ILinks<T> links)
14         {
15             var constants = links.Constants;
16
17             var equalityComparer = EqualityComparer<T>.Default;
18
19             var zero = default(T);
20             var one = Arithmetic.Increment(zero);
21
22             // Create Link
23             Assert.True(equalityComparer.Equals(links.Count(), zero));
24
25             var setter = new Setter<T>(constants.Null);
26             links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);
27
28             Assert.True(equalityComparer.Equals(setter.Result, constants.Null));
29
30             var linkAddress = links.Create();
31
32             var link = new Link<T>(links.GetLink(linkAddress));
33
34             Assert.True(link.Count == 3);
35             Assert.True(equalityComparer.Equals(link.Index, linkAddress));
36             Assert.True(equalityComparer.Equals(link.Source, constants.Null));
37             Assert.True(equalityComparer.Equals(link.Target, constants.Null));
38
39             Assert.True(equalityComparer.Equals(links.Count(), one));
40
41             // Get first link
42             setter = new Setter<T>(constants.Null);
43             links.Each(constants.Any, constants.Any, setter.SetAndReturnFalse);
44
45             Assert.True(equalityComparer.Equals(setter.Result, linkAddress));
46
47             // Update link to reference itself
48             links.Update(linkAddress, linkAddress, linkAddress);
49
50             link = new Link<T>(links.GetLink(linkAddress));
51
52             Assert.True(equalityComparer.Equals(link.Source, linkAddress));

```

```

53     Assert.True(equalityComparer.Equals(link.Target, linkAddress));
54
55     // Update link to reference null (prepare for delete)
56     var updated = links.Update(linkAddress, constants.Null, constants.Null);
57
58     Assert.True(equalityComparer.Equals(updated, linkAddress));
59
60     link = new Link<T>(links.GetLink(linkAddress));
61
62     Assert.True(equalityComparer.Equals(link.Source, constants.Null));
63     Assert.True(equalityComparer.Equals(link.Target, constants.Null));
64
65     // Delete link
66     links.Delete(linkAddress);
67
68     Assert.True(equalityComparer.Equals(links.Count(), zero));
69
70     setter = new Setter<T>(constants.Null);
71     links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);
72
73     Assert.True(equalityComparer.Equals(setter.Result, constants.Null));
74 }
75
76 public static void TestRawNumbersCRUDOperations<T>(this ILinks<T> links)
77 {
78     // Constants
79     var constants = links.Constants;
80     var equalityComparer = EqualityComparer<T>.Default;
81
82     var zero = default(T);
83     var one = Arithmetic.Increment(zero);
84     var two = Arithmetic.Increment(one);
85
86     var h106E = new Hybrid<T>(106L, isExternal: true);
87     var h107E = new Hybrid<T>(-char.ConvertFromUtf32(107)[0]);
88     var h108E = new Hybrid<T>(-108L);
89
90     Assert.Equal(106L, h106E.AbsoluteValue);
91     Assert.Equal(107L, h107E.AbsoluteValue);
92     Assert.Equal(108L, h108E.AbsoluteValue);
93
94     // Create Link (External -> External)
95     var linkAddress1 = links.Create();
96
97     links.Update(linkAddress1, h106E, h108E);
98
99     var link1 = new Link<T>(links.GetLink(linkAddress1));
100
101     Assert.True(equalityComparer.Equals(link1.Source, h106E));
102     Assert.True(equalityComparer.Equals(link1.Target, h108E));
103
104     // Create Link (Internal -> External)
105     var linkAddress2 = links.Create();
106
107     links.Update(linkAddress2, linkAddress1, h108E);
108
109     var link2 = new Link<T>(links.GetLink(linkAddress2));
110
111     Assert.True(equalityComparer.Equals(link2.Source, linkAddress1));
112     Assert.True(equalityComparer.Equals(link2.Target, h108E));
113
114     // Create Link (Internal -> Internal)
115     var linkAddress3 = links.Create();
116
117     links.Update(linkAddress3, linkAddress1, linkAddress2);
118
119     var link3 = new Link<T>(links.GetLink(linkAddress3));
120
121     Assert.True(equalityComparer.Equals(link3.Source, linkAddress1));
122     Assert.True(equalityComparer.Equals(link3.Target, linkAddress2));
123
124     // Search for created link
125     var setter1 = new Setter<T>(constants.Null);
126     links.Each(h106E, h108E, setter1.SetAndReturnFalse);
127
128     Assert.True(equalityComparer.Equals(setter1.Result, linkAddress1));
129
130     // Search for nonexistent link
131     var setter2 = new Setter<T>(constants.Null);
132     links.Each(h106E, h107E, setter2.SetAndReturnFalse);

```

```

133     Assert.True(equalityComparer.Equals(setter2.Result, constants.Null));
134
135     // Update link to reference null (prepare for delete)
136     var updated = links.Update(linkAddress3, constants.Null, constants.Null);
137
138     Assert.True(equalityComparer.Equals(updated, linkAddress3));
139
140     link3 = new Link<T>(links.GetLink(linkAddress3));
141
142     Assert.True(equalityComparer.Equals(link3.Source, constants.Null));
143     Assert.True(equalityComparer.Equals(link3.Target, constants.Null));
144
145     // Delete link
146     links.Delete(linkAddress3);
147
148     Assert.True(equalityComparer.Equals(links.Count(), two));
149
150     var setter3 = new Setter<T>(constants.Null);
151     links.Each(constants.Any, constants.Any, setter3.SetAndReturnTrue);
152
153     Assert.True(equalityComparer.Equals(setter3.Result, linkAddress2));
154 }
155
156 public static void TestMultipleRandomCreationsAndDeletions<TLink>(this ILinks<TLink>
157     ↪ links, int maximumOperationsPerCycle)
158 {
159     var comparer = Comparer<TLink>.Default;
160     var addressToUInt64Converter = CheckedConverter<TLink, ulong>.Default;
161     var uint64ToAddressConverter = CheckedConverter<ulong, TLink>.Default;
162     for (var N = 1; N < maximumOperationsPerCycle; N++)
163     {
164         var random = new System.Random(N);
165         var created = 0UL;
166         var deleted = 0UL;
167         for (var i = 0; i < N; i++)
168         {
169             var linksCount = addressToUInt64Converter.Convert(links.Count());
170             var createPoint = random.NextBoolean();
171             if (linksCount > 2 && createPoint)
172             {
173                 var linksAddressRange = new Range<ulong>(1, linksCount);
174                 TLink source = uint64ToAddressConverter.Convert(random.NextUInt64(linksA_
175                     ↪ ddressRange));
176                 TLink target = uint64ToAddressConverter.Convert(random.NextUInt64(linksA_
177                     ↪ ddressRange));
178                 ↪ //-V3086
179                 var resultLink = links.GetOrCreate(source, target);
180                 if (comparer.Compare(resultLink,
181                     ↪ uint64ToAddressConverter.Convert(linksCount)) > 0)
182                 {
183                     created++;
184                 }
185             }
186             else
187             {
188                 links.Create();
189                 created++;
190             }
191         }
192         Assert.True(created == addressToUInt64Converter.Convert(links.Count()));
193         for (var i = 0; i < N; i++)
194         {
195             TLink link = uint64ToAddressConverter.Convert((ulong)i + 1UL);
196             if (links.Exists(link))
197             {
198                 links.Delete(link);
199                 deleted++;
200             }
201         }
202         Assert.True(addressToUInt64Converter.Convert(links.Count()) == 0L);
203     }
204 }

```

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

```

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

```

```

3 using System.Diagnostics;
4 using System.IO;
5 using System.Text;
6 using System.Threading;
7 using System.Threading.Tasks;
8 using Xunit;
9 using Platform.Disposables;
10 using Platform.Ranges;
11 using Platform.Random;
12 using Platform.Timestamps;
13 using Platform.Reflection;
14 using Platform.Singletons;
15 using Platform.Scopes;
16 using Platform.Counters;
17 using Platform.Diagnostics;
18 using Platform.IO;
19 using Platform.Memory;
20 using Platform.Data.Doublets.Decorators;
21 using Platform.Data.Doublets.Memory.United.Specific;
22
23 namespace Platform.Data.Doublets.Tests
24 {
25     public static class UInt64LinksTests
26     {
27         private static readonly LinksConstants<ulong> _constants =
28             ↪ Default<LinksConstants<ulong>>.Instance;
29
30         private const long Iterations = 10 * 1024;
31
32         #region Concept
33
34         [Fact]
35         public static void MultipleCreateAndDeleteTest()
36         {
37             using (var scope = new Scope<Types<HeapResizableDirectMemory,
38                 ↪ UInt64UnitedMemoryLinks>>())
39             {
40                 new UInt64Links(scope.Use<ILinks<ulong>>()).TestMultipleRandomCreationsAndDeletions(100);
41             }
42         }
43
44         [Fact]
45         public static void CascadeUpdateTest()
46         {
47             var itself = _constants.Itself;
48             using (var scope = new TempLinksTestScope(useLog: true))
49             {
50                 var links = scope.Links;
51
52                 var l1 = links.Create();
53                 var l2 = links.Create();
54
55                 l2 = links.Update(l2, l2, l1, l2);
56
57                 links.CreateAndUpdate(l2, itself);
58                 links.CreateAndUpdate(l2, itself);
59
60                 l2 = links.Update(l2, l1);
61
62                 links.Delete(l2);
63
64                 Global.Trash = links.Count();
65
66                 links.Unsync.DisposeIfPossible(); // Close links to access log
67
68                 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope
69                 ↪ e.TempTransactionLogFilename);
70             }
71         }
72
73         [Fact]
74         public static void BasicTransactionLogTest()
75         {
76             using (var scope = new TempLinksTestScope(useLog: true))
77             {
78                 var links = scope.Links;
79                 var l1 = links.Create();
80                 var l2 = links.Create();
81
82                 Global.Trash = links.Update(l2, l2, l1, l2);
83             }
84         }
85     }
86 }

```

```

80         links.Delete(l1);
81
82         links.Unsync.DisposeIfPossible(); // Close links to access log
83
84         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope
85             ↪ e.TempTransactionLogFilename);
86     }
87 }
88
89 [Fact]
90 public static void TransactionAutoRevertedTest()
91 {
92     // Auto Reverted (Because no commit at transaction)
93     using (var scope = new TempLinksTestScope(useLog: true))
94     {
95         var links = scope.Links;
96         var transactionsLayer = (UInt64LinksTransactionsLayer)scope.MemoryAdapter;
97         using (var transaction = transactionsLayer.BeginTransaction())
98         {
99             var l1 = links.Create();
100             var l2 = links.Create();
101
102             links.Update(l2, l2, l1, l2);
103         }
104
105         Assert.Equal(0UL, links.Count());
106
107         links.Unsync.DisposeIfPossible();
108
109         var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(s
110             ↪ cope.TempTransactionLogFilename);
111         Assert.Single(transitions);
112     }
113 }
114
115 [Fact]
116 public static void TransactionUserCodeErrorNoDataSavedTest()
117 {
118     // User Code Error (Autoreverted), no data saved
119     var itself = _constants.Itself;
120
121     TempLinksTestScope lastScope = null;
122     try
123     {
124         using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
125             ↪ useLog: true))
126         {
127             var links = scope.Links;
128             var transactionsLayer = (UInt64LinksTransactionsLayer)((LinksDisposableDecor
129                 ↪ atorBase<ulong>)links.Unsync).Links;
130             using (var transaction = transactionsLayer.BeginTransaction())
131             {
132                 var l1 = links.CreateAndUpdate(itself, itself);
133                 var l2 = links.CreateAndUpdate(itself, itself);
134
135                 l2 = links.Update(l2, l2, l1, l2);
136
137                 links.CreateAndUpdate(l2, itself);
138                 links.CreateAndUpdate(l2, itself);
139
140                 //Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transi
141                 ↪ tion>(scope.TempTransactionLogFilename);
142
143                 l2 = links.Update(l2, l1);
144
145                 links.Delete(l2);
146
147                 ExceptionThrower();
148
149                 transaction.Commit();
150             }
151
152             Global.Trash = links.Count();
153         }
154     }
155     catch
156     {
157         Assert.False(lastScope == null);
158     }
159 }

```

```

154     var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(l
155     ↪ astScope.TempTransactionLogFilename);
156
157     Assert.True(transitions.Length == 1 && transitions[0].Before.IsNull() &&
158     ↪ transitions[0].After.IsNull());
159
160     lastScope.DeleteFiles();
161 }
162
163 [Fact]
164 public static void TransactionUserCodeErrorSomeDataSavedTest()
165 {
166     // User Code Error (Autoreverted), some data saved
167     var itself = _constants.Itself;
168
169     TempLinksTestScope lastScope = null;
170     try
171     {
172         ulong l1;
173         ulong l2;
174
175         using (var scope = new TempLinksTestScope(useLog: true))
176         {
177             var links = scope.Links;
178             l1 = links.CreateAndUpdate(itself, itself);
179             l2 = links.CreateAndUpdate(itself, itself);
180
181             l2 = links.Update(l2, l2, l1, l2);
182
183             links.CreateAndUpdate(l2, itself);
184             links.CreateAndUpdate(l2, itself);
185
186             links.Unsync.DisposeIfPossible();
187
188             Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(
189             ↪ scope.TempTransactionLogFilename);
190
191             using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
192             ↪ useLog: true))
193             {
194                 var links = scope.Links;
195                 var transactionsLayer = (UInt64LinksTransactionsLayer)links.Unsync;
196                 using (var transaction = transactionsLayer.BeginTransaction())
197                 {
198                     l2 = links.Update(l2, l1);
199
200                     links.Delete(l2);
201
202                     ExceptionThrower();
203
204                     transaction.Commit();
205                 }
206
207                 Global.Trash = links.Count();
208             }
209         }
210     }
211     catch
212     {
213         Assert.False(lastScope == null);
214
215         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(last
216         ↪ Scope.TempTransactionLogFilename);
217
218         lastScope.DeleteFiles();
219     }
220 }
221
222 [Fact]
223 public static void TransactionCommit()
224 {
225     var itself = _constants.Itself;
226
227     var tempDatabaseFilename = Path.GetTempFileName();
228     var tempTransactionLogFilename = Path.GetTempFileName();
229
230     // Commit

```

```

228     using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
    ↪ UInt64UnitedMemoryLinks(tempDatabaseFilename), tempTransactionLogFilename))
229     using (var links = new UInt64Links(memoryAdapter))
230     {
231         using (var transaction = memoryAdapter.BeginTransaction())
232         {
233             var l1 = links.CreateAndUpdate(itself, itself);
234             var l2 = links.CreateAndUpdate(itself, itself);
235
236             Global.Trash = links.Update(l2, l2, l1, l2);
237
238             links.Delete(l1);
239
240             transaction.Commit();
241         }
242
243         Global.Trash = links.Count();
244     }
245
246     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
    ↪ sactionLogFilename);
247
248
249     [Fact]
250     public static void TransactionDamage()
251     {
252         var itself = _constants.Itself;
253
254         var tempDatabaseFilename = Path.GetTempFileName();
255         var tempTransactionLogFilename = Path.GetTempFileName();
256
257         // Commit
258         using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
    ↪ UInt64UnitedMemoryLinks(tempDatabaseFilename), tempTransactionLogFilename))
259         using (var links = new UInt64Links(memoryAdapter))
260         {
261             using (var transaction = memoryAdapter.BeginTransaction())
262             {
263                 var l1 = links.CreateAndUpdate(itself, itself);
264                 var l2 = links.CreateAndUpdate(itself, itself);
265
266                 Global.Trash = links.Update(l2, l2, l1, l2);
267
268                 links.Delete(l1);
269
270                 transaction.Commit();
271             }
272
273             Global.Trash = links.Count();
274         }
275
276         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
    ↪ sactionLogFilename);
277
278         // Damage database
279
280         FileHelpers.WriteFirst(tempTransactionLogFilename, new
    ↪ UInt64LinksTransactionsLayer.Transition(new UniqueTimestampFactory(), 555));
281
282         // Try load damaged database
283         try
284         {
285             // TODO: Fix
286             using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
    ↪ UInt64UnitedMemoryLinks(tempDatabaseFilename), tempTransactionLogFilename))
287             using (var links = new UInt64Links(memoryAdapter))
288             {
289                 Global.Trash = links.Count();
290             }
291         }
292         catch (NotSupportedException ex)
293         {
294             Assert.True(ex.Message == "Database is damaged, autorecovery is not supported
    ↪ yet.");
295         }
296
297         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
    ↪ sactionLogFilename);
298

```



```

299     File.Delete(tempDatabaseFilename);
300     File.Delete(tempTransactionLogFilename);
301 }
302
303 [Fact]
304 public static void Bug1Test()
305 {
306     var tempDatabaseFilename = Path.GetTempFileName();
307     var tempTransactionLogFilename = Path.GetTempFileName();
308
309     var itself = _constants.Itself;
310
311     // User Code Error (Autoreverted), some data saved
312     try
313     {
314         ulong l1;
315         ulong l2;
316
317         using (var memory = new UInt64UnitedMemoryLinks(tempDatabaseFilename))
318         using (var memoryAdapter = new UInt64LinksTransactionsLayer(memory,
319             ↪ tempTransactionLogFilename))
320         using (var links = new UInt64Links(memoryAdapter))
321         {
322             l1 = links.CreateAndUpdate(itself, itself);
323             l2 = links.CreateAndUpdate(itself, itself);
324
325             l2 = links.Update(l2, l2, l1, l2);
326
327             links.CreateAndUpdate(l2, itself);
328             links.CreateAndUpdate(l2, itself);
329         }
330
331         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
332             ↪ TransactionLogFilename);
333
334         using (var memory = new UInt64UnitedMemoryLinks(tempDatabaseFilename))
335         using (var memoryAdapter = new UInt64LinksTransactionsLayer(memory,
336             ↪ tempTransactionLogFilename))
337         using (var links = new UInt64Links(memoryAdapter))
338         {
339             using (var transaction = memoryAdapter.BeginTransaction())
340             {
341                 l2 = links.Update(l2, l1);
342
343                 links.Delete(l2);
344
345                 ExceptionThrower();
346
347                 transaction.Commit();
348             }
349
350             Global.Trash = links.Count();
351         }
352     }
353     catch
354     {
355         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
356             ↪ TransactionLogFilename);
357     }
358
359     File.Delete(tempDatabaseFilename);
360     File.Delete(tempTransactionLogFilename);
361 }
362
363 private static void ExceptionThrower() => throw new InvalidOperationException();
364
365 [Fact]
366 public static void PathsTest()
367 {
368     var source = _constants.SourcePart;
369     var target = _constants.TargetPart;
370
371     using (var scope = new TempLinksTestScope())
372     {
373         var links = scope.Links;
374         var l1 = links.CreatePoint();
375         var l2 = links.CreatePoint();
376
377         var r1 = links.GetByKeys(l1, source, target, source);

```

```

374         var r2 = links.CheckPathExistance(12, 12, 12, 12);
375     }
376 }
377
378 [Fact]
379 public static void RecursiveStringFormattingTest()
380 {
381     using (var scope = new TempLinksTestScope(useSequences: true))
382     {
383         var links = scope.Links;
384         var sequences = scope.Sequences; // TODO: Auto use sequences on Sequences getter.
385
386         var a = links.CreatePoint();
387         var b = links.CreatePoint();
388         var c = links.CreatePoint();
389
390         var ab = links.GetOrCreate(a, b);
391         var cb = links.GetOrCreate(c, b);
392         var ac = links.GetOrCreate(a, c);
393
394         a = links.Update(a, c, b);
395         b = links.Update(b, a, c);
396         c = links.Update(c, a, b);
397
398         Debug.WriteLine(links.FormatStructure(ab, link => link.IsFullPoint(), true));
399         Debug.WriteLine(links.FormatStructure(cb, link => link.IsFullPoint(), true));
400         Debug.WriteLine(links.FormatStructure(ac, link => link.IsFullPoint(), true));
401
402         Assert.True(links.FormatStructure(cb, link => link.IsFullPoint(), true) ==
403             ↪ "(5:(4:5 (6:5 4)) 6)");
404         Assert.True(links.FormatStructure(ac, link => link.IsFullPoint(), true) ==
405             ↪ "(6:(5:(4:5 6) 6) 4)");
406         Assert.True(links.FormatStructure(ab, link => link.IsFullPoint(), true) ==
407             ↪ "(4:(5:4 (6:5 4)) 6)");
408
409         // TODO: Think how to build balanced syntax tree while formatting structure (eg.
410         ↪ "(4:(5:4 6) (6:5 4))" instead of "(4:(5:4 (6:5 4)) 6)"
411
412         Assert.True(sequences.SafeFormatSequence(cb, DefaultFormatter, false) ==
413             ↪ "{{5}{5}{4}{6}}");
414         Assert.True(sequences.SafeFormatSequence(ac, DefaultFormatter, false) ==
415             ↪ "{{5}{6}{6}{4}}");
416         Assert.True(sequences.SafeFormatSequence(ab, DefaultFormatter, false) ==
417             ↪ "{{4}{5}{4}{6}}");
418     }
419 }
420
421 private static void DefaultFormatter(StringBuilder sb, ulong link)
422 {
423     sb.Append(link.ToString());
424 }
425
426 #endregion
427
428 #region Performance
429
430 /*
431 public static void RunAllPerformanceTests()
432 {
433     try
434     {
435         links.TestLinksInSteps();
436     }
437     catch (Exception ex)
438     {
439         ex.WriteToConsole();
440     }
441
442     return;
443
444     try
445     {
446         //ThreadPool.SetMaxThreads(2, 2);
447
448         // Запускаем все тесты дважды, чтобы первоначальная инициализация не повлияла на
449         ↪ результат
450         // Также это дополнительно помогает в отладке
451         // Увеличивает вероятность попадания информации в кэши
452         for (var i = 0; i < 10; i++)

```

```

445     {
446         //0 - 10 ГБ
447         //Каждые 100 МБ срез цифр
448
449         //links.TestGetSourceFunction();
450         //links.TestGetSourceFunctionInParallel();
451         //links.TestGetTargetFunction();
452         //links.TestGetTargetFunctionInParallel();
453         links.Create64BillionLinks();
454
455         links.TestRandomSearchFixed();
456         //links.Create64BillionLinksInParallel();
457         links.TestEachFunction();
458         //links.TestForeach();
459         //links.TestParallelForeach();
460     }
461
462     links.TestDeletionOfAllLinks();
463
464 }
465 catch (Exception ex)
466 {
467     ex.WriteToConsole();
468 }
469 }*/
470
471 /*
472 public static void TestLinksInSteps()
473 {
474     const long gibibyte = 1024 * 1024 * 1024;
475     const long mebibyte = 1024 * 1024;
476
477     var totalLinksToCreate = gibibyte /
↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
478     var linksStep = 102 * mebibyte /
↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
479
480     var creationMeasurements = new List<TimeSpan>();
481     var searchMeasurements = new List<TimeSpan>();
482     var deletionMeasurements = new List<TimeSpan>();
483
484     GetBaseRandomLoopOverhead(linksStep);
485     GetBaseRandomLoopOverhead(linksStep);
486
487     var stepLoopOverhead = GetBaseRandomLoopOverhead(linksStep);
488
489     ConsoleHelpers.Debug("Step loop overhead: {0}.", stepLoopOverhead);
490
491     var loops = totalLinksToCreate / linksStep;
492
493     for (int i = 0; i < loops; i++)
494     {
495         creationMeasurements.Add(Measure(() => links.RunRandomCreations(linksStep)));
496         searchMeasurements.Add(Measure(() => links.RunRandomSearches(linksStep)));
497
498         Console.WriteLine("\rC + S {0}/{1}", i + 1, loops);
499     }
500
501     ConsoleHelpers.Debug();
502
503     for (int i = 0; i < loops; i++)
504     {
505         deletionMeasurements.Add(Measure(() => links.RunRandomDeletions(linksStep)));
506
507         Console.WriteLine("\rD {0}/{1}", i + 1, loops);
508     }
509
510     ConsoleHelpers.Debug();
511
512     ConsoleHelpers.Debug("C S D");
513
514     for (int i = 0; i < loops; i++)
515     {
516         ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i],
↪ searchMeasurements[i], deletionMeasurements[i]);
517     }
518
519     ConsoleHelpers.Debug("C S D (no overhead)");
520

```

```

521         for (int i = 0; i < loops; i++)
522         {
523             ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i] - stepLoopOverhead,
↪ searchMeasurements[i] - stepLoopOverhead, deletionMeasurements[i] - stepLoopOverhead);
524         }
525
526         ConsoleHelpers.Debug("All tests done. Total links left in database: {0}.",
↪ links.Total);
527     }
528
529     private static void CreatePoints(this Platform.Links.Data.Core.Doublets.Links links, long
↪ amountToCreate)
530     {
531         for (long i = 0; i < amountToCreate; i++)
532             links.Create(0, 0);
533     }
534
535     private static TimeSpan GetBaseRandomLoopOverhead(long loops)
536     {
537         return Measure(() =>
538         {
539             ulong maxValue = RandomHelpers.DefaultFactory.NextUInt64();
540             ulong result = 0;
541             for (long i = 0; i < loops; i++)
542             {
543                 var source = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
544                 var target = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
545
546                 result += maxValue + source + target;
547             }
548             Global.Trash = result;
549         });
550     }
551     */
552
553     [Fact(Skip = "performance test")]
554     public static void GetSourceTest()
555     {
556         using (var scope = new TempLinksTestScope())
557         {
558             var links = scope.Links;
559             ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations.",
↪ 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
↪ second), counter result: {3}",
584                 Iterations, elapsedTime, (long)iterationsPerSecond, counter);
585         }
586     }
587
588     [Fact(Skip = "performance test")]
589     public static void GetSourceInParallel()
590     {
591         using (var scope = new TempLinksTestScope())
592         {
593             var links = scope.Links;

```

```

594 ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations in
    ↳ parallel.", Iterations);
595
596 long counter = 0;
597
598 //var firstLink = links.First();
599 var firstLink = links.Create();
600
601 var sw = Stopwatch.StartNew();
602
603 // Тестируем саму функцию
604 Parallel.For(0, Iterations, x =>
605 {
606     Interlocked.Add(ref counter, (long)links.GetSource(firstLink));
607     //Interlocked.Increment(ref counter);
608 });
609
610 var elapsedTime = sw.Elapsed;
611
612 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
613
614 links.Delete(firstLink);
615
616 ConsoleHelpers.Debug(
617     "{0} Iterations of GetSource function done in {1} ({2} Iterations per
    ↳ second), counter result: {3}",
    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.",
628             ↳ Iterations);
629
630         ulong counter = 0;
631
632         //var firstLink = links.First();
633         var firstLink = links.Create();
634
635         var sw = Stopwatch.StartNew();
636
637         for (ulong i = 0; i < Iterations; i++)
638         {
639             counter += links.GetTarget(firstLink);
640         }
641
642         var elapsedTime = sw.Elapsed;
643
644         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
645
646         links.Delete(firstLink);
647
648         ConsoleHelpers.Debug(
649             "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
    ↳ second), counter result: {3}",
            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
660             ↳ parallel.", Iterations);
661
662         long counter = 0;
663
664         //var firstLink = links.First();
665         var firstLink = links.Create();
666
667         var sw = Stopwatch.StartNew();
668

```

```

669         Parallel.For(0, Iterations, x =>
670         {
671             Interlocked.Add(ref counter, (long)links.GetTarget(firstLink));
672             //Interlocked.Increment(ref counter);
673         });
674
675         var elapsedTime = sw.Elapsed;
676
677         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
678
679         links.Delete(firstLink);
680
681         ConsoleHelpers.Debug(
682             "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
        ↪ second), counter result: {3}",
        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,
694 ↪ DefaultLinksSizeStep))
695     {
696         long iterations = 64 * 1024 * 1024 /
697 ↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
698
699         ulong counter = 0;
700         var maxLink = links.Total;
701
702         ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.", iterations);
703
704         var sw = Stopwatch.StartNew();
705
706         for (var i = iterations; i > 0; i--)
707         {
708             var source =
709 ↪ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
710             var target =
711 ↪ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
712
713             counter += links.Search(source, target);
714         }
715
716         var elapsedTime = sw.Elapsed;
717
718         var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
719
720         ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
        ↪ Iterations per second), c: {3}", iterations, elapsedTime, (long)iterationsPerSecond,
        ↪ counter);
721     }
722
723     File.Delete(tempFilename);
724 }*/
725
726 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
727 public static void TestRandomSearchAll()
728 {
729     using (var scope = new TempLinksTestScope())
730     {
731         var links = scope.Links;
732         ulong counter = 0;
733
734         var maxLink = links.Count();
735
736         var iterations = links.Count();
737
738         ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.",
739 ↪ links.Count());
740
741         var sw = Stopwatch.StartNew();
742
743         for (var i = iterations; i > 0; i--)

```

```

740     {
741         var linksAddressRange = new
742             ↪ Range<ulong>(_constants.InternalReferencesRange.Minimum, maxLink);
743
744         var source = RandomHelpers.Default.NextUInt64(linksAddressRange);
745         var target = RandomHelpers.Default.NextUInt64(linksAddressRange);
746
747         counter += links.SearchOrDefault(source, target);
748     }
749
750     var elapsedTime = sw.Elapsed;
751
752     var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
753
754     ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
755         ↪ Iterations per second), c: {3}",
756         iterations, elapsedTime, (long)iterationsPerSecond, counter);
757 }
758
759 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
760 public static void TestEach()
761 {
762     using (var scope = new TempLinksTestScope())
763     {
764         var links = scope.Links;
765
766         var counter = new Counter<IList<ulong>, ulong>(links.Constants.Continue);
767
768         ConsoleHelpers.Debug("Testing Each function.");
769
770         var sw = Stopwatch.StartNew();
771
772         links.Each(counter.IncrementAndReturnTrue);
773
774         var elapsedTime = sw.Elapsed;
775
776         var linksPerSecond = counter.Count / elapsedTime.TotalSeconds;
777
778         ConsoleHelpers.Debug("{0} Iterations of Each's handler function done in {1} ({2}
779             ↪ links per second)",
780             counter, elapsedTime, (long)linksPerSecond);
781     }
782 }
783
784 /*
785 [Fact]
786 public static void TestForeach()
787 {
788     var tempFilename = Path.GetTempFileName();
789
790     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
791         ↪ DefaultLinksSizeStep))
792     {
793         ulong counter = 0;
794
795         ConsoleHelpers.Debug("Testing foreach through links.");
796
797         var sw = Stopwatch.StartNew();
798
799         //foreach (var link in links)
800         //{
801             counter++;
802         //}
803
804         var elapsedTime = sw.Elapsed;
805
806         var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
807
808         ConsoleHelpers.Debug("{0} Iterations of Foreach's handler block done in {1} ({2}
809             ↪ links per second)", counter, elapsedTime, (long)linksPerSecond);
810     }
811
812     File.Delete(tempFilename);
813 }
814 */
815
816 /*
817 [Fact]
818 public static void TestParallelForeach()

```

```

815     {
816         var tempFilename = Path.GetTempFileName();
817         using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
818             ↪ DefaultLinksSizeStep))
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
836             ↪ {1} ({2} links per second)", counter, elapsedTime, (long)linksPerSecond);
837         }
838
839         File.Delete(tempFilename);
840     }
841     */
842
843     [Fact(Skip = "performance test")]
844     public static void Create64BillionLinks()
845     {
846         using (var scope = new TempLinksTestScope())
847         {
848             var links = scope.Links;
849             var linksBeforeTest = links.Count();
850
851             long linksToCreate = 64 * 1024 * 1024 / UInt64UnitedMemoryLinks.LinkSizeInBytes;
852
853             ConsoleHelpers.Debug("Creating {0} links.", linksToCreate);
854
855             var elapsedTime = Performance.Measure(() =>
856             {
857                 for (long i = 0; i < linksToCreate; i++)
858                 {
859                     links.Create();
860                 }
861             });
862
863             var linksCreated = links.Count() - linksBeforeTest;
864             var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
865
866             ConsoleHelpers.Debug("Current links count: {0}.", links.Count());
867
868             ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
869             ↪ linksCreated, elapsedTime,
870             ↪ (long)linksPerSecond);
871         }
872     }
873
874     [Fact(Skip = "performance test")]
875     public static void Create64BillionLinksInParallel()
876     {
877         using (var scope = new TempLinksTestScope())
878         {
879             var links = scope.Links;
880             var linksBeforeTest = links.Count();
881
882             var sw = Stopwatch.StartNew();
883
884             long linksToCreate = 64 * 1024 * 1024 / UInt64UnitedMemoryLinks.LinkSizeInBytes;
885
886             ConsoleHelpers.Debug("Creating {0} links in parallel.", linksToCreate);
887
888             Parallel.For(0, linksToCreate, x => links.Create());
889
890             var elapsedTime = sw.Elapsed;
891
892             var linksCreated = links.Count() - linksBeforeTest;

```



```

892         var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
893
894         ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
895             ↪ linksCreated, elapsedTime,
896             (long)linksPerSecond);
897     }
898 }
899 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
900 public static void TestDeletionOfAllLinks()
901 {
902     using (var scope = new TempLinksTestScope())
903     {
904         var links = scope.Links;
905         var linksBeforeTest = links.Count();
906
907         ConsoleHelpers.Debug("Deleting all links");
908
909         var elapsedTime = Performance.Measure(links.DeleteAll);
910
911         var linksDeleted = linksBeforeTest - links.Count();
912         var linksPerSecond = linksDeleted / elapsedTime.TotalSeconds;
913
914         ConsoleHelpers.Debug("{0} links deleted in {1} ({2} links per second)",
915             ↪ linksDeleted, elapsedTime,
916             (long)linksPerSecond);
917     }
918 }
919 #endregion
920 }
921 }

```

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

```

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

```

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

```

1  using Xunit;
2  using Platform.Converters;
3  using Platform.Memory;
4  using Platform.Reflection;
5  using Platform.Scopes;
6  using Platform.Data.Numbers.Raw;
7  using Platform.Data.Doublets.Incrementers;
8  using Platform.Data.Doublets.Numbers.Unary;
9  using Platform.Data.Doublets.PropertyOperators;
10 using Platform.Data.Doublets.Sequences.Converters;
11 using Platform.Data.Doublets.Sequences.Indexes;
12 using Platform.Data.Doublets.Sequences.Walkers;
13 using Platform.Data.Doublets.Unicode;
14 using Platform.Data.Doublets.Memory.United.Generic;
15
16 namespace Platform.Data.Doublets.Tests
17 {
18     public static class UnicodeConvertersTests
19     {
20         [Fact]
21         public static void CharAndUnaryNumberUnicodeSymbolConvertersTest()
22         {
23             using (var scope = new TempLinksTestScope())
24             {
25                 var links = scope.Links;
26                 var meaningRoot = links.CreatePoint();
27                 var one = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
28                 var powerOf2ToUnaryNumberConverter = new
29                     ↪ PowerOf2ToUnaryNumberConverter<ulong>(links, one);
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                 ↪ UnitedMemoryLinks<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;

```

```

67     var itself = links.Constants.Itself;
68
69     var meaningRoot = links.CreatePoint();
70     var unaryOne = links.CreateAndUpdate(meaningRoot, itself);
71     var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, itself);
72     var unicodeSequenceMarker = links.CreateAndUpdate(meaningRoot, itself);
73     var frequencyMarker = links.CreateAndUpdate(meaningRoot, itself);
74     var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot, itself);
75
76     var powerOf2ToUnaryNumberConverter = new
77     ↪ PowerOf2ToUnaryNumberConverter<ulong>(links, unaryOne);
78     var addressToUnaryNumberConverter = new
79     ↪ AddressToUnaryNumberConverter<ulong>(links, powerOf2ToUnaryNumberConverter);
80     var charToUnicodeSymbolConverter = new
81     ↪ CharToUnicodeSymbolConverter<ulong>(links, addressToUnaryNumberConverter,
82     ↪ unicodeSymbolMarker);
83
84     var unaryNumberToAddressConverter = new
85     ↪ UnaryNumberToAddressOrOperationConverter<ulong>(links,
86     ↪ powerOf2ToUnaryNumberConverter);
87     var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
88     var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
89     ↪ frequencyMarker, unaryOne, unaryNumberIncrementer);
90     var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
91     ↪ frequencyPropertyMarker, frequencyMarker);
92     var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
93     ↪ frequencyPropertyOperator, frequencyIncrementer);
94     var linkToItsFrequencyNumberConverter = new
95     ↪ LinkToItsFrequencyNumberConverter<ulong>(links, frequencyPropertyOperator,
96     ↪ unaryNumberToAddressConverter);
97     var sequenceToItsLocalElementLevelsConverter = new
98     ↪ SequenceToItsLocalElementLevelsConverter<ulong>(links,
99     ↪ linkToItsFrequencyNumberConverter);
100    var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
101    ↪ sequenceToItsLocalElementLevelsConverter);
102
103    var stringToUnicodeSequenceConverter = new
104    ↪ StringToUnicodeSequenceConverter<ulong>(links, charToUnicodeSymbolConverter,
105    ↪ index, optimalVariantConverter, unicodeSequenceMarker);
106
107    var originalString = "Hello";
108
109    var unicodeSequenceLink =
110    ↪ stringToUnicodeSequenceConverter.Convert(originalString);
111
112    var unicodeSymbolCriterionMatcher = new
113    ↪ UnicodeSymbolCriterionMatcher<ulong>(links, unicodeSymbolMarker);
114    var unicodeSymbolToCharConverter = new
115    ↪ UnicodeSymbolToCharConverter<ulong>(links, unaryNumberToAddressConverter,
116    ↪ unicodeSymbolCriterionMatcher);
117
118    var unicodeSequenceCriterionMatcher = new
119    ↪ UnicodeSequenceCriterionMatcher<ulong>(links, unicodeSequenceMarker);
120
121    var sequenceWalker = new LeveledSequenceWalker<ulong>(links,
122    ↪ unicodeSymbolCriterionMatcher.IsMatched);
123
124    var unicodeSequenceToStringConverter = new
125    ↪ UnicodeSequenceToStringConverter<ulong>(links,
126    ↪ unicodeSequenceCriterionMatcher, sequenceWalker,
127    ↪ unicodeSymbolToCharConverter);
128
129    var resultingString =
130    ↪ unicodeSequenceToStringConverter.Convert(unicodeSequenceLink);
131
132    Assert.Equal(originalString, resultingString);
133
134    }
135
136    }
137
138    }

```

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