

# LinksPlatform's Platform.Data.Doublets Class Library

## ./Platform.Data.Doublets/Converters/AddressToUnaryNumberConverter.cs

```

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

```

## ./Platform.Data.Doublets/Converters/LinkToItsFrequencyNumberConveter.cs

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Interfaces;
4
5  namespace Platform.Data.Doublets.Converters
6  {
7      public class LinkToItsFrequencyNumberConveter<TLink> : LinksOperatorBase<TLink>,
8          ⇩ IConverter<Doublet<TLink>, TLink>
9     {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11             ⇩ EqualityComparer<TLink>.Default;
12
13         private readonly IPropertyOperator<TLink, TLink> _frequencyPropertyOperator;
14         private readonly IConverter<TLink> _unaryNumberToAddressConverter;
15
16         public LinkToItsFrequencyNumberConveter(
17             ILinks<TLink> links,
18             IPropertyOperator<TLink, TLink> frequencyPropertyOperator,
19             IConverter<TLink> unaryNumberToAddressConverter)
20             : base(links)
21         {
22             _frequencyPropertyOperator = frequencyPropertyOperator;
23             _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
24         }
25
26         public TLink Convert(Doublet<TLink> doublet)
27         {
28             var link = Links.SearchOrDefault(doublet.Source, doublet.Target);
29             if (_equalityComparer.Equals(link, Links.Constants.Null))
30             {
31                 throw new ArgumentException($"Link ({doublet}) not found.", nameof(doublet));
32             }
33             var frequency = _frequencyPropertyOperator.Get(link);
34             if (_equalityComparer.Equals(frequency, default))
35             {

```

```

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

```

./Platform.Data.Doublets/Converters/PowerOf2ToUnaryNumberConverter.cs

```

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

```

./Platform.Data.Doublets/Converters/UnaryNumberToAddressAddOperationConverter.cs

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Interfaces;
4  using Platform.Numbers;
5
6  namespace Platform.Data.Doublets.Converters
7  {
8      public class UnaryNumberToAddressAddOperationConverter<TLink> : LinksOperatorBase<TLink>,
9          ⇨ IConverter<TLink>
10     {
11         private static readonly EqualityComparer<TLink> _equalityComparer =
12             ⇨ EqualityComparer<TLink>.Default;
13
14         private Dictionary<TLink, TLink> _unaryToUInt64;
15         private readonly TLink _unaryOne;
16
17         public UnaryNumberToAddressAddOperationConverter(ILinks<TLink> links, TLink unaryOne)
18             : base(links)
19         {
20             _unaryOne = unaryOne;
21             InitUnaryToUInt64();
22         }
23
24         private void InitUnaryToUInt64()
25         {
26             var one = Integer<TLink>.One;
27             _unaryToUInt64 = new Dictionary<TLink, TLink>
28             {
29                 { _unaryOne, one }
30             };
31             var unary = _unaryOne;
32             var number = one;
33             for (var i = 1; i < 64; i++)

```

```

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

```

#### ./Platform.Data.Doublets/Converters/UnaryNumberToAddressOrOperationConverter.cs

```

1  using System.Collections.Generic;
2  using Platform.Interfaces;
3  using Platform.Reflection;
4  using Platform.Numbers;
5  using System.Runtime.CompilerServices;
6
7  namespace Platform.Data.Doublets.Converters
8  {
9      public class UnaryNumberToAddressOrOperationConverter<TLink> : LinksOperatorBase<TLink>,
10         ↪ IConverter<TLink>
11     {
12         private static readonly EqualityComparer<TLink> _equalityComparer =
13             ↪ EqualityComparer<TLink>.Default;
14
15         private readonly IDictionary<TLink, int> _unaryNumberPowerOf2Indicies;
16
17         public UnaryNumberToAddressOrOperationConverter(ILinks<TLink> links, IConverter<int,
18             ↪ TLink> powerOf2ToUnaryNumberConverter)
19             : base(links)
20         {
21             _unaryNumberPowerOf2Indicies = new Dictionary<TLink, int>();
22             for (int i = 0; i < Type<TLink>.BitsLength; i++)
23             {
24                 _unaryNumberPowerOf2Indicies.Add(powerOf2ToUnaryNumberConverter.Convert(i), i);
25             }
26         }
27
28         public TLink Convert(TLink sourceNumber)
29         {
30             var nullConstant = Links.Constants.Null;
31             var source = sourceNumber;
32             var target = nullConstant;
33             if (!_equalityComparer.Equals(source, nullConstant))
34             {

```

```

32         while (true)
33         {
34             if (_unaryNumberPowerOf2Indicies.TryGetValue(source, out int powerOf2Index))
35             {
36                 SetBit(ref target, powerOf2Index);
37                 break;
38             }
39             else
40             {
41                 powerOf2Index = _unaryNumberPowerOf2Indicies[Links.GetSource(source)];
42                 SetBit(ref target, powerOf2Index);
43                 source = Links.GetTarget(source);
44             }
45         }
46     }
47     return target;
48 }
49
50 [MethodImpl(MethodImplOptions.AggressiveInlining)]
51 private static void SetBit(ref TLink target, int powerOf2Index) => target =
    ↪ (Integer<TLink>)((Integer<TLink>)target | 1UL << powerOf2Index); // Should be
    ↪ Math.Or(target, Math.ShiftLeft(One, powerOf2Index))
52 }
53 }

```

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

```

1 namespace Platform.Data.Doublets.Decorators
2 {
3     public class LinksCascadeUniquenessAndUsagesResolver<TLink> : LinksUniquenessResolver<TLink>
4     {
5         public LinksCascadeUniquenessAndUsagesResolver(ILinks<TLink> links) : base(links) { }
6
7         protected override TLink ResolveAddressChangeConflict(TLink oldLinkAddress, TLink
            ↪ newLinkAddress)
8         {
9             Links.MergeUsages(oldLinkAddress, newLinkAddress);
10            return base.ResolveAddressChangeConflict(oldLinkAddress, newLinkAddress);
11        }
12    }
13 }

```

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

```

1 namespace Platform.Data.Doublets.Decorators
2 {
3     /// <remarks>
4     /// <para>Must be used in conjunction with NonNullContentsLinkDeletionResolver.</para>
5     /// <para>Должен использоваться вместе с NonNullContentsLinkDeletionResolver.</para>
6     /// </remarks>
7     public class LinksCascadeUsagesResolver<TLink> : LinksDecoratorBase<TLink>
8     {
9         public LinksCascadeUsagesResolver(ILinks<TLink> links) : base(links) { }
10
11         public override void Delete(TLink linkIndex)
12         {
13             this.DeleteAllUsages(linkIndex);
14             Links.Delete(linkIndex);
15         }
16     }
17 }

```

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

```

1 using System;
2 using System.Collections.Generic;
3 using Platform.Data.Constants;
4
5 namespace Platform.Data.Doublets.Decorators
6 {
7     public abstract class LinksDecoratorBase<T> : ILinks<T>
8     {
9         public LinksCombinedConstants<T, T, int> Constants { get; }
10
11         public ILinks<T> Links { get; }
12
13         protected LinksDecoratorBase(ILinks<T> links)
14         {
15             Links = links;
16             Constants = links.Constants;
17         }
18     }
19 }

```

```

18         public virtual T Count(IList<T> restriction) => Links.Count(restriction);
19
20         public virtual T Each(Func<IList<T>, T> handler, IList<T> restrictions) =>
21             ↳ Links.Each(handler, restrictions);
22
23         public virtual T Create() => Links.Create();
24
25         public virtual T Update(IList<T> restrictions) => Links.Update(restrictions);
26
27         public virtual void Delete(T link) => Links.Delete(link);
28     }
29 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Disposables;
4  using Platform.Data.Constants;
5
6  namespace Platform.Data.Doublets.Decorators
7  {
8      public abstract class LinksDisposableDecoratorBase<T> : DisposableBase, ILinks<T>
9      {
10         public LinksCombinedConstants<T, T, int> Constants { get; }
11
12         public ILinks<T> Links { get; }
13
14         protected LinksDisposableDecoratorBase(ILinks<T> links)
15         {
16             Links = links;
17             Constants = links.Constants;
18         }
19
20         public virtual T Count(IList<T> restriction) => Links.Count(restriction);
21
22         public virtual T Each(Func<IList<T>, T> handler, IList<T> restrictions) =>
23             ↳ Links.Each(handler, restrictions);
24
25         public virtual T Create() => Links.Create();
26
27         public virtual T Update(IList<T> restrictions) => Links.Update(restrictions);
28
29         public virtual void Delete(T link) => Links.Delete(link);
30
31         protected override bool AllowMultipleDisposeCalls => true;
32
33         protected override void Dispose(bool manual, bool wasDisposed)
34         {
35             if (!wasDisposed)
36             {
37                 Links.DisposeIfPossible();
38             }
39         }
40     }

```

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

```

1  using System;
2  using System.Collections.Generic;
3
4  namespace Platform.Data.Doublets.Decorators
5  {
6      // TODO: Make LinksExternalReferenceValidator. A layer that checks each link to exist or to
7      ↳ be external (hybrid link's raw number).
8      public class LinksInnerReferenceExistenceValidator<TLink> : LinksDecoratorBase<TLink>
9      {
10         public LinksInnerReferenceExistenceValidator(ILinks<TLink> links) : base(links) { }
11
12         public override TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
13         {
14             Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
15             return Links.Each(handler, restrictions);
16         }
17
18         public override TLink Count(IList<TLink> restriction)
19         {
20             Links.EnsureInnerReferenceExists(restriction, nameof(restriction));
21             return Links.Count(restriction);
22         }

```

```

22
23     public override TLink Update(IList<TLink> restrictions)
24     {
25         // TODO: Possible values: null, ExistentLink or NonExistentHybrid(ExternalReference)
26         Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
27         return Links.Update(restrictions);
28     }
29
30     public override void Delete(TLink link)
31     {
32         Links.EnsureLinkExists(link, nameof(link));
33         Links.Delete(link);
34     }
35 }
36 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3
4  namespace Platform.Data.Doublets.Decorators
5  {
6      public class LinksItselfConstantToSelfReferenceResolver<TLink> : LinksDecoratorBase<TLink>
7      {
8          private static readonly EqualityComparer<TLink> _equalityComparer =
9              ↳ EqualityComparer<TLink>.Default;
10
11          public LinksItselfConstantToSelfReferenceResolver(ILinks<TLink> links) : base(links) { }
12
13          public override TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
14          {
15              var constants = Constants;
16              var itselfConstant = constants.Itself;
17              var indexPartConstant = constants.IndexPart;
18              var sourcePartConstant = constants.SourcePart;
19              var targetPartConstant = constants.TargetPart;
20              var restrictionsCount = restrictions.Count;
21              if (!_equalityComparer.Equals(constants.Any, itselfConstant)
22                  && ((restrictionsCount > indexPartConstant) &&
23                      ↳ _equalityComparer.Equals(restrictions[indexPartConstant], itselfConstant))
24                  || ((restrictionsCount > sourcePartConstant) &&
25                      ↳ _equalityComparer.Equals(restrictions[sourcePartConstant], itselfConstant))
26                  || ((restrictionsCount > targetPartConstant) &&
27                      ↳ _equalityComparer.Equals(restrictions[targetPartConstant], itselfConstant))))
28              {
29                  // Itself constant is not supported for Each method right now, skipping execution
30                  return constants.Continue;
31              }
32              return Links.Each(handler, restrictions);
33          }
34
35          public override TLink Update(IList<TLink> restrictions) =>
36              ↳ Links.Update(Links.ResolveConstantAsSelfReference(Constants.Itself, restrictions));
37      }
38 }

```

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

```

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

```

```
20     }
21 }
```

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

```
1 using System.Collections.Generic;
2
3 namespace Platform.Data.Doublets.Decorators
4 {
5     public class LinksNullConstantToSelfReferenceResolver<TLink> : LinksDecoratorBase<TLink>
6     {
7         public LinksNullConstantToSelfReferenceResolver(ILinks<TLink> links) : base(links) { }
8
9         public override TLink Create()
10        {
11            var link = Links.Create();
12            return Links.Update(link, link, link);
13        }
14
15        public override TLink Update(IList<TLink> restrictions) =>
16            ↪ Links.Update(Links.ResolveConstantAsSelfReference(Constants.Null, restrictions));
17    }
18 }
```

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

```
1 using System.Collections.Generic;
2
3 namespace Platform.Data.Doublets.Decorators
4 {
5     public class LinksUniquenessResolver<TLink> : LinksDecoratorBase<TLink>
6     {
7         private static readonly EqualityComparer<TLink> _equalityComparer =
8             ↪ EqualityComparer<TLink>.Default;
9
10        public LinksUniquenessResolver(ILinks<TLink> links) : base(links) { }
11
12        public override TLink Update(IList<TLink> restrictions)
13        {
14            var newLinkAddress = Links.SearchOrDefault(restrictions[Constants.SourcePart],
15                ↪ restrictions[Constants.TargetPart]);
16            if (_equalityComparer.Equals(newLinkAddress, default))
17            {
18                return Links.Update(restrictions);
19            }
20            return ResolveAddressChangeConflict(restrictions[Constants.IndexPart],
21                ↪ newLinkAddress);
22        }
23
24        protected virtual TLink ResolveAddressChangeConflict(TLink oldLinkAddress, TLink
25            ↪ newLinkAddress)
26        {
27            if (!_equalityComparer.Equals(oldLinkAddress, newLinkAddress) &&
28                ↪ Links.Exists(oldLinkAddress))
29            {
30                Delete(oldLinkAddress);
31            }
32            return newLinkAddress;
33        }
34    }
35 }
```

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

```
1 using System.Collections.Generic;
2
3 namespace Platform.Data.Doublets.Decorators
4 {
5     public class LinksUniquenessValidator<TLink> : LinksDecoratorBase<TLink>
6     {
7         public LinksUniquenessValidator(ILinks<TLink> links) : base(links) { }
8
9         public override TLink Update(IList<TLink> restrictions)
10        {
11            Links.EnsureDoesNotExists(restrictions[Constants.SourcePart],
12                ↪ restrictions[Constants.TargetPart]);
13            return Links.Update(restrictions);
14        }
15    }
16 }
```

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

```
1 using System.Collections.Generic;
2
3 namespace Platform.Data.Doublets.Decorators
4 {
5     public class LinksUsagesValidator<TLink> : LinksDecoratorBase<TLink>
6     {
7         public LinksUsagesValidator(ILinks<TLink> links) : base(links) { }
8
9         public override TLink Update(IList<TLink> restrictions)
10        {
11            Links.EnsureNoUsages(restrictions[Constants.IndexPart]);
12            return Links.Update(restrictions);
13        }
14
15        public override void Delete(TLink link)
16        {
17            Links.EnsureNoUsages(link);
18            Links.Delete(link);
19        }
20    }
21 }
```

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

```
1 namespace Platform.Data.Doublets.Decorators
2 {
3     public class NonNullContentsLinkDeletionResolver<TLink> : LinksDecoratorBase<TLink>
4     {
5         public NonNullContentsLinkDeletionResolver(ILinks<TLink> links) : base(links) { }
6
7         public override void Delete(TLink linkIndex)
8         {
9             Links.EnforceResetValues(linkIndex);
10            Links.Delete(linkIndex);
11        }
12    }
13 }
```

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

```
1 using System;
2 using System.Collections.Generic;
3 using Platform.Collections;
4
5 namespace Platform.Data.Doublets.Decorators
6 {
7     /// <summary>
8     /// Представляет объект для работы с базой данных (файлом) в формате Links (массива связей).
9     /// </summary>
10    /// <remarks>
11    /// Возможные оптимизации:
12    /// Объединение в одном поле Source и Target с уменьшением до 32 бит.
13    ///     + меньше объём БД
14    ///     - меньше производительность
15    ///     - больше ограничение на количество связей в БД)
16    /// Ленивое хранение размеров поддеревьев (расчитываемое по мере использования БД)
17    ///     + меньше объём БД
18    ///     - больше сложность
19    ///
20    /// Текущее теоретическое ограничение на индекс связи, из-за использования 5 бит в размере
21    ///     ↳ поддеревьев для AVL баланса и флагов нитей: 2 в степени(64 минус 5 равно 59 ) равно 576
22    ///     ↳ 460 752 303 423 488
23    /// Желательно реализовать поддержку переключения между деревьями и битовыми индексами
24    ///     ↳ (битовыми строками) - вариант матрицы (выстраиваемой лениво).
25    ///
26    /// Решить отключать ли проверки при компиляции под Release. Т.е. исключения будут
27    ///     ↳ выбрасываться только при #if DEBUG
28    /// </remarks>
29    public class UInt64Links : LinksDisposableDecoratorBase<ulong>
30    {
31        public UInt64Links(ILinks<ulong> links) : base(links) { }
32
33        public override ulong Each(Func<IList<ulong>, ulong> handler, IList<ulong> restrictions)
34        {
35            this.EnsureLinkIsAnyOrExists(restrictions);
36            return Links.Each(handler, restrictions);
37        }
38
39        public override ulong Create() => Links.CreatePoint();
40    }
41 }
```



```

37 public override ulong Update(ICollection<ulong> restrictions)
38 {
39     var constants = Constants;
40     var nullConstant = constants.Null;
41     if (restrictions.IsNullOrEmpty())
42     {
43         return nullConstant;
44     }
45     // TODO: Looks like this is a common type of exceptions linked with restrictions
46     ↪ support
47     if (restrictions.Count != 3)
48     {
49         throw new NotSupportedException();
50     }
51     var indexPartConstant = constants.IndexPart;
52     var updatedLink = restrictions[indexPartConstant];
53     this.EnsureLinkExists(updatedLink,
54         ↪ $"{nameof(restrictions)}[{nameof(indexPartConstant)}]");
55     var sourcePartConstant = constants.SourcePart;
56     var newSource = restrictions[sourcePartConstant];
57     this.EnsureLinkIsItselfOrExists(newSource,
58         ↪ $"{nameof(restrictions)}[{nameof(sourcePartConstant)}]");
59     var targetPartConstant = constants.TargetPart;
60     var newTarget = restrictions[targetPartConstant];
61     this.EnsureLinkIsItselfOrExists(newTarget,
62         ↪ $"{nameof(restrictions)}[{nameof(targetPartConstant)}]");
63     var existedLink = nullConstant;
64     var itselfConstant = constants.Itself;
65     if (newSource != itselfConstant && newTarget != itselfConstant)
66     {
67         existedLink = this.SearchOrDefault(newSource, newTarget);
68     }
69     if (existedLink == nullConstant)
70     {
71         var before = Links.GetLink(updatedLink);
72         if (before[sourcePartConstant] != newSource || before[targetPartConstant] !=
73             ↪ newTarget)
74         {
75             Links.Update(updatedLink, newSource == itselfConstant ? updatedLink :
76                 ↪ newSource,
77                 newTarget == itselfConstant ? updatedLink :
78                 ↪ newTarget);
79         }
80         return updatedLink;
81     }
82     else
83     {
84         return this.MergeAndDelete(updatedLink, existedLink);
85     }
86 }
87
88 public override void Delete(ulong linkIndex)
89 {
90     Links.EnsureLinkExists(linkIndex);
91     Links.EnforceResetValues(linkIndex);
92     this.DeleteAllUsages(linkIndex);
93     Links.Delete(linkIndex);
94 }
95
96 }
97
98 }

```

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

```

1 using System;
2 using System.Collections.Generic;
3 using System.Linq;
4 using Platform.Collections;
5 using Platform.Collections.Arrays;
6 using Platform.Collections.Lists;
7 using Platform.Data.Universal;
8
9 namespace Platform.Data.Doublets.Decorators
10 {
11     /// <remarks>
12     /// What does empty pattern (for condition or substitution) mean? Nothing or Everything?
13     /// Now we go with nothing. And nothing is something one, but empty, and cannot be changed
14     ↪ by itself. But can cause creation (update from nothing) or deletion (update to nothing).
15     ///

```

```

15  /// TODO: Decide to change to IDoubletLinks or not to change. (Better to create
    ↳ DefaultUniLinksBase, that contains logic itself and can be implemented using both
    ↳ IDoubletLinks and ILinks.)
16  /// </remarks>
17  internal class UniLinks<TLink> : LinksDecoratorBase<TLink>, IUniLinks<TLink>
18  {
19      private static readonly EqualityComparer<TLink> _equalityComparer =
    ↳ EqualityComparer<TLink>.Default;

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

```

```

78         ///};
79         ///    if (!Memory.Each(handler, restriction))
80         ///        return Constants.Break;
81         ///    }
82         ///}
83         ///else
84         ///{
85         ///    Func<T, bool> handler = link =>
86         ///    {
87         ///        var matchedLink = Memory.GetLinkValue(link);
88         ///        var matchDecision = matchedHandler(matchedLink, matchedLink);
89         ///        return !Equals(matchDecision, Constants.Break);
90         ///    };
91         ///    if (!Memory.Each(handler, restriction))
92         ///        return Constants.Break;
93         ///    }
94         ///}
95         ///else
96         ///{
97         ///    if (substitution != null)
98         ///    {
99         ///        transitions = new List<IList<T>>>();
100        ///        Func<T, bool> handler = link =>
101        ///        {
102        ///            var matchedLink = Memory.GetLinkValue(link);
103        ///            transitions.Add(matchedLink);
104        ///            return true;
105        ///        };
106        ///        if (!Memory.Each(handler, restriction))
107        ///            return Constants.Break;
108        ///    }
109        ///    else
110        ///    {
111        ///        return Constants.Continue;
112        ///    }
113        ///}
114        ///}
115        ///if (substitution != null)
116        ///{
117        ///    // Есть причина делать замену (запись)
118        ///    if (substitutedHandler != null)
119        ///    {
120        ///    }
121        ///    else
122        ///    {
123        ///    }
124        ///}
125        ///return Constants.Continue;
126
127        ///if (restriction.IsNullOrEmpty()) // Create
128        ///{
129        ///    substitution[Constants.IndexPart] = Memory.AllocateLink();
130        ///    Memory.SetLinkValue(substitution);
131        ///}
132        ///else if (substitution.IsNullOrEmpty()) // Delete
133        ///{
134        ///    Memory.FreeLink(restriction[Constants.IndexPart]);
135        ///}
136        ///else if (restriction.EqualTo(substitution)) // Read or ("repeat" the state) // Each
137        ///{
138        ///    // No need to collect links to list
139        ///    // Skip == Continue
140        ///    // No need to check substitutedHandler
141        ///    if (!Memory.Each(link => !Equals(matchedHandler(Memory.GetLinkValue(link)),
142        ///        ↪ Constants.Break), restriction))
143        ///        return Constants.Break;
144        ///}
145        ///else // Update
146        ///{
147        ///    //List<IList<T>> matchedLinks = null;
148        ///    if (matchedHandler != null)
149        ///    {
150        ///        matchedLinks = new List<IList<T>>>();
151        ///        Func<T, bool> handler = link =>
152        ///        {
153        ///            var matchedLink = Memory.GetLinkValue(link);
154        ///            var matchDecision = matchedHandler(matchedLink);
155        ///            if (Equals(matchDecision, Constants.Break))

```

```

155         //         return false;
156         //         if (!Equals(matchDecision, Constants.Skip))
157             //             matchedLinks.Add(matchedLink);
158         //         return true;
159         //     };
160         //     if (!Memory.Each(handler, restriction))
161             //         return Constants.Break;
162         // }
163         // if (!matchedLinks.IsNullOrEmpty())
164         // {
165             //     var totalMatchedLinks = matchedLinks.Count;
166             //     for (var i = 0; i < totalMatchedLinks; i++)
167             //     {
168                 //         var matchedLink = matchedLinks[i];
169                 //         if (substitutedHandler != null)
170                 //         {
171                     //             var newValue = new List<T>(); // TODO: Prepare value to update here
172                     //             // TODO: Decide is it actually needed to use Before and After
173                     ↪ substitution handling.
174                     //             var substitutedDecision = substitutedHandler(matchedLink,
175                     ↪ newValue);
176                     //             if (Equals(substitutedDecision, Constants.Break))
177                         //                 return Constants.Break;
178                     //             if (Equals(substitutedDecision, Constants.Continue))
179                         //             {
180                             //                 // Actual update here
181                             //                 Memory.SetLinkValue(newValue);
182                         //             }
183                     //             if (Equals(substitutedDecision, Constants.Skip))
184                         //             {
185                             //                 // Cancel the update. TODO: decide use separate Cancel
186                             ↪ constant or Skip is enough?
187                             //             }
188                         //         }
189                     //     }
190                 // }
191             // }
192         // }
193     }
194     return Constants.Continue;
195 }
196
197 public TLink Trigger(IList<TLink> patternOrCondition, Func<IList<TLink>, TLink>
198 ↪ matchHandler, IList<TLink> substitution, Func<IList<TLink>, IList<TLink>, TLink>
199 ↪ substitutionHandler)
200 {
201     if (patternOrCondition.IsNullOrEmpty() && substitution.IsNullOrEmpty())
202     {
203         return Constants.Continue;
204     }
205     else if (patternOrCondition.EqualTo(substitution)) // Should be Each here TODO:
206         ↪ Check if it is a correct condition
207     {
208         // Or it only applies to trigger without matchHandler.
209         throw new NotImplementedException();
210     }
211     else if (!substitution.IsNullOrEmpty()) // Creation
212     {
213         var before = ArrayPool<TLink>.Empty;
214         // Что должно означать False здесь? Остановиться (перестать идти) или пропустить
215         ↪ (пройти мимо) или пустить (взять)?
216         if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
217         ↪ Constants.Break))
218         {
219             return Constants.Break;
220         }
221         var after = (IList<TLink>)substitution.ToArray();
222         if (_equalityComparer.Equals(after[0], default))
223         {
224             var newLink = Links.Create();
225             after[0] = newLink;
226         }
227         if (substitution.Count == 1)
228         {
229             after = Links.GetLink(substitution[0]);
230         }
231         else if (substitution.Count == 3)
232         {
233             Links.Update(after);
234         }
235     }
236 }

```

```

225     else
226     {
227         throw new NotSupportedException();
228     }
229     if (matchHandler != null)
230     {
231         return substitutionHandler(before, after);
232     }
233     return Constants.Continue;
234 }
235 else if (!patternOrCondition.IsNullOrEmpty()) // Deletion
236 {
237     if (patternOrCondition.Count == 1)
238     {
239         var linkToDelete = patternOrCondition[0];
240         var before = Links.GetLink(linkToDelete);
241         if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
242             ↪ Constants.Break))
243         {
244             return Constants.Break;
245         }
246         var after = ArrayPool<TLink>.Empty;
247         Links.Update(linkToDelete, Constants.Null, Constants.Null);
248         Links.Delete(linkToDelete);
249         if (matchHandler != null)
250         {
251             return substitutionHandler(before, after);
252         }
253         return Constants.Continue;
254     }
255     else
256     {
257         throw new NotSupportedException();
258     }
259 }
260 else // Replace / Update
261 {
262     if (patternOrCondition.Count == 1) //-V3125
263     {
264         var linkToUpdate = patternOrCondition[0];
265         var before = Links.GetLink(linkToUpdate);
266         if (matchHandler != null && _equalityComparer.Equals(matchHandler(before),
267             ↪ Constants.Break))
268         {
269             return Constants.Break;
270         }
271         var after = (IList<TLink>)substitution.ToArray(); //-V3125
272         if (_equalityComparer.Equals(after[0], default))
273         {
274             after[0] = linkToUpdate;
275         }
276         if (substitution.Count == 1)
277         {
278             if (!_equalityComparer.Equals(substitution[0], linkToUpdate))
279             {
280                 after = Links.GetLink(substitution[0]);
281                 Links.Update(linkToUpdate, Constants.Null, Constants.Null);
282                 Links.Delete(linkToUpdate);
283             }
284         }
285         else if (substitution.Count == 3)
286         {
287             Links.Update(after);
288         }
289         else
290         {
291             throw new NotSupportedException();
292         }
293         if (matchHandler != null)
294         {
295             return substitutionHandler(before, after);
296         }
297         return Constants.Continue;
298     }
299     else
300     {
301         throw new NotSupportedException();
302     }
303 }

```

```

301     }
302 }
303
304 /// <remarks>
305 /// IList[IList[IList[T]]]
306 /// |         |         |         |
307 /// |         |         |         |
308 /// |         |         |         |
309 /// |         |         |         |
310 /// |         |         |         |
311 /// |         |         |         |
312 /// |         |         |         |
313 /// |         |         |         |
314 public IList<IList<IList<TLink>>> Trigger(IList<TLink> condition, IList<TLink>
    ↳ substitution)
315 {
316     var changes = new List<IList<IList<TLink>>>();
317     Trigger(condition, AlwaysContinue, substitution, (before, after) =>
318     {
319         var change = new[] { before, after };
320         changes.Add(change);
321         return Constants.Continue;
322     });
323     return changes;
324 }
325
326 private TLink AlwaysContinue(IList<TLink> linkToMatch) => Constants.Continue;
327 }
328 }

```

./Platform.Data.Doublets/DoubletComparer.cs

```

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

```

./Platform.Data.Doublets/Doublet.cs

```

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

```

```

24
25     public override int GetHashCode() => (Source, Target).GetHashCode();
26 }
27 }

```

./Platform.Data.Doublets/Hybrid.cs

```

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

```

```

67     public static explicit operator byte(Hybrid<T> hybrid) => Convert.ToByte(hybrid.Value);
68
69     public static explicit operator sbyte(Hybrid<T> hybrid) =>
70         ↪ Convert.ToSByte(hybrid.AbsoluteValue);
71
72     public override string ToString() => IsNothing ? default(T) == null ? "Nothing" :
73         ↪ default(T).ToString() : IsExternal ? $"{<AbsoluteValue>}" : Value.ToString();
74 }

```

./Platform.Data.Doublets/ILinks.cs

```

1  using Platform.Data.Constants;
2
3  namespace Platform.Data.Doublets
4  {
5      public interface ILinks<TLink> : ILinks<TLink, LinksCombinedConstants<TLink, TLink, int>>
6      {
7      }
8  }

```

./Platform.Data.Doublets/ILinksExtensions.cs

```

1  using System;
2  using System.Collections;
3  using System.Collections.Generic;
4  using System.Linq;
5  using System.Runtime.CompilerServices;
6  using Platform.Ranges;
7  using Platform.Collections.Arrays;
8  using Platform.Numbers;
9  using Platform.Random;
10 using Platform.Setters;
11 using Platform.Data.Exceptions;
12
13 namespace Platform.Data.Doublets
14 {
15     public static class ILinksExtensions
16     {
17         public static void RunRandomCreations<TLink>(this ILinks<TLink> links, long
18             ↪ amountOfCreations)
19         {
20             for (long i = 0; i < amountOfCreations; i++)
21             {
22                 var linksAddressRange = new Range<ulong>(0, (Integer<TLink>)links.Count());
23                 Integer<TLink> source = RandomHelpers.Default.NextUInt64(linksAddressRange);
24                 Integer<TLink> target = RandomHelpers.Default.NextUInt64(linksAddressRange);
25                 links.CreateAndUpdate(source, target);
26             }
27
28             public static void RunRandomSearches<TLink>(this ILinks<TLink> links, long
29                 ↪ amountOfSearches)
30             {
31                 for (long i = 0; i < amountOfSearches; i++)
32                 {
33                     var linkAddressRange = new Range<ulong>(1, (Integer<TLink>)links.Count());
34                     Integer<TLink> source = RandomHelpers.Default.NextUInt64(linkAddressRange);
35                     Integer<TLink> target = RandomHelpers.Default.NextUInt64(linkAddressRange);
36                     links.SearchOrDefault(source, target);
37                 }
38
39                 public static void RunRandomDeletions<TLink>(this ILinks<TLink> links, long
40                     ↪ amountOfDeletions)
41                 {
42                     var min = (ulong)amountOfDeletions > (Integer<TLink>)links.Count() ? 1 :
43                         ↪ (Integer<TLink>)links.Count() - (ulong)amountOfDeletions;
44                     for (long i = 0; i < amountOfDeletions; i++)
45                     {
46                         var linksAddressRange = new Range<ulong>(min, (Integer<TLink>)links.Count());
47                         Integer<TLink> link = RandomHelpers.Default.NextUInt64(linksAddressRange);
48                         links.Delete(link);
49                         if ((Integer<TLink>)links.Count() < min)
50                         {
51                             break;
52                         }
53                     }
54                 }
55             }
56         }
57     }
58 }

```



```

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

```

```

128         //throw new Exception(string.Format("Невозможно выбрать путь, так как и
        ↪ Source и Target совпадают с элементом пути {0}.", next));
129         return false;
130     }
131     if (!equalityComparer.Equals(next, source) && !equalityComparer.Equals(next,
        ↪ target))
132     {
133         //throw new Exception(string.Format("Невозможно продолжить путь через
        ↪ элемент пути {0}", next));
134         return false;
135     }
136     current = next;
137 }
138 return true;
139 }
140
141 /// <remarks>
142 /// Может потребовать дополнительного стека для PathElement's при использовании
        ↪ SequenceWalker.
143 /// </remarks>
144 public static TLink GetByKeyes<TLink>(this ILinks<TLink> links, TLink root, params int[]
        ↪ path)
145 {
146     links.EnsureLinkExists(root, "root");
147     var currentLink = root;
148     for (var i = 0; i < path.Length; i++)
149     {
150         currentLink = links.GetLink(currentLink)[path[i]];
151     }
152     return currentLink;
153 }
154
155 public static TLink GetSquareMatrixSequenceElementByIndex<TLink>(this ILinks<TLink>
        ↪ links, TLink root, ulong size, ulong index)
156 {
157     var constants = links.Constants;
158     var source = constants.SourcePart;
159     var target = constants.TargetPart;
160     if (!Numbers.Math.IsPowerOfTwo(size))
161     {
162         throw new ArgumentOutOfRangeException(nameof(size), "Sequences with sizes other
        ↪ than powers of two are not supported.");
163     }
164     var path = new BitArray(BitConverter.GetBytes(index));
165     var length = Bit.GetLowestPosition(size);
166     links.EnsureLinkExists(root, "root");
167     var currentLink = root;
168     for (var i = length - 1; i >= 0; i--)
169     {
170         currentLink = links.GetLink(currentLink)[path[i] ? target : source];
171     }
172     return currentLink;
173 }
174
175 #endregion
176
177 /// <summary>
178 /// Возвращает индекс указанной связи.
179 /// </summary>
180 /// <param name="links">Хранилище связей.</param>
181 /// <param name="link">Связь представленная списком, состоящим из её адреса и
        ↪ содержимого.</param>
182 /// <returns>Индекс начальной связи для указанной связи.</returns>
183 [MethodImpl(MethodImplOptions.AggressiveInlining)]
184 public static TLink GetIndex<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
        ↪ link[links.Constants.IndexPart];
185
186 /// <summary>
187 /// Возвращает индекс начальной (Source) связи для указанной связи.
188 /// </summary>
189 /// <param name="links">Хранилище связей.</param>
190 /// <param name="link">Индекс связи.</param>
191 /// <returns>Индекс начальной связи для указанной связи.</returns>
192 [MethodImpl(MethodImplOptions.AggressiveInlining)]
193 public static TLink GetSource<TLink>(this ILinks<TLink> links, TLink link) =>
        ↪ links.GetLink(link)[links.Constants.SourcePart];
194
195 /// <summary>

```

```

196 /// Возвращает индекс начальной (Source) связи для указанной связи.
197 /// </summary>
198 /// <param name="links">Хранилище связей.</param>
199 /// <param name="link">Связь представленная списком, состоящим из её адреса и
    ↳ содержимого.</param>
200 /// <returns>Индекс начальной связи для указанной связи.</returns>
201 [MethodImpl(MethodImplOptions.AggressiveInlining)]
202 public static TLink GetSource<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
    ↳ link[links.Constants.SourcePart];
203
204 /// <summary>
205 /// Возвращает индекс конечной (Target) связи для указанной связи.
206 /// </summary>
207 /// <param name="links">Хранилище связей.</param>
208 /// <param name="link">Индекс связи.</param>
209 /// <returns>Индекс конечной связи для указанной связи.</returns>
210 [MethodImpl(MethodImplOptions.AggressiveInlining)]
211 public static TLink GetTarget<TLink>(this ILinks<TLink> links, TLink link) =>
    ↳ links.GetLink(link)[links.Constants.TargetPart];
212
213 /// <summary>
214 /// Возвращает индекс конечной (Target) связи для указанной связи.
215 /// </summary>
216 /// <param name="links">Хранилище связей.</param>
217 /// <param name="link">Связь представленная списком, состоящим из её адреса и
    ↳ содержимого.</param>
218 /// <returns>Индекс конечной связи для указанной связи.</returns>
219 [MethodImpl(MethodImplOptions.AggressiveInlining)]
220 public static TLink GetTarget<TLink>(this ILinks<TLink> links, IList<TLink> link) =>
    ↳ link[links.Constants.TargetPart];
221
222 /// <summary>
223 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
    ↳ (handler) для каждой подходящей связи.
224 /// </summary>
225 /// <param name="links">Хранилище связей.</param>
226 /// <param name="handler">Обработчик каждой подходящей связи.</param>
227 /// <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>
228 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
    ↳ случае.</returns>
229 [MethodImpl(MethodImplOptions.AggressiveInlining)]
230 public static bool Each<TLink>(this ILinks<TLink> links, Func<IList<TLink>, TLink>
    ↳ handler, params TLink[] restrictions)
231 => EqualityComparer<TLink>.Default.Equals(links.Each(handler, restrictions),
    ↳ links.Constants.Continue);
232
233 /// <summary>
234 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
    ↳ (handler) для каждой подходящей связи.
235 /// </summary>
236 /// <param name="links">Хранилище связей.</param>
237 /// <param name="source">Значение, определяющее соответствующие шаблону связи.
    ↳ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве начала,
    ↳ Constants.Any - любое начало, 1..∞ конкретное начало)</param>
238 /// <param name="target">Значение, определяющее соответствующие шаблону связи.
    ↳ (Constants.Null - 0-я связь, обозначающая ссылку на пустоту в качестве конца,
    ↳ Constants.Any - любой конец, 1..∞ конкретный конец)</param>
239 /// <param name="handler">Обработчик каждой подходящей связи.</param>
240 /// <returns>True, в случае если проход по связям не был прерван и False в обратном
    ↳ случае.</returns>
241 [MethodImpl(MethodImplOptions.AggressiveInlining)]
242 public static bool Each<TLink>(this ILinks<TLink> links, TLink source, TLink target,
    ↳ Func<TLink, bool> handler)
243 {
244     var constants = links.Constants;
245     return links.Each(link => handler(link[constants.IndexPart]) ? constants.Continue :
    ↳ constants.Break, constants.Any, source, target);
246 }
247
248 /// <summary>
249 /// Выполняет проход по всем связям, соответствующим шаблону, вызывая обработчик
    ↳ (handler) для каждой подходящей связи.
250 /// </summary>
251 /// <param name="links">Хранилище связей.</param>

```

```

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

```

```

315     }
316
317     [MethodImpl(MethodImplOptions.AggressiveInlining)]
318     public static void EnsureLinkIsAnyOrExists<TLink>(this ILinks<TLink> links, TLink link,
319     ↪ string argumentName)
320     {
321         var equalityComparer = EqualityComparer<TLink>.Default;
322         if (!equalityComparer.Equals(link, links.Constants.Any) && !links.Exists(link))
323         {
324             throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
325         }
326     }
327
328     [MethodImpl(MethodImplOptions.AggressiveInlining)]
329     public static void EnsureLinkIsItselfOrExists<TLink>(this ILinks<TLink> links, TLink
330     ↪ link, string argumentName)
331     {
332         var equalityComparer = EqualityComparer<TLink>.Default;
333         if (!equalityComparer.Equals(link, links.Constants.Itself) && !links.Exists(link))
334         {
335             throw new ArgumentLinkDoesNotExistsException<TLink>(link, argumentName);
336         }
337     }
338
339     /// <param name="links">Хранилище связей.</param>
340     [MethodImpl(MethodImplOptions.AggressiveInlining)]
341     public static void EnsureDoesNotExists<TLink>(this ILinks<TLink> links, TLink source,
342     ↪ TLink target)
343     {
344         if (links.Exists(source, target))
345         {
346             throw new LinkWithSameValueAlreadyExistsException();
347         }
348     }
349
350     /// <param name="links">Хранилище связей.</param>
351     public static void EnsureNoUsages<TLink>(this ILinks<TLink> links, TLink link)
352     {
353         if (links.HasUsages(link))
354         {
355             throw new ArgumentLinkHasDependenciesException<TLink>(link);
356         }
357     }
358
359     /// <param name="links">Хранилище связей.</param>
360     public static void EnsureCreated<TLink>(this ILinks<TLink> links, params TLink[]
361     ↪ addresses) => links.EnsureCreated(links.Create, addresses);
362
363     /// <param name="links">Хранилище связей.</param>
364     public static void EnsurePointsCreated<TLink>(this ILinks<TLink> links, params TLink[]
365     ↪ addresses) => links.EnsureCreated(links.CreatePoint, addresses);
366
367     /// <param name="links">Хранилище связей.</param>
368     public static void EnsureCreated<TLink>(this ILinks<TLink> links, Func<TLink> creator,
369     ↪ params TLink[] addresses)
370     {
371         var constants = links.Constants;
372         var nonExistentAddresses = new HashSet<ulong>(addresses.Where(x =>
373     ↪ !links.Exists(x)).Select(x => (ulong)(Integer<TLink>)x));
374         if (nonExistentAddresses.Count > 0)
375         {
376             var max = nonExistentAddresses.Max();
377             // TODO: Эту верхнюю границу нужно разрешить переопределять (проверить
378     ↪ применяется ли эта логика)
379             max = System.Math.Min(max, (Integer<TLink>)constants.MaxPossibleIndex);
380             var createdLinks = new List<TLink>();
381             var equalityComparer = EqualityComparer<TLink>.Default;
382             TLink createdLink = creator();
383             while (!equalityComparer.Equals(createdLink, (Integer<TLink>)max))
384             {
385                 createdLinks.Add(createdLink);
386             }
387             for (var i = 0; i < createdLinks.Count; i++)
388             {
389                 if (!nonExistentAddresses.Contains((Integer<TLink>)createdLinks[i]))
390                 {
391                     links.Delete(createdLinks[i]);
392                 }
393             }
394         }
395     }

```

```

385     }
386 }
387 }
388
389 #endregion
390
391 /// <param name="links">Хранилище связей.</param>
392 public static ulong CountUsages<TLink>(this ILinks<TLink> links, TLink link)
393 {
394     var constants = links.Constants;
395     var values = links.GetLink(link);
396     ulong usagesAsSource = (Integer<TLink>)links.Count(new Link<TLink>(constants.Any,
397     ↪ link, constants.Any));
398     var equalityComparer = EqualityComparer<TLink>.Default;
399     if (equalityComparer.Equals(values[constants.SourcePart], link))
400     {
401         usagesAsSource--;
402     }
403     ulong usagesAsTarget = (Integer<TLink>)links.Count(new Link<TLink>(constants.Any,
404     ↪ constants.Any, link));
405     if (equalityComparer.Equals(values[constants.TargetPart], link))
406     {
407         usagesAsTarget--;
408     }
409     return usagesAsSource + usagesAsTarget;
410 }
411
412 /// <param name="links">Хранилище связей.</param>
413 [MethodImpl(MethodImplOptions.AggressiveInlining)]
414 public static bool HasUsages<TLink>(this ILinks<TLink> links, TLink link) =>
415     ↪ links.CountUsages(link) > 0;
416
417 /// <param name="links">Хранилище связей.</param>
418 [MethodImpl(MethodImplOptions.AggressiveInlining)]
419 public static bool Equals<TLink>(this ILinks<TLink> links, TLink link, TLink source,
420     ↪ TLink target)
421 {
422     var constants = links.Constants;
423     var values = links.GetLink(link);
424     var equalityComparer = EqualityComparer<TLink>.Default;
425     return equalityComparer.Equals(values[constants.SourcePart], source) &&
426     ↪ equalityComparer.Equals(values[constants.TargetPart], target);
427 }
428
429 /// <summary>
430 /// Выполняет поиск связи с указанными Source (началом) и Target (концом).
431 /// </summary>
432 /// <param name="links">Хранилище связей.</param>
433 /// <param name="source">Индекс связи, которая является началом для искомой
434     ↪ связи.</param>
435 /// <param name="target">Индекс связи, которая является концом для искомой связи.</param>
436 /// <returns>Индекс искомой связи с указанными Source (началом) и Target
437     ↪ (концом).</returns>
438 [MethodImpl(MethodImplOptions.AggressiveInlining)]
439 public static TLink SearchOrDefault<TLink>(this ILinks<TLink> links, TLink source, TLink
440     ↪ target)
441 {
442     var constants = links.Constants;
443     var setter = new Setter<TLink, TLink>(constants.Continue, constants.Break, default);
444     links.Each(setter.SetFirstAndReturnFalse, constants.Any, source, target);
445     return setter.Result;
446 }
447
448 /// <param name="links">Хранилище связей.</param>
449 [MethodImpl(MethodImplOptions.AggressiveInlining)]
450 public static TLink CreatePoint<TLink>(this ILinks<TLink> links)
451 {
452     var link = links.Create();
453     return links.Update(link, link, link);
454 }
455
456 /// <param name="links">Хранилище связей.</param>
457 [MethodImpl(MethodImplOptions.AggressiveInlining)]
458 public static TLink CreateAndUpdate<TLink>(this ILinks<TLink> links, TLink source, TLink
459     ↪ target) => links.Update(links.Create(), source, target);
460
461 /// <summary>
462 /// Обновляет связь с указанными началом (Source) и концом (Target)

```

```

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

```

```

519 /// <summary>
520 /// Обновляет связь с указанными началом (Source) и концом (Target)
521 /// на связь с указанными началом (NewSource) и концом (NewTarget).
522 /// </summary>
523 /// <param name="links">Хранилище связей.</param>
524 /// <param name="source">Индекс связи, которая является началом обновляемой
    → связи.</param>
525 /// <param name="target">Индекс связи, которая является концом обновляемой связи.</param>
526 /// <param name="newSource">Индекс связи, которая является началом связи, на которую
    → выполняется обновление.</param>
527 /// <param name="newTarget">Индекс связи, которая является концом связи, на которую
    → выполняется обновление.</param>
528 /// <returns>Индекс обновлённой связи.</returns>
529 [MethodImpl(MethodImplOptions.AggressiveInlining)]
530 public static TLink UpdateOrCreateOrGet<TLink>(this ILinks<TLink> links, TLink source,
    → TLink target, TLink newSource, TLink newTarget)
531 {
532     var equalityComparer = EqualityComparer<TLink>.Default;
533     var link = links.SearchOrDefault(source, target);
534     if (equalityComparer.Equals(link, default))
535     {
536         return links.CreateAndUpdate(newSource, newTarget);
537     }
538     if (equalityComparer.Equals(newSource, source) && equalityComparer.Equals(newTarget,
    → target))
539     {
540         return link;
541     }
542     return links.Update(link, newSource, newTarget);
543 }
544
545 /// <summary>Удаляет связь с указанными началом (Source) и концом (Target).</summary>
546 /// <param name="links">Хранилище связей.</param>
547 /// <param name="source">Индекс связи, которая является началом удаляемой связи.</param>
548 /// <param name="target">Индекс связи, которая является концом удаляемой связи.</param>
549 [MethodImpl(MethodImplOptions.AggressiveInlining)]
550 public static TLink DeleteIfExists<TLink>(this ILinks<TLink> links, TLink source, TLink
    → target)
551 {
552     var link = links.SearchOrDefault(source, target);
553     if (!EqualityComparer<TLink>.Default.Equals(link, default))
554     {
555         links.Delete(link);
556         return link;
557     }
558     return default;
559 }
560
561 /// <summary>Удаляет несколько связей.</summary>
562 /// <param name="links">Хранилище связей.</param>
563 /// <param name="deletedLinks">Список адресов связей к удалению.</param>
564 [MethodImpl(MethodImplOptions.AggressiveInlining)]
565 public static void DeleteMany<TLink>(this ILinks<TLink> links, IList<TLink> deletedLinks)
566 {
567     for (int i = 0; i < deletedLinks.Count; i++)
568     {
569         links.Delete(deletedLinks[i]);
570     }
571 }
572
573 /// <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>
574 public static void DeleteAllUsages<TLink>(this ILinks<TLink> links, TLink linkIndex)
575 {
576     var anyConstant = links.Constants.Any;
577     var usagesAsSourceQuery = new Link<TLink>(anyConstant, linkIndex, anyConstant);
578     links.DeleteByQuery(usagesAsSourceQuery);
579     var usagesAsTargetQuery = new Link<TLink>(anyConstant, linkIndex, anyConstant);
580     links.DeleteByQuery(usagesAsTargetQuery);
581 }
582
583 public static void DeleteByQuery<TLink>(this ILinks<TLink> links, Link<TLink> query)
584 {
585     var count = (Integer<TLink>)links.Count(query);
586     if (count > 0)
587     {
588         var queryResult = new TLink[count];

```



```

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

```

```

657         {
658             var usage = usages[i];
659             if (!equalityComparer.Equals(usage, oldLinkIndex))
660             {
661                 links.Update(usage, newLinkIndex, links.GetTarget(usage));
662             }
663         }
664     }
665     if (usagesAsTargetCount > 0)
666     {
667         links.Each(usagesFiller.AddFirstAndReturnConstant,
668             ↪ usagesAsTargetQuery);
669         for (; i < usages.Length; i++)
670         {
671             var usage = usages[i];
672             if (!equalityComparer.Equals(usage, oldLinkIndex))
673             {
674                 links.Update(usage, links.GetSource(usage), newLinkIndex);
675             }
676         }
677         ArrayPool.Free(usages);
678     }
679 }
680 }
681 return newLinkIndex;
682 }
683
684 /// <summary>
685 /// Replace one link with another (replaced link is deleted, children are updated or
686 ↪ deleted).
687 /// </summary>
688 [MethodImpl(MethodImplOptions.AggressiveInlining)]
689 public static TLink MergeAndDelete<TLink>(this ILinks<TLink> links, TLink oldLinkIndex,
690     ↪ TLink newLinkIndex)
691 {
692     var equalityComparer = EqualityComparer<TLink>.Default;
693     if (!equalityComparer.Equals(oldLinkIndex, newLinkIndex))
694     {
695         links.MergeUsages(oldLinkIndex, newLinkIndex);
696         links.Delete(oldLinkIndex);
697     }
698     return newLinkIndex;
699 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3
4 namespace Platform.Data.Doublets.Incrementers
5 {
6     public class FrequencyIncrementer<TLink> : LinksOperatorBase<TLink>, IIncrementer<TLink>
7     {
8         private static readonly EqualityComparer<TLink> _equalityComparer =
9             ↪ EqualityComparer<TLink>.Default;
10
11         private readonly TLink _frequencyMarker;
12         private readonly TLink _unaryOne;
13         private readonly IIncrementer<TLink> _unaryNumberIncrementer;
14
15         public FrequencyIncrementer(ILinks<TLink> links, TLink frequencyMarker, TLink unaryOne,
16             ↪ IIncrementer<TLink> unaryNumberIncrementer)
17             : base(links)
18         {
19             _frequencyMarker = frequencyMarker;
20             _unaryOne = unaryOne;
21             _unaryNumberIncrementer = unaryNumberIncrementer;
22         }
23
24         public TLink Increment(TLink frequency)
25         {
26             if (_equalityComparer.Equals(frequency, default))
27             {
28                 return Links.GetOrCreate(_unaryOne, _frequencyMarker);
29             }
30             var source = Links.GetSource(frequency);
31             var incrementedSource = _unaryNumberIncrementer.Increment(source);

```

```

30         return Links.GetOrCreate(incrementedSource, _frequencyMarker);
31     }
32 }
33 }

```

# ./Platform.Data.Doublets/Incrementers/LinkFrequencyIncrementer.cs

```

1  using System.Collections.Generic;
2  using Platform.Interfaces;
3
4  namespace Platform.Data.Doublets.Incrementers
5  {
6      public class LinkFrequencyIncrementer<TLink> : LinksOperatorBase<TLink>,
7          ↳ IIncrementer<IList<TLink>>
8      {
9          private readonly IPropertyOperator<TLink, TLink> _frequencyPropertyOperator;
10         private readonly IIncrementer<TLink> _frequencyIncrementer;
11
12         public LinkFrequencyIncrementer(ILinks<TLink> links, IPropertyOperator<TLink, TLink>
13             ↳ frequencyPropertyOperator, IIncrementer<TLink> frequencyIncrementer)
14             : base(links)
15         {
16             _frequencyPropertyOperator = frequencyPropertyOperator;
17             _frequencyIncrementer = frequencyIncrementer;
18
19             /// <remarks>Sequence itseft is not changed, only frequency of its doublets is
20             ↳ incremented.</remarks>
21             public IList<TLink> Increment(IList<TLink> sequence) // TODO: May be move to
22             ↳ ILinksExtensions or make SequenceDoubletsFrequencyIncrementer
23             {
24                 for (var i = 1; i < sequence.Count; i++)
25                 {
26                     Increment(Links.GetOrCreate(sequence[i - 1], sequence[i]));
27                 }
28                 return sequence;
29             }
30
31             public void Increment(TLink link)
32             {
33                 var previousFrequency = _frequencyPropertyOperator.Get(link);
34                 var frequency = _frequencyIncrementer.Increment(previousFrequency);
35                 _frequencyPropertyOperator.Set(link, frequency);
36             }
37         }
38     }
39 }

```

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

```

1  using System.Collections.Generic;
2  using Platform.Interfaces;
3
4  namespace Platform.Data.Doublets.Incrementers
5  {
6      public class UnaryNumberIncrementer<TLink> : LinksOperatorBase<TLink>, IIncrementer<TLink>
7      {
8          private static readonly EqualityComparer<TLink> _equalityComparer =
9              ↳ EqualityComparer<TLink>.Default;
10
11         private readonly TLink _unaryOne;
12
13         public UnaryNumberIncrementer(ILinks<TLink> links, TLink unaryOne) : base(links) =>
14             ↳ _unaryOne = unaryOne;
15
16         public TLink Increment(TLink unaryNumber)
17         {
18             if (_equalityComparer.Equals(unaryNumber, _unaryOne))
19             {
20                 return Links.GetOrCreate(_unaryOne, _unaryOne);
21             }
22             var source = Links.GetSource(unaryNumber);
23             var target = Links.GetTarget(unaryNumber);
24             if (_equalityComparer.Equals(source, target))
25             {
26                 return Links.GetOrCreate(unaryNumber, _unaryOne);
27             }
28             else
29             {
30                 return Links.GetOrCreate(source, Increment(target));
31             }
32         }
33     }
34 }

```

```

31     }
32 }

```

./Platform.Data.Doublets/ISynchronizedLinks.cs

```

1  using Platform.Data.Constants;
2
3  namespace Platform.Data.Doublets
4  {
5      public interface ISynchronizedLinks<TLink> : ISynchronizedLinks<TLink, ILinks<TLink>,
        ↳ LinksCombinedConstants<TLink, TLink, int>>, ILinks<TLink>
6      {
7      }
8  }

```

./Platform.Data.Doublets/Link.cs

```

1  using System;
2  using System.Collections;
3  using System.Collections.Generic;
4  using Platform.Exceptions;
5  using Platform.Ranges;
6  using Platform.Singletons;
7  using Platform.Collections.Lists;
8  using Platform.Data.Constants;
9
10 namespace Platform.Data.Doublets
11 {
12     /// <summary>
13     /// Структура описывающая уникальную связь.
14     /// </summary>
15     public struct Link<TLink> : IEquatable<Link<TLink>>, IReadOnlyList<TLink>, IList<TLink>
16     {
17         public static readonly Link<TLink> Null = new Link<TLink>();
18
19         private static readonly LinksCombinedConstants<bool, TLink, int> _constants =
20             ↳ Default<LinksCombinedConstants<bool, TLink, int>>.Instance;
21         private static readonly EqualityComparer<TLink> _equalityComparer =
22             ↳ EqualityComparer<TLink>.Default;
23
24         private const int Length = 3;
25
26         public readonly TLink Index;
27         public readonly TLink Source;
28         public readonly TLink Target;
29
30         public Link(params TLink[] values)
31         {
32             Index = values.Length > _constants.IndexPart ? values[_constants.IndexPart] :
33                 ↳ _constants.Null;
34             Source = values.Length > _constants.SourcePart ? values[_constants.SourcePart] :
35                 ↳ _constants.Null;
36             Target = values.Length > _constants.TargetPart ? values[_constants.TargetPart] :
37                 ↳ _constants.Null;
38         }
39
40         public Link(IList<TLink> values)
41         {
42             Index = values.Count > _constants.IndexPart ? values[_constants.IndexPart] :
43                 ↳ _constants.Null;
44             Source = values.Count > _constants.SourcePart ? values[_constants.SourcePart] :
45                 ↳ _constants.Null;
46             Target = values.Count > _constants.TargetPart ? values[_constants.TargetPart] :
47                 ↳ _constants.Null;
48         }
49
50         public Link(TLink index, TLink source, TLink target)
51         {
52             Index = index;
53             Source = source;
54             Target = target;
55         }
56
57         public Link(TLink source, TLink target)
58             : this(_constants.Null, source, target)
59         {
60             Source = source;
61             Target = target;
62         }
63
64         public static Link<TLink> Create(TLink source, TLink target) => new Link<TLink>(source,
65             ↳ target);

```

```

57
58 public override int GetHashCode() => (Index, Source, Target).GetHashCode();
59
60 public bool IsNull() => _equalityComparer.Equals(Index, _constants.Null)
61     && _equalityComparer.Equals(Source, _constants.Null)
62     && _equalityComparer.Equals(Target, _constants.Null);
63
64 public override bool Equals(object other) => other is Link<TLink> &&
    ↳ Equals((Link<TLink>)other);
65
66 public bool Equals(Link<TLink> other) => _equalityComparer.Equals(Index, other.Index)
67     && _equalityComparer.Equals(Source, other.Source)
68     && _equalityComparer.Equals(Target, other.Target);
69
70 public static string ToString(TLink index, TLink source, TLink target) => $"({index}:
    ↳ {source}->{target})";
71
72 public static string ToString(TLink source, TLink target) => $"({source}->{target})";
73
74 public static implicit operator TLink[] (Link<TLink> link) => link.ToArray();
75
76 public static implicit operator Link<TLink>(TLink[] linkArray) => new
    ↳ Link<TLink>(linkArray);
77
78 public override string ToString() => _equalityComparer.Equals(Index, _constants.Null) ?
    ↳ ToString(Source, Target) : ToString(Index, Source, Target);
79
80 #region IList
81
82 public int Count => Length;
83
84 public bool IsReadOnly => true;
85
86 public TLink this[int index]
87 {
88     get
89     {
90         Ensure.Always.ArgumentInRange(index, new Range<int>(0, Length - 1),
91             ↳ nameof(index));
92         if (index == _constants.IndexPart)
93         {
94             return Index;
95         }
96         if (index == _constants.SourcePart)
97         {
98             return Source;
99         }
100         if (index == _constants.TargetPart)
101         {
102             return Target;
103         }
104         throw new NotSupportedException(); // Impossible path due to
105             ↳ Ensure.ArgumentInRange
106     }
107     set => throw new NotSupportedException();
108 }
109
110 IEnumerator IEnumerable.GetEnumerator() => GetEnumerator();
111
112 public IEnumerator<TLink> GetEnumerator()
113 {
114     yield return Index;
115     yield return Source;
116     yield return Target;
117 }
118
119 public void Add(TLink item) => throw new NotSupportedException();
120
121 public void Clear() => throw new NotSupportedException();
122
123 public bool Contains(TLink item) => IndexOf(item) >= 0;
124
125 public void CopyTo(TLink[] array, int arrayIndex)
126 {
127     Ensure.Always.ArgumentNotNull(array, nameof(array));
128     Ensure.Always.ArgumentInRange(arrayIndex, new Range<int>(0, array.Length - 1),
        ↳ nameof(arrayIndex));
        if (arrayIndex + Length > array.Length)
        {

```

```

129         throw new InvalidOperationException();
130     }
131     array[arrayIndex++] = Index;
132     array[arrayIndex++] = Source;
133     array[arrayIndex] = Target;
134 }
135
136 public bool Remove(TLink item) => Throw.A.NotSupportedExceptionAndReturn<bool>();
137
138 public int IndexOf(TLink item)
139 {
140     if (_equalityComparer.Equals(Index, item))
141     {
142         return _constants.IndexPart;
143     }
144     if (_equalityComparer.Equals(Source, item))
145     {
146         return _constants.SourcePart;
147     }
148     if (_equalityComparer.Equals(Target, item))
149     {
150         return _constants.TargetPart;
151     }
152     return -1;
153 }
154
155 public void Insert(int index, TLink item) => throw new NotSupportedException();
156
157 public void RemoveAt(int index) => throw new NotSupportedException();
158
159 #endregion
160 }
161 }

```

./Platform.Data.Doublets/LinkExtensions.cs

```

1 namespace Platform.Data.Doublets
2 {
3     public static class LinkExtensions
4     {
5         public static bool IsFullPoint<TLink>(this Link<TLink> link) =>
6             ⇨ Point<TLink>.IsFullPoint(link);
7         public static bool IsPartialPoint<TLink>(this Link<TLink> link) =>
8             ⇨ Point<TLink>.IsPartialPoint(link);
9     }
10 }

```

./Platform.Data.Doublets/LinksOperatorBase.cs

```

1 namespace Platform.Data.Doublets
2 {
3     public abstract class LinksOperatorBase<TLink>
4     {
5         public ILinks<TLink> Links { get; }
6         protected LinksOperatorBase(ILinks<TLink> links) => Links = links;
7     }
8 }

```

./Platform.Data.Doublets/PropertyOperators/DefaultLinkPropertyOperator.cs

```

1 using System.Linq;
2 using System.Collections.Generic;
3 using Platform.Interfaces;
4
5 namespace Platform.Data.Doublets.PropertyOperators
6 {
7     public class DefaultLinkPropertyOperator<TLink> : LinksOperatorBase<TLink>,
8         ⇨ IPropertiesOperator<TLink, TLink, TLink>
9     {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11             ⇨ EqualityComparer<TLink>.Default;
12
13         public DefaultLinkPropertyOperator(ILinks<TLink> links) : base(links) { }
14
15         public TLink GetValue(TLink @object, TLink property)
16         {
17             var objectProperty = Links.SearchOrDefault(@object, property);
18             if (_equalityComparer.Equals(objectProperty, default))
19             {
20                 return default;
21             }
22             var valueLink = Links.All(Links.Constants.Any, objectProperty).SingleOrDefault();

```

```

21         if (valueLink == null)
22         {
23             return default;
24         }
25         return Links.GetTarget(valueLink[Links.Constants.IndexPart]);
26     }
27
28     public void SetValue(TLink @object, TLink property, TLink value)
29     {
30         var objectProperty = Links.GetOrCreate(@object, property);
31         Links.DeleteMany(Links.All(Links.Constants.Any, objectProperty).Select(link =>
32             ↪ link[Links.Constants.IndexPart]).ToList());
33         Links.GetOrCreate(objectProperty, value);
34     }
35 }

```

./Platform.Data.Doublets/PropertyOperators/FrequencyPropertyOperator.cs

```

1  using System.Collections.Generic;
2  using Platform.Interfaces;
3
4  namespace Platform.Data.Doublets.PropertyOperators
5  {
6      public class FrequencyPropertyOperator<TLink> : LinksOperatorBase<TLink>,
7          ↪ IPropertyOperator<TLink, TLink>
8      {
9          private static readonly EqualityComparer<TLink> _equalityComparer =
10             ↪ EqualityComparer<TLink>.Default;
11
12         private readonly TLink _frequencyPropertyMarker;
13         private readonly TLink _frequencyMarker;
14
15         public FrequencyPropertyOperator(ILinks<TLink> links, TLink frequencyPropertyMarker,
16             ↪ TLink frequencyMarker) : base(links)
17         {
18             _frequencyPropertyMarker = frequencyPropertyMarker;
19             _frequencyMarker = frequencyMarker;
20         }
21
22         public TLink Get(TLink link)
23         {
24             var property = Links.SearchOrDefault(link, _frequencyPropertyMarker);
25             var container = GetContainer(property);
26             var frequency = GetFrequency(container);
27             return frequency;
28         }
29
30         private TLink GetContainer(TLink property)
31         {
32             var frequencyContainer = default(TLink);
33             if (_equalityComparer.Equals(property, default))
34             {
35                 return frequencyContainer;
36             }
37             Links.Each(candidate =>
38             {
39                 var candidateTarget = Links.GetTarget(candidate);
40                 var frequencyTarget = Links.GetTarget(candidateTarget);
41                 if (_equalityComparer.Equals(frequencyTarget, _frequencyMarker))
42                 {
43                     frequencyContainer = Links.GetIndex(candidate);
44                     return Links.Constants.Break;
45                 }
46                 return Links.Constants.Continue;
47             }, Links.Constants.Any, property, Links.Constants.Any);
48             return frequencyContainer;
49         }
50
51         private TLink GetFrequency(TLink container) => _equalityComparer.Equals(container,
52             ↪ default) ? default : Links.GetTarget(container);
53
54         public void Set(TLink link, TLink frequency)
55         {
56             var property = Links.GetOrCreate(link, _frequencyPropertyMarker);
57             var container = GetContainer(property);
58             if (_equalityComparer.Equals(container, default))
59             {
60                 Links.GetOrCreate(property, frequency);
61             }
62         }
63     }
64 }

```

```

58         else
59         {
60             Links.Update(container, property, frequency);
61         }
62     }
63 }
64 }

```

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

```

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

```



```

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

```

```

116 [MethodImpl(MethodImplOptions.AggressiveInlining)]
117 public static TLink GetFreeLinks(IntPtr pointer) => (pointer +
    ↳ FreeLinksOffset).GetValue<TLink>();
118 [MethodImpl(MethodImplOptions.AggressiveInlining)]
119 public static TLink GetFirstFreeLink(IntPtr pointer) => (pointer +
    ↳ FirstFreeLinkOffset).GetValue<TLink>();
120 [MethodImpl(MethodImplOptions.AggressiveInlining)]
121 public static TLink GetFirstAsSource(IntPtr pointer) => (pointer +
    ↳ FirstAsSourceOffset).GetValue<TLink>();
122 [MethodImpl(MethodImplOptions.AggressiveInlining)]
123 public static TLink GetFirstAsTarget(IntPtr pointer) => (pointer +
    ↳ FirstAsTargetOffset).GetValue<TLink>();
124 [MethodImpl(MethodImplOptions.AggressiveInlining)]
125 public static TLink GetLastFreeLink(IntPtr pointer) => (pointer +
    ↳ LastFreeLinkOffset).GetValue<TLink>();
126
127 [MethodImpl(MethodImplOptions.AggressiveInlining)]
128 public static IntPtr GetFirstAsSourcePointer(IntPtr pointer) => pointer +
    ↳ FirstAsSourceOffset;
129 [MethodImpl(MethodImplOptions.AggressiveInlining)]
130 public static IntPtr GetFirstAsTargetPointer(IntPtr pointer) => pointer +
    ↳ FirstAsTargetOffset;
131
132 [MethodImpl(MethodImplOptions.AggressiveInlining)]
133 public static void SetAllocatedLinks(IntPtr pointer, TLink value) => (pointer +
    ↳ AllocatedLinksOffset).SetValue(value);
134 [MethodImpl(MethodImplOptions.AggressiveInlining)]
135 public static void SetReservedLinks(IntPtr pointer, TLink value) => (pointer +
    ↳ ReservedLinksOffset).SetValue(value);
136 [MethodImpl(MethodImplOptions.AggressiveInlining)]
137 public static void SetFreeLinks(IntPtr pointer, TLink value) => (pointer +
    ↳ FreeLinksOffset).SetValue(value);
138 [MethodImpl(MethodImplOptions.AggressiveInlining)]
139 public static void SetFirstFreeLink(IntPtr pointer, TLink value) => (pointer +
    ↳ FirstFreeLinkOffset).SetValue(value);
140 [MethodImpl(MethodImplOptions.AggressiveInlining)]
141 public static void SetFirstAsSource(IntPtr pointer, TLink value) => (pointer +
    ↳ FirstAsSourceOffset).SetValue(value);
142 [MethodImpl(MethodImplOptions.AggressiveInlining)]
143 public static void SetFirstAsTarget(IntPtr pointer, TLink value) => (pointer +
    ↳ FirstAsTargetOffset).SetValue(value);
144 [MethodImpl(MethodImplOptions.AggressiveInlining)]
145 public static void SetLastFreeLink(IntPtr pointer, TLink value) => (pointer +
    ↳ LastFreeLinkOffset).SetValue(value);
146 }
147
148 private readonly long _memoryReservationStep;
149
150 private readonly IResizableDirectMemory _memory;
151 private IntPtr _header;
152 private IntPtr _links;
153
154 private LinksTargetsTreeMethods _targetsTreeMethods;
155 private LinksSourcesTreeMethods _sourcesTreeMethods;
156
157 // 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
158 private UnusedLinksListMethods _unusedLinksListMethods;
159
160 /// <summary>
161 /// Возвращает общее число связей находящихся в хранилище.
162 /// </summary>
163 private TLink Total => Subtract(LinksHeader.GetAllocatedLinks(_header),
    ↳ LinksHeader.GetFreeLinks(_header));
164
165 public LinksCombinedConstants<TLink, TLink, int> Constants { get; }
166
167 public ResizableDirectMemoryLinks(string address)
168     : this(address, DefaultLinksSizeStep)
169 {
170 }
171
172 /// <summary>
173 /// Создаёт экземпляр базы данных Links в файле по указанному адресу, с указанным
    ↳ минимальным шагом расширения базы данных.
174 /// </summary>
175 /// <param name="address">Полный путь к файлу базы данных.</param>

```

```

176  /// <param name="memoryReservationStep">Минимальный шаг расширения базы данных в
177  ↪ байтах.</param>
178  public ResizableDirectMemoryLinks(string address, long memoryReservationStep)
179      : this(new FileMappedResizableDirectMemory(address, memoryReservationStep),
180      ↪ memoryReservationStep)
181  {
182  }
183
184  public ResizableDirectMemoryLinks(IResizableDirectMemory memory)
185      : this(memory, DefaultLinksSizeStep)
186  {
187  }
188
189  public ResizableDirectMemoryLinks(IResizableDirectMemory memory, long
190  ↪ memoryReservationStep)
191  {
192      Constants = Default<LinksCombinedConstants<TLink, TLink, int>>.Instance;
193      _memory = memory;
194      _memoryReservationStep = memoryReservationStep;
195      if (memory.ReservedCapacity < memoryReservationStep)
196      {
197          memory.ReservedCapacity = memoryReservationStep;
198      }
199      SetPointers(_memory);
200      // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
201      _memory.UsedCapacity = ((long)(Integer<TLink>)LinksHeader.GetAllocatedLinks(_header)
202      ↪ * LinkSizeInBytes) + LinkHeaderSizeInBytes;
203      // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
204      LinksHeader.SetReservedLinks(_header, (Integer<TLink>)((_memory.ReservedCapacity -
205      ↪ LinkHeaderSizeInBytes) / LinkSizeInBytes));
206  }
207
208  [MethodImpl(MethodImplOptions.AggressiveInlining)]
209  public TLink Count(IList<TLink> restrictions)
210  {
211      // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
212      if (restrictions.Count == 0)
213      {
214          return Total;
215      }
216      if (restrictions.Count == 1)
217      {
218          var index = restrictions[Constants.IndexPart];
219          if (_equalityComparer.Equals(index, Constants.Any))
220          {
221              return Total;
222          }
223          return Exists(index) ? Integer<TLink>.One : Integer<TLink>.Zero;
224      }
225      if (restrictions.Count == 2)
226      {
227          var index = restrictions[Constants.IndexPart];
228          var value = restrictions[1];
229          if (_equalityComparer.Equals(index, Constants.Any))
230          {
231              if (_equalityComparer.Equals(value, Constants.Any))
232              {
233                  return Total; // Any - как отсутствие ограничения
234              }
235              return Add(_sourcesTreeMethods.CountUsages(value),
236              ↪ _targetsTreeMethods.CountUsages(value));
237          }
238          else
239          {
240              if (!Exists(index))
241              {
242                  return Integer<TLink>.Zero;
243              }
244              if (_equalityComparer.Equals(value, Constants.Any))
245              {
246                  return Integer<TLink>.One;
247              }
248              var storedLinkValue = GetLinkUnsafe(index);
249              if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), value) ||
250              ↪ _equalityComparer.Equals(Link.GetTarget(storedLinkValue), value))
251              {
252                  return Integer<TLink>.One;
253              }
254          }
255      }
256  }

```

```

248         return Integer<TLink>.Zero;
249     }
250 }
251 if (restrictions.Count == 3)
252 {
253     var index = restrictions[Constants.IndexPart];
254     var source = restrictions[Constants.SourcePart];
255     var target = restrictions[Constants.TargetPart];
256
257     if (_equalityComparer.Equals(index, Constants.Any))
258     {
259         if (_equalityComparer.Equals(source, Constants.Any) &&
260             ↪ _equalityComparer.Equals(target, Constants.Any))
261         {
262             return Total;
263         }
264         else if (_equalityComparer.Equals(source, Constants.Any))
265         {
266             return _targetsTreeMethods.CountUsages(target);
267         }
268         else if (_equalityComparer.Equals(target, Constants.Any))
269         {
270             return _sourcesTreeMethods.CountUsages(source);
271         }
272         else //if(source != Any && target != Any)
273         {
274             // Эквивалент Exists(source, target) => Count(Any, source, target) > 0
275             var link = _sourcesTreeMethods.Search(source, target);
276             return _equalityComparer.Equals(link, Constants.Null) ?
277                 ↪ Integer<TLink>.Zero : Integer<TLink>.One;
278         }
279     }
280     else
281     {
282         if (!Exists(index))
283         {
284             return Integer<TLink>.Zero;
285         }
286         if (_equalityComparer.Equals(source, Constants.Any) &&
287             ↪ _equalityComparer.Equals(target, Constants.Any))
288         {
289             return Integer<TLink>.One;
290         }
291         var storedLinkValue = GetLinkUnsafe(index);
292         if (!_equalityComparer.Equals(source, Constants.Any) &&
293             ↪ !_equalityComparer.Equals(target, Constants.Any))
294         {
295             if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), source) &&
296                 ↪ _equalityComparer.Equals(Link.GetTarget(storedLinkValue), target))
297             {
298                 return Integer<TLink>.One;
299             }
300             return Integer<TLink>.Zero;
301         }
302         if (_equalityComparer.Equals(source, Constants.Any))
303         {
304             value = target;
305         }
306         if (_equalityComparer.Equals(target, Constants.Any))
307         {
308             value = source;
309         }
310         if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), value) ||
311             ↪ _equalityComparer.Equals(Link.GetTarget(storedLinkValue), value))
312         {
313             return Integer<TLink>.One;
314         }
315         return Integer<TLink>.Zero;
316     }
317 }
318 throw new NotSupportedException("Другие размеры и способы ограничений не
319     ↪ поддерживаются.");
320 }
321
322 [MethodImpl(MethodImplOptions.AggressiveInlining)]
323 public TLink Each(Func<IList<TLink>, TLink> handler, IList<TLink> restrictions)
324 {

```

```

321 if (restrictions.Count == 0)
322 {
323     for (TLink link = Integer<TLink>.One; _comparer.Compare(link,
324         ↪ (Integer<TLink>)LinksHeader.GetAllocatedLinks(_header)) <= 0; link =
325         ↪ Increment(link))
326     {
327         if (Exists(link) && _equalityComparer.Equals(handler(GetLinkStruct(link)),
328             ↪ Constants.Break))
329         {
330             return Constants.Break;
331         }
332     }
333     return Constants.Continue;
334 }
335 if (restrictions.Count == 1)
336 {
337     var index = restrictions[Constants.IndexPart];
338     if (_equalityComparer.Equals(index, Constants.Any))
339     {
340         return Each(handler, ArrayPool<TLink>.Empty);
341     }
342     if (!Exists(index))
343     {
344         return Constants.Continue;
345     }
346     return handler(GetLinkStruct(index));
347 }
348 if (restrictions.Count == 2)
349 {
350     var index = restrictions[Constants.IndexPart];
351     var value = restrictions[1];
352     if (_equalityComparer.Equals(index, Constants.Any))
353     {
354         if (_equalityComparer.Equals(value, Constants.Any))
355         {
356             return Each(handler, ArrayPool<TLink>.Empty);
357         }
358         if (_equalityComparer.Equals(Each(handler, new[] { index, value,
359             ↪ Constants.Any }), Constants.Break))
360         {
361             return Constants.Break;
362         }
363         return Each(handler, new[] { index, Constants.Any, value });
364     }
365     else
366     {
367         if (!Exists(index))
368         {
369             return Constants.Continue;
370         }
371         if (_equalityComparer.Equals(value, Constants.Any))
372         {
373             return handler(GetLinkStruct(index));
374         }
375         var storedLinkValue = GetLinkUnsafe(index);
376         if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), value) ||
377             ↪ _equalityComparer.Equals(Link.GetTarget(storedLinkValue), value))
378         {
379             return handler(GetLinkStruct(index));
380         }
381         return Constants.Continue;
382     }
383 }
384 if (restrictions.Count == 3)
385 {
386     var index = restrictions[Constants.IndexPart];
387     var source = restrictions[Constants.SourcePart];
388     var target = restrictions[Constants.TargetPart];
389     if (_equalityComparer.Equals(index, Constants.Any))
390     {
391         if (_equalityComparer.Equals(source, Constants.Any) &&
392             ↪ _equalityComparer.Equals(target, Constants.Any))
393         {
394             return Each(handler, ArrayPool<TLink>.Empty);
395         }
396         else if (_equalityComparer.Equals(source, Constants.Any))
397         {

```

```

394         return _targetsTreeMethods.EachUsage(target, handler);
395     }
396     else if (_equalityComparer.Equals(target, Constants.Any))
397     {
398         return _sourcesTreeMethods.EachUsage(source, handler);
399     }
400     else //if(source != Any && target != Any)
401     {
402         var link = _sourcesTreeMethods.Search(source, target);
403         return _equalityComparer.Equals(link, Constants.Null) ?
            ↳ Constants.Continue : handler(GetLinkStruct(link));
404     }
405 }
406 else
407 {
408     if (!Exists(index))
409     {
410         return Constants.Continue;
411     }
412     if (_equalityComparer.Equals(source, Constants.Any) &&
        ↳ _equalityComparer.Equals(target, Constants.Any))
413     {
414         return handler(GetLinkStruct(index));
415     }
416     var storedLinkValue = GetLinkUnsafe(index);
417     if (!_equalityComparer.Equals(source, Constants.Any) &&
        ↳ !_equalityComparer.Equals(target, Constants.Any))
418     {
419         if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), source) &&
            ↳ _equalityComparer.Equals(Link.GetTarget(storedLinkValue), target))
420         {
421             return handler(GetLinkStruct(index));
422         }
423         return Constants.Continue;
424     }
425     var value = default(TLink);
426     if (_equalityComparer.Equals(source, Constants.Any))
427     {
428         value = target;
429     }
430     if (_equalityComparer.Equals(target, Constants.Any))
431     {
432         value = source;
433     }
434     if (_equalityComparer.Equals(Link.GetSource(storedLinkValue), value) ||
        ↳ _equalityComparer.Equals(Link.GetTarget(storedLinkValue), value))
435     {
436         return handler(GetLinkStruct(index));
437     }
438     return Constants.Continue;
439 }
440 }
441 }
442 throw new NotSupportedException("Другие размеры и способы ограничений не
443 ↳ поддерживаются.");
444 }
445
446 /// <remarks>
447 /// TODO: Возможно можно перемещать значения, если указан индекс, но значение существует
448 ↳ в другом месте (но не в менеджере памяти, а в логике Links)
449 /// </remarks>
450 [MethodImpl(MethodImplOptions.AggressiveInlining)]
451 public TLink Update(IList<TLink> values)
452 {
453     var linkIndex = values[Constants.IndexPart];
454     var link = GetLinkUnsafe(linkIndex);
455     // Будет корректно работать только в том случае, если пространство выделенной связи
456     ↳ предварительно заполнено нулями
457     if (!_equalityComparer.Equals(Link.GetSource(link), Constants.Null))
458     {
459         _sourcesTreeMethods.Detach(LinksHeader.GetFirstAsSourcePointer(_header),
            ↳ linkIndex);
460     }
461     if (!_equalityComparer.Equals(Link.GetTarget(link), Constants.Null))
462     {
463         _targetsTreeMethods.Detach(LinksHeader.GetFirstAsTargetPointer(_header),
            ↳ linkIndex);
464     }
465     Link.SetSource(link, values[Constants.SourcePart]);

```

```

464     Link.SetTarget(link, values[Constants.TargetPart]);
465     if (!_equalityComparer.Equals(Link.GetSource(link), Constants.Null))
466     {
467         _sourcesTreeMethods.Attach(LinksHeader.GetFirstAsSourcePointer(_header),
468             ↪ linkIndex);
469     }
470     if (!_equalityComparer.Equals(Link.GetTarget(link), Constants.Null))
471     {
472         _targetsTreeMethods.Attach(LinksHeader.GetFirstAsTargetPointer(_header),
473             ↪ linkIndex);
474     }
475     return linkIndex;
476 }
477
478 [MethodImpl(MethodImplOptions.AggressiveInlining)]
479 public Link<TLink> GetLinkStruct(TLink linkIndex)
480 {
481     var link = GetLinkUnsafe(linkIndex);
482     return new Link<TLink>(linkIndex, Link.GetSource(link), Link.GetTarget(link));
483 }
484
485 [MethodImpl(MethodImplOptions.AggressiveInlining)]
486 private IntPtr GetLinkUnsafe(TLink linkIndex) => _links.GetElement(LinkSizeInBytes,
487     ↪ linkIndex);
488
489 /// <remarks>
490 /// TODO: Возможно нужно будет заполнение нулями, если внешнее API ими не заполняет
491 ↪ пространство
492 /// </remarks>
493 public TLink Create()
494 {
495     var freeLink = LinksHeader.GetFirstFreeLink(_header);
496     if (!_equalityComparer.Equals(freeLink, Constants.Null))
497     {
498         _unusedLinksListMethods.Detach(freeLink);
499     }
500     else
501     {
502         if (_comparer.Compare(LinksHeader.GetAllocatedLinks(_header),
503             ↪ Constants.MaxPossibleIndex) > 0)
504         {
505             throw new
506                 ↪ LinksLimitReachedException((Integer<TLink>)Constants.MaxPossibleIndex);
507         }
508         if (_comparer.Compare(LinksHeader.GetAllocatedLinks(_header),
509             ↪ Decrement(LinksHeader.GetReservedLinks(_header))) >= 0)
510         {
511             _memory.ReservedCapacity += _memory.ReservationStep;
512             SetPointers(_memory);
513             LinksHeader.SetReservedLinks(_header,
514                 ↪ (Integer<TLink>)(_memory.ReservedCapacity / LinkSizeInBytes));
515         }
516         LinksHeader.SetAllocatedLinks(_header,
517             ↪ Increment(LinksHeader.GetAllocatedLinks(_header)));
518         _memory.UsedCapacity += LinkSizeInBytes;
519         freeLink = LinksHeader.GetAllocatedLinks(_header);
520     }
521     return freeLink;
522 }
523
524 public void Delete(TLink link)
525 {
526     if (_comparer.Compare(link, LinksHeader.GetAllocatedLinks(_header)) < 0)
527     {
528         _unusedLinksListMethods.AttachAsFirst(link);
529     }
530     else if (_equalityComparer.Equals(link, LinksHeader.GetAllocatedLinks(_header)))
531     {
532         LinksHeader.SetAllocatedLinks(_header,
533             ↪ Decrement(LinksHeader.GetAllocatedLinks(_header)));
534         _memory.UsedCapacity -= LinkSizeInBytes;
535         // Убираем все связи, находящиеся в списке свободных в конце файла, до тех пор,
536         ↪ пока не дойдём до первой существующей связи
537         // Позволяет оптимизировать количество выделенных связей (AllocatedLinks)
538         while ((_comparer.Compare(LinksHeader.GetAllocatedLinks(_header),
539             ↪ Integer<TLink>.Zero) > 0) &&
540             ↪ IsUnusedLink(LinksHeader.GetAllocatedLinks(_header)))
541         {

```

```

529         _unusedLinksListMethods.Detach(LinksHeader.GetAllocatedLinks(_header));
530         LinksHeader.SetAllocatedLinks(_header,
531         ↪ Decrement(LinksHeader.GetAllocatedLinks(_header)));
532         _memory.UsedCapacity -= LinkSizeInBytes;
533     }
534 }
535
536 /// <remarks>
537 /// TODO: Возможно это должно быть событием, вызываемым из IMemory, в том случае, если
538 ↪ адрес реально поменялся
539 ///
540 /// Указатель this.links может быть в том же месте,
541 /// так как 0-я связь не используется и имеет такой же размер как Header,
542 /// поэтому header размещается в том же месте, что и 0-я связь
543 /// </remarks>
544 private void SetPointers(IDirectMemory memory)
545 {
546     if (memory == null)
547     {
548         _links = IntPtr.Zero;
549         _header = _links;
550         _unusedLinksListMethods = null;
551         _targetsTreeMethods = null;
552         _unusedLinksListMethods = null;
553     }
554     else
555     {
556         _links = memory.Pointer;
557         _header = _links;
558         _sourcesTreeMethods = new LinksSourcesTreeMethods(this);
559         _targetsTreeMethods = new LinksTargetsTreeMethods(this);
560         _unusedLinksListMethods = new UnusedLinksListMethods(_links, _header);
561     }
562 }
563
564 [MethodImpl(MethodImplOptions.AggressiveInlining)]
565 private bool Exists(TLink link)
566     => (_comparer.Compare(link, Constants.MinPossibleIndex) >= 0)
567     && (_comparer.Compare(link, LinksHeader.GetAllocatedLinks(_header)) <= 0)
568     && !IsUnusedLink(link);
569
570 [MethodImpl(MethodImplOptions.AggressiveInlining)]
571 private bool IsUnusedLink(TLink link)
572     => _equalityComparer.Equals(LinksHeader.GetFirstFreeLink(_header), link)
573     || (_equalityComparer.Equals(Link.GetSizeAsSource(GetLinkUnsafe(link)),
574     ↪ Constants.Null)
575     && !_equalityComparer.Equals(Link.GetSource(GetLinkUnsafe(link)), Constants.Null));
576
577 #region DisposableBase
578
579 protected override bool AllowMultipleDisposeCalls => true;
580
581 protected override void Dispose(bool manual, bool wasDisposed)
582 {
583     if (!wasDisposed)
584     {
585         SetPointers(null);
586         _memory.DisposeIfPossible();
587     }
588 }
589
590 #endregion
591 }
592

```

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

```

1  using System;
2  using Platform.Unsafe;
3  using Platform.Collections.Methods.Lists;
4
5  namespace Platform.Data.Doublets.ResizableDirectMemory
6  {
7      partial class ResizableDirectMemoryLinks<TLink>
8      {
9          private class UnusedLinksListMethods : CircularDoublyLinkedListMethods<TLink>
10          {
11              private readonly IntPtr _links;
12              private readonly IntPtr _header;
13

```



```

14     public UnusedLinksListMethods(IntPtr links, IntPtr header)
15     {
16         _links = links;
17         _header = header;
18     }
19
20     protected override TLink GetFirst() => (_header +
21     ↪ LinksHeader.FirstFreeLinkOffset).GetValue<TLink>();
22
23     protected override TLink GetLast() => (_header +
24     ↪ LinksHeader.LastFreeLinkOffset).GetValue<TLink>();
25
26     protected override TLink GetPrevious(TLink element) =>
27     ↪ (_links.GetElement(LinkSizeInBytes, element) +
28     ↪ Link.SourceOffset).GetValue<TLink>();
29
30     protected override TLink GetNext(TLink element) =>
31     ↪ (_links.GetElement(LinkSizeInBytes, element) +
32     ↪ Link.TargetOffset).GetValue<TLink>();
33
34     protected override TLink GetSize() => (_header +
35     ↪ LinksHeader.FreeLinksOffset).GetValue<TLink>();
36
37     protected override void SetFirst(TLink element) => (_header +
38     ↪ LinksHeader.FirstFreeLinkOffset).SetValue(element);
39
40     protected override void SetLast(TLink element) => (_header +
41     ↪ LinksHeader.LastFreeLinkOffset).SetValue(element);
42
43     protected override void SetPrevious(TLink element, TLink previous) =>
44     ↪ (_links.GetElement(LinkSizeInBytes, element) +
45     ↪ Link.SourceOffset).SetValue(previous);
46
47     protected override void SetNext(TLink element, TLink next) =>
48     ↪ (_links.GetElement(LinkSizeInBytes, element) + Link.TargetOffset).SetValue(next);
49
50     protected override void SetSize(TLink size) => (_header +
51     ↪ LinksHeader.FreeLinksOffset).SetValue(size);
52 }
53 }
54 }

```

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

```

1  using System;
2  using System.Text;
3  using System.Collections.Generic;
4  using System.Runtime.CompilerServices;
5  using Platform.Numbers;
6  using Platform.Unsafe;
7  using Platform.Collections.Methods.Trees;
8  using Platform.Data.Constants;
9
10 namespace Platform.Data.Doublets.ResizableDirectMemory
11 {
12     partial class ResizableDirectMemoryLinks<TLink>
13     {
14         private abstract class LinksTreeMethodsBase :
15         ↪ SizedAndThreadedAVLBalancedTreeMethods<TLink>
16         {
17             private readonly ResizableDirectMemoryLinks<TLink> _memory;
18             private readonly LinksCombinedConstants<TLink, TLink, int> _constants;
19             protected readonly IntPtr Links;
20             protected readonly IntPtr Header;
21
22             protected LinksTreeMethodsBase(ResizableDirectMemoryLinks<TLink> memory)
23             {
24                 Links = memory._links;
25                 Header = memory._header;
26                 _memory = memory;
27                 _constants = memory.Constants;
28             }
29
30             [MethodImpl(MethodImplOptions.AggressiveInlining)]
31             protected abstract TLink GetTreeRoot();
32
33             [MethodImpl(MethodImplOptions.AggressiveInlining)]
34             protected abstract TLink GetBasePartValue(TLink link);
35
36             public TLink this[TLink index]
37             {

```

```

37     get
38     {
39         var root = GetTreeRoot();
40         if (GreaterOrEqualThan(index, GetSize(root)))
41         {
42             return GetZero();
43         }
44         while (!EqualToZero(root))
45         {
46             var left = GetLeftOrDefault(root);
47             var leftSize = GetSizeOrZero(left);
48             if (LessThan(index, leftSize))
49             {
50                 root = left;
51                 continue;
52             }
53             if (IsEquals(index, leftSize))
54             {
55                 return root;
56             }
57             root = GetRightOrDefault(root);
58             index = Subtract(index, Increment(leftSize));
59         }
60         return GetZero(); // TODO: Impossible situation exception (only if tree
        ↳ structure broken)
61     }
62 }
63
64 // TODO: Return indices range instead of references count
65 public TLink CountUsages(TLink link)
66 {
67     var root = GetTreeRoot();
68     var total = GetSize(root);
69     var totalRightIgnore = GetZero();
70     while (!EqualToZero(root))
71     {
72         var @base = GetBasePartValue(root);
73         if (LessOrEqualThan(@base, link))
74         {
75             root = GetRightOrDefault(root);
76         }
77         else
78         {
79             totalRightIgnore = Add(totalRightIgnore, Increment(GetRightSize(root)));
80             root = GetLeftOrDefault(root);
81         }
82     }
83     root = GetTreeRoot();
84     var totalLeftIgnore = GetZero();
85     while (!EqualToZero(root))
86     {
87         var @base = GetBasePartValue(root);
88         if (GreaterOrEqualThan(@base, link))
89         {
90             root = GetLeftOrDefault(root);
91         }
92         else
93         {
94             totalLeftIgnore = Add(totalLeftIgnore, Increment(GetLeftSize(root)));
95             root = GetRightOrDefault(root);
96         }
97     }
98     return Subtract(Subtract(total, totalRightIgnore), totalLeftIgnore);
99 }
100
101
102 public TLink EachUsage(TLink link, Func<IList<TLink>, TLink> handler)
103 {
104     var root = GetTreeRoot();
105     if (EqualToZero(root))
106     {
107         return _constants.Continue;
108     }
109     TLink first = GetZero(), current = root;
110     while (!EqualToZero(current))
111     {
112         var @base = GetBasePartValue(current);
113         if (GreaterOrEqualThan(@base, link))

```

```

114         {
115             if (IsEquals(@base, link))
116             {
117                 first = current;
118             }
119             current = GetLeftOrDefault(current);
120         }
121         else
122         {
123             current = GetRightOrDefault(current);
124         }
125     }
126     if (!EqualToZero(first))
127     {
128         current = first;
129         while (true)
130         {
131             if (IsEquals(handler(_memory.GetLinkStruct(current)), _constants.Break))
132             {
133                 return _constants.Break;
134             }
135             current = GetNext(current);
136             if (EqualToZero(current) || !IsEquals(GetBasePartValue(current), link))
137             {
138                 break;
139             }
140         }
141     }
142     return _constants.Continue;
143 }
144
145 protected override void PrintNodeValue(TLink node, StringBuilder sb)
146 {
147     sb.Append(' ');
148     sb.Append((Links.GetElement(LinkSizeInBytes, node) +
149         ↪ Link.SourceOffset).GetValue<TLink>());
150     sb.Append('-');
151     sb.Append('>');
152     sb.Append((Links.GetElement(LinkSizeInBytes, node) +
153         ↪ Link.TargetOffset).GetValue<TLink>());
154 }
155
156 private class LinksSourcesTreeMethods : LinksTreeMethodsBase
157 {
158     public LinksSourcesTreeMethods(ResizableDirectMemoryLinks<TLink> memory)
159         : base(memory)
160     {
161     }
162
163     protected override IntPtr GetLeftPointer(TLink node) =>
164         ↪ Links.GetElement(LinkSizeInBytes, node) + Link.LeftAsSourceOffset;
165
166     protected override IntPtr GetRightPointer(TLink node) =>
167         ↪ Links.GetElement(LinkSizeInBytes, node) + Link.RightAsSourceOffset;
168
169     protected override TLink GetLeftValue(TLink node) =>
170         ↪ (Links.GetElement(LinkSizeInBytes, node) +
171         ↪ Link.LeftAsSourceOffset).GetValue<TLink>();
172
173     protected override TLink GetRightValue(TLink node) =>
174         ↪ (Links.GetElement(LinkSizeInBytes, node) +
175         ↪ Link.RightAsSourceOffset).GetValue<TLink>();
176
177     protected override TLink GetSize(TLink node)
178     {
179         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
180             ↪ Link.SizeAsSourceOffset).GetValue<TLink>();
181         return Bit.PartialRead(previousValue, 5, -5);
182     }
183
184     protected override void SetLeft(TLink node, TLink left) =>
185         ↪ (Links.GetElement(LinkSizeInBytes, node) +
186         ↪ Link.LeftAsSourceOffset).SetValue(left);
187
188     protected override void SetRight(TLink node, TLink right) =>
189         ↪ (Links.GetElement(LinkSizeInBytes, node) +
190         ↪ Link.RightAsSourceOffset).SetValue(right);

```

```

179
180 protected override void SetSize(TLink node, TLink size)
181 {
182     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
183         ↳ Link.SizeAsSourceOffset).GetValue<TLink>();
184     (Links.GetElement(LinkSizeInBytes, node) +
185         ↳ Link.SizeAsSourceOffset).SetValue(Bit.PartialWrite(previousValue, size, 5,
186         ↳ -5));
187 }
188
189 protected override bool GetLeftIsChild(TLink node)
190 {
191     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
192         ↳ Link.SizeAsSourceOffset).GetValue<TLink>();
193     return (Integer<TLink>)Bit.PartialRead(previousValue, 4, 1);
194 }
195
196 protected override void SetLeftIsChild(TLink node, bool value)
197 {
198     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
199         ↳ Link.SizeAsSourceOffset).GetValue<TLink>();
200     var modified = Bit.PartialWrite(previousValue, (TLink)(Integer<TLink>)value, 4,
201         ↳ 1);
202     (Links.GetElement(LinkSizeInBytes, node) +
203         ↳ Link.SizeAsSourceOffset).SetValue(modified);
204 }
205
206 protected override bool GetRightIsChild(TLink node)
207 {
208     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
209         ↳ Link.SizeAsSourceOffset).GetValue<TLink>();
210     return (Integer<TLink>)Bit.PartialRead(previousValue, 3, 1);
211 }
212
213 protected override void SetRightIsChild(TLink node, bool value)
214 {
215     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
216         ↳ Link.SizeAsSourceOffset).GetValue<TLink>();
217     var modified = Bit.PartialWrite(previousValue, (TLink)(Integer<TLink>)value, 3,
218         ↳ 1);
219     (Links.GetElement(LinkSizeInBytes, node) +
220         ↳ Link.SizeAsSourceOffset).SetValue(modified);
221 }
222
223 protected override sbyte GetBalance(TLink node)
224 {
225     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
226         ↳ Link.SizeAsSourceOffset).GetValue<TLink>();
227     var value = (ulong)(Integer<TLink>)Bit.PartialRead(previousValue, 0, 3);
228     var unpackedValue = (sbyte)((value & 4) > 0 ? ((value & 4) << 5) | value & 3 |
229         ↳ 124 : value & 3);
230     return unpackedValue;
231 }
232
233 protected override void SetBalance(TLink node, sbyte value)
234 {
235     var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
236         ↳ Link.SizeAsSourceOffset).GetValue<TLink>();
237     var packagedValue = (TLink)(Integer<TLink>)(((byte)value >> 5) & 4) | value &
238         ↳ 3;
239     var modified = Bit.PartialWrite(previousValue, packagedValue, 0, 3);
240     (Links.GetElement(LinkSizeInBytes, node) +
241         ↳ Link.SizeAsSourceOffset).SetValue(modified);
242 }
243
244 protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
245 {
246     var firstSource = (Links.GetElement(LinkSizeInBytes, first) +
247         ↳ Link.SourceOffset).GetValue<TLink>();
248     var secondSource = (Links.GetElement(LinkSizeInBytes, second) +
249         ↳ Link.SourceOffset).GetValue<TLink>();
250     return LessThan(firstSource, secondSource) ||
251         ↳ (IsEquals(firstSource, secondSource) &&
252         ↳ ↳ LessThan((Links.GetElement(LinkSizeInBytes, first) +
253         ↳ ↳ ↳ Link.TargetOffset).GetValue<TLink>(),
254         ↳ ↳ ↳ (Links.GetElement(LinkSizeInBytes, second) +
255         ↳ ↳ ↳ Link.TargetOffset).GetValue<TLink>()));
256 }

```

```

234     }
235
236     protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
237     {
238         var firstSource = (Links.GetElement(LinkSizeInBytes, first) +
239             ↪ Link.SourceOffset).GetValue<TLink>();
240         var secondSource = (Links.GetElement(LinkSizeInBytes, second) +
241             ↪ Link.SourceOffset).GetValue<TLink>();
242         return GreaterThan(firstSource, secondSource) ||
243             (IsEquals(firstSource, secondSource) &&
244                 ↪ GreaterThan((Links.GetElement(LinkSizeInBytes, first) +
245                     ↪ Link.TargetOffset).GetValue<TLink>(),
246                     ↪ (Links.GetElement(LinkSizeInBytes, second) +
247                         ↪ Link.TargetOffset).GetValue<TLink>()));
248     }
249
250     protected override TLink GetTreeRoot() => (Header +
251         ↪ LinksHeader.FirstAsSourceOffset).GetValue<TLink>();
252
253     protected override TLink GetBasePartValue(TLink link) =>
254         ↪ (Links.GetElement(LinkSizeInBytes, link) + Link.SourceOffset).GetValue<TLink>();
255
256     /// <summary>
257     /// Выполняет поиск и возвращает индекс связи с указанными Source (началом) и Target
258     ↪ (концом)
259     /// по дереву (индексу) связей, отсортированному по Source, а затем по Target.
260     /// </summary>
261     /// <param name="source">Индекс связи, которая является началом на искомой
262     ↪ связи.</param>
263     /// <param name="target">Индекс связи, которая является концом на искомой
264     ↪ связи.</param>
265     /// <returns>Индекс искомой связи.</returns>
266     public TLink Search(TLink source, TLink target)
267     {
268         var root = GetTreeRoot();
269         while (!EqualToZero(root))
270         {
271             var rootSource = (Links.GetElement(LinkSizeInBytes, root) +
272                 ↪ Link.SourceOffset).GetValue<TLink>();
273             var rootTarget = (Links.GetElement(LinkSizeInBytes, root) +
274                 ↪ Link.TargetOffset).GetValue<TLink>();
275             if (FirstIsToTheLeftOfSecond(source, target, rootSource, rootTarget)) //
276                 ↪ node.Key < root.Key
277             {
278                 root = GetLeftOrDefault(root);
279             }
280             else if (FirstIsToTheRightOfSecond(source, target, rootSource, rootTarget))
281                 ↪ // node.Key > root.Key
282             {
283                 root = GetRightOrDefault(root);
284             }
285             else // node.Key == root.Key
286             {
287                 return root;
288             }
289         }
290         return GetZero();
291     }
292
293     [MethodImpl(MethodImplOptions.AggressiveInlining)]
294     private bool FirstIsToTheLeftOfSecond(TLink firstSource, TLink firstTarget, TLink
295         ↪ secondSource, TLink secondTarget) => LessThan(firstSource, secondSource) ||
296         ↪ (IsEquals(firstSource, secondSource) && LessThan(firstTarget, secondTarget));
297
298     [MethodImpl(MethodImplOptions.AggressiveInlining)]
299     private bool FirstIsToTheRightOfSecond(TLink firstSource, TLink firstTarget, TLink
300         ↪ secondSource, TLink secondTarget) => GreaterThan(firstSource, secondSource) ||
301         ↪ (IsEquals(firstSource, secondSource) && GreaterThan(firstTarget, secondTarget));
302
303     private class LinksTargetsTreeMethods : LinksTreeMethodsBase
304     {
305         public LinksTargetsTreeMethods(ResizableDirectMemoryLinks<TLink> memory)
306             : base(memory)
307         {
308         }
309     }

```

```

292     protected override IntPtr GetLeftPointer(TLink node) =>
293         ↳ Links.GetElement(LinkSizeInBytes, node) + Link.LeftAsTargetOffset;
294
295     protected override IntPtr GetRightPointer(TLink node) =>
296         ↳ Links.GetElement(LinkSizeInBytes, node) + Link.RightAsTargetOffset;
297
298     protected override TLink GetLeftValue(TLink node) =>
299         ↳ (Links.GetElement(LinkSizeInBytes, node) +
300         ↳ Link.LeftAsTargetOffset).GetValue<TLink>();
301
302     protected override TLink GetRightValue(TLink node) =>
303         ↳ (Links.GetElement(LinkSizeInBytes, node) +
304         ↳ Link.RightAsTargetOffset).GetValue<TLink>();
305
306     protected override TLink GetSize(TLink node)
307     {
308         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
309         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
310         return Bit.PartialRead(previousValue, 5, -5);
311     }
312
313     protected override void SetLeft(TLink node, TLink left) =>
314         ↳ (Links.GetElement(LinkSizeInBytes, node) +
315         ↳ Link.LeftAsTargetOffset).SetValue(left);
316
317     protected override void SetRight(TLink node, TLink right) =>
318         ↳ (Links.GetElement(LinkSizeInBytes, node) +
319         ↳ Link.RightAsTargetOffset).SetValue(right);
320
321     protected override void SetSize(TLink node, TLink size)
322     {
323         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
324         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
325         (Links.GetElement(LinkSizeInBytes, node) +
326         ↳ Link.SizeAsTargetOffset).SetValue(Bit.PartialWrite(previousValue, size, 5,
327         ↳ -5));
328     }
329
330     protected override bool GetLeftIsChild(TLink node)
331     {
332         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
333         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
334         return (Integer<TLink>)Bit.PartialRead(previousValue, 4, 1);
335     }
336
337     protected override void SetLeftIsChild(TLink node, bool value)
338     {
339         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
340         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
341         var modified = Bit.PartialWrite(previousValue, (TLink)(Integer<TLink>)value, 4,
342         ↳ 1);
343         (Links.GetElement(LinkSizeInBytes, node) +
344         ↳ Link.SizeAsTargetOffset).SetValue(modified);
345     }
346
347     protected override bool GetRightIsChild(TLink node)
348     {
349         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
350         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
351         return (Integer<TLink>)Bit.PartialRead(previousValue, 3, 1);
352     }
353
354     protected override void SetRightIsChild(TLink node, bool value)
355     {
356         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
357         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
358         var modified = Bit.PartialWrite(previousValue, (TLink)(Integer<TLink>)value, 3,
359         ↳ 1);
360         (Links.GetElement(LinkSizeInBytes, node) +
361         ↳ Link.SizeAsTargetOffset).SetValue(modified);
362     }
363
364     protected override sbyte GetBalance(TLink node)
365     {
366         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
367         ↳ Link.SizeAsTargetOffset).GetValue<TLink>();
368         var value = (ulong)(Integer<TLink>)Bit.PartialRead(previousValue, 0, 3);

```

```

346         var unpackedValue = (sbyte)((value & 4) > 0 ? ((value & 4) << 5) | value & 3 |
347             ↪ 124 : value & 3);
348         return unpackedValue;
349     }
350     protected override void SetBalance(TLink node, sbyte value)
351     {
352         var previousValue = (Links.GetElement(LinkSizeInBytes, node) +
353             ↪ Link.SizeAsTargetOffset).GetValue<TLink>();
354         var packagedValue = (TLink)(Integer<TLink>)((((byte)value >> 5) & 4) | value &
355             ↪ 3);
356         var modified = Bit.PartialWrite(previousValue, packagedValue, 0, 3);
357         (Links.GetElement(LinkSizeInBytes, node) +
358             ↪ Link.SizeAsTargetOffset).SetValue(modified);
359     }
360     protected override bool FirstIsToTheLeftOfSecond(TLink first, TLink second)
361     {
362         var firstTarget = (Links.GetElement(LinkSizeInBytes, first) +
363             ↪ Link.TargetOffset).GetValue<TLink>();
364         var secondTarget = (Links.GetElement(LinkSizeInBytes, second) +
365             ↪ Link.TargetOffset).GetValue<TLink>();
366         return LessThan(firstTarget, secondTarget) ||
367             (IsEquals(firstTarget, secondTarget) &&
368                 ↪ LessThan((Links.GetElement(LinkSizeInBytes, first) +
369                     ↪ Link.SourceOffset).GetValue<TLink>(),
370                     ↪ (Links.GetElement(LinkSizeInBytes, second) +
371                         ↪ Link.SourceOffset).GetValue<TLink>()));
372     }
373     protected override bool FirstIsToTheRightOfSecond(TLink first, TLink second)
374     {
375         var firstTarget = (Links.GetElement(LinkSizeInBytes, first) +
376             ↪ Link.TargetOffset).GetValue<TLink>();
377         var secondTarget = (Links.GetElement(LinkSizeInBytes, second) +
378             ↪ Link.TargetOffset).GetValue<TLink>();
379         return GreaterThan(firstTarget, secondTarget) ||
380             (IsEquals(firstTarget, secondTarget) &&
381                 ↪ GreaterThan((Links.GetElement(LinkSizeInBytes, first) +
382                     ↪ Link.SourceOffset).GetValue<TLink>(),
383                     ↪ (Links.GetElement(LinkSizeInBytes, second) +
384                         ↪ Link.SourceOffset).GetValue<TLink>()));
385     }
386     protected override TLink GetTreeRoot() => (Header +
387         ↪ LinksHeader.FirstAsTargetOffset).GetValue<TLink>();
388     protected override TLink GetBasePartValue(TLink link) =>
389         ↪ (Links.GetElement(LinkSizeInBytes, link) + Link.TargetOffset).GetValue<TLink>();
390 }
391 }
392 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Disposables;
5  using Platform.Collections.Arrays;
6  using Platform.Singletons;
7  using Platform.Memory;
8  using Platform.Data.Exceptions;
9  using Platform.Data.Constants;
10
11  //#define ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
12
13  #pragma warning disable 0649
14  #pragma warning disable 169
15
16  // ReSharper disable BuiltInTypeReferenceStyle
17
18  namespace Platform.Data.Doublets.ResizableDirectMemory
19  {
20      using id = UInt64;
21
22      public unsafe partial class UInt64ResizableDirectMemoryLinks : DisposableBase, ILinks<id>
23      {
24          /// <summary>Возвращает размер одной связи в байтах.</summary>
25          /// <remarks>

```

```

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

```



```

98 // Гарантия корректности _memory.UsedCapacity относительно _header->AllocatedLinks
99 _memory.UsedCapacity = ((long)_header->AllocatedLinks * sizeof(Link)) +
    ↳ sizeof(LinksHeader);
100 // Гарантия корректности _header->ReservedLinks относительно _memory.ReservedCapacity
101 _header->ReservedLinks = (id)((_memory.ReservedCapacity - sizeof(LinksHeader)) /
    ↳ sizeof(Link));
102 }
103
104 [MethodImpl(MethodImplOptions.AggressiveInlining)]
105 public id Count(IList<id> restrictions)
106 {
107     // Если нет ограничений, тогда возвращаем общее число связей находящихся в хранилище.
108     if (restrictions.Count == 0)
109     {
110         return Total;
111     }
112     if (restrictions.Count == 1)
113     {
114         var index = restrictions[Constants.IndexPart];
115         if (index == Constants.Any)
116         {
117             return Total;
118         }
119         return Exists(index) ? 1UL : 0UL;
120     }
121     if (restrictions.Count == 2)
122     {
123         var index = restrictions[Constants.IndexPart];
124         var value = restrictions[1];
125         if (index == Constants.Any)
126         {
127             if (value == Constants.Any)
128             {
129                 return Total; // Any - как отсутствие ограничения
130             }
131             return _sourcesTreeMethods.CountUsages(value)
132                 + _targetsTreeMethods.CountUsages(value);
133         }
134         else
135         {
136             if (!Exists(index))
137             {
138                 return 0;
139             }
140             if (value == Constants.Any)
141             {
142                 return 1;
143             }
144             var storedLinkValue = GetLinkUnsafe(index);
145             if (storedLinkValue->Source == value ||
146                 storedLinkValue->Target == value)
147             {
148                 return 1;
149             }
150             return 0;
151         }
152     }
153     if (restrictions.Count == 3)
154     {
155         var index = restrictions[Constants.IndexPart];
156         var source = restrictions[Constants.SourcePart];
157         var target = restrictions[Constants.TargetPart];
158         if (index == Constants.Any)
159         {
160             if (source == Constants.Any && target == Constants.Any)
161             {
162                 return Total;
163             }
164             else if (source == Constants.Any)
165             {
166                 return _targetsTreeMethods.CountUsages(target);
167             }
168             else if (target == Constants.Any)
169             {
170                 return _sourcesTreeMethods.CountUsages(source);
171             }
172             else //if(source != Any && target != Any)
173             {

```

```

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

```

```

252 var value = restrictions[1];
253 if (index == Constants.Any)
254 {
255     if (value == Constants.Any)
256     {
257         return Each(handler, ArrayPool<ulong>.Empty);
258     }
259     if (Each(handler, new[] { index, value, Constants.Any }) == Constants.Break)
260     {
261         return Constants.Break;
262     }
263     return Each(handler, new[] { index, Constants.Any, value });
264 }
265 else
266 {
267     if (!Exists(index))
268     {
269         return Constants.Continue;
270     }
271     if (value == Constants.Any)
272     {
273         return handler(GetLinkStruct(index));
274     }
275     var storedLinkValue = GetLinkUnsafe(index);
276     if (storedLinkValue->Source == value ||
277         storedLinkValue->Target == value)
278     {
279         return handler(GetLinkStruct(index));
280     }
281     return Constants.Continue;
282 }
283 }
284 if (restrictions.Count == 3)
285 {
286     var index = restrictions[Constants.IndexPart];
287     var source = restrictions[Constants.SourcePart];
288     var target = restrictions[Constants.TargetPart];
289     if (index == Constants.Any)
290     {
291         if (source == Constants.Any && target == Constants.Any)
292         {
293             return Each(handler, ArrayPool<ulong>.Empty);
294         }
295         else if (source == Constants.Any)
296         {
297             return _targetsTreeMethods.EachReference(target, handler);
298         }
299         else if (target == Constants.Any)
300         {
301             return _sourcesTreeMethods.EachReference(source, handler);
302         }
303         else //if(source != Any && target != Any)
304         {
305             var link = _sourcesTreeMethods.Search(source, target);
306             return link == Constants.Null ? Constants.Continue :
307                 ↪ handler(GetLinkStruct(link));
308         }
309     }
310     else
311     {
312         if (!Exists(index))
313         {
314             return Constants.Continue;
315         }
316         if (source == Constants.Any && target == Constants.Any)
317         {
318             return handler(GetLinkStruct(index));
319         }
320         var storedLinkValue = GetLinkUnsafe(index);
321         if (source != Constants.Any && target != Constants.Any)
322         {
323             if (storedLinkValue->Source == source &&
324                 storedLinkValue->Target == target)
325             {
326                 return handler(GetLinkStruct(index));
327             }
328             return Constants.Continue;
329         }
330     }
331 }

```

```

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

```

```

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

```

```

480     }
481
482     [MethodImpl(MethodImplOptions.AggressiveInlining)]
483     private bool Exists(id link) => link >= Constants.MinPossibleIndex && link <=
        ↳ _header->AllocatedLinks && !IsUnusedLink(link);
484
485     [MethodImpl(MethodImplOptions.AggressiveInlining)]
486     private bool IsUnusedLink(id link) => _header->FirstFreeLink == link
487         || (_links[link].SizeAsSource == Constants.Null &&
            ↳ _links[link].Source != Constants.Null);
488
489     #region Disposable
490
491     protected override bool AllowMultipleDisposeCalls => true;
492
493     protected override void Dispose(bool manual, bool wasDisposed)
494     {
495         if (!wasDisposed)
496         {
497             SetPointers(null);
498             _memory.DisposeIfPossible();
499         }
500     }
501
502     #endregion
503 }
504 }

```

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

```

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

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using System.Text;
5  using Platform.Collections.Methods.Trees;
6  using Platform.Data.Constants;
7
8  namespace Platform.Data.Doublets.ResizableDirectMemory

```

```

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

```

```

87         {
88             root = GetLeftOrDefault(root);
89         }
90         else
91         {
92             totalLeftIgnore += GetLeftSize(root) + 1;
93             root = GetRightOrDefault(root);
94         }
95     }
96     return total - totalRightIgnore - totalLeftIgnore;
97 }
98
99 public ulong EachReference(ulong link, Func<IList<ulong>, ulong> handler)
100 {
101     var root = GetTreeRoot();
102     if (root == 0)
103     {
104         return _constants.Continue;
105     }
106     ulong first = 0, current = root;
107     while (current != 0)
108     {
109         var @base = GetBasePartValue(current);
110         if (@base >= link)
111         {
112             if (@base == link)
113             {
114                 first = current;
115             }
116             current = GetLeftOrDefault(current);
117         }
118         else
119         {
120             current = GetRightOrDefault(current);
121         }
122     }
123     if (first != 0)
124     {
125         current = first;
126         while (true)
127         {
128             if (handler(_memory.GetLinkStruct(current)) == _constants.Break)
129             {
130                 return _constants.Break;
131             }
132             current = GetNext(current);
133             if (current == 0 || GetBasePartValue(current) != link)
134             {
135                 break;
136             }
137         }
138     }
139     return _constants.Continue;
140 }
141
142 protected override void PrintNodeValue(ulong node, StringBuilder sb)
143 {
144     sb.Append(' ');
145     sb.Append(Links[node].Source);
146     sb.Append('-');
147     sb.Append('>');
148     sb.Append(Links[node].Target);
149 }
150
151
152 private class LinksSourcesTreeMethods : LinksTreeMethodsBase
153 {
154     public LinksSourcesTreeMethods(UInt64ResizableDirectMemoryLinks memory)
155         : base(memory)
156     {
157     }
158
159     protected override IntPtr GetLeftPointer(ulong node) => new
160     ↪ IntPtr(&Links[node].LeftAsSource);
161
162     protected override IntPtr GetRightPointer(ulong node) => new
163     ↪ IntPtr(&Links[node].RightAsSource);
164
165     protected override ulong GetLeftValue(ulong node) => Links[node].LeftAsSource;

```



```

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

```

```

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

```

```

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

```

```

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

```

```

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

```

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

```

1  using System.Collections.Generic;
2
3  namespace Platform.Data.Doublets.Sequences.Converters
4  {
5      public class BalancedVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
6      {
7          public BalancedVariantConverter(ILinks<TLink> links) : base(links) { }
8
9          public override TLink Convert(IList<TLink> sequence)
10         {
11             var length = sequence.Count;
12             if (length < 1)
13             {
14                 return default;
15             }
16             if (length == 1)
17             {
18                 return sequence[0];
19             }
20             // Make copy of next layer
21             if (length > 2)
22             {
23                 // TODO: Try to use stackalloc (which at the moment is not working with
24                 ↪ generics) but will be possible with Sigil
25                 var halvedSequence = new TLink[(length / 2) + (length % 2)];
26                 HalveSequence(halvedSequence, sequence, length);
27                 sequence = halvedSequence;
28                 length = halvedSequence.Length;
29             }
30             // Keep creating layer after layer
31             while (length > 2)
32             {
33                 HalveSequence(sequence, sequence, length);
34                 length = (length / 2) + (length % 2);
35             }
36             return Links.GetOrCreate(sequence[0], sequence[1]);
37         }
38
39         private void HalveSequence(IList<TLink> destination, IList<TLink> source, int length)
40         {
41             var loopedLength = length - (length % 2);
42             for (var i = 0; i < loopedLength; i += 2)
43             {
44                 destination[i / 2] = Links.GetOrCreate(source[i], source[i + 1]);
45             }
46             if (length > loopedLength)
47             {
48                 destination[length / 2] = source[length - 1];
49             }
50         }
51     }
52 }

```

```

49     }
50 }
51 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Runtime.CompilerServices;
4  using Platform.Interfaces;
5  using Platform.Collections;
6  using Platform.Singletons;
7  using Platform.Numbers;
8  using Platform.Data.Constants;
9  using Platform.Data.Doublets.Sequences.Frequencies.Cache;
10
11 namespace Platform.Data.Doublets.Sequences.Converters
12 {
13     /// <remarks>
14     /// TODO: Возможно будет лучше если алгоритм будет выполняться полностью изолированно от
15     ///     ↳ Links на этапе сжатия.
16     ///     А именно будет создаваться временный список пар необходимых для выполнения сжатия, в
17     ///     ↳ таком случае тип значения элемента массива может быть любым, как char так и ulong.
18     ///     Как только список/словарь пар был выявлен можно разом выполнить создание всех этих
19     ///     ↳ пар, а так же разом выполнить замену.
20     /// </remarks>
21     public class CompressingConverter<TLink> : LinksListToSequenceConverterBase<TLink>
22     {
23         private static readonly LinksCombinedConstants<bool, TLink, long> _constants =
24             ↳ Default<LinksCombinedConstants<bool, TLink, long>>.Instance;
25         private static readonly EqualityComparer<TLink> _equalityComparer =
26             ↳ EqualityComparer<TLink>.Default;
27         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
28
29         private readonly IConverter<IList<TLink>, TLink> _baseConverter;
30         private readonly LinkFrequenciesCache<TLink> _doubletFrequenciesCache;
31         private readonly TLink _minFrequencyToCompress;
32         private readonly bool _doInitialFrequenciesIncrement;
33         private Doublet<TLink> _maxDoublet;
34         private LinkFrequency<TLink> _maxDoubletData;
35
36         private struct HalfDoublet
37         {
38             public TLink Element;
39             public LinkFrequency<TLink> DoubletData;
40
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         public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
51             ↳ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache)
52             : this(links, baseConverter, doubletFrequenciesCache, Integer<TLink>.One, true)
53         {
54         }
55
56         public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
57             ↳ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, bool
58             ↳ doInitialFrequenciesIncrement)
59             : this(links, baseConverter, doubletFrequenciesCache, Integer<TLink>.One,
60                 ↳ doInitialFrequenciesIncrement)
61         {
62         }
63
64         public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
65             ↳ baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, TLink
66             ↳ minFrequencyToCompress, bool doInitialFrequenciesIncrement)
67             : base(links)
68         {
69             _baseConverter = baseConverter;
70             _doubletFrequenciesCache = doubletFrequenciesCache;
71             if (_comparer.Compare(minFrequencyToCompress, Integer<TLink>.One) < 0)
72             {
73                 minFrequencyToCompress = Integer<TLink>.One;
74             }
75             _minFrequencyToCompress = minFrequencyToCompress;
76             _doInitialFrequenciesIncrement = doInitialFrequenciesIncrement;
77         }
78     }
79 }

```

```

66     ResetMaxDoublet();
67 }
68
69 public override TLink Convert(ICollection<TLink> source) =>
    ↪ _baseConverter.Convert(Compress(source));
70
71 /// <remarks>
72 /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte\_pair\_encoding .
73 /// Faster version (doublets' frequencies dictionary is not recreated).
74 /// </remarks>
75 private ICollection<TLink> Compress(ICollection<TLink> sequence)
76 {
77     if (sequence.IsNullOrEmpty())
78     {
79         return null;
80     }
81     if (sequence.Count == 1)
82     {
83         return sequence;
84     }
85     if (sequence.Count == 2)
86     {
87         return new[] { Links.GetOrCreate(sequence[0], sequence[1]) };
88     }
89     // TODO: arraypool with min size (to improve cache locality) or stackalloc with Sigil
90     var copy = new HalfDoublet[sequence.Count];
91     Doublet<TLink> doublet = default;
92     for (var i = 1; i < sequence.Count; i++)
93     {
94         doublet.Source = sequence[i - 1];
95         doublet.Target = sequence[i];
96         LinkFrequency<TLink> data;
97         if (_doInitialFrequenciesIncrement)
98         {
99             data = _doubletFrequenciesCache.IncrementFrequency(ref doublet);
100         }
101         else
102         {
103             data = _doubletFrequenciesCache.GetFrequency(ref doublet);
104             if (data == null)
105             {
106                 throw new NotSupportedException("If you ask not to increment
                    ↪ frequencies, it is expected that all frequencies for the sequence
                    ↪ are prepared.");
107             }
108         }
109         copy[i - 1].Element = sequence[i - 1];
110         copy[i - 1].DoubletData = data;
111         UpdateMaxDoublet(ref doublet, data);
112     }
113     copy[sequence.Count - 1].Element = sequence[sequence.Count - 1];
114     copy[sequence.Count - 1].DoubletData = new LinkFrequency<TLink>();
115     if (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
116     {
117         var newLength = ReplaceDoublets(copy);
118         sequence = new TLink[newLength];
119         for (int i = 0; i < newLength; i++)
120         {
121             sequence[i] = copy[i].Element;
122         }
123     }
124     return sequence;
125 }
126
127 /// <remarks>
128 /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte\_pair\_encoding
129 /// </remarks>
130 private int ReplaceDoublets(HalfDoublet[] copy)
131 {
132     var oldLength = copy.Length;
133     var newLength = copy.Length;
134     while (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
135     {
136         var maxDoubletSource = _maxDoublet.Source;
137         var maxDoubletTarget = _maxDoublet.Target;
138         if (_equalityComparer.Equals(_maxDoubletData.Link, _constants.Null))
139         {
140             _maxDoubletData.Link = Links.GetOrCreate(maxDoubletSource, maxDoubletTarget);
141         }

```

```

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

```



```

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

```

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

```

1  using System.Collections.Generic;
2  using Platform.Interfaces;
3
4  namespace Platform.Data.Doublets.Sequences.Converters
5  {
6      public abstract class LinksListToSequenceConverterBase<TLink> : IConverter<IList<TLink>,
        ↪     TLink>
7      {
8          protected readonly ILinks<TLink> Links;
9          public LinksListToSequenceConverterBase(ILinks<TLink> links) => Links = links;
10         public abstract TLink Convert(IList<TLink> source);
11     }
12 }

```

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

```

1  using System.Collections.Generic;
2  using System.Linq;
3  using Platform.Interfaces;
4
5  namespace Platform.Data.Doublets.Sequences.Converters
6  {
7      public class OptimalVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
8      {
9          private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪     EqualityComparer<TLink>.Default;
10         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
11
12         private readonly IConverter<IList<TLink>> _sequenceToItsLocalElementLevelsConverter;
13
14         public OptimalVariantConverter(ILinks<TLink> links, IConverter<IList<TLink>>
        ↪     sequenceToItsLocalElementLevelsConverter) : base(links)
15         => _sequenceToItsLocalElementLevelsConverter =
        ↪     sequenceToItsLocalElementLevelsConverter;
16
17         public override TLink Convert(IList<TLink> sequence)
18         {
19             var length = sequence.Count;
20             if (length == 1)
21             {
22                 return sequence[0];
23             }
24             var links = Links;
25             if (length == 2)
26             {
27                 return links.GetOrCreate(sequence[0], sequence[1]);
28             }
29             sequence = sequence.ToArray();
30             var levels = _sequenceToItsLocalElementLevelsConverter.Convert(sequence);
31             while (length > 2)
32             {
33                 var levelRepeat = 1;
34                 var currentLevel = levels[0];
35                 var previousLevel = levels[0];
36                 var skipOnce = false;
37                 var w = 0;
38                 for (var i = 1; i < length; i++)
39                 {
40                     if (_equalityComparer.Equals(currentLevel, levels[i]))
41                     {
42                         levelRepeat++;
43                         skipOnce = false;
44                         if (levelRepeat == 2)
45                         {
46                             sequence[w] = links.GetOrCreate(sequence[i - 1], sequence[i]);

```

```

47         var newLevel = i >= length - 1 ?
48             GetPreviousLowerThanCurrentOrCurrent(previousLevel,
49                 ↪ currentLevel) :
50             i < 2 ?
51                 GetNextLowerThanCurrentOrCurrent(currentLevel, levels[i + 1]) :
52                 GetGreatestNeighbourLowerThanCurrentOrCurrent(previousLevel,
53                     ↪ currentLevel, levels[i + 1]);
54         levels[w] = newLevel;
55         previousLevel = currentLevel;
56         w++;
57         levelRepeat = 0;
58         skipOnce = true;
59     }
60     else if (i == length - 1)
61     {
62         sequence[w] = sequence[i];
63         levels[w] = levels[i];
64         w++;
65     }
66     else
67     {
68         currentLevel = levels[i];
69         levelRepeat = 1;
70         if (skipOnce)
71         {
72             skipOnce = false;
73         }
74         else
75         {
76             sequence[w] = sequence[i - 1];
77             levels[w] = levels[i - 1];
78             previousLevel = levels[w];
79             w++;
80         }
81         if (i == length - 1)
82         {
83             sequence[w] = sequence[i];
84             levels[w] = levels[i];
85             w++;
86         }
87     }
88     length = w;
89 }
90 return links.GetOrCreate(sequence[0], sequence[1]);
91 }
92
93 private static TLink GetGreatestNeighbourLowerThanCurrentOrCurrent(TLink previous, TLink
94     ↪ current, TLink next)
95 {
96     return _comparer.Compare(previous, next) > 0
97         ? _comparer.Compare(previous, current) < 0 ? previous : current
98         : _comparer.Compare(next, current) < 0 ? next : current;
99 }
100
101 private static TLink GetNextLowerThanCurrentOrCurrent(TLink current, TLink next) =>
102     ↪ _comparer.Compare(next, current) < 0 ? next : current;
103
104 private static TLink GetPreviousLowerThanCurrentOrCurrent(TLink previous, TLink current)
105     ↪ => _comparer.Compare(previous, current) < 0 ? previous : current;
106 }
107 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3
4 namespace Platform.Data.Doublets.Sequences.Converters
5 {
6     public class SequenceToItsLocalElementLevelsConverter<TLink> : LinksOperatorBase<TLink>,
7         ↪ IConverter<IList<TLink>>
8     {
9         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
10         private readonly IConverter<Doublet<TLink>, TLink> _linkToItsFrequencyToNumberConveter;
11         public SequenceToItsLocalElementLevelsConverter(ILinks<TLink> links,
12             ↪ IConverter<Doublet<TLink>, TLink> linkToItsFrequencyToNumberConveter) : base(links)
13             ↪ => _linkToItsFrequencyToNumberConveter = linkToItsFrequencyToNumberConveter;
14         public IList<TLink> Convert(IList<TLink> sequence)

```

```

12     {
13         var levels = new TLink[sequence.Count];
14         levels[0] = GetFrequencyNumber(sequence[0], sequence[1]);
15         for (var i = 1; i < sequence.Count - 1; i++)
16         {
17             var previous = GetFrequencyNumber(sequence[i - 1], sequence[i]);
18             var next = GetFrequencyNumber(sequence[i], sequence[i + 1]);
19             levels[i] = _comparer.Compare(previous, next) > 0 ? previous : next;
20         }
21         levels[levels.Length - 1] = GetFrequencyNumber(sequence[sequence.Count - 2],
22             ↪ sequence[sequence.Count - 1]);
23         return levels;
24     }
25     public TLink GetFrequencyNumber(TLink source, TLink target) =>
26         ↪ _linkToItsFrequencyToNumberConveter.Convert(new Doublet<TLink>(source, target));
27 }

```

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

```

1 using Platform.Interfaces;
2
3 namespace Platform.Data.Doublets.Sequences.CreteriaMatchers
4 {
5     public class DefaultSequenceElementCreteriaMatcher<TLink> : LinksOperatorBase<TLink>,
6         ↪ ICriterionMatcher<TLink>
7     {
8         public DefaultSequenceElementCreteriaMatcher(ILinks<TLink> links) : base(links) { }
9         public bool IsMatched(TLink argument) => Links.IsPartialPoint(argument);
10    }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3
4 namespace Platform.Data.Doublets.Sequences.CreteriaMatchers
5 {
6     public class MarkedSequenceCreteriaMatcher<TLink> : ICriterionMatcher<TLink>
7     {
8         private static readonly EqualityComparer<TLink> _equalityComparer =
9             ↪ EqualityComparer<TLink>.Default;
10
11         private readonly ILinks<TLink> _links;
12         private readonly TLink _sequenceMarkerLink;
13
14         public MarkedSequenceCreteriaMatcher(ILinks<TLink> links, TLink sequenceMarkerLink)
15         {
16             _links = links;
17             _sequenceMarkerLink = sequenceMarkerLink;
18         }
19
20         public bool IsMatched(TLink sequenceCandidate)
21             => _equalityComparer.Equals(_links.GetSource(sequenceCandidate), _sequenceMarkerLink)
22             || !_equalityComparer.Equals(_links.SearchOrDefault(_sequenceMarkerLink,
23                 ↪ sequenceCandidate), _links.Constants.Null);
24    }
25 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Collections.Stacks;
3 using Platform.Data.Doublets.Sequences.HeightProviders;
4 using Platform.Data.Sequences;
5
6 namespace Platform.Data.Doublets.Sequences
7 {
8     public class DefaultSequenceAppender<TLink> : LinksOperatorBase<TLink>,
9         ↪ ISequenceAppender<TLink>
10    {
11         private static readonly EqualityComparer<TLink> _equalityComparer =
12             ↪ EqualityComparer<TLink>.Default;
13
14         private readonly IStack<TLink> _stack;
15         private readonly ISequenceHeightProvider<TLink> _heightProvider;
16
17         public DefaultSequenceAppender(ILinks<TLink> links, IStack<TLink> stack,
18             ↪ ISequenceHeightProvider<TLink> heightProvider)
19             : base(links)
20         {
21         }
22    }

```

```

17     {
18         _stack = stack;
19         _heightProvider = heightProvider;
20     }
21
22     public TLink Append(TLink sequence, TLink appendant)
23     {
24         var cursor = sequence;
25         while (!_equalityComparer.Equals(_heightProvider.Get(cursor), default))
26         {
27             var source = Links.GetSource(cursor);
28             var target = Links.GetTarget(cursor);
29             if (_equalityComparer.Equals(_heightProvider.Get(source),
30                 ↪ _heightProvider.Get(target)))
31             {
32                 break;
33             }
34             else
35             {
36                 _stack.Push(source);
37                 cursor = target;
38             }
39         }
40         var left = cursor;
41         var right = appendant;
42         while (!_equalityComparer.Equals(cursor = _stack.Pop(), Links.Constants.Null))
43         {
44             right = Links.GetOrCreate(left, right);
45             left = cursor;
46         }
47         return Links.GetOrCreate(left, right);
48     }
49 }

```

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

```

1 using System.Collections.Generic;
2 using System.Linq;
3 using Platform.Interfaces;
4
5 namespace Platform.Data.Doublets.Sequences
6 {
7     public class DuplicateSegmentsCounter<TLink> : ICounter<int>
8     {
9         private readonly IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
10             ↪ _duplicateFragmentsProvider;
11         public DuplicateSegmentsCounter(IProvider<IList<KeyValuePair<IList<TLink>,
12             ↪ IList<TLink>>>> duplicateFragmentsProvider) => _duplicateFragmentsProvider =
13             ↪ duplicateFragmentsProvider;
14         public int Count() => _duplicateFragmentsProvider.Get().Sum(x => x.Value.Count);
15     }
16 }

```

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

```

1 using System;
2 using System.Linq;
3 using System.Collections.Generic;
4 using Platform.Interfaces;
5 using Platform.Collections;
6 using Platform.Collections.Lists;
7 using Platform.Collections.Segments;
8 using Platform.Collections.Segments.Walkers;
9 using Platform.Singletons;
10 using Platform.Numbers;
11 using Platform.Data.Sequences;
12
13 namespace Platform.Data.Doublets.Sequences
14 {
15     public class DuplicateSegmentsProvider<TLink> :
16         ↪ DictionaryBasedDuplicateSegmentsWalkerBase<TLink>,
17         ↪ IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
18     {
19         private readonly ILinks<TLink> _links;
20         private readonly ISegments<TLink> _sequences;
21         private HashSet<KeyValuePair<IList<TLink>, IList<TLink>>> _groups;
22         private BitString _visited;
23
24         private class ItemEquilityComparer : IEqualityComparer<KeyValuePair<IList<TLink>,
25             ↪ IList<TLink>>>
26         {
27
28         }
29     }
30 }

```

```

24     private readonly IListEqualityComparer<TLink> _listComparer;
25     public ItemEqualityComparer() => _listComparer =
    ↪     Default<IListEqualityComparer<TLink>>.Instance;
26     public bool Equals(KeyValuePair<IList<TLink>, IList<TLink>> left,
    ↪     KeyValuePair<IList<TLink>, IList<TLink>> right) =>
    ↪     _listComparer.Equals(left.Key, right.Key) && _listComparer.Equals(left.Value,
    ↪     right.Value);
27     public int GetHashCode(KeyValuePair<IList<TLink>, IList<TLink>> pair) =>
    ↪     (_listComparer.GetHashCode(pair.Key),
    ↪     _listComparer.GetHashCode(pair.Value)).GetHashCode();
28 }
29
30 private class ItemComparer : IComparer<KeyValuePair<IList<TLink>, IList<TLink>>>
31 {
32     private readonly IListComparer<TLink> _listComparer;
33
34     public ItemComparer() => _listComparer = Default<IListComparer<TLink>>.Instance;
35
36     public int Compare(KeyValuePair<IList<TLink>, IList<TLink>> left,
    ↪     KeyValuePair<IList<TLink>, IList<TLink>> right)
37     {
38         var intermediateResult = _listComparer.Compare(left.Key, right.Key);
39         if (intermediateResult == 0)
40         {
41             intermediateResult = _listComparer.Compare(left.Value, right.Value);
42         }
43         return intermediateResult;
44     }
45 }
46
47 public DuplicateSegmentsProvider(ILinks<TLink> links, ISequences<TLink> sequences)
48     : base(minimumStringSegmentLength: 2)
49 {
50     _links = links;
51     _sequences = sequences;
52 }
53
54 public IList<KeyValuePair<IList<TLink>, IList<TLink>>> Get()
55 {
56     _groups = new HashSet<KeyValuePair<IList<TLink>,
    ↪     IList<TLink>>>(Default<ItemEqualityComparer>.Instance);
57     var count = _links.Count();
58     _visited = new BitString((long)(Integer<TLink>)count + 1);
59     _links.Each(link =>
60     {
61         var linkIndex = _links.GetIndex(link);
62         var linkBitIndex = (long)(Integer<TLink>)linkIndex;
63         if (!_visited.Get(linkBitIndex))
64         {
65             var sequenceElements = new List<TLink>();
66             _sequences.EachPart(sequenceElements.AddAndReturnTrue, linkIndex);
67             if (sequenceElements.Count > 2)
68             {
69                 WalkAll(sequenceElements);
70             }
71         }
72         return _links.Constants.Continue;
73     });
74     var resultList = _groups.ToList();
75     var comparer = Default<ItemComparer>.Instance;
76     resultList.Sort(comparer);
77     #if DEBUG
78     foreach (var item in resultList)
79     {
80         PrintDuplicates(item);
81     }
82     #endif
83     return resultList;
84 }
85
86 protected override Segment<TLink> CreateSegment(IList<TLink> elements, int offset, int
    ↪     length) => new Segment<TLink>(elements, offset, length);
87
88 protected override void OnDuplicateFound(Segment<TLink> segment)
89 {
90     var duplicates = CollectDuplicatesForSegment(segment);
91     if (duplicates.Count > 1)
92     {

```

```

93         _groups.Add(new KeyValuePair<IList<TLink>, IList<TLink>>(segment.ToArray(),
94             ↪ duplicates));
95     }
96 }
97 private List<TLink> CollectDuplicatesForSegment(Segment<TLink> segment)
98 {
99     var duplicates = new List<TLink>();
100     var readAsElement = new HashSet<TLink>();
101     _sequences.Each(sequence =>
102     {
103         duplicates.Add(sequence);
104         readAsElement.Add(sequence);
105         return true; // Continue
106     }, segment);
107     if (duplicates.Any(x => _visited.Get((Integer<TLink>)x)))
108     {
109         return new List<TLink>();
110     }
111     foreach (var duplicate in duplicates)
112     {
113         var duplicateBitIndex = (long)(Integer<TLink>)duplicate;
114         _visited.Set(duplicateBitIndex);
115     }
116     if (_sequences is Sequences sequencesExperiments)
117     {
118         var partiallyMatched = sequencesExperiments.GetAllPartiallyMatchingSequences4((H
119             ↪ ashSet<ulong>)(object)readAsElement,
120             ↪ (IList<ulong>)segment);
121         foreach (var partiallyMatchedSequence in partiallyMatched)
122         {
123             TLink sequenceIndex = (Integer<TLink>)partiallyMatchedSequence;
124             duplicates.Add(sequenceIndex);
125         }
126     }
127     duplicates.Sort();
128     return duplicates;
129 }
130 private void PrintDuplicates(KeyValuePair<IList<TLink>, IList<TLink>> duplicatesItem)
131 {
132     if (!(_links is ILinks<ulong> ulongLinks))
133     {
134         return;
135     }
136     var duplicatesKey = duplicatesItem.Key;
137     var keyString = UnicodeMap.FromLinksToString((IList<ulong>)duplicatesKey);
138     Console.WriteLine($"> {keyString} ({string.Join(", ", duplicatesKey)}");
139     var duplicatesList = duplicatesItem.Value;
140     for (int i = 0; i < duplicatesList.Count; i++)
141     {
142         ulong sequenceIndex = (Integer<TLink>)duplicatesList[i];
143         var formattedSequenceStructure = ulongLinks.FormatStructure(sequenceIndex, x =>
144             ↪ Point<ulong>.IsPartialPoint(x), (sb, link) => _ =
145             ↪ UnicodeMap.IsCharLink(link.Index) ?
146             ↪ sb.Append(UnicodeMap.FromLinkToChar(link.Index)) : sb.Append(link.Index));
147         Console.WriteLine(formattedSequenceStructure);
148         var sequenceString = UnicodeMap.FromSequenceLinkToString(sequenceIndex,
149             ↪ ulongLinks);
150         Console.WriteLine(sequenceString);
151     }
152     Console.WriteLine();
153 }
154 }
155 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3
4 namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
5 {
6     public class FrequenciesCacheBasedLinkFrequencyIncrementer<TLink> :
7         ↪ IIncrementer<IList<TLink>>
8     {
9         private readonly LinkFrequenciesCache<TLink> _cache;

```

```

10     public FrequenciesCacheBasedLinkFrequencyIncrementer(LinkFrequenciesCache<TLink> cache)
11         => _cache = cache;
12
13     /// <remarks>Sequence itseft is not changed, only frequency of its doublets is
14     incremented.</remarks>
15     public IList<TLink> Increment(IList<TLink> sequence)
16     {
17         _cache.IncrementFrequencies(sequence);
18         return sequence;
19     }

```

./Platform.Data.Doublets/Sequences/Frequencies/Cache/FrequenciesCacheBasedLinkToItsFrequencyNumberConverter

```

1 using Platform.Interfaces;
2
3 namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
4 {
5     public class FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<TLink> :
6         IConverter<Doublet<TLink>, TLink>
7     {
8         private readonly LinkFrequenciesCache<TLink> _cache;
9         public
10             FrequenciesCacheBasedLinkToItsFrequencyNumberConverter(LinkFrequenciesCache<TLink>
11                 cache) => _cache = cache;
12         public TLink Convert(Doublet<TLink> source) => _cache.GetFrequency(ref source).Frequency;
13     }
14 }

```

./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 namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
8 {
9     /// <remarks>
10     /// Can be used to operate with many CompressingConverters (to keep global frequencies data
11     /// between them).
12     /// TODO: Extract interface to implement frequencies storage inside Links storage
13     /// </remarks>
14     public class LinkFrequenciesCache<TLink> : LinksOperatorBase<TLink>
15     {
16         private static readonly EqualityComparer<TLink> _equalityComparer =
17             EqualityComparer<TLink>.Default;
18         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
19
20         private readonly Dictionary<Doublet<TLink>, LinkFrequency<TLink>> _doubletsCache;
21         private readonly ICounter<TLink, TLink> _frequencyCounter;
22
23         public LinkFrequenciesCache(ILinks<TLink> links, ICounter<TLink, TLink> frequencyCounter)
24             : base(links)
25         {
26             _doubletsCache = new Dictionary<Doublet<TLink>, LinkFrequency<TLink>>(4096,
27                 DoubletComparer<TLink>.Default);
28             _frequencyCounter = frequencyCounter;
29         }
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         public LinkFrequency<TLink> GetFrequency(TLink source, TLink target)
33         {
34             var doublet = new Doublet<TLink>(source, target);
35             return GetFrequency(ref doublet);
36         }
37
38         [MethodImpl(MethodImplOptions.AggressiveInlining)]
39         public LinkFrequency<TLink> GetFrequency(ref Doublet<TLink> doublet)
40         {
41             _doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data);
42             return data;
43         }
44
45         public void IncrementFrequencies(IList<TLink> sequence)
46         {
47             for (var i = 1; i < sequence.Count; i++)
48             {
49                 IncrementFrequency(sequence[i - 1], sequence[i]);
50             }
51         }
52     }
53 }

```

```

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

```



```

119         //}
120     }
121 }
122 }
123 }

```

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

```

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

```

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

```

1 using Platform.Interfaces;
2
3 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
4 {
5     public class MarkedSequenceSymbolFrequencyOneOffCounter<TLink> :
6         ↳ SequenceSymbolFrequencyOneOffCounter<TLink>
7     {
8         private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
9
10        public MarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
11        ↳ ICriterionMatcher<TLink> markedSequenceMatcher, TLink sequenceLink, TLink symbol)
12        : base(links, sequenceLink, symbol)
13        => _markedSequenceMatcher = markedSequenceMatcher;
14
15        public override TLink Count()
16        {
17            if (!_markedSequenceMatcher.IsMatched(_sequenceLink))
18            {
19                return default;
20            }
21            return base.Count();
22        }
23    }
24 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3 using Platform.Numbers;
4 using Platform.Data.Sequences;
5
6 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
7 {
8     public class SequenceSymbolFrequencyOneOffCounter<TLink> : ICounter<TLink>
9     {
10         private static readonly EqualityComparer<TLink> _equalityComparer =
11         ↳ EqualityComparer<TLink>.Default;
12         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
13
14         protected readonly ILinks<TLink> _links;
15         protected readonly TLink _sequenceLink;
16         protected readonly TLink _symbol;
17         protected TLink _total;
18     }
19 }

```

```

18     public SequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink sequenceLink,
19         ↪ TLink symbol)
20     {
21         _links = links;
22         _sequenceLink = sequenceLink;
23         _symbol = symbol;
24         _total = default;
25     }
26
27     public virtual TLink Count()
28     {
29         if (_comparer.Compare(_total, default) > 0)
30         {
31             return _total;
32         }
33         StopableSequenceWalker.WalkRight(_sequenceLink, _links.GetSource, _links.GetTarget,
34             ↪ IsElement, VisitElement);
35         return _total;
36     }
37
38     private bool IsElement(TLink x) => _equalityComparer.Equals(x, _symbol) ||
39         ↪ _links.IsPartialPoint(x); // TODO: Use SequenceElementCriteriaMatcher instead of
40         ↪ IsPartialPoint
41
42     private bool VisitElement(TLink element)
43     {
44         if (_equalityComparer.Equals(element, _symbol))
45         {
46             _total = Arithmetic.Increment(_total);
47         }
48         return true;
49     }
50 }

```

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

```

1  using Platform.Interfaces;
2
3  namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
4  {
5      public class TotalMarkedSequenceSymbolFrequencyCounter<TLink> : ICounter<TLink, TLink>
6      {
7          private readonly ILinks<TLink> _links;
8          private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
9
10         public TotalMarkedSequenceSymbolFrequencyCounter(ILinks<TLink> links,
11             ↪ ICriterionMatcher<TLink> markedSequenceMatcher)
12         {
13             _links = links;
14             _markedSequenceMatcher = markedSequenceMatcher;
15         }
16
17         public TLink Count(TLink argument) => new
18             ↪ TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
19             ↪ _markedSequenceMatcher, argument).Count();
20     }
21 }

```

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

```

1  using Platform.Interfaces;
2  using Platform.Numbers;
3
4  namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
5  {
6      public class TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink> :
7          ↪ TotalSequenceSymbolFrequencyOneOffCounter<TLink>
8      {
9          private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;
10
11         public TotalMarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
12             ↪ ICriterionMatcher<TLink> markedSequenceMatcher, TLink symbol) : base(links, symbol)
13             => _markedSequenceMatcher = markedSequenceMatcher;
14
15         protected override void CountSequenceSymbolFrequency(TLink link)
16         {
17             var symbolFrequencyCounter = new
18                 ↪ MarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
19                 ↪ _markedSequenceMatcher, link, _symbol);
20             _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
21         }
22     }
23 }

```

```

17     }
18 }
19 }

```

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

```

1 using Platform.Interfaces;
2
3 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
4 {
5     public class TotalSequenceSymbolFrequencyCounter<TLink> : ICounter<TLink, TLink>
6     {
7         private readonly ILinks<TLink> _links;
8         public TotalSequenceSymbolFrequencyCounter(ILinks<TLink> links) => _links = links;
9         public TLink Count(TLink symbol) => new
10             ↪ TotalSequenceSymbolFrequencyOneOffCounter<TLink>(_links, symbol).Count();
11     }
12 }

```

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

```

1 using System.Collections.Generic;
2 using Platform.Interfaces;
3 using Platform.Numbers;
4
5 namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
6 {
7     public class TotalSequenceSymbolFrequencyOneOffCounter<TLink> : ICounter<TLink>
8     {
9         private static readonly EqualityComparer<TLink> _equalityComparer =
10             ↪ EqualityComparer<TLink>.Default;
11         private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
12
13         protected readonly ILinks<TLink> _links;
14         protected readonly TLink _symbol;
15         protected readonly HashSet<TLink> _visits;
16         protected TLink _total;
17
18         public TotalSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink symbol)
19         {
20             _links = links;
21             _symbol = symbol;
22             _visits = new HashSet<TLink>();
23             _total = default;
24         }
25
26         public TLink Count()
27         {
28             if (_comparer.Compare(_total, default) > 0 || _visits.Count > 0)
29             {
30                 return _total;
31             }
32             CountCore(_symbol);
33             return _total;
34         }
35
36         private void CountCore(TLink link)
37         {
38             var any = _links.Constants.Any;
39             if (_equalityComparer.Equals(_links.Count(any, link), default))
40             {
41                 CountSequenceSymbolFrequency(link);
42             }
43             else
44             {
45                 _links.Each(EachElementHandler, any, link);
46             }
47         }
48
49         protected virtual void CountSequenceSymbolFrequency(TLink link)
50         {
51             var symbolFrequencyCounter = new SequenceSymbolFrequencyOneOffCounter<TLink>(_links,
52                 ↪ link, _symbol);
53             _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
54         }
55
56         private TLink EachElementHandler(IList<TLink> doublet)
57         {
58             var constants = _links.Constants;
59             var doubletIndex = doublet[constants.IndexPart];
60             if (_visits.Add(doubletIndex))
61             {

```

```

60         CountCore(doupletIndex);
61     }
62     return constants.Continue;
63 }
64 }
65 }

```

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

```

1  using System.Collections.Generic;
2  using Platform.Interfaces;
3
4  namespace Platform.Data.Doublents.Sequences.HeightProviders
5  {
6      public class CachedSequenceHeightProvider<TLink> : LinksOperatorBase<TLink>,
7          ↳ ISequenceHeightProvider<TLink>
8      {
9          private static readonly EqualityComparer<TLink> _equalityComparer =
10             ↳ EqualityComparer<TLink>.Default;
11
12         private readonly TLink _heightPropertyMarker;
13         private readonly ISequenceHeightProvider<TLink> _baseHeightProvider;
14         private readonly IConverter<TLink> _addressToUnaryNumberConverter;
15         private readonly IConverter<TLink> _unaryNumberToAddressConverter;
16         private readonly IPropertiesOperator<TLink, TLink, TLink> _propertyOperator;
17
18         public CachedSequenceHeightProvider(
19             ILinks<TLink> links,
20             ISequenceHeightProvider<TLink> baseHeightProvider,
21             IConverter<TLink> addressToUnaryNumberConverter,
22             IConverter<TLink> unaryNumberToAddressConverter,
23             TLink heightPropertyMarker,
24             IPropertiesOperator<TLink, TLink, TLink> propertyOperator)
25             : base(links)
26         {
27             _heightPropertyMarker = heightPropertyMarker;
28             _baseHeightProvider = baseHeightProvider;
29             _addressToUnaryNumberConverter = addressToUnaryNumberConverter;
30             _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
31             _propertyOperator = propertyOperator;
32         }
33
34         public TLink Get(TLink sequence)
35         {
36             TLink height;
37             var heightValue = _propertyOperator.GetValue(sequence, _heightPropertyMarker);
38             if (_equalityComparer.Equals(heightValue, default))
39             {
40                 height = _baseHeightProvider.Get(sequence);
41                 heightValue = _addressToUnaryNumberConverter.Convert(height);
42                 _propertyOperator.SetValue(sequence, _heightPropertyMarker, heightValue);
43             }
44             else
45             {
46                 height = _unaryNumberToAddressConverter.Convert(heightValue);
47             }
48             return height;
49         }
50     }
51 }

```

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

```

1  using Platform.Interfaces;
2  using Platform.Numbers;
3
4  namespace Platform.Data.Doublents.Sequences.HeightProviders
5  {
6      public class DefaultSequenceRightHeightProvider<TLink> : LinksOperatorBase<TLink>,
7          ↳ ISequenceHeightProvider<TLink>
8      {
9          private readonly ICriterionMatcher<TLink> _elementMatcher;
10
11         public DefaultSequenceRightHeightProvider(ILinks<TLink> links, ICriterionMatcher<TLink>
12             ↳ elementMatcher) : base(links) => _elementMatcher = elementMatcher;
13
14         public TLink Get(TLink sequence)
15         {
16             var height = default(TLink);
17             var pairOrElement = sequence;
18             while (!_elementMatcher.IsMatched(pairOrElement))
19             {

```

```

18         pairOrElement = Links.GetTarget(pairOrElement);
19         height = Arithmetic.Increment(height);
20     }
21     return height;
22 }
23 }
24 }

```

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

```

1 using Platform.Interfaces;
2
3 namespace Platform.Data.Doublets.Sequences.HeightProviders
4 {
5     public interface ISequenceHeightProvider<TLink> : IProvider<TLink, TLink>
6     {
7     }
8 }

```

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

```

1 using System;
2 using System.Collections.Generic;
3 using System.Linq;
4 using System.Runtime.CompilerServices;
5 using Platform.Collections;
6 using Platform.Collections.Lists;
7 using Platform.Threading.Synchronization;
8 using Platform.Singletons;
9 using LinkIndex = System.UInt64;
10 using Platform.Data.Constants;
11 using Platform.Data.Sequences;
12 using Platform.Data.Doublets.Sequences.Walkers;
13
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     /// Блокчейн и/или гит для распределённой записи транзакций.
52     ///
53     /// </remarks>
54     public partial class Sequences : ISequences<ulong> // IList<string>, IList<ulong[]> (после
55     ↪ завершения реализации Sequences)
56     {
57         private static readonly LinksCombinedConstants<bool, ulong, long> _constants =
58         ↪ Default<LinksCombinedConstants<bool, ulong, long>>.Instance;
59     }
60 }

```

```

54     /// <summary>Возвращает значение ulong, обозначающее любое количество связей.</summary>
55     public const ulong ZeroOrMany = ulong.MaxValue;
56
57     public SequencesOptions<ulong> Options;
58     public readonly SynchronizedLinks<ulong> Links;
59     public readonly ISynchronization Sync;
60
61     public Sequences(SynchronizedLinks<ulong> links)
62         : this(links, new SequencesOptions<ulong>())
63     {
64     }
65
66     public Sequences(SynchronizedLinks<ulong> links, SequencesOptions<ulong> options)
67     {
68         Links = links;
69         Sync = links.SyncRoot;
70         Options = options;
71
72         Options.ValidateOptions();
73         Options.InitOptions(Links);
74     }
75
76     public bool IsSequence(ulong 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 ulong GetSequenceByElements(ulong sequence)
90     {
91         if (Options.UseSequenceMarker)
92         {
93             return Links.SearchOrDefault(Options.SequenceMarkerLink, sequence);
94         }
95         return sequence;
96     }
97
98     private ulong GetSequenceElements(ulong sequence)
99     {
100         if (Options.UseSequenceMarker)
101         {
102             var linkContents = new UInt64Link(Links.GetLink(sequence));
103             if (linkContents.Source == Options.SequenceMarkerLink)
104             {
105                 return linkContents.Target;
106             }
107             if (linkContents.Target == Options.SequenceMarkerLink)
108             {
109                 return linkContents.Source;
110             }
111         }
112         return sequence;
113     }
114
115     #region Count
116
117     public ulong Count(params ulong[] sequence)
118     {
119         if (sequence.Length == 0)
120         {
121             return Links.Count(_constants.Any, Options.SequenceMarkerLink, _constants.Any);
122         }
123         if (sequence.Length == 1) // Первая связь это адрес
124         {
125             if (sequence[0] == _constants.Null)
126             {
127                 return 0;
128             }
129             if (sequence[0] == _constants.Any)
130             {
131                 return Count();
132             }
133         }
134     }

```

```

133         if (Options.UseSequenceMarker)
134         {
135             return Links.Count(_constants.Any, Options.SequenceMarkerLink, sequence[0]);
136         }
137         return Links.Exists(sequence[0]) ? 1UL : 0;
138     }
139     throw new NotImplementedException();
140 }
141
142 private ulong CountUsages(params ulong[] restrictions)
143 {
144     if (restrictions.Length == 0)
145     {
146         return 0;
147     }
148     if (restrictions.Length == 1) // Первая связь это адрес
149     {
150         if (restrictions[0] == _constants.Null)
151         {
152             return 0;
153         }
154         if (Options.UseSequenceMarker)
155         {
156             var elementsLink = GetSequenceElements(restrictions[0]);
157             var sequenceLink = GetSequenceByElements(elementsLink);
158             if (sequenceLink != _constants.Null)
159             {
160                 return Links.Count(sequenceLink) + Links.Count(elementsLink) - 1;
161             }
162             return Links.Count(elementsLink);
163         }
164         return Links.Count(restrictions[0]);
165     }
166     throw new NotImplementedException();
167 }
168
169 #endregion
170
171 #region Create
172
173 public ulong Create(params ulong[] sequence)
174 {
175     return Sync.ExecuteWriteOperation(() =>
176     {
177         if (sequence.IsNullOrEmpty())
178         {
179             return _constants.Null;
180         }
181         Links.EnsureEachLinkExists(sequence);
182         return CreateCore(sequence);
183     });
184 }
185
186 private ulong CreateCore(params ulong[] sequence)
187 {
188     if (Options.UseIndex)
189     {
190         Options.Indexer.Index(sequence);
191     }
192     var sequenceRoot = default(ulong);
193     if (Options.EnforceSingleSequenceVersionOnWriteBasedOnExisting)
194     {
195         var matches = Each(sequence);
196         if (matches.Count > 0)
197         {
198             sequenceRoot = matches[0];
199         }
200     }
201     else if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew)
202     {
203         return CompactCore(sequence);
204     }
205     if (sequenceRoot == default)
206     {
207         sequenceRoot = Options.LinksToSequenceConverter.Convert(sequence);
208     }
209     if (Options.UseSequenceMarker)
210     {

```

```

211         Links.Unsync.CreateAndUpdate(Options.SequenceMarkerLink, sequenceRoot);
212     }
213     return sequenceRoot; // Возвращаем корень последовательности (т.е. сами элементы)
214 }
215
216 #endregion
217
218 #region Each
219
220 public List<ulong> Each(params ulong[] sequence)
221 {
222     var results = new List<ulong>();
223     Each(results.AddAndReturnTrue, sequence);
224     return results;
225 }
226
227 public bool Each(Func<ulong, bool> handler, IList<ulong> sequence)
228 {
229     return Sync.ExecuteReadOperation(() =>
230     {
231         if (sequence.IsNullOrEmpty())
232         {
233             return true;
234         }
235         Links.EnsureEachLinkIsAnyOrExists(sequence);
236         if (sequence.Count == 1)
237         {
238             var link = sequence[0];
239             if (link == _constants.Any)
240             {
241                 return Links.Unsync.Each(_constants.Any, _constants.Any, handler);
242             }
243             return handler(link);
244         }
245         if (sequence.Count == 2)
246         {
247             return Links.Unsync.Each(sequence[0], sequence[1], handler);
248         }
249         if (Options.UseIndex && !Options.Indexer.CheckIndex(sequence))
250         {
251             return false;
252         }
253         return EachCore(handler, sequence);
254     });
255 }
256
257 private bool EachCore(Func<ulong, bool> handler, IList<ulong> sequence)
258 {
259     var matcher = new Matcher(this, sequence, new HashSet<LinkIndex>(), handler);
260     // TODO: Find out why matcher.HandleFullMatched executed twice for the same sequence
261     ↪ Id.
262     Func<ulong, bool> innerHandler = Options.UseSequenceMarker ? (Func<ulong,
263     ↪ bool>)matcher.HandleFullMatchedSequence : matcher.HandleFullMatched;
264     //if (sequence.Length >= 2)
265     if (!StepRight(innerHandler, sequence[0], sequence[1]))
266     {
267         return false;
268     }
269     var last = sequence.Count - 2;
270     for (var i = 1; i < last; i++)
271     {
272         if (!PartialStepRight(innerHandler, sequence[i], sequence[i + 1]))
273         {
274             return false;
275         }
276     }
277     if (sequence.Count >= 3)
278     {
279         if (!StepLeft(innerHandler, sequence[sequence.Count - 2],
280         ↪ sequence[sequence.Count - 1]))
281         {
282             return false;
283         }
284     }
285     return true;
286 }
287
288 private bool PartialStepRight(Func<ulong, bool> handler, ulong left, ulong right)
289 {

```



```

287     return Links.Unsync.Each(_constants.Any, left, doublet =>
288     {
289         if (!StepRight(handler, doublet, right))
290         {
291             return false;
292         }
293         if (left != doublet)
294         {
295             return PartialStepRight(handler, doublet, right);
296         }
297         return true;
298     });
299 }
300
301 private bool StepRight(Func<ulong, bool> handler, ulong left, ulong right) =>
    ↳ Links.Unsync.Each(left, _constants.Any, rightStep => TryStepRightUp(handler, right,
    ↳ rightStep));
302
303 private bool TryStepRightUp(Func<ulong, bool> handler, ulong right, ulong stepFrom)
304 {
305     var upStep = stepFrom;
306     var firstSource = Links.Unsync.GetTarget(upStep);
307     while (firstSource != right && firstSource != upStep)
308     {
309         upStep = firstSource;
310         firstSource = Links.Unsync.GetSource(upStep);
311     }
312     if (firstSource == right)
313     {
314         return handler(stepFrom);
315     }
316     return true;
317 }
318
319 private bool StepLeft(Func<ulong, bool> handler, ulong left, ulong right) =>
    ↳ Links.Unsync.Each(_constants.Any, right, leftStep => TryStepLeftUp(handler, left,
    ↳ leftStep));
320
321 private bool TryStepLeftUp(Func<ulong, bool> handler, ulong left, ulong stepFrom)
322 {
323     var upStep = stepFrom;
324     var firstTarget = Links.Unsync.GetSource(upStep);
325     while (firstTarget != left && firstTarget != upStep)
326     {
327         upStep = firstTarget;
328         firstTarget = Links.Unsync.GetTarget(upStep);
329     }
330     if (firstTarget == left)
331     {
332         return handler(stepFrom);
333     }
334     return true;
335 }
336
337 #endregion
338
339 #region Update
340
341 public ulong Update(ulong[] sequence, ulong[] newSequence)
342 {
343     if (sequence.IsNullOrEmpty() && newSequence.IsNullOrEmpty())
344     {
345         return _constants.Null;
346     }
347     if (sequence.IsNullOrEmpty())
348     {
349         return Create(newSequence);
350     }
351     if (newSequence.IsNullOrEmpty())
352     {
353         Delete(sequence);
354         return _constants.Null;
355     }
356     return Sync.ExecuteWriteOperation(() =>
357     {
358         Links.EnsureEachLinkIsAnyOrExists(sequence);
359         Links.EnsureEachLinkExists(newSequence);
360         return UpdateCore(sequence, newSequence);
361     });

```

```

362 }
363
364 private ulong UpdateCore(ulong[] sequence, ulong[] newSequence)
365 {
366     ulong bestVariant;
367     if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew &&
368         ↪ !sequence.EqualTo(newSequence))
369     {
370         bestVariant = CompactCore(newSequence);
371     }
372     else
373     {
374         bestVariant = CreateCore(newSequence);
375     }
376     // TODO: Check all options only ones before loop execution
377     // Возможно нужно две версии Each, возвращающий фактические последовательности и с
378     ↪ маркером,
379     // или возможно даже возвращать и тот и тот вариант. С другой стороны все варианты
380     ↪ можно получить имея только фактические последовательности.
381     foreach (var variant in Each(sequence))
382     {
383         if (variant != bestVariant)
384         {
385             UpdateOneCore(variant, bestVariant);
386         }
387     }
388     return bestVariant;
389 }
390
391 private void UpdateOneCore(ulong sequence, ulong newSequence)
392 {
393     if (Options.UseGarbageCollection)
394     {
395         var sequenceElements = GetSequenceElements(sequence);
396         var sequenceElementsContents = new UInt64Link(Links.GetLink(sequenceElements));
397         var sequenceLink = GetSequenceByElements(sequenceElements);
398         var newSequenceElements = GetSequenceElements(newSequence);
399         var newSequenceLink = GetSequenceByElements(newSequenceElements);
400         if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
401         {
402             if (sequenceLink != _constants.Null)
403             {
404                 Links.Unsync.MergeUsages(sequenceLink, newSequenceLink);
405             }
406             Links.Unsync.MergeUsages(sequenceElements, newSequenceElements);
407         }
408         ClearGarbage(sequenceElementsContents.Source);
409         ClearGarbage(sequenceElementsContents.Target);
410     }
411     else
412     {
413         if (Options.UseSequenceMarker)
414         {
415             var sequenceElements = GetSequenceElements(sequence);
416             var sequenceLink = GetSequenceByElements(sequenceElements);
417             var newSequenceElements = GetSequenceElements(newSequence);
418             var newSequenceLink = GetSequenceByElements(newSequenceElements);
419             if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
420             {
421                 if (sequenceLink != _constants.Null)
422                 {
423                     Links.Unsync.MergeUsages(sequenceLink, newSequenceLink);
424                 }
425                 Links.Unsync.MergeUsages(sequenceElements, newSequenceElements);
426             }
427         }
428         else
429         {
430             if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
431             {
432                 Links.Unsync.MergeUsages(sequence, newSequence);
433             }
434         }
435     }
436 }
437
438 #endregion

```

```

437 #region Delete
438
439 public void Delete(params ulong[] sequence)
440 {
441     Sync.ExecuteWriteOperation(() =>
442     {
443         // TODO: Check all options only ones before loop execution
444         foreach (var linkToDelete in Each(sequence))
445         {
446             DeleteOneCore(linkToDelete);
447         }
448     });
449 }
450
451 private void DeleteOneCore(ulong link)
452 {
453     if (Options.UseGarbageCollection)
454     {
455         var sequenceElements = GetSequenceElements(link);
456         var sequenceElementsContents = new UInt64Link(Links.GetLink(sequenceElements));
457         var sequenceLink = GetSequenceByElements(sequenceElements);
458         if (Options.UseCascadeDelete || CountUsages(link) == 0)
459         {
460             if (sequenceLink != _constants.Null)
461             {
462                 Links.Unsync.Delete(sequenceLink);
463             }
464             Links.Unsync.Delete(link);
465         }
466         ClearGarbage(sequenceElementsContents.Source);
467         ClearGarbage(sequenceElementsContents.Target);
468     }
469     else
470     {
471         if (Options.UseSequenceMarker)
472         {
473             var sequenceElements = GetSequenceElements(link);
474             var sequenceLink = GetSequenceByElements(sequenceElements);
475             if (Options.UseCascadeDelete || CountUsages(link) == 0)
476             {
477                 if (sequenceLink != _constants.Null)
478                 {
479                     Links.Unsync.Delete(sequenceLink);
480                 }
481                 Links.Unsync.Delete(link);
482             }
483         }
484         else
485         {
486             if (Options.UseCascadeDelete || CountUsages(link) == 0)
487             {
488                 Links.Unsync.Delete(link);
489             }
490         }
491     }
492 }
493
494 #endregion
495
496 #region Compactification
497
498 /// <remarks>
499 /// bestVariant можно выбирать по максимальному числу использований,
500 /// но сбалансированный позволяет гарантировать уникальность (если есть возможность,
501 /// гарантировать его использование в других местах).
502 ///
503 /// Получается этот метод должен игнорировать Options.EnforceSingleSequenceVersionOnWrite
504 /// </remarks>
505 public ulong Compact(params ulong[] sequence)
506 {
507     return Sync.ExecuteWriteOperation(() =>
508     {
509         if (sequence.IsNullOrEmpty())
510         {
511             return _constants.Null;
512         }
513         Links.EnsureEachLinkExists(sequence);
514         return CompactCore(sequence);
515     });
516 }

```

```

515     });
516 }
517
518 [MethodImpl(MethodImplOptions.AggressiveInlining)]
519 private ulong CompactCore(params ulong[] sequence) => UpdateCore(sequence, sequence);
520
521 #endregion
522
523 #region Garbage Collection
524
525 /// <remarks>
526 /// TODO: Добавить дополнительный обработчик / событие CanBeDeleted которое можно
527   ↳ определить извне или в унаследованном классе
528 /// </remarks>
529 [MethodImpl(MethodImplOptions.AggressiveInlining)]
530 private bool IsGarbage(ulong link) => link != Options.SequenceMarkerLink &&
531   ↳ !Links.Unsync.IsPartialPoint(link) && Links.Count(link) == 0;
532
533 private void ClearGarbage(ulong link)
534 {
535     if (IsGarbage(link))
536     {
537         var contents = new UInt64Link(Links.GetLink(link));
538         Links.Unsync.Delete(link);
539         ClearGarbage(contents.Source);
540         ClearGarbage(contents.Target);
541     }
542 }
543
544 #endregion
545
546 #region Walkers
547
548 public bool EachPart(Func<ulong, bool> handler, ulong sequence)
549 {
550     return Sync.ExecuteReadOperation(() =>
551     {
552         var links = Links.Unsync;
553         var walker = new RightSequenceWalker<ulong>(links);
554         foreach (var part in walker.Walk(sequence))
555         {
556             if (!handler(links.GetIndex(part)))
557             {
558                 return false;
559             }
560         }
561         return true;
562     });
563 }
564
565 public class Matcher : RightSequenceWalker<ulong>
566 {
567     private readonly Sequences _sequences;
568     private readonly IList<LinkIndex> _patternSequence;
569     private readonly HashSet<LinkIndex> _linksInSequence;
570     private readonly HashSet<LinkIndex> _results;
571     private readonly Func<ulong, bool> _stopableHandler;
572     private readonly HashSet<ulong> _readAsElements;
573     private int _filterPosition;
574
575     public Matcher(Sequences sequences, IList<LinkIndex> patternSequence,
576   ↳ HashSet<LinkIndex> results, Func<LinkIndex, bool> stopableHandler,
577   ↳ HashSet<LinkIndex> readAsElements = null)
578       : base(sequences.Links.Unsync)
579     {
580         _sequences = sequences;
581         _patternSequence = patternSequence;
582         _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
583   ↳ _constants.Any && x != ZeroOrMany));
584         _results = results;
585         _stopableHandler = stopableHandler;
586         _readAsElements = readAsElements;
587     }
588
589     protected override bool IsElement(IList<ulong> link) => base.IsElement(link) ||
590   ↳ (_readAsElements != null && _readAsElements.Contains(Links.GetIndex(link))) ||
591   ↳ _linksInSequence.Contains(Links.GetIndex(link));
592
593     public bool FullMatch(LinkIndex sequenceToMatch)
594     {

```

```

588     _filterPosition = 0;
589     foreach (var part in Walk(sequenceToMatch))
590     {
591         if (!FullMatchCore(Links.GetIndex(part)))
592         {
593             break;
594         }
595     }
596     return _filterPosition == _patternSequence.Count;
597 }
598
599 private bool FullMatchCore(LinkIndex element)
600 {
601     if (_filterPosition == _patternSequence.Count)
602     {
603         _filterPosition = -2; // Длиннее чем нужно
604         return false;
605     }
606     if (_patternSequence[_filterPosition] != _constants.Any
607         && element != _patternSequence[_filterPosition])
608     {
609         _filterPosition = -1;
610         return false; // Начинается/Продолжается иначе
611     }
612     _filterPosition++;
613     return true;
614 }
615
616 public void AddFullMatchedToResults(ulong sequenceToMatch)
617 {
618     if (FullMatch(sequenceToMatch))
619     {
620         _results.Add(sequenceToMatch);
621     }
622 }
623
624 public bool HandleFullMatched(ulong sequenceToMatch)
625 {
626     if (FullMatch(sequenceToMatch) && _results.Add(sequenceToMatch))
627     {
628         return _stopableHandler(sequenceToMatch);
629     }
630     return true;
631 }
632
633 public bool HandleFullMatchedSequence(ulong sequenceToMatch)
634 {
635     var sequence = _sequences.GetSequenceByElements(sequenceToMatch);
636     if (sequence != _constants.Null && FullMatch(sequenceToMatch) &&
637         ↪ _results.Add(sequenceToMatch))
638     {
639         return _stopableHandler(sequence);
640     }
641     return true;
642 }
643
644 /// <remarks>
645 /// TODO: Add support for LinksConstants.Any
646 /// </remarks>
647 public bool PartialMatch(LinkIndex sequenceToMatch)
648 {
649     _filterPosition = -1;
650     foreach (var part in Walk(sequenceToMatch))
651     {
652         if (!PartialMatchCore(Links.GetIndex(part)))
653         {
654             break;
655         }
656     }
657     return _filterPosition == _patternSequence.Count - 1;
658 }
659
660 private bool PartialMatchCore(LinkIndex element)
661 {
662     if (_filterPosition == (_patternSequence.Count - 1))
663     {
664         return false; // Нашлось
665     }
666     if (_filterPosition >= 0)

```

```

666     {
667         if (element == _patternSequence[_filterPosition + 1])
668         {
669             _filterPosition++;
670         }
671         else
672         {
673             _filterPosition = -1;
674         }
675     }
676     if (_filterPosition < 0)
677     {
678         if (element == _patternSequence[0])
679         {
680             _filterPosition = 0;
681         }
682     }
683     return true; // Ищем дальше
684 }
685
686 public void AddPartialMatchedToResults(ulong sequenceToMatch)
687 {
688     if (PartialMatch(sequenceToMatch))
689     {
690         _results.Add(sequenceToMatch);
691     }
692 }
693
694 public bool HandlePartialMatched(ulong sequenceToMatch)
695 {
696     if (PartialMatch(sequenceToMatch))
697     {
698         return _stopableHandler(sequenceToMatch);
699     }
700     return true;
701 }
702
703 public void AddAllPartialMatchedToResults(IEnumerable<ulong> sequencesToMatch)
704 {
705     foreach (var sequenceToMatch in sequencesToMatch)
706     {
707         if (PartialMatch(sequenceToMatch))
708         {
709             _results.Add(sequenceToMatch);
710         }
711     }
712 }
713
714 public void AddAllPartialMatchedToResultsAndReadAsElements(IEnumerable<ulong>
↪ sequencesToMatch)
715 {
716     foreach (var sequenceToMatch in sequencesToMatch)
717     {
718         if (PartialMatch(sequenceToMatch))
719         {
720             _readAsElements.Add(sequenceToMatch);
721             _results.Add(sequenceToMatch);
722         }
723     }
724 }
725 }
726
727 #endregion
728 }
729 }

```

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

```

1  using System;
2  using LinkIndex = System.UInt64;
3  using System.Collections.Generic;
4  using Stack = System.Collections.Generic.Stack<ulong>;
5  using System.Linq;
6  using System.Text;
7  using Platform.Collections;
8  using Platform.Numbers;
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

```

```

14 namespace Platform.Data.Doublets.Sequences
15 {
16     partial class Sequences
17     {
18         #region Create All Variants (Not Practical)
19
20         /// <remarks>
21         /// Number of links that is needed to generate all variants for
22         /// sequence of length N corresponds to https://oeis.org/A014143/list sequence.
23         /// </remarks>
24         public ulong[] CreateAllVariants2(ulong[] sequence)
25         {
26             return Sync.ExecuteWriteOperation(() =>
27             {
28                 if (sequence.IsNullOrEmpty())
29                 {
30                     return new ulong[0];
31                 }
32                 Links.EnsureEachLinkExists(sequence);
33                 if (sequence.Length == 1)
34                 {
35                     return sequence;
36                 }
37                 return CreateAllVariants2Core(sequence, 0, sequence.Length - 1);
38             });
39         }
40
41         private ulong[] CreateAllVariants2Core(ulong[] sequence, long startAt, long stopAt)
42         {
43             #if DEBUG
44                 if ((stopAt - startAt) < 0)
45                 {
46                     throw new ArgumentOutOfRangeException(nameof(startAt), "startAt должен быть
47                     ↪ меньше или равен stopAt");
48                 }
49                 #endif
50                 if ((stopAt - startAt) == 0)
51                 {
52                     return new[] { sequence[startAt] };
53                 }
54                 if ((stopAt - startAt) == 1)
55                 {
56                     return new[] { Links.Unsync.CreateAndUpdate(sequence[startAt], sequence[stopAt])
57                     ↪ };
58                 }
59                 var variants = new ulong[(ulong)Numbers.Math.Catalan(stopAt - startAt)];
60                 var last = 0;
61                 for (var splitter = startAt; splitter < stopAt; splitter++)
62                 {
63                     var left = CreateAllVariants2Core(sequence, startAt, splitter);
64                     var right = CreateAllVariants2Core(sequence, splitter + 1, stopAt);
65                     for (var i = 0; i < left.Length; i++)
66                     {
67                         for (var j = 0; j < right.Length; j++)
68                         {
69                             var variant = Links.Unsync.CreateAndUpdate(left[i], right[j]);
70                             if (variant == _constants.Null)
71                             {
72                                 throw new NotImplementedException("Creation cancellation is not
73                                 ↪ implemented.");
74                             }
75                             variants[last++] = variant;
76                         }
77                     }
78                 }
79                 return variants;
80             }
81
82             public List<ulong> CreateAllVariants1(params ulong[] sequence)
83             {
84                 return Sync.ExecuteWriteOperation(() =>
85                 {
86                     if (sequence.IsNullOrEmpty())
87                     {
88                         return new List<ulong>();
89                     }
90                     Links.Unsync.EnsureEachLinkExists(sequence);
91                     if (sequence.Length == 1)

```

```

89         {
90             return new List<ulong> { sequence[0] };
91         }
92         var results = new List<ulong>((int)Numbers.Math.Catalan(sequence.Length));
93         return CreateAllVariants1Core(sequence, results);
94     });
95 }
96
97 private List<ulong> CreateAllVariants1Core(ulong[] sequence, List<ulong> results)
98 {
99     if (sequence.Length == 2)
100     {
101         var link = Links.Unsync.CreateAndUpdate(sequence[0], sequence[1]);
102         if (link == _constants.Null)
103         {
104             throw new NotImplementedException("Creation cancellation is not
105                 ↳ implemented.");
106         }
107         results.Add(link);
108         return results;
109     }
110     var innerSequenceLength = sequence.Length - 1;
111     var innerSequence = new ulong[innerSequenceLength];
112     for (var li = 0; li < innerSequenceLength; li++)
113     {
114         var link = Links.Unsync.CreateAndUpdate(sequence[li], sequence[li + 1]);
115         if (link == _constants.Null)
116         {
117             throw new NotImplementedException("Creation cancellation is not
118                 ↳ implemented.");
119         }
120         for (var isi = 0; isi < li; isi++)
121         {
122             innerSequence[isi] = sequence[isi];
123         }
124         innerSequence[li] = link;
125         for (var isi = li + 1; isi < innerSequenceLength; isi++)
126         {
127             innerSequence[isi] = sequence[isi + 1];
128         }
129         CreateAllVariants1Core(innerSequence, results);
130     }
131     return results;
132 }
133
134 #endregion
135
136 public HashSet<ulong> Each1(params ulong[] sequence)
137 {
138     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
139     Each1(link =>
140     {
141         if (!visitedLinks.Contains(link))
142         {
143             visitedLinks.Add(link); // изучить почему случаются повторы
144         }
145         return true;
146     }, sequence);
147     return visitedLinks;
148 }
149
150 private void Each1(Func<ulong, bool> handler, params ulong[] sequence)
151 {
152     if (sequence.Length == 2)
153     {
154         Links.Unsync.Each(sequence[0], sequence[1], handler);
155     }
156     else
157     {
158         var innerSequenceLength = sequence.Length - 1;
159         for (var li = 0; li < innerSequenceLength; li++)
160         {
161             var left = sequence[li];
162             var right = sequence[li + 1];
163             if (left == 0 && right == 0)
164             {
165                 continue;
166             }
167             var linkIndex = li;

```



```

166         ulong[] innerSequence = null;
167         Links.Unsync.Each(left, right, doublet =>
168         {
169             if (innerSequence == null)
170             {
171                 innerSequence = new ulong[innerSequenceLength];
172                 for (var isi = 0; isi < linkIndex; isi++)
173                 {
174                     innerSequence[isi] = sequence[isi];
175                 }
176                 for (var isi = linkIndex + 1; isi < innerSequenceLength; isi++)
177                 {
178                     innerSequence[isi] = sequence[isi + 1];
179                 }
180             }
181             innerSequence[linkIndex] = doublet;
182             Each1(handler, innerSequence);
183             return _constants.Continue;
184         });
185     }
186 }
187
188
189 public HashSet<ulong> EachPart(params ulong[] sequence)
190 {
191     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
192     EachPartCore(link =>
193     {
194         if (!visitedLinks.Contains(link))
195         {
196             visitedLinks.Add(link); // изучить почему случаются повторы
197         }
198         return true;
199     }, sequence);
200     return visitedLinks;
201 }
202
203 public void EachPart(Func<ulong, bool> handler, params ulong[] sequence)
204 {
205     var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
206     EachPartCore(link =>
207     {
208         if (!visitedLinks.Contains(link))
209         {
210             visitedLinks.Add(link); // изучить почему случаются повторы
211             return handler(link);
212         }
213         return true;
214     }, sequence);
215 }
216
217 private void EachPartCore(Func<ulong, bool> handler, params ulong[] sequence)
218 {
219     if (sequence.IsNullOrEmpty())
220     {
221         return;
222     }
223     Links.EnsureEachLinkIsAnyOrExists(sequence);
224     if (sequence.Length == 1)
225     {
226         var link = sequence[0];
227         if (link > 0)
228         {
229             handler(link);
230         }
231         else
232         {
233             Links.Each(_constants.Any, _constants.Any, handler);
234         }
235     }
236     else if (sequence.Length == 2)
237     {
238         // _links.Each(sequence[0], sequence[1], handler);
239         // o_|      x_o ...
240         // x_|      |__|
241         Links.Each(sequence[1], _constants.Any, doublet =>
242         {
243             var match = Links.SearchOrDefault(sequence[0], doublet);

```

```

244         if (match != _constants.Null)
245         {
246             handler(match);
247         }
248         return true;
249     });
250     // |_x      ... x_o
251     // |_o      |___|
252     Links.Each(_constants.Any, sequence[0], doublet =>
253     {
254         var match = Links.SearchOrDefault(doublet, sequence[1]);
255         if (match != 0)
256         {
257             handler(match);
258         }
259         return true;
260     });
261     //      ..x o_.
262     //      |___|
263     PartialStepRight(x => handler(x), sequence[0], sequence[1]);
264 }
265 else
266 {
267     // TODO: Implement other variants
268     return;
269 }
270 }
271
272 private void PartialStepRight(Action<ulong> handler, ulong left, ulong right)
273 {
274     Links.Unsync.Each(_constants.Any, left, doublet =>
275     {
276         StepRight(handler, doublet, right);
277         if (left != doublet)
278         {
279             PartialStepRight(handler, doublet, right);
280         }
281         return true;
282     });
283 }
284
285 private void StepRight(Action<ulong> handler, ulong left, ulong right)
286 {
287     Links.Unsync.Each(left, _constants.Any, rightStep =>
288     {
289         TryStepRightUp(handler, right, rightStep);
290         return true;
291     });
292 }
293
294 private void TryStepRightUp(Action<ulong> handler, ulong right, ulong stepFrom)
295 {
296     var upStep = stepFrom;
297     var firstSource = Links.Unsync.GetTarget(upStep);
298     while (firstSource != right && firstSource != upStep)
299     {
300         upStep = firstSource;
301         firstSource = Links.Unsync.GetSource(upStep);
302     }
303     if (firstSource == right)
304     {
305         handler(stepFrom);
306     }
307 }
308
309 // TODO: Test
310 private void PartialStepLeft(Action<ulong> handler, ulong left, ulong right)
311 {
312     Links.Unsync.Each(right, _constants.Any, doublet =>
313     {
314         StepLeft(handler, left, doublet);
315         if (right != doublet)
316         {
317             PartialStepLeft(handler, left, doublet);
318         }
319         return true;
320     });
321 }
322

```

```

323 private void StepLeft(Action<ulong> handler, ulong left, ulong right)
324 {
325     Links.Unsync.Each(_constants.Any, right, leftStep =>
326     {
327         TryStepLeftUp(handler, left, leftStep);
328         return true;
329     });
330 }
331
332 private void TryStepLeftUp(Action<ulong> handler, ulong left, ulong stepFrom)
333 {
334     var upStep = stepFrom;
335     var firstTarget = Links.Unsync.GetSource(upStep);
336     while (firstTarget != left && firstTarget != upStep)
337     {
338         upStep = firstTarget;
339         firstTarget = Links.Unsync.GetTarget(upStep);
340     }
341     if (firstTarget == left)
342     {
343         handler(stepFrom);
344     }
345 }
346
347 private bool StartsWith(ulong sequence, ulong link)
348 {
349     var upStep = sequence;
350     var firstSource = Links.Unsync.GetSource(upStep);
351     while (firstSource != link && firstSource != upStep)
352     {
353         upStep = firstSource;
354         firstSource = Links.Unsync.GetSource(upStep);
355     }
356     return firstSource == link;
357 }
358
359 private bool EndsWith(ulong sequence, ulong link)
360 {
361     var upStep = sequence;
362     var lastTarget = Links.Unsync.GetTarget(upStep);
363     while (lastTarget != link && lastTarget != upStep)
364     {
365         upStep = lastTarget;
366         lastTarget = Links.Unsync.GetTarget(upStep);
367     }
368     return lastTarget == link;
369 }
370
371 public List<ulong> GetAllMatchingSequences0(params ulong[] sequence)
372 {
373     return Sync.ExecuteReadOperation(() =>
374     {
375         var results = new List<ulong>();
376         if (sequence.Length > 0)
377         {
378             Links.EnsureEachLinkExists(sequence);
379             var firstElement = sequence[0];
380             if (sequence.Length == 1)
381             {
382                 results.Add(firstElement);
383                 return results;
384             }
385             if (sequence.Length == 2)
386             {
387                 var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
388                 if (doublet != _constants.Null)
389                 {
390                     results.Add(doublet);
391                 }
392                 return results;
393             }
394             var linksInSequence = new HashSet<ulong>(sequence);
395             void handler(ulong result)
396             {
397                 var filterPosition = 0;
398                 StopableSequenceWalker.WalkRight(result, Links.Unsync.GetSource,
399                     ↪ Links.Unsync.GetTarget,
400                     x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
401                     ↪ x =>

```

```

    {
        if (filterPosition == sequence.Length)
        {
            filterPosition = -2; // Длиннее чем нужно
            return false;
        }
        if (x != sequence[filterPosition])
        {
            filterPosition = -1;
            return false; // Начинается иначе
        }
        filterPosition++;

        return true;
    });
    if (filterPosition == sequence.Length)
    {
        results.Add(result);
    }
}
if (sequence.Length >= 2)
{
    StepRight(handler, sequence[0], sequence[1]);
}
var last = sequence.Length - 2;
for (var i = 1; i < last; i++)
{
    PartialStepRight(handler, sequence[i], sequence[i + 1]);
}
if (sequence.Length >= 3)
{
    StepLeft(handler, sequence[sequence.Length - 2],
        ↪ sequence[sequence.Length - 1]);
}
}
return results;
});
}

public HashSet<ulong> GetAllMatchingSequences1(params ulong[] sequence)
{
    return Sync.ExecuteReadOperation(() =>
    {
        var results = new HashSet<ulong>();
        if (sequence.Length > 0)
        {
            Links.EnsureEachLinkExists(sequence);
            var firstElement = sequence[0];
            if (sequence.Length == 1)
            {
                results.Add(firstElement);
                return results;
            }
            if (sequence.Length == 2)
            {
                var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
                if (doublet != _constants.Null)
                {
                    results.Add(doublet);
                }
                return results;
            }
        }
        var matcher = new Matcher(this, sequence, results, null);
        if (sequence.Length >= 2)
        {
            StepRight(matcher.AddFullMatchedToResults, sequence[0], sequence[1]);
        }
        var last = sequence.Length - 2;
        for (var i = 1; i < last; i++)
        {
            PartialStepRight(matcher.AddFullMatchedToResults, sequence[i],
                ↪ sequence[i + 1]);
        }
        if (sequence.Length >= 3)
        {
            StepLeft(matcher.AddFullMatchedToResults, sequence[sequence.Length - 2],
                ↪ sequence[sequence.Length - 1]);
        }
    });
}

```

```

475     }
476     return results;
477 });
478 }
479
480 public const int MaxSequenceFormatSize = 200;
481
482 public string FormatSequence(LinkIndex sequenceLink, params LinkIndex[] knownElements)
483     => FormatSequence(sequenceLink, (sb, x) => sb.Append(x), true, knownElements);
484
485 public string FormatSequence(LinkIndex sequenceLink, Action<StringBuilder, LinkIndex>
486     elementToString, bool insertComma, params LinkIndex[] knownElements) =>
487     Links.SyncRoot.ExecuteReadOperation(() => FormatSequence(Links.Unsync, sequenceLink,
488         elementToString, insertComma, knownElements));
489
490 private string FormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
491     Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
492     LinkIndex[] knownElements)
493 {
494     var linksInSequence = new HashSet<ulong>(knownElements);
495     //var entered = new HashSet<ulong>();
496     var sb = new StringBuilder();
497     sb.Append('{');
498     if (links.Exists(sequenceLink))
499     {
500         StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
501             x => linksInSequence.Contains(x) || links.IsPartialPoint(x), element => //
502             => entered.AddAndReturnVoid, x => { }, entered.DoNotContains
503             {
504                 if (insertComma && sb.Length > 1)
505                 {
506                     sb.Append(',');
507                 }
508                 //if (entered.Contains(element))
509                 //{
510                     sb.Append('{');
511                     elementToString(sb, element);
512                     sb.Append('}');
513                 }
514                 //else
515                 elementToString(sb, element);
516                 if (sb.Length < MaxSequenceFormatSize)
517                 {
518                     return true;
519                 }
520                 sb.Append(insertComma ? ", ..." : "...");
521                 return false;
522             }
523     });
524     sb.Append('}');
525     return sb.ToString();
526 }
527
528 public string SafeFormatSequence(LinkIndex sequenceLink, params LinkIndex[]
529     knownElements) => SafeFormatSequence(sequenceLink, (sb, x) => sb.Append(x), true,
530     knownElements);
531
532 public string SafeFormatSequence(LinkIndex sequenceLink, Action<StringBuilder,
533     LinkIndex> elementToString, bool insertComma, params LinkIndex[] knownElements) =>
534     Links.SyncRoot.ExecuteReadOperation(() => SafeFormatSequence(Links.Unsync,
535         sequenceLink, elementToString, insertComma, knownElements));
536
537 private string SafeFormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
538     Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
539     LinkIndex[] knownElements)
540 {
541     var linksInSequence = new HashSet<ulong>(knownElements);
542     var entered = new HashSet<ulong>();
543     var sb = new StringBuilder();
544     sb.Append('{');
545     if (links.Exists(sequenceLink))
546     {
547         StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
548             x => linksInSequence.Contains(x) || links.IsFullPoint(x),
549             => entered.AddAndReturnVoid, x => { }, entered.DoNotContains, element =>
550             {
551                 if (insertComma && sb.Length > 1)
552                 {

```

```

538         sb.Append(',');
539     }
540     if (entered.Contains(element))
541     {
542         sb.Append('{');
543         elementToString(sb, element);
544         sb.Append('}');
545     }
546     else
547     {
548         elementToString(sb, element);
549     }
550     if (sb.Length < MaxSequenceFormatSize)
551     {
552         return true;
553     }
554     sb.Append(insertComma ? ", ..." : "...");
555     return false;
556 });
557 }
558 sb.Append('}');
559 return sb.ToString();
560 }
561
562 public List<ulong> GetAllPartiallyMatchingSequences0(params ulong[] sequence)
563 {
564     return Sync.ExecuteReadOperation(() =>
565     {
566         if (sequence.Length > 0)
567         {
568             Links.EnsureEachLinkExists(sequence);
569             var results = new HashSet<ulong>();
570             for (var i = 0; i < sequence.Length; i++)
571             {
572                 AllUsagesCore(sequence[i], results);
573             }
574             var filteredResults = new List<ulong>();
575             var linksInSequence = new HashSet<ulong>(sequence);
576             foreach (var result in results)
577             {
578                 var filterPosition = -1;
579                 StopableSequenceWalker.WalkRight(result, Links.Unsync.GetSource,
580                     ↪ Links.Unsync.GetTarget,
581                     ↪ x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
582                     ↪ x =>
583                     {
584                         if (filterPosition == (sequence.Length - 1))
585                         {
586                             return false;
587                         }
588                         if (filterPosition >= 0)
589                         {
590                             if (x == sequence[filterPosition + 1])
591                             {
592                                 filterPosition++;
593                             }
594                             else
595                             {
596                                 return false;
597                             }
598                         }
599                         if (filterPosition < 0)
600                         {
601                             if (x == sequence[0])
602                             {
603                                 filterPosition = 0;
604                             }
605                         }
606                         return true;
607                     }
608                 );
609                 if (filterPosition == (sequence.Length - 1))
610                 {
611                     filteredResults.Add(result);
612                 }
613             }
614             return filteredResults;
615         }
616         return new List<ulong>();
617     });
618 }

```

```

615 }
616
617 public HashSet<ulong> GetAllPartiallyMatchingSequences1(params ulong[] sequence)
618 {
619     return Sync.ExecuteReadOperation(() =>
620     {
621         if (sequence.Length > 0)
622         {
623             Links.EnsureEachLinkExists(sequence);
624             var results = new HashSet<ulong>();
625             for (var i = 0; i < sequence.Length; i++)
626             {
627                 AllUsagesCore(sequence[i], results);
628             }
629             var filteredResults = new HashSet<ulong>();
630             var matcher = new Matcher(this, sequence, filteredResults, null);
631             matcher.AddAllPartialMatchedToResults(results);
632             return filteredResults;
633         }
634         return new HashSet<ulong>();
635     });
636 }
637
638 public bool GetAllPartiallyMatchingSequences2(Func<ulong, bool> handler, params ulong[]
639 → sequence)
640 {
641     return Sync.ExecuteReadOperation(() =>
642     {
643         if (sequence.Length > 0)
644         {
645             Links.EnsureEachLinkExists(sequence);
646
647             var results = new HashSet<ulong>();
648             var filteredResults = new HashSet<ulong>();
649             var matcher = new Matcher(this, sequence, filteredResults, handler);
650             for (var i = 0; i < sequence.Length; i++)
651             {
652                 if (!AllUsagesCore1(sequence[i], results, matcher.HandlePartialMatched))
653                 {
654                     return false;
655                 }
656                 return true;
657             }
658             return true;
659         });
660 }
661
662 //public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
663 //{
664 //    return Sync.ExecuteReadOperation(() =>
665 //    {
666 //        if (sequence.Length > 0)
667 //        {
668 //            _links.EnsureEachLinkIsAnyOrExists(sequence);
669 //
670 //            var firstResults = new HashSet<ulong>();
671 //            var lastResults = new HashSet<ulong>();
672 //
673 //            var first = sequence.First(x => x != LinksConstants.Any);
674 //            var last = sequence.Last(x => x != LinksConstants.Any);
675 //
676 //            AllUsagesCore(first, firstResults);
677 //            AllUsagesCore(last, lastResults);
678 //
679 //            firstResults.IntersectWith(lastResults);
680 //
681 //            //for (var i = 0; i < sequence.Length; i++)
682 //            //    AllUsagesCore(sequence[i], results);
683 //
684 //            var filteredResults = new HashSet<ulong>();
685 //            var matcher = new Matcher(this, sequence, filteredResults, null);
686 //            matcher.AddAllPartialMatchedToResults(firstResults);
687 //            return filteredResults;
688 //        }
689 //
690 //        return new HashSet<ulong>();
691 //    });
692 //}

```

```

693 public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
694 {
695     return Sync.ExecuteReadOperation(() =>
696     {
697         if (sequence.Length > 0)
698         {
699             Links.EnsureEachLinkIsAnyOrExists(sequence);
700             var firstResults = new HashSet<ulong>();
701             var lastResults = new HashSet<ulong>();
702             var first = sequence.First(x => x != _constants.Any);
703             var last = sequence.Last(x => x != _constants.Any);
704             AllUsagesCore(first, firstResults);
705             AllUsagesCore(last, lastResults);
706             firstResults.IntersectWith(lastResults);
707             //for (var i = 0; i < sequence.Length; i++)
708             //    AllUsagesCore(sequence[i], results);
709             var filteredResults = new HashSet<ulong>();
710             var matcher = new Matcher(this, sequence, filteredResults, null);
711             matcher.AddAllPartialMatchedToResults(firstResults);
712             return filteredResults;
713         }
714     }
715     return new HashSet<ulong>();
716 });
717 }
718
719 public HashSet<ulong> GetAllPartiallyMatchingSequences4(HashSet<ulong> readAsElements,
720 ↪ IList<ulong> sequence)
721 {
722     return Sync.ExecuteReadOperation(() =>
723     {
724         if (sequence.Count > 0)
725         {
726             Links.EnsureEachLinkExists(sequence);
727             var results = new HashSet<LinkIndex>();
728             //var nextResults = new HashSet<ulong>();
729             //for (var i = 0; i < sequence.Length; i++)
730             //{
731             //    AllUsagesCore(sequence[i], nextResults);
732             //    if (results.IsNullOrEmpty())
733             //    {
734             //        results = nextResults;
735             //        nextResults = new HashSet<ulong>();
736             //    }
737             //    else
738             //    {
739             //        results.IntersectWith(nextResults);
740             //        nextResults.Clear();
741             //    }
742             //}
743             var collector1 = new AllUsagesCollector1(Links.Unsync, results);
744             collector1.Collect(Links.Unsync.GetLink(sequence[0]));
745             var next = new HashSet<ulong>();
746             for (var i = 1; i < sequence.Count; i++)
747             {
748                 var collector = new AllUsagesCollector1(Links.Unsync, next);
749                 collector.Collect(Links.Unsync.GetLink(sequence[i]));
750
751                 results.IntersectWith(next);
752                 next.Clear();
753             }
754             var filteredResults = new HashSet<ulong>();
755             var matcher = new Matcher(this, sequence, filteredResults, null,
756 ↪ readAsElements);
757             matcher.AddAllPartialMatchedToResultsAndReadAsElements(results.OrderBy(x =>
758 ↪ x)); // OrderBy is a Hack
759             return filteredResults;
760         }
761     }
762     return new HashSet<ulong>();
763 });
764 }
765
766 // Does not work
767 public HashSet<ulong> GetAllPartiallyMatchingSequences5(HashSet<ulong> readAsElements,
768 ↪ params ulong[] sequence)
769 {
770     var visited = new HashSet<ulong>();
771     var results = new HashSet<ulong>();

```



```

767     var matcher = new Matcher(this, sequence, visited, x => { results.Add(x); return
768         ↳ true; }, readAsElements);
769     var last = sequence.Length - 1;
770     for (var i = 0; i < last; i++)
771     {
772         PartialStepRight(matcher.PartialMatch, sequence[i], sequence[i + 1]);
773     }
774     return results;
775 }
776
777 public List<ulong> GetAllPartiallyMatchingSequences(params ulong[] sequence)
778 {
779     return Sync.ExecuteReadOperation(() =>
780     {
781         if (sequence.Length > 0)
782         {
783             Links.EnsureEachLinkExists(sequence);
784             //var firstElement = sequence[0];
785             //if (sequence.Length == 1)
786             //{
787                 //results.Add(firstElement);
788                 //return results;
789             //}
790             //if (sequence.Length == 2)
791             //{
792                 //var doublet = _links.SearchCore(firstElement, sequence[1]);
793                 //if (doublet != Doublets.Links.Null)
794                 //    results.Add(doublet);
795                 //return results;
796             //}
797             //var lastElement = sequence[sequence.Length - 1];
798             //Func<ulong, bool> handler = x =>
799             //{
800                 //if (StartsWith(x, firstElement) && EndsWith(x, lastElement))
801                 //    ↳ results.Add(x);
802                 //return true;
803             //};
804             //if (sequence.Length >= 2)
805             //    StepRight(handler, sequence[0], sequence[1]);
806             //var last = sequence.Length - 2;
807             //for (var i = 1; i < last; i++)
808             //    PartialStepRight(handler, sequence[i], sequence[i + 1]);
809             //if (sequence.Length >= 3)
810             //    StepLeft(handler, sequence[sequence.Length - 2],
811                 ↳ sequence[sequence.Length - 1]);
812             //if (sequence.Length == 1)
813             //    throw new NotImplementedException(); // all sequences, containing
814                 ↳ this element?
815             //if (sequence.Length == 2)
816             //{
817                 var results = new List<ulong>();
818                 PartialStepRight(results.Add, sequence[0], sequence[1]);
819                 return results;
820             //}
821             //var matches = new List<List<ulong>>();
822             //var last = sequence.Length - 1;
823             //for (var i = 0; i < last; i++)
824             //{
825                 var results = new List<ulong>();
826                 //StepRight(results.Add, sequence[i], sequence[i + 1]);
827                 PartialStepRight(results.Add, sequence[i], sequence[i + 1]);
828                 if (results.Count > 0)
829                     matches.Add(results);
830                 else
831                     return results;
832                 if (matches.Count == 2)
833                 {
834                     var merged = new List<ulong>();
835                     for (var j = 0; j < matches[0].Count; j++)
836                         for (var k = 0; k < matches[1].Count; k++)
837                             CloseInnerConnections(merged.Add, matches[0][j],
838                                 ↳ matches[1][k]);
839                     if (merged.Count > 0)
840                         matches = new List<List<ulong>> { merged };
841                     else

```

```

839         return new List<ulong>();
840     }
841 }
842 //if (matches.Count > 0)
843 //{
844     var usages = new HashSet<ulong>();
845     for (int i = 0; i < sequence.Length; i++)
846     {
847         AllUsagesCore(sequence[i], usages);
848     }
849     //for (int i = 0; i < matches[0].Count; i++)
850     //    AllUsagesCore(matches[0][i], usages);
851     //usages.UnionWith(matches[0]);
852     return usages.ToList();
853 }
854 var firstLinkUsages = new HashSet<ulong>();
855 AllUsagesCore(sequence[0], firstLinkUsages);
856 firstLinkUsages.Add(sequence[0]);
857 //var previousMatchings = firstLinkUsages.ToList(); //new List<ulong>() {
858 //    sequence[0] }; // or all sequences, containing this element?
859 //return GetAllPartiallyMatchingSequencesCore(sequence, firstLinkUsages,
860 //    1).ToList();
861 var results = new HashSet<ulong>();
862 foreach (var match in GetAllPartiallyMatchingSequencesCore(sequence,
863     firstLinkUsages, 1))
864 {
865     AllUsagesCore(match, results);
866 }
867 return results.ToList();
868 }
869 return new List<ulong>();
870 });
871 }
872
873 /// <remarks>
874 /// TODO: Может потребоваться ограничение на уровень глубины рекурсии
875 /// </remarks>
876 public HashSet<ulong> AllUsages(ulong link)
877 {
878     return Sync.ExecuteReadOperation(() =>
879     {
880         var usages = new HashSet<ulong>();
881         AllUsagesCore(link, usages);
882         return usages;
883     });
884 }
885
886 // При сборе всех использований (последовательностей) можно сохранять обратный путь к
887 // той связи с которой начинался поиск (STTTSSSTT),
888 // причём достаточно одного бита для хранения перехода влево или вправо
889 private void AllUsagesCore(ulong link, HashSet<ulong> usages)
890 {
891     bool handler(ulong doublet)
892     {
893         if (usages.Add(doublet))
894         {
895             AllUsagesCore(doublet, usages);
896         }
897         return true;
898     }
899     Links.Unsync.Each(link, _constants.Any, handler);
900     Links.Unsync.Each(_constants.Any, link, handler);
901 }
902
903 public HashSet<ulong> AllBottomUsages(ulong link)
904 {
905     return Sync.ExecuteReadOperation(() =>
906     {
907         var visits = new HashSet<ulong>();
908         var usages = new HashSet<ulong>();
909         AllBottomUsagesCore(link, visits, usages);
910         return usages;
911     });
912 }
913
914 private void AllBottomUsagesCore(ulong link, HashSet<ulong> visits, HashSet<ulong>
915     usages)
916 {

```

```

912     bool handler(ulong doublet)
913     {
914         if (visits.Add(doublet))
915         {
916             AllBottomUsagesCore(doublet, visits, usages);
917         }
918         return true;
919     }
920     if (Links.Unsync.Count(_constants.Any, link) == 0)
921     {
922         usages.Add(link);
923     }
924     else
925     {
926         Links.Unsync.Each(link, _constants.Any, handler);
927         Links.Unsync.Each(_constants.Any, link, handler);
928     }
929 }
930
931 public ulong CalculateTotalSymbolFrequencyCore(ulong symbol)
932 {
933     if (Options.UseSequenceMarker)
934     {
935         var counter = new TotalMarkedSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
936             ↪ Options.MarkedSequenceMatcher, symbol);
937         return counter.Count();
938     }
939     else
940     {
941         var counter = new TotalSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
942             ↪ symbol);
943         return counter.Count();
944     }
945 }
946
947 private bool AllUsagesCore1(ulong link, HashSet<ulong> usages, Func<ulong, bool>
948     ↪ outerHandler)
949 {
950     bool handler(ulong doublet)
951     {
952         if (usages.Add(doublet))
953         {
954             if (!outerHandler(doublet))
955             {
956                 return false;
957             }
958             if (!AllUsagesCore1(doublet, usages, outerHandler))
959             {
960                 return false;
961             }
962         }
963         return true;
964     }
965     return Links.Unsync.Each(link, _constants.Any, handler)
966         && Links.Unsync.Each(_constants.Any, link, handler);
967 }
968
969 public void CalculateAllUsages(ulong[] totals)
970 {
971     var calculator = new AllUsagesCalculator(Links, totals);
972     calculator.Calculate();
973 }
974
975 public void CalculateAllUsages2(ulong[] totals)
976 {
977     var calculator = new AllUsagesCalculator2(Links, totals);
978     calculator.Calculate();
979 }
980
981 private class AllUsagesCalculator
982 {
983     private readonly SynchronizedLinks<ulong> _links;
984     private readonly ulong[] _totals;
985
986     public AllUsagesCalculator(SynchronizedLinks<ulong> links, ulong[] totals)
987     {
988         _links = links;
989         _totals = totals;
990     }

```

```

988 public void Calculate() => _links.Each(_constants.Any, _constants.Any,
989     ↪ CalculateCore);
990
991 private bool CalculateCore(ulong link)
992 {
993     if (_totals[link] == 0)
994     {
995         var total = 1UL;
996         _totals[link] = total;
997         var visitedChildren = new HashSet<ulong>();
998         bool linkCalculator(ulong child)
999         {
1000             if (link != child && visitedChildren.Add(child))
1001             {
1002                 total += _totals[child] == 0 ? 1 : _totals[child];
1003             }
1004             return true;
1005         }
1006         _links.Unsync.Each(link, _constants.Any, linkCalculator);
1007         _links.Unsync.Each(_constants.Any, link, linkCalculator);
1008         _totals[link] = total;
1009     }
1010     return true;
1011 }
1012
1013
1014 private class AllUsagesCalculator2
1015 {
1016     private readonly SynchronizedLinks<ulong> _links;
1017     private readonly ulong[] _totals;
1018
1019     public AllUsagesCalculator2(SynchronizedLinks<ulong> links, ulong[] totals)
1020     {
1021         _links = links;
1022         _totals = totals;
1023     }
1024
1025     public void Calculate() => _links.Each(_constants.Any, _constants.Any,
1026         ↪ CalculateCore);
1027
1028     private bool IsElement(ulong link)
1029     {
1030         // _linksInSequence.Contains(link) ||
1031         return _links.Unsync.GetTarget(link) == link || _links.Unsync.GetSource(link) ==
1032             ↪ link;
1033     }
1034
1035     private bool CalculateCore(ulong link)
1036     {
1037         // TODO: Проработать защиту от заикливания
1038         // Основано на SequenceWalker.WalkLeft
1039         Func<ulong, ulong> getSource = _links.Unsync.GetSource;
1040         Func<ulong, ulong> getTarget = _links.Unsync.GetTarget;
1041         Func<ulong, bool> isElement = IsElement;
1042         void visitLeaf(ulong parent)
1043         {
1044             if (link != parent)
1045             {
1046                 _totals[parent]++;
1047             }
1048         }
1049         void visitNode(ulong parent)
1050         {
1051             if (link != parent)
1052             {
1053                 _totals[parent]++;
1054             }
1055         }
1056         var stack = new Stack();
1057         var element = link;
1058         if (isElement(element))
1059         {
1060             visitLeaf(element);
1061         }
1062         else
1063         {
1064             while (true)
1065             {

```

```

1064         if (isElement(element))
1065         {
1066             if (stack.Count == 0)
1067             {
1068                 break;
1069             }
1070             element = stack.Pop();
1071             var source = getSource(element);
1072             var target = getTarget(element);
1073             // Обработка элемента
1074             if (isElement(target))
1075             {
1076                 visitLeaf(target);
1077             }
1078             if (isElement(source))
1079             {
1080                 visitLeaf(source);
1081             }
1082             element = source;
1083         }
1084         else
1085         {
1086             stack.Push(element);
1087             visitNode(element);
1088             element = getTarget(element);
1089         }
1090     }
1091 }
1092 _totals[link]++;
1093 return true;
1094 }
1095 }
1096
1097 private class AllUsagesCollector
1098 {
1099     private readonly ILinks<ulong> _links;
1100     private readonly HashSet<ulong> _usages;
1101
1102     public AllUsagesCollector(ILinks<ulong> links, HashSet<ulong> usages)
1103     {
1104         _links = links;
1105         _usages = usages;
1106     }
1107
1108     public bool Collect(ulong link)
1109     {
1110         if (_usages.Add(link))
1111         {
1112             _links.Each(link, _constants.Any, Collect);
1113             _links.Each(_constants.Any, link, Collect);
1114         }
1115         return true;
1116     }
1117 }
1118
1119 private class AllUsagesCollector1
1120 {
1121     private readonly ILinks<ulong> _links;
1122     private readonly HashSet<ulong> _usages;
1123     private readonly ulong _continue;
1124
1125     public AllUsagesCollector1(ILinks<ulong> links, HashSet<ulong> usages)
1126     {
1127         _links = links;
1128         _usages = usages;
1129         _continue = _links.Constants.Continue;
1130     }
1131
1132     public ulong Collect(IList<ulong> link)
1133     {
1134         var linkIndex = _links.GetIndex(link);
1135         if (_usages.Add(linkIndex))
1136         {
1137             _links.Each(Collect, _constants.Any, linkIndex);
1138         }
1139         return _continue;
1140     }
1141 }
1142
1143 private class AllUsagesCollector2

```

```

1144 {
1145     private readonly ILinks<ulong> _links;
1146     private readonly BitString _usages;
1147
1148     public AllUsagesCollector2(ILinks<ulong> links, BitString usages)
1149     {
1150         _links = links;
1151         _usages = usages;
1152     }
1153
1154     public bool Collect(ulong link)
1155     {
1156         if (_usages.Add((long)link))
1157         {
1158             _links.Each(link, _constants.Any, Collect);
1159             _links.Each(_constants.Any, link, Collect);
1160         }
1161         return true;
1162     }
1163 }
1164
1165 private class AllUsagesIntersectingCollector
1166 {
1167     private readonly SynchronizedLinks<ulong> _links;
1168     private readonly HashSet<ulong> _intersectWith;
1169     private readonly HashSet<ulong> _usages;
1170     private readonly HashSet<ulong> _enter;
1171
1172     public AllUsagesIntersectingCollector(SynchronizedLinks<ulong> links, HashSet<ulong>
↵ intersectWith, HashSet<ulong> usages)
1173     {
1174         _links = links;
1175         _intersectWith = intersectWith;
1176         _usages = usages;
1177         _enter = new HashSet<ulong>(); // защита от зацикливания
1178     }
1179
1180     public bool Collect(ulong link)
1181     {
1182         if (_enter.Add(link))
1183         {
1184             if (_intersectWith.Contains(link))
1185             {
1186                 _usages.Add(link);
1187             }
1188             _links.Unsync.Each(link, _constants.Any, Collect);
1189             _links.Unsync.Each(_constants.Any, link, Collect);
1190         }
1191         return true;
1192     }
1193 }
1194
1195 private void CloseInnerConnections(Action<ulong> handler, ulong left, ulong right)
1196 {
1197     TryStepLeftUp(handler, left, right);
1198     TryStepRightUp(handler, right, left);
1199 }
1200
1201 private void AllCloseConnections(Action<ulong> handler, ulong left, ulong right)
1202 {
1203     // Direct
1204     if (left == right)
1205     {
1206         handler(left);
1207     }
1208     var doublet = Links.Unsync.SearchOrDefault(left, right);
1209     if (doublet != _constants.Null)
1210     {
1211         handler(doublet);
1212     }
1213     // Inner
1214     CloseInnerConnections(handler, left, right);
1215     // Outer
1216     StepLeft(handler, left, right);
1217     StepRight(handler, left, right);
1218     PartialStepRight(handler, left, right);
1219     PartialStepLeft(handler, left, right);
1220 }
1221

```

```

1222 private HashSet<ulong> GetAllPartiallyMatchingSequencesCore(ulong[] sequence,
1223     ↳ HashSet<ulong> previousMatchings, long startAt)
1224 {
1225     if (startAt >= sequence.Length) // ?
1226     {
1227         return previousMatchings;
1228     }
1229     var secondLinkUsages = new HashSet<ulong>();
1230     AllUsagesCore(sequence[startAt], secondLinkUsages);
1231     secondLinkUsages.Add(sequence[startAt]);
1232     var matchings = new HashSet<ulong>();
1233     //for (var i = 0; i < previousMatchings.Count; i++)
1234     foreach (var secondLinkUsage in secondLinkUsages)
1235     {
1236         foreach (var previousMatching in previousMatchings)
1237         {
1238             //AllCloseConnections(matchings.AddAndReturnVoid, previousMatching,
1239             ↳ secondLinkUsage);
1240             StepRight(matchings.AddAndReturnVoid, previousMatching, secondLinkUsage);
1241             TryStepRightUp(matchings.AddAndReturnVoid, secondLinkUsage,
1242             ↳ previousMatching);
1243             //PartialStepRight(matchings.AddAndReturnVoid, secondLinkUsage,
1244             ↳ sequence[startAt]); // почему-то эта ошибочная запись приводит к
1245             ↳ желаемым результатам.
1246             PartialStepRight(matchings.AddAndReturnVoid, previousMatching,
1247             ↳ secondLinkUsage);
1248         }
1249     }
1250     if (matchings.Count == 0)
1251     {
1252         return matchings;
1253     }
1254     return GetAllPartiallyMatchingSequencesCore(sequence, matchings, startAt + 1); // ??
1255 }
1256
1257 private static void EnsureEachLinkIsAnyOrZeroOrManyOrExists(SynchronizedLinks<ulong>
1258     ↳ links, params ulong[] sequence)
1259 {
1260     if (sequence == null)
1261     {
1262         return;
1263     }
1264     for (var i = 0; i < sequence.Length; i++)
1265     {
1266         if (sequence[i] != _constants.Any && sequence[i] != ZeroOrMany &&
1267             ↳ !links.Exists(sequence[i]))
1268         {
1269             throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
1270             ↳ $"patternSequence[{i}]");
1271         }
1272     }
1273 }
1274
1275 // Pattern Matching -> Key To Triggers
1276 public HashSet<ulong> MatchPattern(params ulong[] patternSequence)
1277 {
1278     return Sync.ExecuteReadOperation(() =>
1279     {
1280         patternSequence = Simplify(patternSequence);
1281         if (patternSequence.Length > 0)
1282         {
1283             EnsureEachLinkIsAnyOrZeroOrManyOrExists(links, patternSequence);
1284             var uniqueSequenceElements = new HashSet<ulong>();
1285             for (var i = 0; i < patternSequence.Length; i++)
1286             {
1287                 if (patternSequence[i] != _constants.Any && patternSequence[i] !=
1288                 ↳ ZeroOrMany)
1289                 {
1290                     uniqueSequenceElements.Add(patternSequence[i]);
1291                 }
1292             }
1293             var results = new HashSet<ulong>();
1294             foreach (var uniqueSequenceElement in uniqueSequenceElements)
1295             {
1296                 AllUsagesCore(uniqueSequenceElement, results);
1297             }
1298             var filteredResults = new HashSet<ulong>();

```

```

1289         var matcher = new PatternMatcher(this, patternSequence, filteredResults);
1290         matcher.AddAllPatternMatchedToResults(results);
1291         return filteredResults;
1292     }
1293     return new HashSet<ulong>();
1294 });
1295 }
1296
1297 // Найти все возможные связи между указанным списком связей.
1298 // Находит связи между всеми указанными связями в любом порядке.
1299 // TODO: решить что делать с повторами (когда одни и те же элементы встречаются
1300 // → несколько раз в последовательности)
1301 public HashSet<ulong> GetAllConnections(params ulong[] linksToConnect)
1302 {
1303     return Sync.ExecuteReadOperation(() =>
1304     {
1305         var results = new HashSet<ulong>();
1306         if (linksToConnect.Length > 0)
1307         {
1308             Links.EnsureEachLinkExists(linksToConnect);
1309             AllUsagesCore(linksToConnect[0], results);
1310             for (var i = 1; i < linksToConnect.Length; i++)
1311             {
1312                 var next = new HashSet<ulong>();
1313                 AllUsagesCore(linksToConnect[i], next);
1314                 results.IntersectWith(next);
1315             }
1316             return results;
1317         }
1318     });
1319 }
1320
1321 public HashSet<ulong> GetAllConnections1(params ulong[] linksToConnect)
1322 {
1323     return Sync.ExecuteReadOperation(() =>
1324     {
1325         var results = new HashSet<ulong>();
1326         if (linksToConnect.Length > 0)
1327         {
1328             Links.EnsureEachLinkExists(linksToConnect);
1329             var collector1 = new AllUsagesCollector(Links.Unsync, results);
1330             collector1.Collect(linksToConnect[0]);
1331             var next = new HashSet<ulong>();
1332             for (var i = 1; i < linksToConnect.Length; i++)
1333             {
1334                 var collector = new AllUsagesCollector(Links.Unsync, next);
1335                 collector.Collect(linksToConnect[i]);
1336                 results.IntersectWith(next);
1337                 next.Clear();
1338             }
1339             return results;
1340         }
1341     });
1342 }
1343
1344 public HashSet<ulong> GetAllConnections2(params ulong[] linksToConnect)
1345 {
1346     return Sync.ExecuteReadOperation(() =>
1347     {
1348         var results = new HashSet<ulong>();
1349         if (linksToConnect.Length > 0)
1350         {
1351             Links.EnsureEachLinkExists(linksToConnect);
1352             var collector1 = new AllUsagesCollector(Links, results);
1353             collector1.Collect(linksToConnect[0]);
1354             //AllUsagesCore(linksToConnect[0], results);
1355             for (var i = 1; i < linksToConnect.Length; i++)
1356             {
1357                 var next = new HashSet<ulong>();
1358                 var collector = new AllUsagesIntersectingCollector(Links, results, next);
1359                 collector.Collect(linksToConnect[i]);
1360                 //AllUsagesCore(linksToConnect[i], next);
1361                 //results.IntersectWith(next);
1362                 results = next;
1363             }
1364             return results;
1365         }
1366     });
1367 }

```



```

1366 }
1367
1368 public List<ulong> GetAllConnections3(params ulong[] linksToConnect)
1369 {
1370     return Sync.ExecuteReadOperation(() =>
1371     {
1372         var results = new BitString((long)Links.Unsync.Count() + 1); // new
1373         ↪ BitArray((int)_links.Total + 1);
1374         if (linksToConnect.Length > 0)
1375         {
1376             Links.EnsureEachLinkExists(linksToConnect);
1377             var collector1 = new AllUsagesCollector2(Links.Unsync, results);
1378             collector1.Collect(linksToConnect[0]);
1379             for (var i = 1; i < linksToConnect.Length; i++)
1380             {
1381                 var next = new BitString((long)Links.Unsync.Count() + 1); //new
1382                 ↪ BitArray((int)_links.Total + 1);
1383                 var collector = new AllUsagesCollector2(Links.Unsync, next);
1384                 collector.Collect(linksToConnect[i]);
1385                 results = results.And(next);
1386             }
1387             return results.GetSetUInt64Indices();
1388         }
1389     });
1390 }
1391
1392 private static ulong[] Simplify(ulong[] sequence)
1393 {
1394     // Считаем новый размер последовательности
1395     long newLength = 0;
1396     var zeroOrManyStepped = false;
1397     for (var i = 0; i < sequence.Length; i++)
1398     {
1399         if (sequence[i] == ZeroOrMany)
1400         {
1401             if (zeroOrManyStepped)
1402             {
1403                 continue;
1404             }
1405             zeroOrManyStepped = true;
1406         }
1407         else
1408         {
1409             //if (zeroOrManyStepped) Is it efficient?
1410             zeroOrManyStepped = false;
1411             newLength++;
1412         }
1413     }
1414     // Строим новую последовательность
1415     zeroOrManyStepped = false;
1416     var newSequence = new ulong[newLength];
1417     long j = 0;
1418     for (var i = 0; i < sequence.Length; i++)
1419     {
1420         //var current = zeroOrManyStepped;
1421         //zeroOrManyStepped = patternSequence[i] == zeroOrMany;
1422         //if (current && zeroOrManyStepped)
1423         //    continue;
1424         //var newZeroOrManyStepped = patternSequence[i] == zeroOrMany;
1425         //if (zeroOrManyStepped && newZeroOrManyStepped)
1426         //    continue;
1427         //zeroOrManyStepped = newZeroOrManyStepped;
1428         if (sequence[i] == ZeroOrMany)
1429         {
1430             if (zeroOrManyStepped)
1431             {
1432                 continue;
1433             }
1434             zeroOrManyStepped = true;
1435         }
1436         else
1437         {
1438             //if (zeroOrManyStepped) Is it efficient?
1439             zeroOrManyStepped = false;
1440             newSequence[j++] = sequence[i];
1441         }
1442     }
1443     return newSequence;
1444 }

```

```

1443
1444 public static void TestSimplify()
1445 {
1446     var sequence = new ulong[] { ZeroOrMany, ZeroOrMany, 2, 3, 4, ZeroOrMany,
        ↪ ZeroOrMany, ZeroOrMany, 4, ZeroOrMany, ZeroOrMany, ZeroOrMany };
1447     var simplifiedSequence = Simplify(sequence);
1448 }
1449
1450 public List<ulong> GetSimilarSequences() => new List<ulong>();
1451
1452 public void Prediction()
1453 {
1454     //_links
1455     //_sequences
1456 }
1457
1458 #region From Triplets
1459
1460 //public static void DeleteSequence(Link sequence)
1461 //{
1462 //}
1463
1464 public List<ulong> CollectMatchingSequences(ulong[] links)
1465 {
1466     if (links.Length == 1)
1467     {
1468         throw new Exception("Подпоследовательности с одним элементом не
        ↪ поддерживаются.");
1469     }
1470     var leftBound = 0;
1471     var rightBound = links.Length - 1;
1472     var left = links[leftBound++];
1473     var right = links[rightBound--];
1474     var results = new List<ulong>();
1475     CollectMatchingSequences(left, leftBound, links, right, rightBound, ref results);
1476     return results;
1477 }
1478
1479 private void CollectMatchingSequences(ulong leftLink, int leftBound, ulong[]
        ↪ middleLinks, ulong rightLink, int rightBound, ref List<ulong> results)
1480 {
1481     var leftLinkTotalReferers = Links.Unsync.Count(leftLink);
1482     var rightLinkTotalReferers = Links.Unsync.Count(rightLink);
1483     if (leftLinkTotalReferers <= rightLinkTotalReferers)
1484     {
1485         var nextLeftLink = middleLinks[leftBound];
1486         var elements = GetRightElements(leftLink, nextLeftLink);
1487         if (leftBound <= rightBound)
1488         {
1489             for (var i = elements.Length - 1; i >= 0; i--)
1490             {
1491                 var element = elements[i];
1492                 if (element != 0)
1493                 {
1494                     CollectMatchingSequences(element, leftBound + 1, middleLinks,
        ↪ rightLink, rightBound, ref results);
1495                 }
1496             }
1497         }
1498         else
1499         {
1500             for (var i = elements.Length - 1; i >= 0; i--)
1501             {
1502                 var element = elements[i];
1503                 if (element != 0)
1504                 {
1505                     results.Add(element);
1506                 }
1507             }
1508         }
1509     }
1510     else
1511     {
1512         var nextRightLink = middleLinks[rightBound];
1513         var elements = GetLeftElements(rightLink, nextRightLink);
1514         if (leftBound <= rightBound)
1515         {
1516             for (var i = elements.Length - 1; i >= 0; i--)

```

```

1517         {
1518             var element = elements[i];
1519             if (element != 0)
1520             {
1521                 CollectMatchingSequences(leftLink, leftBound, middleLinks,
1522                                         ↪ elements[i], rightBound - 1, ref results);
1523             }
1524         }
1525     else
1526     {
1527         for (var i = elements.Length - 1; i >= 0; i--)
1528         {
1529             var element = elements[i];
1530             if (element != 0)
1531             {
1532                 results.Add(element);
1533             }
1534         }
1535     }
1536 }
1537
1538 public ulong[] GetRightElements(ulong startLink, ulong rightLink)
1539 {
1540     var result = new ulong[5];
1541     TryStepRight(startLink, rightLink, result, 0);
1542     Links.Each(_constants.Any, startLink, couple =>
1543     {
1544         if (couple != startLink)
1545         {
1546             if (TryStepRight(couple, rightLink, result, 2))
1547             {
1548                 return false;
1549             }
1550         }
1551         return true;
1552     });
1553     if (Links.GetTarget(Links.GetTarget(startLink)) == rightLink)
1554     {
1555         result[4] = startLink;
1556     }
1557     return result;
1558 }
1559
1560 public bool TryStepRight(ulong startLink, ulong rightLink, ulong[] result, int offset)
1561 {
1562     var added = 0;
1563     Links.Each(startLink, _constants.Any, couple =>
1564     {
1565         if (couple != startLink)
1566         {
1567             var coupleTarget = Links.GetTarget(couple);
1568             if (coupleTarget == rightLink)
1569             {
1570                 result[offset] = couple;
1571                 if (++added == 2)
1572                 {
1573                     return false;
1574                 }
1575             }
1576             else if (Links.GetSource(coupleTarget) == rightLink) // coupleTarget.Linker
1577                 ↪ == Net.And &&
1578             {
1579                 result[offset + 1] = couple;
1580                 if (++added == 2)
1581                 {
1582                     return false;
1583                 }
1584             }
1585         }
1586         return true;
1587     });
1588     return added > 0;
1589 }
1590
1591 public ulong[] GetLeftElements(ulong startLink, ulong leftLink)
1592 {

```

```

1593     var result = new ulong[5];
1594     TryStepLeft(startLink, leftLink, result, 0);
1595     Links.Each(startLink, _constants.Any, couple =>
1596     {
1597         if (couple != startLink)
1598         {
1599             if (TryStepLeft(couple, leftLink, result, 2))
1600             {
1601                 return false;
1602             }
1603         }
1604         return true;
1605     });
1606     if (Links.GetSource(Links.GetSource(leftLink)) == startLink)
1607     {
1608         result[4] = leftLink;
1609     }
1610     return result;
1611 }
1612
1613 public bool TryStepLeft(ulong startLink, ulong leftLink, ulong[] result, int offset)
1614 {
1615     var added = 0;
1616     Links.Each(_constants.Any, startLink, couple =>
1617     {
1618         if (couple != startLink)
1619         {
1620             var coupleSource = Links.GetSource(couple);
1621             if (coupleSource == leftLink)
1622             {
1623                 result[offset] = couple;
1624                 if (++added == 2)
1625                 {
1626                     return false;
1627                 }
1628             }
1629             else if (Links.GetTarget(coupleSource) == leftLink) // coupleSource.Linker
1630                 == Net.And &&
1631             {
1632                 result[offset + 1] = couple;
1633                 if (++added == 2)
1634                 {
1635                     return false;
1636                 }
1637             }
1638             return true;
1639         });
1640     return added > 0;
1641 }
1642
1643 #endregion
1644
1645 #region Walkers
1646
1647 public class PatternMatcher : RightSequenceWalker<ulong>
1648 {
1649     private readonly Sequences _sequences;
1650     private readonly ulong[] _patternSequence;
1651     private readonly HashSet<LinkIndex> _linksInSequence;
1652     private readonly HashSet<LinkIndex> _results;
1653
1654     #region Pattern Match
1655
1656     enum PatternBlockType
1657     {
1658         Undefined,
1659         Gap,
1660         Elements
1661     }
1662
1663     struct PatternBlock
1664     {
1665         public PatternBlockType Type;
1666         public long Start;
1667         public long Stop;
1668     }
1669
1670     private readonly List<PatternBlock> _pattern;
1671     private int _patternPosition;
1672     private long _sequencePosition;

```

```

1673 #endregion
1674
1675 public PatternMatcher(Sequences sequences, LinkIndex[] patternSequence,
1676 ↪ HashSet<LinkIndex> results)
1677     : base(sequences.Links.Unsync)
1678 {
1679     _sequences = sequences;
1680     _patternSequence = patternSequence;
1681     _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
1682 ↪ _constants.Any && x != ZeroOrMany));
1683     _results = results;
1684     _pattern = CreateDetailedPattern();
1685 }
1686
1687 protected override bool IsElement(IList<ulong> link) =>
1688 ↪ _linksInSequence.Contains(Links.GetIndex(link)) || base.IsElement(link);
1689
1690 public bool PatternMatch(LinkIndex sequenceToMatch)
1691 {
1692     _patternPosition = 0;
1693     _sequencePosition = 0;
1694     foreach (var part in Walk(sequenceToMatch))
1695     {
1696         if (!PatternMatchCore(Links.GetIndex(part)))
1697         {
1698             break;
1699         }
1700     }
1701     return _patternPosition == _pattern.Count || (_patternPosition == _pattern.Count
1702 ↪ - 1 && _pattern[_patternPosition].Start == 0);
1703 }
1704
1705 private List<PatternBlock> CreateDetailedPattern()
1706 {
1707     var pattern = new List<PatternBlock>();
1708     var patternBlock = new PatternBlock();
1709     for (var i = 0; i < _patternSequence.Length; i++)
1710     {
1711         if (patternBlock.Type == PatternBlockType.Undefined)
1712         {
1713             if (_patternSequence[i] == _constants.Any)
1714             {
1715                 patternBlock.Type = PatternBlockType.Gap;
1716                 patternBlock.Start = 1;
1717                 patternBlock.Stop = 1;
1718             }
1719             else if (_patternSequence[i] == ZeroOrMany)
1720             {
1721                 patternBlock.Type = PatternBlockType.Gap;
1722                 patternBlock.Start = 0;
1723                 patternBlock.Stop = long.MaxValue;
1724             }
1725             else
1726             {
1727                 patternBlock.Type = PatternBlockType.Elements;
1728                 patternBlock.Start = i;
1729                 patternBlock.Stop = i;
1730             }
1731         }
1732         else if (patternBlock.Type == PatternBlockType.Elements)
1733         {
1734             if (_patternSequence[i] == _constants.Any)
1735             {
1736                 pattern.Add(patternBlock);
1737                 patternBlock = new PatternBlock
1738                 {
1739                     Type = PatternBlockType.Gap,
1740                     Start = 1,
1741                     Stop = 1
1742                 };
1743             }
1744             else if (_patternSequence[i] == ZeroOrMany)
1745             {
1746                 pattern.Add(patternBlock);
1747                 patternBlock = new PatternBlock
1748                 {
1749                     Type = PatternBlockType.Gap,
1750                     Start = 0,
1751                     Stop = long.MaxValue

```

```

1749         };
1750     }
1751     else
1752     {
1753         patternBlock.Stop = i;
1754     }
1755 }
1756 else // patternBlock.Type == PatternBlockType.Gap
1757 {
1758     if (_patternSequence[i] == _constants.Any)
1759     {
1760         patternBlock.Start++;
1761         if (patternBlock.Stop < patternBlock.Start)
1762         {
1763             patternBlock.Stop = patternBlock.Start;
1764         }
1765     }
1766     else if (_patternSequence[i] == ZeroOrMany)
1767     {
1768         patternBlock.Stop = long.MaxValue;
1769     }
1770     else
1771     {
1772         pattern.Add(patternBlock);
1773         patternBlock = new PatternBlock
1774         {
1775             Type = PatternBlockType.Elements,
1776             Start = i,
1777             Stop = i
1778         };
1779     }
1780 }
1781 }
1782 if (patternBlock.Type != PatternBlockType.Undefined)
1783 {
1784     pattern.Add(patternBlock);
1785 }
1786 return pattern;
1787 }
1788
1789 /* match: search for regexp anywhere in text */
1790 int match(char* regexp, char* text)
1791 {
1792     do
1793     {
1794         } while (*text++ != '\0');
1795     return 0;
1796 }
1797
1798 /* matchhere: search for regexp at beginning of text */
1799 int matchhere(char* regexp, char* text)
1800 {
1801     if (regexp[0] == '\0')
1802         return 1;
1803     if (regexp[1] == '*')
1804         return matchstar(regexp[0], regexp + 2, text);
1805     if (regexp[0] == '$' && regexp[1] == '\0')
1806         return *text == '\0';
1807     if (*text != '\0' && (regexp[0] == '.' || regexp[0] == *text))
1808         return matchhere(regexp + 1, text + 1);
1809     return 0;
1810 }
1811
1812 /* matchstar: search for c*regexp at beginning of text */
1813 int matchstar(int c, char* regexp, char* text)
1814 {
1815     do
1816     {
1817         /* a * matches zero or more instances */
1818         if (matchhere(regexp, text))
1819             return 1;
1820     } while (*text != '\0' && (*text++ == c || c == '.'));
1821     return 0;
1822 }
1823
1824 //private void GetNextPatternElement(out LinkIndex element, out long mininumGap, out
1825 //    long maximumGap)
1826 {
1827     mininumGap = 0;
1828     maximumGap = 0;

```

```

1827 //     element = 0;
1828 //     for (; _patternPosition < _patternSequence.Length; _patternPosition++)
1829 //     {
1830 //         if (_patternSequence[_patternPosition] == Doublets.Links.Null)
1831 //             mininumGap++;
1832 //         else if (_patternSequence[_patternPosition] == ZeroOrMany)
1833 //             maximumGap = long.MaxValue;
1834 //         else
1835 //             break;
1836 //     }
1837
1838 //     if (maximumGap < mininumGap)
1839 //         maximumGap = mininumGap;
1840 // }
1841
1842 private bool PatternMatchCore(LinkIndex element)
1843 {
1844     if (_patternPosition >= _pattern.Count)
1845     {
1846         _patternPosition = -2;
1847         return false;
1848     }
1849     var currentPatternBlock = _pattern[_patternPosition];
1850     if (currentPatternBlock.Type == PatternBlockType.Gap)
1851     {
1852         //var currentMatchingBlockLength = (_sequencePosition -
1853         ↪ _lastMatchedBlockPosition);
1854         if (_sequencePosition < currentPatternBlock.Start)
1855         {
1856             _sequencePosition++;
1857             return true; // Двигаемся дальше
1858         }
1859         // Это последний блок
1860         if (_pattern.Count == _patternPosition + 1)
1861         {
1862             _patternPosition++;
1863             _sequencePosition = 0;
1864             return false; // Полное соответствие
1865         }
1866         else
1867         {
1868             if (_sequencePosition > currentPatternBlock.Stop)
1869             {
1870                 return false; // Соответствие невозможно
1871             }
1872             var nextPatternBlock = _pattern[_patternPosition + 1];
1873             if (_patternSequence[nextPatternBlock.Start] == element)
1874             {
1875                 if (nextPatternBlock.Start < nextPatternBlock.Stop)
1876                 {
1877                     _patternPosition++;
1878                     _sequencePosition = 1;
1879                 }
1880                 else
1881                 {
1882                     _patternPosition += 2;
1883                     _sequencePosition = 0;
1884                 }
1885             }
1886         }
1887     }
1888     else // currentPatternBlock.Type == PatternBlockType.Elements
1889     {
1890         var patternElementPosition = currentPatternBlock.Start + _sequencePosition;
1891         if (_patternSequence[patternElementPosition] != element)
1892         {
1893             return false; // Соответствие невозможно
1894         }
1895         if (patternElementPosition == currentPatternBlock.Stop)
1896         {
1897             _patternPosition++;
1898             _sequencePosition = 0;
1899         }
1900         else
1901         {
1902             _sequencePosition++;
1903         }
1904     }
1905     return true;

```

```

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

```

```

./Platform.Data.Doublets/Sequences/Sequences.Experiments.ReadSequence.cs
1  // #define USEARRAYPOOL
2  using System;
3  using System.Runtime.CompilerServices;
4  #if USEARRAYPOOL
5  using Platform.Collections;
6  #endif
7
8  namespace Platform.Data.Doublets.Sequences
9  {
10     partial class Sequences
11     {
12         public ulong[] ReadSequenceCore(ulong sequence, Func<ulong, bool> isElement)
13         {
14             var links = Links.Unsync;
15             var length = 1;
16             var array = new ulong[length];
17             array[0] = sequence;
18
19             if (isElement(sequence))
20             {
21                 return array;
22             }
23
24             bool hasElements;
25             do
26             {

```



```

27         length *= 2;
28     #if USEARRAYPOOL
29         var nextArray = ArrayPool.Allocate<ulong>(length);
30     #else
31         var nextArray = new ulong[length];
32     #endif
33     hasElements = false;
34     for (var i = 0; i < array.Length; i++)
35     {
36         var candidate = array[i];
37         if (candidate == 0)
38         {
39             continue;
40         }
41         var doubletOffset = i * 2;
42         if (isElement(candidate))
43         {
44             nextArray[doubletOffset] = candidate;
45         }
46         else
47         {
48             var link = links.GetLink(candidate);
49             var linkSource = links.GetSource(link);
50             var linkTarget = links.GetTarget(link);
51             nextArray[doubletOffset] = linkSource;
52             nextArray[doubletOffset + 1] = linkTarget;
53             if (!hasElements)
54             {
55                 hasElements = !(isElement(linkSource) && isElement(linkTarget));
56             }
57         }
58     }
59     #if USEARRAYPOOL
60     if (array.Length > 1)
61     {
62         ArrayPool.Free(array);
63     }
64     #endif
65     array = nextArray;
66 }
67 while (hasElements);
68 var filledElementsCount = CountFilledElements(array);
69 if (filledElementsCount == array.Length)
70 {
71     return array;
72 }
73 else
74 {
75     return CopyFilledElements(array, filledElementsCount);
76 }
77 }
78
79 [MethodImpl(MethodImplOptions.AggressiveInlining)]
80 private static ulong[] CopyFilledElements(ulong[] array, int filledElementsCount)
81 {
82     var finalArray = new ulong[filledElementsCount];
83     for (int i = 0, j = 0; i < array.Length; i++)
84     {
85         if (array[i] > 0)
86         {
87             finalArray[j] = array[i];
88             j++;
89         }
90     }
91     #if USEARRAYPOOL
92     ArrayPool.Free(array);
93     #endif
94     return finalArray;
95 }
96
97 [MethodImpl(MethodImplOptions.AggressiveInlining)]
98 private static int CountFilledElements(ulong[] array)
99 {
100     var count = 0;
101     for (var i = 0; i < array.Length; i++)
102     {
103         if (array[i] > 0)
104         {
105             count++;

```

```

106         }
107     }
108     return count;
109 }
110 }
111 }

```

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

```

1 using Platform.Data.Sequences;
2 using System.Collections.Generic;
3
4 namespace Platform.Data.Doublets.Sequences
5 {
6     public static class SequencesExtensions
7     {
8         public static TLink Create<TLink>(this ISequences<TLink> sequences, IList<TLink[]>
9             → groupedSequence)
10         {
11             var finalSequence = new TLink[groupedSequence.Count];
12             for (var i = 0; i < finalSequence.Length; i++)
13             {
14                 var part = groupedSequence[i];
15                 finalSequence[i] = part.Length == 1 ? part[0] : sequences.Create(part);
16             }
17             return sequences.Create(finalSequence);
18         }
19     }

```

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

```

1 using System.Collections.Generic;
2
3 namespace Platform.Data.Doublets.Sequences
4 {
5     public class SequencesIndexer<TLink>
6     {
7         private static readonly EqualityComparer<TLink> _equalityComparer =
8             → EqualityComparer<TLink>.Default;
9
10         private readonly ISynchronizedLinks<TLink> _links;
11         private readonly TLink _null;
12
13         public SequencesIndexer(ISynchronizedLinks<TLink> links)
14         {
15             _links = links;
16             _null = _links.Constants.Null;
17         }
18
19         /// <summary>
20         /// Индексирует последовательность глобально, и возвращает значение,
21         /// определяющие была ли запрошенная последовательность проиндексирована ранее.
22         /// </summary>
23         /// <param name="sequence">Последовательность для индексации.</param>
24         /// <returns>
25         /// True если последовательность уже была проиндексирована ранее и
26         /// False если последовательность была проиндексирована только что.
27         /// </returns>
28         public bool Index(TLink[] sequence)
29         {
30             var indexed = true;
31             var i = sequence.Length;
32             while (--i >= 1 && (indexed =
33                 → !_equalityComparer.Equals(_links.SearchOrDefault(sequence[i - 1], sequence[i]),
34                 → _null))) { }
35             for (; i >= 1; i--)
36             {
37                 _links.GetOrCreate(sequence[i - 1], sequence[i]);
38             }
39             return indexed;
40         }
41
42         public bool BulkIndex(TLink[] sequence)
43         {
44             var indexed = true;
45             var i = sequence.Length;
46             var links = _links.Unsync;
47             links.SyncRoot.ExecuteReadOperation(() =>

```

```

46         while (--i >= 1 && (indexed =
           ↳ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
           ↳ sequence[i]), _null))) { }
47     });
48     if (indexed == false)
49     {
50         _links.SyncRoot.ExecuteWriteOperation(() =>
51         {
52             for (; i >= 1; i--)
53             {
54                 links.GetOrCreate(sequence[i - 1], sequence[i]);
55             }
56         });
57     }
58     return indexed;
59 }
60
61 public bool BulkIndexUnsync(TLink[] sequence)
62 {
63     var indexed = true;
64     var i = sequence.Length;
65     var links = _links.Unsync;
66     while (--i >= 1 && (indexed =
           ↳ !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1], sequence[i]),
           ↳ _null))) { }
67     for (; i >= 1; i--)
68     {
69         links.GetOrCreate(sequence[i - 1], sequence[i]);
70     }
71     return indexed;
72 }
73
74 public bool CheckIndex(IList<TLink> sequence)
75 {
76     var indexed = true;
77     var i = sequence.Count;
78     while (--i >= 1 && (indexed =
           ↳ !_equalityComparer.Equals(_links.SearchOrDefault(sequence[i - 1], sequence[i]),
           ↳ _null))) { }
79     return indexed;
80 }
81 }
82 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Interfaces;
4  using Platform.Data.Doublets.Sequences.Frequencies.Cache;
5  using Platform.Data.Doublets.Sequences.Frequencies.Counters;
6  using Platform.Data.Doublets.Sequences.Converters;
7  using Platform.Data.Doublets.Sequences.CreteriaMatchers;
8
9  namespace Platform.Data.Doublets.Sequences
10 {
11     public class SequencesOptions<TLink> // TODO: To use type parameter <TLink> the
           ↳ ILinks<TLink> must contain GetConstants function.
12     {
13         private static readonly EqualityComparer<TLink> _equalityComparer =
           ↳ EqualityComparer<TLink>.Default;
14
15         public TLink SequenceMarkerLink { get; set; }
16         public bool UseCascadeUpdate { get; set; }
17         public bool UseCascadeDelete { get; set; }
18         public bool UseIndex { get; set; } // TODO: Update Index on sequence update/delete.
19         public bool UseSequenceMarker { get; set; }
20         public bool UseCompression { get; set; }
21         public bool UseGarbageCollection { get; set; }
22         public bool EnforceSingleSequenceVersionOnWriteBasedOnExisting { get; set; }
23         public bool EnforceSingleSequenceVersionOnWriteBasedOnNew { get; set; }
24
25         public MarkedSequenceCreteriaMatcher<TLink> MarkedSequenceMatcher { get; set; }
26         public IConverter<IList<TLink>, TLink> LinksToSequenceConverter { get; set; }
27         public SequencesIndexer<TLink> Indexer { get; set; }
28
29         // TODO: Реализовать компактификацию при чтении
30         //public bool EnforceSingleSequenceVersionOnRead { get; set; }
31         //public bool UseRequestMarker { get; set; }
32         //public bool StoreRequestResults { get; set; }

```

```

33
34 public void InitOptions(ISynchronizedLinks<TLink> links)
35 {
36     if (UseSequenceMarker)
37     {
38         if (_equalityComparer.Equals(SequenceMarkerLink, links.Constants.Null))
39         {
40             SequenceMarkerLink = links.CreatePoint();
41         }
42         else
43         {
44             if (!links.Exists(SequenceMarkerLink))
45             {
46                 var link = links.CreatePoint();
47                 if (!_equalityComparer.Equals(link, SequenceMarkerLink))
48                 {
49                     throw new InvalidOperationException("Cannot recreate sequence marker
50                                     ↪ link.");
51                 }
52             }
53             if (MarkedSequenceMatcher == null)
54             {
55                 MarkedSequenceMatcher = new MarkedSequenceCriteriaMatcher<TLink>(links,
56                                     ↪ SequenceMarkerLink);
57             }
58             var balancedVariantConverter = new BalancedVariantConverter<TLink>(links);
59             if (UseCompression)
60             {
61                 if (LinksToSequenceConverter == null)
62                 {
63                     ICounter<TLink, TLink> totalSequenceSymbolFrequencyCounter;
64                     if (UseSequenceMarker)
65                     {
66                         totalSequenceSymbolFrequencyCounter = new
67                             ↪ TotalMarkedSequenceSymbolFrequencyCounter<TLink>(links,
68                             ↪ MarkedSequenceMatcher);
69                     }
70                     else
71                     {
72                         totalSequenceSymbolFrequencyCounter = new
73                             ↪ TotalSequenceSymbolFrequencyCounter<TLink>(links);
74                     }
75                     var doubletFrequenciesCache = new LinkFrequenciesCache<TLink>(links,
76                                     ↪ totalSequenceSymbolFrequencyCounter);
77                     var compressingConverter = new CompressingConverter<TLink>(links,
78                                     ↪ balancedVariantConverter, doubletFrequenciesCache);
79                     LinksToSequenceConverter = compressingConverter;
80                 }
81             }
82             else
83             {
84                 if (LinksToSequenceConverter == null)
85                 {
86                     LinksToSequenceConverter = balancedVariantConverter;
87                 }
88             }
89             if (UseIndex && Indexer == null)
90             {
91                 Indexer = new SequencesIndexer<TLink>(links);
92             }
93         }
94     }
95 }
96
97 public void ValidateOptions()
98 {
99     if (UseGarbageCollection && !UseSequenceMarker)
100     {
101         throw new NotSupportedException("To use garbage collection UseSequenceMarker
102                                     ↪ option must be on.");
103     }
104 }
105 }

```

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

```

```

81     var sb = new StringBuilder();
82     if (links.Exists(link))
83     {
84         StopableSequenceWalker.WalkRight(link, links.GetSource, links.GetTarget,
85             x => x <= MapSize || links.GetSource(x) == x || links.GetTarget(x) == x,
86             element =>
87             {
88                 sb.Append(FromLinkToChar(element));
89                 return true;
90             }
91     }
92     return sb.ToString();
93 }
94 public static ulong[] FromCharsToLinkArray(char[] chars) => FromCharsToLinkArray(chars,
95     ↪ chars.Length);
96 public static ulong[] FromCharsToLinkArray(char[] chars, int count)
97 {
98     // char array to ulong array
99     var linksSequence = new ulong[count];
100     for (var i = 0; i < count; i++)
101     {
102         linksSequence[i] = FromCharToLink(chars[i]);
103     }
104     return linksSequence;
105 }
106 public static ulong[] FromStringToLinkArray(string sequence)
107 {
108     // char array to ulong array
109     var linksSequence = new ulong[sequence.Length];
110     for (var i = 0; i < sequence.Length; i++)
111     {
112         linksSequence[i] = FromCharToLink(sequence[i]);
113     }
114     return linksSequence;
115 }
116 }
117 public static List<ulong[]> FromStringToLinkArrayGroups(string sequence)
118 {
119     var result = new List<ulong[]>();
120     var offset = 0;
121     while (offset < sequence.Length)
122     {
123         var currentCategory = CharUnicodeInfo.GetUnicodeCategory(sequence[offset]);
124         var relativeLength = 1;
125         var absoluteLength = offset + relativeLength;
126         while (absoluteLength < sequence.Length &&
127             currentCategory ==
128             ↪ CharUnicodeInfo.GetUnicodeCategory(sequence[absoluteLength]))
129         {
130             relativeLength++;
131             absoluteLength++;
132         }
133         // char array to ulong array
134         var innerSequence = new ulong[relativeLength];
135         var maxLength = offset + relativeLength;
136         for (var i = offset; i < maxLength; i++)
137         {
138             innerSequence[i - offset] = FromCharToLink(sequence[i]);
139         }
140         result.Add(innerSequence);
141         offset += relativeLength;
142     }
143     return result;
144 }
145 public static List<ulong[]> FromLinkArrayToLinkArrayGroups(ulong[] array)
146 {
147     var result = new List<ulong[]>();
148     var offset = 0;
149     while (offset < array.Length)
150     {
151         var relativeLength = 1;
152         if (array[offset] <= LastCharLink)
153         {
154             var currentCategory =
155                 ↪ CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(array[offset]));

```

```

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

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3
4 namespace Platform.Data.Doublets.Sequences.Walkers
5 {
6     public class LeftSequenceWalker<TLink> : SequenceWalkerBase<TLink>
7     {
8         public LeftSequenceWalker(ILinks<TLink> links) : base(links) { }
9
10        [MethodImpl(MethodImplOptions.AggressiveInlining)]
11        protected override IList<TLink> GetNextElementAfterPop(IList<TLink> element) =>
12            ↪ Links.GetLink(Links.GetSource(element));
13
14        [MethodImpl(MethodImplOptions.AggressiveInlining)]
15        protected override IList<TLink> GetNextElementAfterPush(IList<TLink> element) =>
16            ↪ Links.GetLink(Links.GetTarget(element));
17
18        [MethodImpl(MethodImplOptions.AggressiveInlining)]
19        protected override IEnumerable<IList<TLink>> WalkContents(IList<TLink> element)
20        {
21            var start = Links.Constants.IndexPart + 1;
22            for (var i = element.Count - 1; i >= start; i--)
23            {
24                var partLink = Links.GetLink(element[i]);
25                if (IsElement(partLink))
26                {
27                    yield return partLink;
28                }
29            }
30        }
31    }
32 }

```

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

```

1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3
4 namespace Platform.Data.Doublets.Sequences.Walkers
5 {
6     public class RightSequenceWalker<TLink> : SequenceWalkerBase<TLink>
7     {
8         public RightSequenceWalker(ILinks<TLink> links) : base(links) { }
9
10        [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

11     protected override IList<TLink> GetNextElementAfterPop(IList<TLink> element) =>
12         ↪ Links.GetLink(Links.GetTarget(element));
13
14     [MethodImpl(MethodImplOptions.AggressiveInlining)]
15     protected override IList<TLink> GetNextElementAfterPush(IList<TLink> element) =>
16         ↪ Links.GetLink(Links.GetSource(element));
17
18     [MethodImpl(MethodImplOptions.AggressiveInlining)]
19     protected override IEnumerable<IList<TLink>> WalkContents(IList<TLink> element)
20     {
21         for (var i = Links.Constants.IndexPart + 1; i < element.Count; i++)
22         {
23             var partLink = Links.GetLink(element[i]);
24             if (IsElement(partLink))
25             {
26                 yield return partLink;
27             }
28         }
29     }

```

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

```

1  using System.Collections.Generic;
2  using System.Runtime.CompilerServices;
3  using Platform.Data.Sequences;
4
5  namespace Platform.Data.Doublets.Sequences.Walkers
6  {
7      public abstract class SequenceWalkerBase<TLink> : LinksOperatorBase<TLink>,
8          ↪ ISequenceWalker<TLink>
9      {
10         // TODO: Use IStack instead of System.Collections.Generic.Stack, but IStack should
11         ↪ contain IsEmpty property
12         private readonly Stack<IList<TLink>> _stack;
13
14         protected SequenceWalkerBase(ILinks<TLink> links) : base(links) => _stack = new
15             ↪ Stack<IList<TLink>>();
16
17         public IEnumerable<IList<TLink>> Walk(TLink sequence)
18         {
19             if (_stack.Count > 0)
20             {
21                 _stack.Clear(); // This can be replaced with while(!_stack.IsEmpty) _stack.Pop()
22             }
23             var element = Links.GetLink(sequence);
24             if (IsElement(element))
25             {
26                 yield return element;
27             }
28             else
29             {
30                 while (true)
31                 {
32                     if (IsElement(element))
33                     {
34                         if (_stack.Count == 0)
35                         {
36                             break;
37                         }
38                         element = _stack.Pop();
39                         foreach (var output in WalkContents(element))
40                         {
41                             yield return output;
42                         }
43                         element = GetNextElementAfterPop(element);
44                     }
45                     else
46                     {
47                         _stack.Push(element);
48                         element = GetNextElementAfterPush(element);
49                     }
50                 }
51             }
52         }
53
54         [MethodImpl(MethodImplOptions.AggressiveInlining)]
55         protected virtual bool IsElement(IList<TLink> elementLink) =>
56             ↪ Point<TLink>.IsPartialPointUnchecked(elementLink);

```



```

53     [MethodImpl(MethodImplOptions.AggressiveInlining)]
54     protected abstract IList<TLink> GetNextElementAfterPop(IList<TLink> element);
55
56     [MethodImpl(MethodImplOptions.AggressiveInlining)]
57     protected abstract IList<TLink> GetNextElementAfterPush(IList<TLink> element);
58
59     [MethodImpl(MethodImplOptions.AggressiveInlining)]
60     protected abstract IEnumerable<IList<TLink>> WalkContents(IList<TLink> element);
61 }
62
63 }

```

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

```

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

```

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

```

1  namespace Platform.Data.Doublets.Stacks
2  {
3      public static class StackExtensions
4      {
5          public static TLink CreateStack<TLink>(this ILinks<TLink> links, TLink stackMarker)
6          {
7              var stackPoint = links.CreatePoint();
8              var stack = links.Update(stackPoint, stackMarker, stackPoint);
9              return stack;
10          }
11      }
12  }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Platform.Data.Constants;
4  using Platform.Data.Doublets;
5  using Platform.Threading.Synchronization;
6

```

```

7 namespace Platform.Data.Doublets
8 {
9     /// <remarks>
10    /// TODO: Autogeneration of synchronized wrapper (decorator).
11    /// TODO: Try to unfold code of each method using IL generation for performance improvements.
12    /// TODO: Or even to unfold multiple layers of implementations.
13    /// </remarks>
14    public class SynchronizedLinks<T> : ISynchronizedLinks<T>
15    {
16        public LinksCombinedConstants<T, T, int> Constants { get; }
17        public ISynchronization SyncRoot { get; }
18        public ILinks<T> Sync { get; }
19        public ILinks<T> Unsync { get; }
20
21        public SynchronizedLinks(ILinks<T> links) : this(new ReaderWriterLockSynchronization(),
22            ↪ links) { }
23
24        public SynchronizedLinks(ISynchronization synchronization, ILinks<T> links)
25        {
26            SyncRoot = synchronization;
27            Sync = this;
28            Unsync = links;
29            Constants = links.Constants;
30        }
31
32        public T Count(IList<T> restriction) => SyncRoot.ExecuteReadOperation(restriction,
33            ↪ Unsync.Count);
34        public T Each(Func<IList<T>, T> handler, IList<T> restrictions) =>
35            ↪ SyncRoot.ExecuteReadOperation(handler, restrictions, (handler1, restrictions1) =>
36            ↪ Unsync.Each(handler1, restrictions1));
37        public T Create() => SyncRoot.ExecuteWriteOperation(Unsync.Create);
38        public T Update(IList<T> restrictions) => SyncRoot.ExecuteWriteOperation(restrictions,
39            ↪ Unsync.Update);
40        public void Delete(T link) => SyncRoot.ExecuteWriteOperation(link, Unsync.Delete);
41
42        //public T Trigger(IList<T> restriction, Func<IList<T>, IList<T>, T> matchedHandler,
43        //    ↪ IList<T> substitution, Func<IList<T>, IList<T>, T> substitutedHandler)
44        //{
45        //    if (restriction != null && substitution != null &&
46        //        ↪ !substitution.EqualTo(restriction))
47        //        return SyncRoot.ExecuteWriteOperation(restriction, matchedHandler,
48        //            ↪ substitution, substitutedHandler, Unsync.Trigger);
49        //    return SyncRoot.ExecuteReadOperation(restriction, matchedHandler, substitution,
50        //        ↪ substitutedHandler, Unsync.Trigger);
51        //}
52    }
53 }

```

./Platform.Data.Doublets/UInt64Link.cs

```

1 using System;
2 using System.Collections;
3 using System.Collections.Generic;
4 using Platform.Exceptions;
5 using Platform.Ranges;
6 using Platform.Singletons;
7 using Platform.Collections.Lists;
8 using Platform.Data.Constants;
9
10 namespace Platform.Data.Doublets
11 {
12     /// <summary>
13     /// Структура описывающая уникальную связь.
14     /// </summary>
15     public struct UInt64Link : IEquatable<UInt64Link>, IReadOnlyList<ulong>, IList<ulong>
16     {
17         private static readonly LinksCombinedConstants<bool, ulong, int> _constants =
18             ↪ Default<LinksCombinedConstants<bool, ulong, int>>.Instance;
19
20         private const int Length = 3;
21
22         public readonly ulong Index;
23         public readonly ulong Source;
24         public readonly ulong Target;
25
26         public static readonly UInt64Link Null = new UInt64Link();
27
28         public UInt64Link(params ulong[] values)
29         {

```

```

29         Index = values.Length > _constants.IndexPart ? values[_constants.IndexPart] :
        ↪ _constants.Null;
30         Source = values.Length > _constants.SourcePart ? values[_constants.SourcePart] :
        ↪ _constants.Null;
31         Target = values.Length > _constants.TargetPart ? values[_constants.TargetPart] :
        ↪ _constants.Null;
32     }
33
34     public UInt64Link(IList<ulong> values)
35     {
36         Index = values.Count > _constants.IndexPart ? values[_constants.IndexPart] :
        ↪ _constants.Null;
37         Source = values.Count > _constants.SourcePart ? values[_constants.SourcePart] :
        ↪ _constants.Null;
38         Target = values.Count > _constants.TargetPart ? values[_constants.TargetPart] :
        ↪ _constants.Null;
39     }
40
41     public UInt64Link(ulong index, ulong source, ulong target)
42     {
43         Index = index;
44         Source = source;
45         Target = target;
46     }
47
48     public UInt64Link(ulong source, ulong target)
49         : this(_constants.Null, source, target)
50     {
51         Source = source;
52         Target = target;
53     }
54
55     public static UInt64Link Create(ulong source, ulong target) => new UInt64Link(source,
        ↪ target);
56
57     public override int GetHashCode() => (Index, Source, Target).GetHashCode();
58
59     public bool IsNull() => Index == _constants.Null
60         && Source == _constants.Null
61         && Target == _constants.Null;
62
63     public override bool Equals(object other) => other is UInt64Link &&
        ↪ Equals((UInt64Link)other);
64
65     public bool Equals(UInt64Link other) => Index == other.Index
66         && Source == other.Source
67         && Target == other.Target;
68
69     public static string ToString(ulong index, ulong source, ulong target) => $"{({index}:
        ↪ {source}->{target})}";
70
71     public static string ToString(ulong source, ulong target) => $"{({source}->{target})}";
72
73     public static implicit operator ulong[] (UInt64Link link) => link.ToArray();
74
75     public static implicit operator UInt64Link(ulong[] linkArray) => new
        ↪ UInt64Link(linkArray);
76
77     public override string ToString() => Index == _constants.Null ? ToString(Source, Target)
        ↪ : ToString(Index, Source, Target);
78
79     #region IList
80
81     public ulong this[int index]
82     {
83         get
84         {
85             Ensure.Always.ArgumentInRange(index, new Range<int>(0, Length - 1),
            ↪ nameof(index));
86             if (index == _constants.IndexPart)
87             {
88                 return Index;
89             }
90             if (index == _constants.SourcePart)
91             {
92                 return Source;
93             }
94             if (index == _constants.TargetPart)
95             {

```

```

96         return Target;
97     }
98     throw new NotSupportedException(); // Impossible path due to
    ↪ Ensure.ArgumentInRange
99 }
100 set => throw new NotSupportedException();
101 }
102
103 public int Count => Length;
104
105 public bool IsReadOnly => true;
106
107 IEnumerator IEnumerable.GetEnumerator() => GetEnumerator();
108
109 public IEnumerator<ulong> GetEnumerator()
110 {
111     yield return Index;
112     yield return Source;
113     yield return Target;
114 }
115
116 public void Add(ulong item) => throw new NotSupportedException();
117
118 public void Clear() => throw new NotSupportedException();
119
120 public bool Contains(ulong item) => IndexOf(item) >= 0;
121
122 public void CopyTo(ulong[] array, int arrayIndex)
123 {
124     Ensure.Always.ArgumentNotNull(array, nameof(array));
125     Ensure.Always.ArgumentInRange(arrayIndex, new Range<int>(0, array.Length - 1),
    ↪ nameof(arrayIndex));
126     if (arrayIndex + Length > array.Length)
127     {
128         throw new ArgumentException();
129     }
130     array[arrayIndex++] = Index;
131     array[arrayIndex++] = Source;
132     array[arrayIndex] = Target;
133 }
134
135 public bool Remove(ulong item) => Throw.A.NotSupportedExceptionAndReturn<bool>();
136
137 public int IndexOf(ulong item)
138 {
139     if (Index == item)
140     {
141         return _constants.IndexPart;
142     }
143     if (Source == item)
144     {
145         return _constants.SourcePart;
146     }
147     if (Target == item)
148     {
149         return _constants.TargetPart;
150     }
151
152     return -1;
153 }
154
155 public void Insert(int index, ulong item) => throw new NotSupportedException();
156
157 public void RemoveAt(int index) => throw new NotSupportedException();
158
159 #endregion
160 }
161 }

```

./Platform.Data.Doublets/UInt64LinkExtensions.cs

```

1 namespace Platform.Data.Doublets
2 {
3     public static class UInt64LinkExtensions
4     {
5         public static bool IsFullPoint(this UInt64Link link) => Point<ulong>.IsFullPoint(link);
6         public static bool IsPartialPoint(this UInt64Link link) =>
    ↪ Point<ulong>.IsPartialPoint(link);
7     }
8 }

```

./Platform.Data.Doublets/UInt64LinksExtensions.cs

```
1  using System;
2  using System.Text;
3  using System.Collections.Generic;
4  using Platform.Singletons;
5  using Platform.Data.Constants;
6  using Platform.Data.Exceptions;
7  using Platform.Data.Doublets.Sequences;
8
9  namespace Platform.Data.Doublets
10 {
11     public static class UInt64LinksExtensions
12     {
13         public static readonly LinksCombinedConstants<bool, ulong, int> Constants =
14             ↪ Default<LinksCombinedConstants<bool, ulong, int>>.Instance;
15
16         public static void UseUnicode(this ILinks<ulong> links) => UnicodeMap.InitNew(links);
17
18         public static void EnsureEachLinkExists(this ILinks<ulong> links, IList<ulong> sequence)
19         {
20             if (sequence == null)
21             {
22                 return;
23             }
24             for (var i = 0; i < sequence.Count; i++)
25             {
26                 if (!links.Exists(sequence[i]))
27                 {
28                     throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
29                         ↪ $"sequence[{i}]");
30                 }
31             }
32         }
33
34         public static void EnsureEachLinkIsAnyOrExists(this ILinks<ulong> links, IList<ulong>
35             ↪ sequence)
36         {
37             if (sequence == null)
38             {
39                 return;
40             }
41             for (var i = 0; i < sequence.Count; i++)
42             {
43                 if (sequence[i] != Constants.Any && !links.Exists(sequence[i]))
44                 {
45                     throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
46                         ↪ $"sequence[{i}]");
47                 }
48             }
49         }
50
51         public static bool AnyLinkIsAny(this ILinks<ulong> links, params ulong[] sequence)
52         {
53             if (sequence == null)
54             {
55                 return false;
56             }
57             var constants = links.Constants;
58             for (var i = 0; i < sequence.Length; i++)
59             {
60                 if (sequence[i] == constants.Any)
61                 {
62                     return true;
63                 }
64             }
65             return false;
66         }
67
68         public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
69             ↪ Func<UInt64Link, bool> isElement, bool renderIndex = false, bool renderDebug = false)
70         {
71             var sb = new StringBuilder();
72             var visited = new HashSet<ulong>();
73             links.AppendStructure(sb, visited, linkIndex, isElement, (innerSb, link) =>
74                 ↪ innerSb.Append(link.Index), renderIndex, renderDebug);
75             return sb.ToString();
76         }
77     }
78 }
```

```

72 public static string FormatStructure(this ILinks<ulong> links, ulong linkIndex,
    ↳ Func<UInt64Link, bool> isElement, Action<StringBuilder, UInt64Link> appendElement,
    ↳ bool renderIndex = false, bool renderDebug = false)
73 {
74     var sb = new StringBuilder();
75     var visited = new HashSet<ulong>();
76     links.AppendStructure(sb, visited, linkIndex, isElement, appendElement, renderIndex,
    ↳ renderDebug);
77     return sb.ToString();
78 }
79
80 public static void AppendStructure(this ILinks<ulong> links, StringBuilder sb,
    ↳ HashSet<ulong> visited, ulong linkIndex, Func<UInt64Link, bool> isElement,
    ↳ Action<StringBuilder, UInt64Link> appendElement, bool renderIndex = false, bool
    ↳ renderDebug = false)
81 {
82     if (sb == null)
83     {
84         throw new ArgumentNullException(nameof(sb));
85     }
86     if (linkIndex == Constants.Null || linkIndex == Constants.Any || linkIndex ==
    ↳ Constants.Itself)
87     {
88         return;
89     }
90     if (links.Exists(linkIndex))
91     {
92         if (visited.Add(linkIndex))
93         {
94             sb.Append('(');
95             var link = new UInt64Link(links.GetLink(linkIndex));
96             if (renderIndex)
97             {
98                 sb.Append(link.Index);
99                 sb.Append(':');
100             }
101             if (link.Source == link.Index)
102             {
103                 sb.Append(link.Index);
104             }
105             else
106             {
107                 var source = new UInt64Link(links.GetLink(link.Source));
108                 if (isElement(source))
109                 {
110                     appendElement(sb, source);
111                 }
112                 else
113                 {
114                     links.AppendStructure(sb, visited, source.Index, isElement,
    ↳ appendElement, renderIndex);
115                 }
116             }
117             sb.Append(' ');
118             if (link.Target == link.Index)
119             {
120                 sb.Append(link.Index);
121             }
122             else
123             {
124                 var target = new UInt64Link(links.GetLink(link.Target));
125                 if (isElement(target))
126                 {
127                     appendElement(sb, target);
128                 }
129                 else
130                 {
131                     links.AppendStructure(sb, visited, target.Index, isElement,
    ↳ appendElement, renderIndex);
132                 }
133             }
134             sb.Append(')');
135         }
136         else
137         {
138             if (renderDebug)
139             {
140                 sb.Append('*');

```

```

141         }
142         sb.Append(linkIndex);
143     }
144 }
145 else
146 {
147     if (renderDebug)
148     {
149         sb.Append('~');
150     }
151     sb.Append(linkIndex);
152 }
153 }
154 }
155 }

```

./Platform.Data.Doublets/UInt64LinksTransactionsLayer.cs

```

1  using System;
2  using System.Linq;
3  using System.Collections.Generic;
4  using System.IO;
5  using System.Runtime.CompilerServices;
6  using System.Threading;
7  using System.Threading.Tasks;
8  using Platform.Disposables;
9  using Platform.Timestamps;
10 using Platform.Unsafe;
11 using Platform.IO;
12 using Platform.Data.Doublets.Decorators;
13
14 namespace Platform.Data.Doublets
15 {
16     public class UInt64LinksTransactionsLayer : LinksDisposableDecoratorBase<ulong> //-V3073
17     {
18         /// <remarks>
19         /// Альтернативные варианты хранения трансформации (элемента транзакции):
20         ///
21         /// private enum TransitionType
22         /// {
23         ///     Creation,
24         ///     UpdateOf,
25         ///     UpdateTo,
26         ///     Deletion
27         /// }
28         ///
29         /// private struct Transition
30         /// {
31         ///     public ulong TransactionId;
32         ///     public UniqueTimestamp Timestamp;
33         ///     public TransactionItemType Type;
34         ///     public Link Source;
35         ///     public Link Linker;
36         ///     public Link Target;
37         /// }
38         ///
39         /// Или
40         ///
41         /// public struct TransitionHeader
42         /// {
43         ///     public ulong TransactionIdCombined;
44         ///     public ulong TimestampCombined;
45         ///
46         ///     public ulong TransactionId
47         ///     {
48         ///         get
49         ///         {
50             return (ulong) mask & TransactionIdCombined;
51         }
52         }
53         ///
54         ///     public UniqueTimestamp Timestamp
55         ///     {
56         ///         get
57         ///         {
58             return (UniqueTimestamp)mask & TransactionIdCombined;
59         }
60         }
61         ///
62         ///     public TransactionItemType Type

```

```

63     /// {
64     ///     get
65     ///     {
66     ///         // Использовать по одному биту из TransactionId и Timestamp,
67     ///         // для значения в 2 бита, которое представляет тип операции
68     ///         throw new NotImplementedException();
69     ///     }
70     /// }
71 }
72
73 /// private struct Transition
74 /// {
75 ///     public TransitionHeader Header;
76 ///     public Link Source;
77 ///     public Link Linker;
78 ///     public Link Target;
79 /// }
80
81 /// </remarks>
82 public struct Transition
83 {
84     public static readonly long Size = Structure<Transition>.Size;
85
86     public readonly ulong TransactionId;
87     public readonly UInt64Link Before;
88     public readonly UInt64Link After;
89     public readonly Timestamp Timestamp;
90
91     public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
92     ↪ transactionId, UInt64Link before, UInt64Link after)
93     {
94         TransactionId = transactionId;
95         Before = before;
96         After = after;
97         Timestamp = uniqueTimestampFactory.Create();
98     }
99
100     public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong
101     ↪ transactionId, UInt64Link before)
102     : this(uniqueTimestampFactory, transactionId, before, default)
103     {
104     }
105
106     public Transition(UniqueTimestampFactory uniqueTimestampFactory, ulong transactionId
107     : this(uniqueTimestampFactory, transactionId, default, default)
108     {
109     }
110
111     public override string ToString() => $"{Timestamp} {TransactionId}: {Before} =>
112     ↪ {After}";
113 }
114
115 /// <remarks>
116 /// Другие варианты реализации транзакций (атомарности):
117 /// 1. Разделение хранения значения связи ((Source Target) или (Source Linker
118 ↪ Target)) и индексов.
119 /// 2. Хранение трансформаций/операций в отдельном хранилище Links, но дополнительно
120 ↪ потребуется решить вопрос
121 /// со ссылками на внешние идентификаторы, или как-то иначе решить вопрос с
122 ↪ пересечениями идентификаторов.
123 ///
124 /// Где хранить промежуточный список транзакций?
125 ///
126 /// В оперативной памяти:
127 /// Минусы:
128 /// 1. Может усложнить систему, если она будет функционировать самостоятельно,
129 /// так как нужно отдельно выделять память под список трансформаций.
130 /// 2. Выделенной оперативной памяти может не хватить, в том случае,
131 /// если транзакция использует слишком много трансформаций.
132 /// -> Можно использовать жёсткий диск для слишком длинных транзакций.
133 /// -> Максимальный размер списка трансформаций можно ограничить / задать
134 ↪ константой.
135 /// 3. При подтверждении транзакции (Commit) все трансформации записываются разом
136 ↪ создавая задержку.
137 ///
138 /// На жёстком диске:
139 /// Минусы:
140 /// 1. Длительный отклик, на запись каждой трансформации.

```



```

133  ///      2. Лог транзакций дополнительно наполняется отменёнными транзакциями.
134  ///      -> Это может решаться упаковкой/исключением дублирующих операций.
135  ///      -> Также это может решаться тем, что короткие транзакции вообще
136  ///      не будут записываться в случае отката.
137  ///      3. Перед тем как выполнять отмену операций транзакции нужно дождаться пока все
    ↪ операции (трансформации)
138  ///      будут записаны в лог.
139  ///
140  /// </remarks>
141  public class Transaction : DisposableBase
142  {
143      private readonly Queue<Transition> _transitions;
144      private readonly UInt64LinksTransactionsLayer _layer;
145      public bool IsCommitted { get; private set; }
146      public bool IsReverted { get; private set; }
147
148      public Transaction(UInt64LinksTransactionsLayer layer)
149      {
150          _layer = layer;
151          if (_layer._currentTransactionId != 0)
152          {
153              throw new NotSupportedException("Nested transactions not supported.");
154          }
155          IsCommitted = false;
156          IsReverted = false;
157          _transitions = new Queue<Transition>();
158          SetCurrentTransaction(layer, this);
159      }
160
161      public void Commit()
162      {
163          EnsureTransactionAllowsWriteOperations(this);
164          while (_transitions.Count > 0)
165          {
166              var transition = _transitions.Dequeue();
167              _layer._transitions.Enqueue(transition);
168          }
169          _layer._lastCommittedTransactionId = _layer._currentTransactionId;
170          IsCommitted = true;
171      }
172
173      private void Revert()
174      {
175          EnsureTransactionAllowsWriteOperations(this);
176          var transitionsToRevert = new Transition[_transitions.Count];
177          _transitions.CopyTo(transitionsToRevert, 0);
178          for (var i = transitionsToRevert.Length - 1; i >= 0; i--)
179          {
180              _layer.RevertTransition(transitionsToRevert[i]);
181          }
182          IsReverted = true;
183      }
184
185      public static void SetCurrentTransaction(UInt64LinksTransactionsLayer layer,
    ↪ Transaction transaction)
186      {
187          layer._currentTransactionId = layer._lastCommittedTransactionId + 1;
188          layer._currentTransactionTransitions = transaction._transitions;
189          layer._currentTransaction = transaction;
190      }
191
192      public static void EnsureTransactionAllowsWriteOperations(Transaction transaction)
193      {
194          if (transaction.IsReverted)
195          {
196              throw new InvalidOperationException("Transation is reverted.");
197          }
198          if (transaction.IsCommitted)
199          {
200              throw new InvalidOperationException("Transation is committed.");
201          }
202      }
203
204      protected override void Dispose(bool manual, bool wasDisposed)
205      {
206          if (!wasDisposed && _layer != null && !_layer.IsDisposed)
207          {
208              if (!IsCommitted && !IsReverted)
209              {

```

```

210         Revert();
211     }
212     _layer.ResetCurrentTransation();
213 }
214 }
215 }
216
217 public static readonly TimeSpan DefaultPushDelay = TimeSpan.FromSeconds(0.1);
218
219 private readonly string _logAddress;
220 private readonly FileStream _log;
221 private readonly Queue<Transition> _transitions;
222 private readonly UniqueTimestampFactory _uniqueTimestampFactory;
223 private Task _transitionsPusher;
224 private Transition _lastCommittedTransition;
225 private ulong _currentTransactionId;
226 private Queue<Transition> _currentTransactionTransitions;
227 private Transaction _currentTransaction;
228 private ulong _lastCommittedTransactionId;
229
230 public UInt64LinksTransactionsLayer(ILinks<ulong> links, string logAddress)
231     : base(links)
232 {
233     if (string.IsNullOrEmpty(logAddress))
234     {
235         throw new ArgumentNullException(nameof(logAddress));
236     }
237     // В первой строке файла хранится последняя закоммиченную транзакцию.
238     // При запуске это используется для проверки удачного закрытия файла лога.
239     // In the first line of the file the last committed transaction is stored.
240     // On startup, this is used to check that the log file is successfully closed.
241     var lastCommittedTransition = FileHelpers.ReadFirstOrDefault<Transition>(logAddress);
242     var lastWrittenTransition = FileHelpers.ReadLastOrDefault<Transition>(logAddress);
243     if (!lastCommittedTransition.Equals(lastWrittenTransition))
244     {
245         Dispose();
246         throw new NotSupportedException("Database is damaged, autorecovery is not
247             ↳ supported yet.");
248     }
249     if (lastCommittedTransition.Equals(default(Transition)))
250     {
251         FileHelpers.WriteFirst(logAddress, lastCommittedTransition);
252     }
253     _lastCommittedTransition = lastCommittedTransition;
254     // TODO: Think about a better way to calculate or store this value
255     var allTransitions = FileHelpers.ReadAll<Transition>(logAddress);
256     _lastCommittedTransactionId = allTransitions.Max(x => x.TransactionId);
257     _uniqueTimestampFactory = new UniqueTimestampFactory();
258     _logAddress = logAddress;
259     _log = FileHelpers.Append(logAddress);
260     _transitions = new Queue<Transition>();
261     _transitionsPusher = new Task(TransitionsPusher);
262     _transitionsPusher.Start();
263 }
264
265 public IList<ulong> GetLinkValue(ulong link) => Links.GetLink(link);
266
267 public override ulong Create()
268 {
269     var createdLinkIndex = Links.Create();
270     var createdLink = new UInt64Link(Links.GetLink(createdLinkIndex));
271     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
272         ↳ default, createdLink));
273     return createdLinkIndex;
274 }
275
276 public override ulong Update(IList<ulong> parts)
277 {
278     var linkIndex = parts[Constants.IndexPart];
279     var beforeLink = new UInt64Link(Links.GetLink(linkIndex));
280     linkIndex = Links.Update(parts);
281     var afterLink = new UInt64Link(Links.GetLink(linkIndex));
282     CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
283         ↳ beforeLink, afterLink));
284     return linkIndex;
285 }
286
287 public override void Delete(ulong link)
288 {

```

```

286         var deletedLink = new UInt64Link(Links.GetLink(link));
287         Links.Delete(link);
288         CommitTransition(new Transition(_uniqueTimestampFactory, _currentTransactionId,
        ↪ deletedLink, default));
289     }
290
291     [MethodImpl(MethodImplOptions.AggressiveInlining)]
292     private Queue<Transition> GetCurrentTransitions() => _currentTransactionTransitions ??
        ↪ _transitions;
293
294     private void CommitTransition(Transition transition)
295     {
296         if (_currentTransaction != null)
297         {
298             Transaction.EnsureTransactionAllowsWriteOperations(_currentTransaction);
299         }
300         var transitions = GetCurrentTransitions();
301         transitions.Enqueue(transition);
302     }
303
304     private void RevertTransition(Transition transition)
305     {
306         if (transition.After.IsNull()) // Revert Deletion with Creation
307         {
308             Links.Create();
309         }
310         else if (transition.Before.IsNull()) // Revert Creation with Deletion
311         {
312             Links.Delete(transition.After.Index);
313         }
314         else // Revert Update
315         {
316             Links.Update(new[] { transition.After.Index, transition.Before.Source,
        ↪ transition.Before.Target });
317         }
318     }
319
320     private void ResetCurrentTransation()
321     {
322         _currentTransactionId = 0;
323         _currentTransactionTransitions = null;
324         _currentTransaction = null;
325     }
326
327     private void PushTransitions()
328     {
329         if (_log == null || _transitions == null)
330         {
331             return;
332         }
333         for (var i = 0; i < _transitions.Count; i++)
334         {
335             var transition = _transitions.Dequeue();
336
337             _log.Write(transition);
338             _lastCommittedTransition = transition;
339         }
340     }
341
342     private void TransitionsPusher()
343     {
344         while (!IsDisposed && _transitionsPusher != null)
345         {
346             Thread.Sleep(DefaultPushDelay);
347             PushTransitions();
348         }
349     }
350
351     public Transaction BeginTransaction() => new Transaction(this);
352
353     private void DisposeTransitions()
354     {
355         try
356         {
357             var pusher = _transitionsPusher;
358             if (pusher != null)
359             {
360                 _transitionsPusher = null;
361                 pusher.Wait();

```

```

362     }
363     if (_transitions != null)
364     {
365         PushTransitions();
366     }
367     _log.DisposeIfPossible();
368     FileHelpers.WriteFirst(_logAddress, _lastCommittedTransition);
369 }
370 catch
371 {
372 }
373 }
374
375 #region DisposalBase
376
377 protected override void Dispose(bool manual, bool wasDisposed)
378 {
379     if (!wasDisposed)
380     {
381         DisposeTransitions();
382     }
383     base.Dispose(manual, wasDisposed);
384 }
385
386 #endregion
387 }
388 }

```

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

```

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

```

```

52     }
53 });
54
55 var comparer2 = new UInt64Comparer();
56
57 var ts4 = Performance.Measure(() =>
58 {
59     for (int i = 0; i < N; i++)
60     {
61         result = comparer2.Compare(x, y) >= 0;
62     }
63 });
64
65 Console.WriteLine($"{ts1} {ts2} {ts3} {ts4} {result}");
66 }
67 }
68 }

```

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

```

1  using System.Collections.Generic;
2  using Xunit;
3  using Platform.Reflection;
4  using Platform.Numbers;
5  using Platform.Memory;
6  using Platform.Scopes;
7  using Platform.Setters;
8  using Platform.Data.Doublets.ResizableDirectMemory;
9
10 namespace Platform.Data.Doublets.Tests
11 {
12     public static class DoubletLinksTests
13     {
14         [Fact]
15         public static void UInt64CRUDTest()
16         {
17             using (var scope = new Scope<Types<HeapResizableDirectMemory,
18                 ↳ ResizableDirectMemoryLinks<ulong>>>())
19             {
20                 scope.Use<ILinks<ulong>>().TestCRUDOperations();
21             }
22
23             [Fact]
24             public static void UInt32CRUDTest()
25             {
26                 using (var scope = new Scope<Types<HeapResizableDirectMemory,
27                 ↳ ResizableDirectMemoryLinks<uint>>>())
28                 {
29                     scope.Use<ILinks<uint>>().TestCRUDOperations();
30                 }
31
32                 [Fact]
33                 public static void UInt16CRUDTest()
34                 {
35                     using (var scope = new Scope<Types<HeapResizableDirectMemory,
36                     ↳ ResizableDirectMemoryLinks<ushort>>>())
37                     {
38                         scope.Use<ILinks<ushort>>().TestCRUDOperations();
39                     }
40
41                     [Fact]
42                     public static void UInt8CRUDTest()
43                     {
44                         using (var scope = new Scope<Types<HeapResizableDirectMemory,
45                         ↳ ResizableDirectMemoryLinks<byte>>>())
46                         {
47                             scope.Use<ILinks<byte>>().TestCRUDOperations();
48                         }
49
50                         private static void TestCRUDOperations<T>(this ILinks<T> links)
51                         {
52                             var constants = links.Constants;
53
54                             var equalityComparer = EqualityComparer<T>.Default;
55
56                             // Create Link

```

```

57     Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.Zero));
58
59     var setter = new Setter<T>(constants.Null);
60     links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);
61
62     Assert.True(equalityComparer.Equals(setter.Result, constants.Null));
63
64     var linkAddress = links.Create();
65
66     var link = new Link<T>(links.GetLink(linkAddress));
67
68     Assert.True(link.Count == 3);
69     Assert.True(equalityComparer.Equals(link.Index, linkAddress));
70     Assert.True(equalityComparer.Equals(link.Source, constants.Null));
71     Assert.True(equalityComparer.Equals(link.Target, constants.Null));
72
73     Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.One));
74
75     // Get first link
76     setter = new Setter<T>(constants.Null);
77     links.Each(constants.Any, constants.Any, setter.SetAndReturnFalse);
78
79     Assert.True(equalityComparer.Equals(setter.Result, linkAddress));
80
81     // Update link to reference itself
82     links.Update(linkAddress, linkAddress, linkAddress);
83
84     link = new Link<T>(links.GetLink(linkAddress));
85
86     Assert.True(equalityComparer.Equals(link.Source, linkAddress));
87     Assert.True(equalityComparer.Equals(link.Target, linkAddress));
88
89     // Update link to reference null (prepare for delete)
90     var updated = links.Update(linkAddress, constants.Null, constants.Null);
91
92     Assert.True(equalityComparer.Equals(updated, linkAddress));
93
94     link = new Link<T>(links.GetLink(linkAddress));
95
96     Assert.True(equalityComparer.Equals(link.Source, constants.Null));
97     Assert.True(equalityComparer.Equals(link.Target, constants.Null));
98
99     // Delete link
100    links.Delete(linkAddress);
101
102    Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.Zero));
103
104    setter = new Setter<T>(constants.Null);
105    links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);
106
107    Assert.True(equalityComparer.Equals(setter.Result, constants.Null));
108}
109
110[Fact]
111public static void UInt64RawNumbersCRUDTest()
112{
113    using (var scope = new Scope<Types<HeapResizableDirectMemory,
114        ↳ ResizableDirectMemoryLinks<ulong>>>())
115    {
116        scope.Use<ILinks<ulong>>().TestRawNumbersCRUDOperations();
117    }
118}
119
120[Fact]
121public static void UInt32RawNumbersCRUDTest()
122{
123    using (var scope = new Scope<Types<HeapResizableDirectMemory,
124        ↳ ResizableDirectMemoryLinks<uint>>>())
125    {
126        scope.Use<ILinks<uint>>().TestRawNumbersCRUDOperations();
127    }
128}
129
130[Fact]
131public static void UInt16RawNumbersCRUDTest()
132{
133    using (var scope = new Scope<Types<HeapResizableDirectMemory,
134        ↳ ResizableDirectMemoryLinks<ushort>>>())
135    {

```

```

133         scope.Use<ILinks<ushort>>>().TestRawNumbersCRUDOperations();
134     }
135 }
136
137 [Fact]
138 public static void UInt8RawNumbersCRUDTest()
139 {
140     using (var scope = new Scope<Types<HeapResizableDirectMemory,
141         ↳ ResizableDirectMemoryLinks<byte>>>())
142     {
143         scope.Use<ILinks<byte>>>().TestRawNumbersCRUDOperations();
144     }
145
146 private static void TestRawNumbersCRUDOperations<T>(this ILinks<T> links)
147 {
148     // Constants
149     var constants = links.Constants;
150     var equalityComparer = EqualityComparer<T>.Default;
151
152     var h106E = new Hybrid<T>(106L, isExternal: true);
153     var h107E = new Hybrid<T>(-char.ConvertFromUtf32(107)[0]);
154     var h108E = new Hybrid<T>(-108L);
155
156     Assert.Equal(106L, h106E.AbsoluteValue);
157     Assert.Equal(107L, h107E.AbsoluteValue);
158     Assert.Equal(108L, h108E.AbsoluteValue);
159
160     // Create Link (External -> External)
161     var linkAddress1 = links.Create();
162
163     links.Update(linkAddress1, h106E, h108E);
164
165     var link1 = new Link<T>(links.GetLink(linkAddress1));
166
167     Assert.True(equalityComparer.Equals(link1.Source, h106E));
168     Assert.True(equalityComparer.Equals(link1.Target, h108E));
169
170     // Create Link (Internal -> External)
171     var linkAddress2 = links.Create();
172
173     links.Update(linkAddress2, linkAddress1, h108E);
174
175     var link2 = new Link<T>(links.GetLink(linkAddress2));
176
177     Assert.True(equalityComparer.Equals(link2.Source, linkAddress1));
178     Assert.True(equalityComparer.Equals(link2.Target, h108E));
179
180     // Create Link (Internal -> Internal)
181     var linkAddress3 = links.Create();
182
183     links.Update(linkAddress3, linkAddress1, linkAddress2);
184
185     var link3 = new Link<T>(links.GetLink(linkAddress3));
186
187     Assert.True(equalityComparer.Equals(link3.Source, linkAddress1));
188     Assert.True(equalityComparer.Equals(link3.Target, linkAddress2));
189
190     // Search for created link
191     var setter1 = new Setter<T>(constants.Null);
192     links.Each(h106E, h108E, setter1.SetAndReturnFalse);
193
194     Assert.True(equalityComparer.Equals(setter1.Result, linkAddress1));
195
196     // Search for nonexistent link
197     var setter2 = new Setter<T>(constants.Null);
198     links.Each(h106E, h107E, setter2.SetAndReturnFalse);
199
200     Assert.True(equalityComparer.Equals(setter2.Result, constants.Null));
201
202     // Update link to reference null (prepare for delete)
203     var updated = links.Update(linkAddress3, constants.Null, constants.Null);
204
205     Assert.True(equalityComparer.Equals(updated, linkAddress3));
206
207     link3 = new Link<T>(links.GetLink(linkAddress3));
208
209     Assert.True(equalityComparer.Equals(link3.Source, constants.Null));
210     Assert.True(equalityComparer.Equals(link3.Target, constants.Null));
211

```

```

212         // Delete link
213         links.Delete(linkAddress3);
214
215         Assert.True(equalityComparer.Equals(links.Count(), Integer<T>.Two));
216
217         var setter3 = new Setter<T>(constants.Null);
218         links.Each(constants.Any, constants.Any, setter3.SetAndReturnTrue);
219
220         Assert.True(equalityComparer.Equals(setter3.Result, linkAddress2));
221     }
222
223     // TODO: Test layers
224 }
225 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using Xunit;
4  using Platform.Diagnostics;
5
6  namespace Platform.Data.Doublets.Tests
7  {
8      public static class EqualityTests
9      {
10         protected class UInt64EqualityComparer : IEqualityComparer<ulong>
11         {
12             public bool Equals(ulong x, ulong y) => x == y;
13
14             public int GetHashCode(ulong obj) => obj.GetHashCode();
15         }
16
17         private static bool Equals1<T>(T x, T y) => Equals(x, y);
18
19         private static bool Equals2<T>(T x, T y) => x.Equals(y);
20
21         private static bool Equals3(ulong x, ulong y) => x == y;
22
23         [Fact]
24         public static void EqualsPerfomanceTest()
25         {
26             const int N = 1000000;
27
28             ulong x = 10;
29             ulong y = 500;
30
31             bool result = false;
32
33             var ts1 = Performance.Measure(() =>
34             {
35                 for (int i = 0; i < N; i++)
36                 {
37                     result = Equals1(x, y);
38                 }
39             });
40
41             var ts2 = Performance.Measure(() =>
42             {
43                 for (int i = 0; i < N; i++)
44                 {
45                     result = Equals2(x, y);
46                 }
47             });
48
49             var ts3 = Performance.Measure(() =>
50             {
51                 for (int i = 0; i < N; i++)
52                 {
53                     result = Equals3(x, y);
54                 }
55             });
56
57             var equalityComparer1 = EqualityComparer<ulong>.Default;
58
59             var ts4 = Performance.Measure(() =>
60             {
61                 for (int i = 0; i < N; i++)
62                 {
63                     result = equalityComparer1.Equals(x, y);
64                 }
65             });
66         }
67     }
68 }

```



```

65     });
66
67     var equalityComparer2 = new UInt64EqualityComparer();
68
69     var ts5 = Performance.Measure(() =>
70     {
71         for (int i = 0; i < N; i++)
72         {
73             result = equalityComparer2.Equals(x, y);
74         }
75     });
76
77     Func<ulong, ulong, bool> equalityComparer3 = equalityComparer2.Equals;
78
79     var ts6 = Performance.Measure(() =>
80     {
81         for (int i = 0; i < N; i++)
82         {
83             result = equalityComparer3(x, y);
84         }
85     });
86
87     var comparer = Comparer<ulong>.Default;
88
89     var ts7 = Performance.Measure(() =>
90     {
91         for (int i = 0; i < N; i++)
92         {
93             result = comparer.Compare(x, y) == 0;
94         }
95     });
96
97     Assert.True(ts2 < ts1);
98     Assert.True(ts3 < ts2);
99     Assert.True(ts5 < ts4);
100    Assert.True(ts5 < ts6);
101
102    Console.WriteLine($"{ts1} {ts2} {ts3} {ts4} {ts5} {ts6} {ts7} {result}");
103    }
104 }
105

```

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

```

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

```

```

38     var links = scope.Links;
39
40     for (var N = 0; N < 100; N++)
41     {
42         var random = new System.Random(N);
43
44         var created = 0;
45         var deleted = 0;
46
47         for (var i = 0; i < N; i++)
48         {
49             var linksCount = links.Count();
50
51             var createPoint = random.NextBoolean();
52
53             if (linksCount > 2 && createPoint)
54             {
55                 var linksAddressRange = new Range<ulong>(1, linksCount);
56                 var source = random.NextUInt64(linksAddressRange);
57                 var target = random.NextUInt64(linksAddressRange); //-V3086
58
59                 var resultLink = links.CreateAndUpdate(source, target);
60                 if (resultLink > linksCount)
61                 {
62                     created++;
63                 }
64             }
65             else
66             {
67                 links.Create();
68                 created++;
69             }
70         }
71
72         Assert.True(created == (int)links.Count());
73
74         for (var i = 0; i < N; i++)
75         {
76             var link = (ulong)i + 1;
77             if (links.Exists(link))
78             {
79                 links.Delete(link);
80                 deleted++;
81             }
82         }
83
84         Assert.True(links.Count() == 0);
85     }
86 }
87
88 [Fact]
89 public static void CascadeUpdateTest()
90 {
91     var itself = _constants.Itself;
92
93     using (var scope = new TempLinksTestScope(useLog: true))
94     {
95         var links = scope.Links;
96
97         var l1 = links.Create();
98         var l2 = links.Create();
99
100         l2 = links.Update(l2, l2, l1, l2);
101
102         links.CreateAndUpdate(l2, itself);
103         links.CreateAndUpdate(l2, itself);
104
105         l2 = links.Update(l2, l1);
106
107         links.Delete(l2);
108
109         Global.Trash = links.Count();
110
111         links.Unsync.DisposeIfPossible(); // Close links to access log
112
113         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope
114             ↪ e.TempTransactionLogFilename);
115     }
116 }

```

```

117 [Fact]
118 public static void BasicTransactionLogTest()
119 {
120     using (var scope = new TempLinksTestScope(useLog: true))
121     {
122         var links = scope.Links;
123         var l1 = links.Create();
124         var l2 = links.Create();
125
126         Global.Trash = links.Update(l2, l2, l1, l2);
127
128         links.Delete(l1);
129
130         links.Unsync.DisposeIfPossible(); // Close links to access log
131
132         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scope
133             ↪ e.TempTransactionLogFilename);
134     }
135 }
136
137 [Fact]
138 public static void TransactionAutoRevertedTest()
139 {
140     // Auto Reverted (Because no commit at transaction)
141     using (var scope = new TempLinksTestScope(useLog: true))
142     {
143         var links = scope.Links;
144         var transactionsLayer = (UInt64LinksTransactionsLayer)scope.MemoryAdapter;
145         using (var transaction = transactionsLayer.BeginTransaction())
146         {
147             var l1 = links.Create();
148             var l2 = links.Create();
149
150             links.Update(l2, l2, l1, l2);
151         }
152
153         Assert.Equal(0UL, links.Count());
154
155         links.Unsync.DisposeIfPossible();
156
157         var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(s
158             ↪ cope.TempTransactionLogFilename);
159         Assert.Single(transitions);
160     }
161 }
162
163 [Fact]
164 public static void TransactionUserCodeErrorNoDataSavedTest()
165 {
166     // User Code Error (Autoreverted), no data saved
167     var itself = _constants.Itself;
168
169     TempLinksTestScope lastScope = null;
170     try
171     {
172         using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
173             ↪ useLog: true))
174         {
175             var links = scope.Links;
176             var transactionsLayer = (UInt64LinksTransactionsLayer)((LinksDisposableDecor
177                 ↪ atorBase<ulong>)links.Unsync).Links;
178             using (var transaction = transactionsLayer.BeginTransaction())
179             {
180                 var l1 = links.CreateAndUpdate(itself, itself);
181                 var l2 = links.CreateAndUpdate(itself, itself);
182
183                 l2 = links.Update(l2, l2, l1, l2);
184
185                 links.CreateAndUpdate(l2, itself);
186                 links.CreateAndUpdate(l2, itself);
187
188                 //Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transi
189                 ↪ tion>(scope.TempTransactionLogFilename);
190
191                 l2 = links.Update(l2, l1);
192
193                 links.Delete(l2);
194             }
195         }
196     }
197     catch { }
198 }

```

```

191         ExceptionThrower();
192
193         transaction.Commit();
194     }
195
196     Global.Trash = links.Count();
197 }
198
199 catch
200 {
201     Assert.False(lastScope == null);
202
203     var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(l
        ↪ astScope.TempTransactionLogFilename);
204
205     Assert.True(transitions.Length == 1 && transitions[0].Before.IsNull() &&
        ↪ transitions[0].After.IsNull());
206
207     lastScope.DeleteFiles();
208 }
209
210 }
211
212 [Fact]
213 public static void TransactionUserCodeErrorSomeDataSavedTest()
214 {
215     // User Code Error (Autoreverted), some data saved
216     var itself = _constants.Itself;
217
218     TempLinksTestScope lastScope = null;
219     try
220     {
221         ulong l1;
222         ulong l2;
223
224         using (var scope = new TempLinksTestScope(useLog: true))
225         {
226             var links = scope.Links;
227             l1 = links.CreateAndUpdate(itself, itself);
228             l2 = links.CreateAndUpdate(itself, itself);
229
230             l2 = links.Update(l2, l2, l1, l2);
231
232             links.CreateAndUpdate(l2, itself);
233             links.CreateAndUpdate(l2, itself);
234
235             links.Unsync.DisposeIfPossible();
236
237             Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(
        ↪ scope.TempTransactionLogFilename);
238
239         }
240
241         using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
        ↪ useLog: true))
242         {
243             var links = scope.Links;
244             var transactionsLayer = (UInt64LinksTransactionsLayer)links.Unsync;
245             using (var transaction = transactionsLayer.BeginTransaction())
246             {
247                 l2 = links.Update(l2, l1);
248
249                 links.Delete(l2);
250
251                 ExceptionThrower();
252
253                 transaction.Commit();
254             }
255
256             Global.Trash = links.Count();
257         }
258     }
259     catch
260     {
261         Assert.False(lastScope == null);
262
263         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(last
        ↪ Scope.TempTransactionLogFilename);
264
265         lastScope.DeleteFiles();
266     }
267 }

```

```

266 [Fact]
267 public static void TransactionCommit()
268 {
269     var itself = _constants.Itself;
270
271     var tempDatabaseFilename = Path.GetTempFileName();
272     var tempTransactionLogFilename = Path.GetTempFileName();
273
274     // Commit
275     using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
276         ↪ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
277         ↪ tempTransactionLogFilename))
278     using (var links = new UInt64Links(memoryAdapter))
279     {
280         using (var transaction = memoryAdapter.BeginTransaction())
281         {
282             var l1 = links.CreateAndUpdate(itself, itself);
283             var l2 = links.CreateAndUpdate(itself, itself);
284
285             Global.Trash = links.Update(l2, l2, l1, l2);
286
287             links.Delete(l1);
288
289             transaction.Commit();
290         }
291
292         Global.Trash = links.Count();
293     }
294
295     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran_
296         ↪ sactionLogFilename);
297 }
298
299 [Fact]
300 public static void TransactionDamage()
301 {
302     var itself = _constants.Itself;
303
304     var tempDatabaseFilename = Path.GetTempFileName();
305     var tempTransactionLogFilename = Path.GetTempFileName();
306
307     // Commit
308     using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
309         ↪ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
310         ↪ tempTransactionLogFilename))
311     using (var links = new UInt64Links(memoryAdapter))
312     {
313         using (var transaction = memoryAdapter.BeginTransaction())
314         {
315             var l1 = links.CreateAndUpdate(itself, itself);
316             var l2 = links.CreateAndUpdate(itself, itself);
317
318             Global.Trash = links.Update(l2, l2, l1, l2);
319
320             links.Delete(l1);
321
322             transaction.Commit();
323         }
324
325         Global.Trash = links.Count();
326     }
327
328     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran_
329         ↪ sactionLogFilename);
330
331     // Damage database
332     FileHelpers.WriteFirst(tempTransactionLogFilename, new
333         ↪ UInt64LinksTransactionsLayer.Transition(new UniqueTimestampFactory(), 555));
334
335     // Try load damaged database
336     try
337     {
338         // TODO: Fix
339         using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
340             ↪ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
341             ↪ tempTransactionLogFilename))
342         using (var links = new UInt64Links(memoryAdapter))

```

```

336         {
337             Global.Trash = links.Count();
338         }
339     }
340     catch (NotSupportedException ex)
341     {
342         Assert.True(ex.Message == "Database is damaged, autorecovery is not supported
        ↳ yet.");
343     }
344
345     Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran_
        ↳ sactionLogFilename);
346
347     File.Delete(tempDatabaseFilename);
348     File.Delete(tempTransactionLogFilename);
349 }
350
351 [Fact]
352 public static void Bug1Test()
353 {
354     var tempDatabaseFilename = Path.GetTempFileName();
355     var tempTransactionLogFilename = Path.GetTempFileName();
356
357     var itself = _constants.Itself;
358
359     // User Code Error (Autoreverted), some data saved
360     try
361     {
362         ulong l1;
363         ulong l2;
364
365         using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
        ↳ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
        ↳ tempTransactionLogFilename))
366         using (var links = new UInt64Links(memoryAdapter))
367         {
368             l1 = links.CreateAndUpdate(itself, itself);
369             l2 = links.CreateAndUpdate(itself, itself);
370
371             l2 = links.Update(l2, l2, l1, l2);
372
373             links.CreateAndUpdate(l2, itself);
374             links.CreateAndUpdate(l2, itself);
375         }
376
377         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp_
        ↳ TransactionLogFilename);
378
379         using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
        ↳ UInt64ResizableDirectMemoryLinks(tempDatabaseFilename),
        ↳ tempTransactionLogFilename))
380         using (var links = new UInt64Links(memoryAdapter))
381         {
382             using (var transaction = memoryAdapter.BeginTransaction())
383             {
384                 l2 = links.Update(l2, l1);
385
386                 links.Delete(l2);
387
388                 ExceptionThrower();
389
390                 transaction.Commit();
391             }
392
393             Global.Trash = links.Count();
394         }
395     }
396     catch
397     {
398         Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp_
        ↳ TransactionLogFilename);
399     }
400
401     File.Delete(tempDatabaseFilename);
402     File.Delete(tempTransactionLogFilename);
403 }
404
405 private static void ExceptionThrower()
406 {

```

```

407     throw new Exception();
408 }
409
410 [Fact]
411 public static void PathsTest()
412 {
413     var source = _constants.SourcePart;
414     var target = _constants.TargetPart;
415
416     using (var scope = new TempLinksTestScope())
417     {
418         var links = scope.Links;
419         var l1 = links.CreatePoint();
420         var l2 = links.CreatePoint();
421
422         var r1 = links.GetByKeys(l1, source, target, source);
423         var r2 = links.CheckPathExistence(l2, l2, l2, l2);
424     }
425 }
426
427 [Fact]
428 public static void RecursiveStringFormattingTest()
429 {
430     using (var scope = new TempLinksTestScope(useSequences: true))
431     {
432         var links = scope.Links;
433         var sequences = scope.Sequences; // TODO: Auto use sequences on Sequences getter.
434
435         var a = links.CreatePoint();
436         var b = links.CreatePoint();
437         var c = links.CreatePoint();
438
439         var ab = links.CreateAndUpdate(a, b);
440         var cb = links.CreateAndUpdate(c, b);
441         var ac = links.CreateAndUpdate(a, c);
442
443         a = links.Update(a, c, b);
444         b = links.Update(b, a, c);
445         c = links.Update(c, a, b);
446
447         Debug.WriteLine(links.FormatStructure(ab, link => link.IsFullPoint(), true));
448         Debug.WriteLine(links.FormatStructure(cb, link => link.IsFullPoint(), true));
449         Debug.WriteLine(links.FormatStructure(ac, link => link.IsFullPoint(), true));
450
451         Assert.True(links.FormatStructure(cb, link => link.IsFullPoint(), true) ==
452             ↳ "(5:(4:5 (6:5 4)) 6)");
453         Assert.True(links.FormatStructure(ac, link => link.IsFullPoint(), true) ==
454             ↳ "(6:(5:(4:5 6) 6) 4)");
455         Assert.True(links.FormatStructure(ab, link => link.IsFullPoint(), true) ==
456             ↳ "(4:(5:4 (6:5 4)) 6)");
457
458         // TODO: Think how to build balanced syntax tree while formatting structure (eg.
459         ↳ "(4:(5:4 6) (6:5 4))" instead of "(4:(5:4 (6:5 4)) 6)"
460
461         Assert.True(sequences.SafeFormatSequence(cb, DefaultFormatter, false) ==
462             ↳ "{{5}}{5}{4}{6}}");
463         Assert.True(sequences.SafeFormatSequence(ac, DefaultFormatter, false) ==
464             ↳ "{{5}}{6}{6}{4}}");
465         Assert.True(sequences.SafeFormatSequence(ab, DefaultFormatter, false) ==
466             ↳ "{{4}}{5}{4}{6}}");
467     }
468 }
469
470 private static void DefaultFormatter(StringBuilder sb, ulong link)
471 {
472     sb.Append(link.ToString());
473 }
474
475 #endregion
476
477 #region Performance
478
479 /*
480 public static void RunAllPerformanceTests()
481 {
482     try
483     {
484         links.TestLinksInSteps();
485     }
486 }

```

```

479         catch (Exception ex)
480         {
481             ex.WriteToConsole();
482         }
483
484         return;
485
486         try
487         {
488             //ThreadPool.SetMaxThreads(2, 2);
489
490             // Запускаем все тесты дважды, чтобы первоначальная инициализация не повлияла на
↪ результат
491             // Также это дополнительно помогает в отладке
492             // Увеличивает вероятность попадания информации в кэши
493             for (var i = 0; i < 10; i++)
494             {
495                 //0 - 10 ГБ
496                 //Каждые 100 МБ срез цифр
497
498                 //links.TestGetSourceFunction();
499                 //links.TestGetSourceFunctionInParallel();
500                 //links.TestGetTargetFunction();
501                 //links.TestGetTargetFunctionInParallel();
502                 links.Create64BillionLinks();
503
504                 links.TestRandomSearchFixed();
505                 //links.Create64BillionLinksInParallel();
506                 links.TestEachFunction();
507                 //links.TestForeach();
508                 //links.TestParallelForeach();
509             }
510
511             links.TestDeletionOfAllLinks();
512
513         }
514         catch (Exception ex)
515         {
516             ex.WriteToConsole();
517         }
518     }*/
519
520     /*
521     public static void TestLinksInSteps()
522     {
523         const long gibibyte = 1024 * 1024 * 1024;
524         const long mebibyte = 1024 * 1024;
525
526         var totalLinksToCreate = gibibyte /
↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
527         var linksStep = 102 * mebibyte /
↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
528
529         var creationMeasurements = new List<TimeSpan>();
530         var searchMeasurements = new List<TimeSpan>();
531         var deletionMeasurements = new List<TimeSpan>();
532
533         GetBaseRandomLoopOverhead(linksStep);
534         GetBaseRandomLoopOverhead(linksStep);
535
536         var stepLoopOverhead = GetBaseRandomLoopOverhead(linksStep);
537
538         ConsoleHelpers.Debug("Step loop overhead: {0}.", stepLoopOverhead);
539
540         var loops = totalLinksToCreate / linksStep;
541
542         for (int i = 0; i < loops; i++)
543         {
544             creationMeasurements.Add(Measure(() => links.RunRandomCreations(linksStep)));
545             searchMeasurements.Add(Measure(() => links.RunRandomSearches(linksStep)));
546
547             Console.WriteLine("\rC + S {0}/{1}", i + 1, loops);
548         }
549
550         ConsoleHelpers.Debug();
551
552         for (int i = 0; i < loops; i++)
553         {
554             deletionMeasurements.Add(Measure(() => links.RunRandomDeletions(linksStep)));
555

```



```

556         Console.WriteLine("\rD {0}/{1}", i + 1, loops);
557     }
558
559     ConsoleHelpers.Debug();
560
561     ConsoleHelpers.Debug("C S D");
562
563     for (int i = 0; i < loops; i++)
564     {
565         ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i],
↵ searchMeasurements[i], deletionMeasurements[i]);
566     }
567
568     ConsoleHelpers.Debug("C S D (no overhead)");
569
570     for (int i = 0; i < loops; i++)
571     {
572         ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i] - stepLoopOverhead,
↵ searchMeasurements[i] - stepLoopOverhead, deletionMeasurements[i] - stepLoopOverhead);
573     }
574
575     ConsoleHelpers.Debug("All tests done. Total links left in database: {0}.",
↵ links.Total);
576 }
577
578 private static void CreatePoints(this Platform.Links.Data.Core.Doublets.Links links, long
↵ amountToCreate)
579 {
580     for (long i = 0; i < amountToCreate; i++)
581         links.Create(0, 0);
582 }
583
584 private static TimeSpan GetBaseRandomLoopOverhead(long loops)
585 {
586     return Measure(() =>
587     {
588         ulong maxValue = RandomHelpers.DefaultFactory.NextUInt64();
589         ulong result = 0;
590         for (long i = 0; i < loops; i++)
591         {
592             var source = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
593             var target = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
594
595             result += maxValue + source + target;
596         }
597         Global.Trash = result;
598     });
599 }
600 */
601
602 [Fact(Skip = "performance test")]
603 public static void GetSourceTest()
604 {
605     using (var scope = new TempLinksTestScope())
606     {
607         var links = scope.Links;
608         ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations.",
↵ Iterations);
609
610         ulong counter = 0;
611
612         //var firstLink = links.First();
613         // Создаём одну связь, из которой будет производить считывание
614         var firstLink = links.Create();
615
616         var sw = Stopwatch.StartNew();
617
618         // Тестируем саму функцию
619         for (ulong i = 0; i < Iterations; i++)
620         {
621             counter += links.GetSource(firstLink);
622         }
623
624         var elapsedTime = sw.Elapsed;
625
626         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
627
628         // Удаляем связь, из которой производилось считывание
629         links.Delete(firstLink);

```

```

630         ConsoleHelpers.Debug(
631             "{0} Iterations of GetSource function done in {1} ({2} Iterations per
632             ↪ second), counter result: {3}",
633             Iterations, elapsedTime, (long)iterationsPerSecond, counter);
634     }
635 }
636
637 [Fact(Skip = "performance test")]
638 public static void GetSourceInParallel()
639 {
640     using (var scope = new TempLinksTestScope())
641     {
642         var links = scope.Links;
643         ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations in
644         ↪ parallel.", Iterations);
645
646         long counter = 0;
647
648         //var firstLink = links.First();
649         var firstLink = links.Create();
650
651         var sw = Stopwatch.StartNew();
652
653         // Тестируем саму функцию
654         Parallel.For(0, Iterations, x =>
655         {
656             Interlocked.Add(ref counter, (long)links.GetSource(firstLink));
657             //Interlocked.Increment(ref counter);
658         });
659
660         var elapsedTime = sw.Elapsed;
661
662         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
663
664         links.Delete(firstLink);
665
666         ConsoleHelpers.Debug(
667             "{0} Iterations of GetSource function done in {1} ({2} Iterations per
668             ↪ second), counter result: {3}",
669             Iterations, elapsedTime, (long)iterationsPerSecond, counter);
670     }
671 }
672
673 [Fact(Skip = "performance test")]
674 public static void TestGetTarget()
675 {
676     using (var scope = new TempLinksTestScope())
677     {
678         var links = scope.Links;
679         ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations.",
680         ↪ Iterations);
681
682         ulong counter = 0;
683
684         //var firstLink = links.First();
685         var firstLink = links.Create();
686
687         var sw = Stopwatch.StartNew();
688
689         for (ulong i = 0; i < Iterations; i++)
690         {
691             counter += links.GetTarget(firstLink);
692         }
693
694         var elapsedTime = sw.Elapsed;
695
696         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
697
698         links.Delete(firstLink);
699
700         ConsoleHelpers.Debug(
701             "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
702             ↪ second), counter result: {3}",
703             Iterations, elapsedTime, (long)iterationsPerSecond, counter);
704     }
705 }
706
707 [Fact(Skip = "performance test")]

```

```

704 public static void TestGetTargetInParallel()
705 {
706     using (var scope = new TempLinksTestScope())
707     {
708         var links = scope.Links;
709         ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations in
↳ parallel.", Iterations);
710
711         long counter = 0;
712
713         //var firstLink = links.First();
714         var firstLink = links.Create();
715
716         var sw = Stopwatch.StartNew();
717
718         Parallel.For(0, Iterations, x =>
719         {
720             Interlocked.Add(ref counter, (long)links.GetTarget(firstLink));
721             //Interlocked.Increment(ref counter);
722         });
723
724         var elapsedTime = sw.Elapsed;
725
726         var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
727
728         links.Delete(firstLink);
729
730         ConsoleHelpers.Debug(
731             "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
↳ second), counter result: {3}",
732             Iterations, elapsedTime, (long)iterationsPerSecond, counter);
733     }
734 }
735
736 // TODO: Заполнить базу данных перед тестом
737 /*
738 [Fact]
739 public void TestRandomSearchFixed()
740 {
741     var tempFilename = Path.GetTempFileName();
742
743     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
↳ DefaultLinksSizeStep))
744     {
745         long iterations = 64 * 1024 * 1024 /
↳ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
746
747         ulong counter = 0;
748         var maxLink = links.Total;
749
750         ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.", iterations);
751
752         var sw = Stopwatch.StartNew();
753
754         for (var i = iterations; i > 0; i--)
755         {
756             var source =
↳ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
757             var target =
↳ RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
758
759             counter += links.Search(source, target);
760         }
761
762         var elapsedTime = sw.Elapsed;
763
764         var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
765
766         ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
↳ Iterations per second), c: {3}", iterations, elapsedTime, (long)iterationsPerSecond,
↳ counter);
767     }
768
769     File.Delete(tempFilename);
770 }*/
771
772 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
773 public static void TestRandomSearchAll()
774 {

```

```

775 using (var scope = new TempLinksTestScope())
776 {
777     var links = scope.Links;
778     ulong counter = 0;
779
780     var maxLink = links.Count();
781
782     var iterations = links.Count();
783
784     ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.",
785         ↪ links.Count());
786
787     var sw = Stopwatch.StartNew();
788
789     for (var i = iterations; i > 0; i--)
790     {
791         var linksAddressRange = new Range<ulong>(_constants.MinPossibleIndex,
792             ↪ maxLink);
793
794         var source = RandomHelpers.Default.NextUInt64(linksAddressRange);
795         var target = RandomHelpers.Default.NextUInt64(linksAddressRange);
796
797         counter += links.SearchOrDefault(source, target);
798     }
799
800     var elapsedTime = sw.Elapsed;
801
802     var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;
803
804     ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
805         ↪ Iterations per second), c: {3}",
806         iterations, elapsedTime, (long)iterationsPerSecond, counter);
807 }
808
809 [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
810 public static void TestEach()
811 {
812     using (var scope = new TempLinksTestScope())
813     {
814         var links = scope.Links;
815
816         var counter = new Counter<IList<ulong>, ulong>(links.Constants.Continue);
817
818         ConsoleHelpers.Debug("Testing Each function.");
819
820         var sw = Stopwatch.StartNew();
821
822         links.Each(counter.IncrementAndReturnTrue);
823
824         var elapsedTime = sw.Elapsed;
825
826         var linksPerSecond = counter.Count / elapsedTime.TotalSeconds;
827
828         ConsoleHelpers.Debug("{0} Iterations of Each's handler function done in {1} ({2}
829             ↪ links per second)",
830             counter, elapsedTime, (long)linksPerSecond);
831     }
832 }
833
834 /*
835 [Fact]
836 public static void TestForeach()
837 {
838     var tempFilename = Path.GetTempFileName();
839
840     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
841         ↪ DefaultLinksSizeStep))
842     {
843         ulong counter = 0;
844
845         ConsoleHelpers.Debug("Testing foreach through links.");
846
847         var sw = Stopwatch.StartNew();
848
849         //foreach (var link in links)
850         //{
851             counter++;
852         //}

```

```

850         var elapsedTime = sw.Elapsed;
851
852         var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
853
854         ConsoleHelpers.Debug("{0} Iterations of Foreach's handler block done in {1} ({2}
↪ links per second)", counter, elapsedTime, (long)linksPerSecond);
855     }
856
857     File.Delete(tempFilename);
858 }
859 */
860
861 /*
862 [Fact]
863 public static void TestParallelForeach()
864 {
865     var tempFilename = Path.GetTempFileName();
866
867     using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
↪ DefaultLinksSizeStep))
868     {
869
870         long counter = 0;
871
872         ConsoleHelpers.Debug("Testing parallel foreach through links.");
873
874         var sw = Stopwatch.StartNew();
875
876         //Parallel.ForEach((IEnumerable<ulong>)links, x =>
877         //{
878         //    Interlocked.Increment(ref counter);
879         //});
880
881         var elapsedTime = sw.Elapsed;
882
883         var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
884
885         ConsoleHelpers.Debug("{0} Iterations of Parallel Foreach's handler block done in
↪ {1} ({2} links per second)", counter, elapsedTime, (long)linksPerSecond);
886     }
887
888     File.Delete(tempFilename);
889 }
890 */
891
892 [Fact(Skip = "performance test")]
893 public static void Create64BillionLinks()
894 {
895     using (var scope = new TempLinksTestScope())
896     {
897         var links = scope.Links;
898         var linksBeforeTest = links.Count();
899
900         long linksToCreate = 64 * 1024 * 1024 /
↪ UInt64ResizableDirectMemoryLinks.LinkSizeInBytes;
901
902         ConsoleHelpers.Debug("Creating {0} links.", linksToCreate);
903
904         var elapsedTime = Performance.Measure(() =>
905         {
906             for (long i = 0; i < linksToCreate; i++)
907             {
908                 links.Create();
909             }
910         });
911
912         var linksCreated = links.Count() - linksBeforeTest;
913         var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
914
915         ConsoleHelpers.Debug("Current links count: {0}.", links.Count());
916
917         ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
↪ linksCreated, elapsedTime,
918             (long)linksPerSecond);
919     }
920 }
921
922 [Fact(Skip = "performance test")]
923 public static void Create64BillionLinksInParallel()

```

```

924 {
925     using (var scope = new TempLinksTestScope())
926     {
927         var links = scope.Links;
928         var linksBeforeTest = links.Count();
929
930         var sw = Stopwatch.StartNew();
931
932         long linksToCreate = 64 * 1024 * 1024 /
933             ↳ UInt64ResizableDirectMemoryLinks.LinkSizeInBytes;
934
935         ConsoleHelpers.Debug("Creating {0} links in parallel.", linksToCreate);
936
937         Parallel.For(0, linksToCreate, x => links.Create());
938
939         var elapsedTime = sw.Elapsed;
940
941         var linksCreated = links.Count() - linksBeforeTest;
942         var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
943
944         ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
945             ↳ linksCreated, elapsedTime,
946             (long)linksPerSecond);
947     }
948
949     [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
950     public static void TestDeletionOfAllLinks()
951     {
952         using (var scope = new TempLinksTestScope())
953         {
954             var links = scope.Links;
955             var linksBeforeTest = links.Count();
956
957             ConsoleHelpers.Debug("Deleting all links");
958
959             var elapsedTime = Performance.Measure(links.DeleteAll);
960
961             var linksDeleted = linksBeforeTest - links.Count();
962             var linksPerSecond = linksDeleted / elapsedTime.TotalSeconds;
963
964             ConsoleHelpers.Debug("{0} links deleted in {1} ({2} links per second)",
965                 ↳ linksDeleted, elapsedTime,
966                 (long)linksPerSecond);
967         }
968     }
969 }
970 }

```

#endregion

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

```

1  using System;
2  using System.Linq;
3  using System.Collections.Generic;
4  using Xunit;
5  using Platform.Interfaces;
6  using Platform.Data.Doublets.Sequences;
7  using Platform.Data.Doublets.Sequences.Frequencies.Cache;
8  using Platform.Data.Doublets.Sequences.Frequencies.Counters;
9  using Platform.Data.Doublets.Sequences.Converters;
10 using Platform.Data.Doublets.PropertyOperators;
11 using Platform.Data.Doublets.Incrementers;
12 using Platform.Data.Doublets.Converters;
13
14 namespace Platform.Data.Doublets.Tests
15 {
16     public static class OptimalVariantSequenceTests
17     {
18         private const string SequenceExample = "зеленела зелёная зелень";
19
20         [Fact]
21         public static void LinksBasedFrequencyStoredOptimalVariantSequenceTest()
22         {
23             using (var scope = new TempLinksTestScope(useSequences: true))
24             {
25                 var links = scope.Links;
26                 var sequences = scope.Sequences;
27                 var constants = links.Constants;
28
29                 links.UseUnicode();

```

```

30
31     var sequence = UnicodeMap.FromStringToLinkArray(SequenceExample);
32
33     var meaningRoot = links.CreatePoint();
34     var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
35     var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
36     var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
37         ↳ constants.Itself);
38
39     var unaryNumberToAddressConveter = new
40         ↳ UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
41     var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
42     var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
43         ↳ frequencyMarker, unaryOne, unaryNumberIncrementer);
44     var frequencyPropertyOperator = new FrequencyPropertyOperator<ulong>(links,
45         ↳ frequencyPropertyMarker, frequencyMarker);
46     var linkFrequencyIncrementer = new LinkFrequencyIncrementer<ulong>(links,
47         ↳ frequencyPropertyOperator, frequencyIncrementer);
48     var linkToItsFrequencyNumberConverter = new
49         ↳ LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
50         ↳ unaryNumberToAddressConveter);
51     var sequenceToItsLocalElementLevelsConverter = new
52         ↳ SequenceToItsLocalElementLevelsConverter<ulong>(links,
53         ↳ linkToItsFrequencyNumberConverter);
54     var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
55         ↳ sequenceToItsLocalElementLevelsConverter);
56
57     ExecuteTest(links, sequences, sequence,
58         ↳ sequenceToItsLocalElementLevelsConverter, linkFrequencyIncrementer,
59         ↳ optimalVariantConverter);
60 }
61
62 [Fact]
63 public static void DictionaryBasedFrequencyStoredOptimalVariantSequenceTest()
64 {
65     using (var scope = new TempLinksTestScope(useSequences: true))
66     {
67         var links = scope.Links;
68         var sequences = scope.Sequences;
69
70         links.UseUnicode();
71
72         var sequence = UnicodeMap.FromStringToLinkArray(SequenceExample);
73
74         var linksToFrequencies = new Dictionary<ulong, ulong>();
75
76         var totalSequenceSymbolFrequencyCounter = new
77             ↳ TotalSequenceSymbolFrequencyCounter<ulong>(links);
78
79         var linkFrequenciesCache = new LinkFrequenciesCache<ulong>(links,
80             ↳ totalSequenceSymbolFrequencyCounter);
81
82         var linkFrequencyIncrementer = new
83             ↳ FrequenciesCacheBasedLinkFrequencyIncrementer<ulong>(linkFrequenciesCache);
84         var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFreque
85             ↳ ncyNumberConverter<ulong>(linkFrequenciesCache);
86
87         var sequenceToItsLocalElementLevelsConverter = new
88             ↳ SequenceToItsLocalElementLevelsConverter<ulong>(links,
89             ↳ linkToItsFrequencyNumberConverter);
90         var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
91             ↳ sequenceToItsLocalElementLevelsConverter);
92
93         ExecuteTest(links, sequences, sequence,
94             ↳ sequenceToItsLocalElementLevelsConverter, linkFrequencyIncrementer,
95             ↳ optimalVariantConverter);
96     }
97 }
98
99 private static void ExecuteTest(SynchronizedLinks<ulong> links, Sequences.Sequences
100     ↳ sequences, ulong[] sequence, SequenceToItsLocalElementLevelsConverter<ulong>
101     ↳ sequenceToItsLocalElementLevelsConverter, IIncrementer<IList<ulong>>
102     ↳ linkFrequencyIncrementer, OptimalVariantConverter<ulong> optimalVariantConverter)
103 {
104     linkFrequencyIncrementer.Increment(sequence);
105
106     var levels = sequenceToItsLocalElementLevelsConverter.Convert(sequence);

```

```

84
85         var optimalVariant = optimalVariantConverter.Convert(sequence);
86
87         var readSequence1 = sequences.ReadSequenceCore(optimalVariant, links.IsPartialPoint);
88
89         Assert.True(sequence.SequenceEqual(readSequence1));
90     }
91 }
92

```

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

```

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

```

1  using System.IO;
2  using Xunit;
3  using Platform.Singletons;
4  using Platform.Memory;

```



```

5 using Platform.Data.Constants;
6 using Platform.Data.Doublets.ResizableDirectMemory;
7
8 namespace Platform.Data.Doublets.Tests
9 {
10     public static class ResizableDirectMemoryLinksTests
11     {
12         private static readonly LinksCombinedConstants<ulong, ulong, int> _constants =
13             ↳ Default<LinksCombinedConstants<ulong, ulong, int>>.Instance;
14
15         [Fact]
16         public static void BasicFileMappedMemoryTest()
17         {
18             var tempFilename = Path.GetTempFileName();
19             using (var memoryAdapter = new UInt64ResizableDirectMemoryLinks(tempFilename))
20             {
21                 memoryAdapter.TestBasicMemoryOperations();
22             }
23             File.Delete(tempFilename);
24
25             [Fact]
26             public static void BasicHeapMemoryTest()
27             {
28                 using (var memory = new
29                     ↳ HeapResizableDirectMemory(UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep))
30                 using (var memoryAdapter = new UInt64ResizableDirectMemoryLinks(memory,
31                     ↳ UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep))
32                 {
33                     memoryAdapter.TestBasicMemoryOperations();
34                 }
35
36                 private static void TestBasicMemoryOperations(this ILinks<ulong> memoryAdapter)
37                 {
38                     var link = memoryAdapter.Create();
39                     memoryAdapter.Delete(link);
40
41                     [Fact]
42                     public static void NonexistentReferencesHeapMemoryTest()
43                     {
44                         using (var memory = new
45                             ↳ HeapResizableDirectMemory(UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep))
46                         using (var memoryAdapter = new UInt64ResizableDirectMemoryLinks(memory,
47                             ↳ UInt64ResizableDirectMemoryLinks.DefaultLinksSizeStep))
48                         {
49                             memoryAdapter.TestNonexistentReferences();
50                         }
51
52                         private static void TestNonexistentReferences(this ILinks<ulong> memoryAdapter)
53                         {
54                             var link = memoryAdapter.Create();
55                             memoryAdapter.Update(link, ulong.MaxValue, ulong.MaxValue);
56                             var resultLink = _constants.Null;
57                             memoryAdapter.Each(foundLink =>
58                             {
59                                 resultLink = foundLink[_constants.IndexPart];
60                                 return _constants.Break;
61                             }, _constants.Any, ulong.MaxValue, ulong.MaxValue);
62                             Assert.True(resultLink == link);
63                             Assert.True(memoryAdapter.Count(ulong.MaxValue) == 0);
64                             memoryAdapter.Delete(link);
65                         }
66                     }
67                 }
68             }
69         }
70     }
71 }

```

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

```

1 using Xunit;
2 using Platform.Scopes;
3 using Platform.Memory;
4 using Platform.Data.Doublets.ResizableDirectMemory;
5 using Platform.Data.Doublets.Decorators;
6
7 namespace Platform.Data.Doublets.Tests
8 {
9     public static class ScopeTests
10     {

```

```

11     [Fact]
12     public static void SingleDependencyTest()
13     {
14         using (var scope = new Scope())
15         {
16             scope.IncludeAssemblyOf<IMemory>();
17             var instance = scope.Use<IDirectMemory>();
18             Assert.IsType<HeapResizableDirectMemory>(instance);
19         }
20     }
21
22     [Fact]
23     public static void CascadeDependencyTest()
24     {
25         using (var scope = new Scope())
26         {
27             scope.Include<TemporaryFileMappedResizableDirectMemory>();
28             scope.Include<UInt64ResizableDirectMemoryLinks>();
29             var instance = scope.Use<ILinks<ulong>>();
30             Assert.IsType<UInt64ResizableDirectMemoryLinks>(instance);
31         }
32     }
33
34     [Fact]
35     public static void FullAutoResolutionTest()
36     {
37         using (var scope = new Scope(autoInclude: true, autoExplore: true))
38         {
39             var instance = scope.Use<UInt64Links>();
40             Assert.IsType<UInt64Links>(instance);
41         }
42     }
43 }
44 }

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Diagnostics;
4  using System.Linq;
5  using Xunit;
6  using Platform.Collections;
7  using Platform.Random;
8  using Platform.IO;
9  using Platform.Singletons;
10 using Platform.Data.Constants;
11 using Platform.Data.Doublets.Sequences;
12 using Platform.Data.Doublets.Sequences.Frequencies.Cache;
13 using Platform.Data.Doublets.Sequences.Frequencies.Counters;
14 using Platform.Data.Doublets.Sequences.Converters;
15
16 namespace Platform.Data.Doublets.Tests
17 {
18     public static class SequencesTests
19     {
20         private static readonly LinksCombinedConstants<bool, ulong, int> _constants =
21             ↪ Default<LinksCombinedConstants<bool, ulong, int>>.Instance;
22
23         static SequencesTests()
24         {
25             // Trigger static constructor to not mess with performance measurements
26             _ = BitString.GetBitMaskFromIndex(1);
27         }
28
29         [Fact]
30         public static void CreateAllVariantsTest()
31         {
32             const long sequenceLength = 8;
33
34             using (var scope = new TempLinksTestScope(useSequences: true))
35             {
36                 var links = scope.Links;
37                 var sequences = scope.Sequences;
38
39                 var sequence = new ulong[sequenceLength];
40                 for (var i = 0; i < sequenceLength; i++)
41                 {
42                     sequence[i] = links.Create();
43                 }
44             }
45         }
46     }
47 }

```

```

44     var sw1 = Stopwatch.StartNew();
45     var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
46
47     var sw2 = Stopwatch.StartNew();
48     var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();
49
50     Assert.True(results1.Count > results2.Length);
51     Assert.True(sw1.Elapsed > sw2.Elapsed);
52
53     for (var i = 0; i < sequenceLength; i++)
54     {
55         links.Delete(sequence[i]);
56     }
57
58     Assert.True(links.Count() == 0);
59 }
60
61
62 //[Fact]
63 //public void CUDTest()
64 //{
65 //    var tempFilename = Path.GetTempFileName();
66
67 //    const long sequenceLength = 8;
68
69 //    const ulong itself = LinksConstants.Itself;
70
71 //    using (var memoryAdapter = new ResizableDirectMemoryLinks(tempFilename,
72 //        ↪ DefaultLinksSizeStep))
73 //    using (var links = new Links(memoryAdapter))
74 //    {
75 //        var sequence = new ulong[sequenceLength];
76 //        for (var i = 0; i < sequenceLength; i++)
77 //            sequence[i] = links.Create(itself, itself);
78
79 //        SequencesOptions o = new SequencesOptions();
80
81 //        TODO: Из числа в bool значения o.UseSequenceMarker = ((value & 1) != 0)
82 //        o.
83
84
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); 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);
146     Assert.True(intersection2.Count == createResults.Length);
147
148     var intersection3 = createResults.Intersect(searchResults3).ToList();
149     Assert.True(intersection3.Count == searchResults3.Count);
150     Assert.True(intersection3.Count == createResults.Length);
151
152     for (var i = 0; i < sequenceLength; i++)
153     {
154         links.Delete(sequence[i]);
155     }
156 }
157
158 [Fact]
159 public static void BalancedVariantSearchTest()
160 {
161     const long sequenceLength = 200;
162
163     using (var scope = new TempLinksTestScope(useSequences: true))
164     {
165         var links = scope.Links;
166         var sequences = scope.Sequences;
167
168         var sequence = new ulong[sequenceLength];
169         for (var i = 0; i < sequenceLength; i++)
170         {
171             sequence[i] = links.Create();
172         }
173
174         var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
175
176         var sw1 = Stopwatch.StartNew();
177         var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();
178
179         var sw2 = Stopwatch.StartNew();
180         var searchResults2 = sequences.GetAllMatchingSequences0(sequence); sw2.Stop();
181
182         var sw3 = Stopwatch.StartNew();
183         var searchResults3 = sequences.GetAllMatchingSequences1(sequence); sw3.Stop();
184
185         // На количестве в 200 элементов это будет занимать вечность
186         //var sw4 = Stopwatch.StartNew();
187         //var searchResults4 = sequences.Each(sequence); sw4.Stop();
188
189         Assert.True(searchResults2.Count == 1 && balancedVariant == searchResults2[0]);
190
191         Assert.True(searchResults3.Count == 1 && balancedVariant ==
192             ↪ searchResults3.First());
193
194         //Assert.True(sw1.Elapsed < sw2.Elapsed);
195
196         for (var i = 0; i < sequenceLength; i++)
197         {
198             links.Delete(sequence[i]);
199         }
200     }

```

```

201 }
202
203 [Fact]
204 public static void AllPartialVariantsSearchTest()
205 {
206     const long sequenceLength = 8;
207
208     using (var scope = new TempLinksTestScope(useSequences: true))
209     {
210         var links = scope.Links;
211         var sequences = scope.Sequences;
212
213         var sequence = new ulong[sequenceLength];
214         for (var i = 0; i < sequenceLength; i++)
215         {
216             sequence[i] = links.Create();
217         }
218
219         var createResults = sequences.CreateAllVariants2(sequence);
220
221         //var createResultsStrings = createResults.Select(x => x + ": " +
222         ↪ sequences.FormatSequence(x)).ToList();
223         //Global.Trash = createResultsStrings;
224
225         var partialSequence = new ulong[sequenceLength - 2];
226
227         Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
228
229         var sw1 = Stopwatch.StartNew();
230         var searchResults1 =
231         ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
232
233         var sw2 = Stopwatch.StartNew();
234         var searchResults2 =
235         ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
236
237         //var sw3 = Stopwatch.StartNew();
238         //var searchResults3 =
239         ↪ sequences.GetAllPartiallyMatchingSequences2(partialSequence); sw3.Stop();
240
241         var sw4 = Stopwatch.StartNew();
242         var searchResults4 =
243         ↪ sequences.GetAllPartiallyMatchingSequences3(partialSequence); sw4.Stop();
244
245         //Global.Trash = searchResults3;
246
247         //var searchResults1Strings = searchResults1.Select(x => x + ": " +
248         ↪ sequences.FormatSequence(x)).ToList();
249         //Global.Trash = searchResults1Strings;
250
251         var intersection1 = createResults.Intersect(searchResults1).ToList();
252         Assert.True(intersection1.Count == createResults.Length);
253
254         var intersection2 = createResults.Intersect(searchResults2).ToList();
255         Assert.True(intersection2.Count == createResults.Length);
256
257         var intersection4 = createResults.Intersect(searchResults4).ToList();
258         Assert.True(intersection4.Count == createResults.Length);
259
260         for (var i = 0; i < sequenceLength; i++)
261         {
262             links.Delete(sequence[i]);
263         }
264     }
265 }
266
267 [Fact]
268 public static void BalancedPartialVariantsSearchTest()
269 {
270     const long sequenceLength = 200;
271
272     using (var scope = new TempLinksTestScope(useSequences: true))
273     {
274         var links = scope.Links;
275         var sequences = scope.Sequences;
276
277         var sequence = new ulong[sequenceLength];
278         for (var i = 0; i < sequenceLength; i++)
279         {
280             sequence[i] = links.Create();
281         }
282     }
283 }

```

```

275     }
276
277     var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
278
279     var balancedVariant = balancedVariantConverter.Convert(sequence);
280
281     var partialSequence = new ulong[sequenceLength - 2];
282
283     Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
284
285     var sw1 = Stopwatch.StartNew();
286     var searchResults1 =
287         ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
288
289     var sw2 = Stopwatch.StartNew();
290     var searchResults2 =
291         ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
292
293     Assert.True(searchResults1.Count == 1 && balancedVariant == searchResults1[0]);
294
295     Assert.True(searchResults2.Count == 1 && balancedVariant ==
296         ↪ searchResults2.First());
297
298     for (var i = 0; i < sequenceLength; i++)
299     {
300         links.Delete(sequence[i]);
301     }
302 }
303
304 [Fact(Skip = "Correct implementation is pending")]
305 public static void PatternMatchTest()
306 {
307     var zeroOrMany = Sequences.Sequences.ZeroOrMany;
308
309     using (var scope = new TempLinksTestScope(useSequences: true))
310     {
311         var links = scope.Links;
312         var sequences = scope.Sequences;
313
314         var e1 = links.Create();
315         var e2 = links.Create();
316
317         var sequence = new[]
318         {
319             e1, e2, e1, e2 // mama / papa
320         };
321
322         var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
323
324         var balancedVariant = balancedVariantConverter.Convert(sequence);
325
326         // 1: [1]
327         // 2: [2]
328         // 3: [1,2]
329         // 4: [1,2,1,2]
330
331         var doublet = links.GetSource(balancedVariant);
332
333         var matchedSequences1 = sequences.MatchPattern(e2, e1, zeroOrMany);
334
335         Assert.True(matchedSequences1.Count == 0);
336
337         var matchedSequences2 = sequences.MatchPattern(zeroOrMany, e2, e1);
338
339         Assert.True(matchedSequences2.Count == 0);
340
341         var matchedSequences3 = sequences.MatchPattern(e1, zeroOrMany, e1);
342
343         Assert.True(matchedSequences3.Count == 0);
344
345         var matchedSequences4 = sequences.MatchPattern(e1, zeroOrMany, e2);
346
347         Assert.Contains(doublet, matchedSequences4);
348         Assert.Contains(balancedVariant, matchedSequences4);
349
350         for (var i = 0; i < sequence.Length; i++)
351         {
352             links.Delete(sequence[i]);
353         }
354     }
355 }

```

```

352     }
353 }
354
355 [Fact]
356 public static void IndexTest()
357 {
358     using (var scope = new TempLinksTestScope(new SequencesOptions<ulong> { UseIndex =
359         ↪ true }, useSequences: true))
360     {
361         var links = scope.Links;
362         var sequences = scope.Sequences;
363         var indexer = sequences.Options.Indexer;
364
365         var e1 = links.Create();
366         var e2 = links.Create();
367
368         var sequence = new[]
369         {
370             e1, e2, e1, e2 // mama / papa
371         };
372
373         Assert.False(indexer.Index(sequence));
374
375         Assert.True(indexer.Index(sequence));
376     }
377
378     /// <summary>Imported from https://raw.githubusercontent.com/Konard/LinksPlatform/%
379     ↪ DO%9E-%D1%82%D0%BE%D0%BC%2C-%D0%BA%D0%B0%D0%BA-%D0%B2%D1%81%D1%91-%D0%BD%D0%B0%D1%87
380     ↪ %D0%B8%D0%BD%D0%B0%D0%BB%D0%BE%D1%81%D1%8C.md</summary>
381     private static readonly string _exampleText =
382         @"([english
383         ↪ version] (https://github.com/Konard/LinksPlatform/wiki/About-the-beginning))

```

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

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

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

![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)

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

![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)

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

![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)

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?

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

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

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

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

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

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

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

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

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

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

419  
420 `[[белая обычная и направленная связи с рекурсивной внутренней структурой, чёрная типизированная`  
→ `связь с рекурсивной внутренней`  
→ `структурой](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/10.png`  
→ `"белая обычная и направленная связи с рекурсивной внутренней структурой, чёрная`  
→ `типизированная связь с рекурсивной внутренней структурой")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/10.png)`

421  
422 На один уровень внутрь (вниз)? Или на один уровень во вне (вверх)? Или это можно назвать шагом  
→ рекурсии или фрактала?

423  
424 `[[белая обычная и направленная связи с двойной рекурсивной внутренней структурой, чёрная`  
→ `типизированная связь с двойной рекурсивной внутренней`  
→ `структурой](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/11.png`  
→ `"белая обычная и направленная связи с двойной рекурсивной внутренней структурой, чёрная`  
→ `типизированная связь с двойной рекурсивной внутренней структурой")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/11.png)`

425  
426 Последовательность? Массив? Список? Множество? Объект? Таблица? Элементы? Цвета? Символы? Буквы?  
→ Слово? Цифры? Число? Алфавит? Дерево? Сеть? Граф? Гиперграф?

427  
428 `[[белая обычная и направленная связи со структурой из 8 цветных элементов последовательности,`  
→ `чёрная типизированная связь со структурой из 8 цветных элементов последовательности](https://`  
→ `/raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/12.png` `"белая обычная и`  
→ `направленная связи со структурой из 8 цветных элементов последовательности, чёрная`  
→ `типизированная связь со структурой из 8 цветных элементов последовательности")](https://raw`  
→ `.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/12.png)`

429  
430 ...

431  
432 `[[анимация](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro-animat`  
→ `ion-500.gif`  
→ `"анимация")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro`  
→ `-animation-500.gif)";`

433



```

434 private static readonly string _exampleLoremIpsumText =
435     @"Lorem ipsum dolor sit amet, consectetur adipiscing elit, sed do eiusmod tempor
436     ↳ incididunt ut labore et dolore magna aliqua.
437 Ut enim ad minim veniam, quis nostrud exercitation ullamco laboris nisi ut aliquip ex ea commodo
438     ↳ consequat.";

```

```

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 }

```

```

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

```

```

562     {
563         compressed2[i] = balancedVariantConverter2.Convert(arrays[i]);
564     }
565
566     var elapsed2 = sw2.Elapsed;
567
568     for (int i = START; i < END; i++)
569     {
570         linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
571     }
572
573     var initialCount3 = scope3.Links.Unsync.Count();
574
575     var sw3 = Stopwatch.StartNew();
576
577     for (int i = START; i < END; i++)
578     {
579         //linkFrequenciesCache3.IncrementFrequencies(arrays[i]);
580         compressed3[i] = optimalVariantConverter.Convert(arrays[i]);
581     }
582
583     var elapsed3 = sw3.Elapsed;
584
585     Console.WriteLine($"Compressor: {elapsed1}, Balanced variant: {elapsed2},
586         ↳ Optimal variant: {elapsed3}");
587
588     // Assert.True(elapsed1 > elapsed2);
589
590     // Checks
591     for (int i = START; i < END; i++)
592     {
593         var sequence1 = compressed1[i];
594         var sequence2 = compressed2[i];
595         var sequence3 = compressed3[i];
596
597         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
598             ↳ scope1.Links.Unsync);
599
600         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
601             ↳ scope2.Links.Unsync);
602
603         var decompress3 = UnicodeMap.FromSequenceLinkToString(sequence3,
604             ↳ scope3.Links.Unsync);
605
606         var structure1 = scope1.Links.Unsync.FormatStructure(sequence1, link =>
607             ↳ link.IsPartialPoint());
608         var structure2 = scope2.Links.Unsync.FormatStructure(sequence2, link =>
609             ↳ link.IsPartialPoint());
610         var structure3 = scope3.Links.Unsync.FormatStructure(sequence3, link =>
611             ↳ link.IsPartialPoint());
612
613         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
614             ↳ arrays[i].Length > 3)
615         //    Assert.False(structure1 == structure2);
616         //if (sequence3 != Constants.Null && sequence2 != Constants.Null &&
617             ↳ arrays[i].Length > 3)
618         //    Assert.False(structure3 == structure2);
619
620         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
621         Assert.True(strings[i] == decompress3 && decompress3 == decompress2);
622     }
623
624     Assert.True((int)(scope1.Links.Unsync.Count() - initialCount1) <
625         ↳ totalCharacters);
626     Assert.True((int)(scope2.Links.Unsync.Count() - initialCount2) <
627         ↳ totalCharacters);
628     Assert.True((int)(scope3.Links.Unsync.Count() - initialCount3) <
629         ↳ totalCharacters);
630
631     Console.WriteLine($"{{(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);

```

```

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

```

```

698 //      // TODO: Find a solution for this case
699 //  }
700 //}
701
702 for (int i = START; i < END; i++)
703 {
704     var first = compressor1.Create(arrays[i]);
705     var second = compressor1.Create(arrays[i]);
706
707     if (first == second)
708     {
709         compressed1[i] = first;
710     }
711     else
712     {
713         // TODO: Find a solution for this case
714     }
715 }
716
717 var elapsed1 = sw1.Elapsed;
718
719 var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
720
721 var sw2 = Stopwatch.StartNew();
722
723 for (int i = START; i < END; i++)
724 {
725     var first = balancedVariantConverter.Convert(arrays[i]);
726     var second = balancedVariantConverter.Convert(arrays[i]);
727
728     if (first == second)
729     {
730         compressed2[i] = first;
731     }
732 }
733
734 var elapsed2 = sw2.Elapsed;
735
736 Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
737 ↪ {elapsed2}");
738
739 Assert.True(elapsed1 > elapsed2);
740
741 // Checks
742 for (int i = START; i < END; i++)
743 {
744     var sequence1 = compressed1[i];
745     var sequence2 = compressed2[i];
746
747     if (sequence1 != _constants.Null && sequence2 != _constants.Null)
748     {
749         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
750 ↪ scope1.Links);
751
752         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
753 ↪ scope2.Links);
754
755         //var structure1 = scope1.Links.FormatStructure(sequence1, link =>
756 ↪ link.IsPartialPoint());
757         //var structure2 = scope2.Links.FormatStructure(sequence2, link =>
758 ↪ link.IsPartialPoint());
759
760         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
761 ↪ arrays[i].Length > 3)
762         //    Assert.False(structure1 == structure2);
763
764         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
765     }
766 }
767
768 Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
769 Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
770
771 Debug.WriteLine($"{{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
772 ↪ totalCharacters}} | {{(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
773 ↪ totalCharacters}}");
774
775 Assert.True(scope1.Links.Count() <= scope2.Links.Count());
776
777
778

```

```

769         //compressor1.ValidateFrequencies();
770     }
771 }
772
773 [Fact]
774 public static void RandomNumbersCompressionQualityTest()
775 {
776     const ulong N = 500;
777
778     //const ulong minNumbers = 10000;
779     //const ulong maxNumbers = 20000;
780
781     //var strings = new List<string>();
782
783     //for (ulong i = 0; i < N; i++)
784     //    strings.Add(RandomHelpers.DefaultFactory.NextUInt64(minNumbers,
785         ↪ maxNumbers).ToString());
786
787     var strings = new List<string>();
788
789     for (ulong i = 0; i < N; i++)
790     {
791         strings.Add(RandomHelpers.Default.NextUInt64().ToString());
792     }
793
794     strings = strings.Distinct().ToList();
795
796     var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
797     var totalCharacters = arrays.Select(x => x.Length).Sum();
798
799     using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
800         ↪ SequencesOptions<ulong> { UseCompression = true,
801         ↪ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
802     using (var scope2 = new TempLinksTestScope(useSequences: true))
803     {
804         scope1.Links.UseUnicode();
805         scope2.Links.UseUnicode();
806
807         var compressor1 = scope1.Sequences;
808         var compressor2 = scope2.Sequences;
809
810         var compressed1 = new ulong[arrays.Length];
811         var compressed2 = new ulong[arrays.Length];
812
813         var sw1 = Stopwatch.StartNew();
814
815         var START = 0;
816         var END = arrays.Length;
817
818         for (int i = START; i < END; i++)
819         {
820             compressed1[i] = compressor1.Create(arrays[i]);
821         }
822
823         var elapsed1 = sw1.Elapsed;
824
825         var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);
826
827         var sw2 = Stopwatch.StartNew();
828
829         for (int i = START; i < END; i++)
830         {
831             compressed2[i] = balancedVariantConverter.Convert(arrays[i]);
832         }
833
834         var elapsed2 = sw2.Elapsed;
835
836         Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
837             ↪ {elapsed2}");
838
839         Assert.True(elapsed1 > elapsed2);
840
841         // Checks
842         for (int i = START; i < END; i++)
843         {
844             var sequence1 = compressed1[i];
845             var sequence2 = compressed2[i];
846
847             if (sequence1 != _constants.Null && sequence2 != _constants.Null)
848             {

```

```

845         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
846             ↪ scope1.Links);
847         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
848             ↪ scope2.Links);
849         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
850     }
851 }
852
853 Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
854 Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
855
856 Debug.WriteLine($"{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
857     ↪ totalCharacters} | {(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
858     ↪ totalCharacters}");
859
860 // Can be worse than balanced variant
861 //Assert.True(scope1.Links.Count() <= scope2.Links.Count());
862 //compressor1.ValidateFrequencies();
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         Global.Trash = createResults;
887
888         for (var i = 0; i < sequenceLength; i++)
889         {
890             links.Delete(sequence[i]);
891         }
892     }
893 }
894
895 [Fact]
896 public static void AllPossibleConnectionsTest()
897 {
898     const long sequenceLength = 5;
899
900     using (var scope = new TempLinksTestScope(useSequences: true))
901     {
902         var links = scope.Links;
903         var sequences = scope.Sequences;
904
905         var sequence = new ulong[sequenceLength];
906         for (var i = 0; i < sequenceLength; i++)
907         {
908             sequence[i] = links.Create();
909         }
910
911         var createResults = sequences.CreateAllVariants2(sequence);
912         var reverseResults = sequences.CreateAllVariants2(sequence.Reverse().ToArray());
913
914         for (var i = 0; i < 1; i++)
915         {
916             var sw1 = Stopwatch.StartNew();
917             var searchResults1 = sequences.GetAllConnections(sequence); sw1.Stop();
918
919

```

```

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

```



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

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

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

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

```

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

```

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