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

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Converters
{
    public class BalancedVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public BalancedVariantConverter(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Convert(IList<TLink> sequence)
        {
            var length = sequence.Count;
            if (length < 1)
            {
                return default;
            }
            if (length == 1)
            {
                return sequence[0];
            }
            // Make copy of next layer
            if (length > 2)
            {
                // TODO: Try to use stackalloc (which at the moment is not working with
                ↪  generics) but will be possible with Sigil
                var halvedSequence = new TLink[(length / 2) + (length % 2)];
                HalveSequence(halvedSequence, sequence, length);
                sequence = halvedSequence;
                length = halvedSequence.Length;
            }
            // Keep creating layer after layer
            while (length > 2)
            {
                HalveSequence(sequence, sequence, length);
                length = (length / 2) + (length % 2);
            }
            return _links.GetOrCreate(sequence[0], sequence[1]);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void HalveSequence(IList<TLink> destination, IList<TLink> source, int length)
        {
            var loopedLength = length - (length % 2);
            for (var i = 0; i < loopedLength; i += 2)
            {
                destination[i / 2] = _links.GetOrCreate(source[i], source[i + 1]);
            }
            if (length > loopedLength)
            {
                destination[length / 2] = source[length - 1];
            }
        }
    }
}
```

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

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections;
using Platform.Converters;
using Platform.Singletons;
using Platform.Numbers;
using Platform.Data.Doublets.Sequences.Frequencies.Cache;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Converters
{
    /// <remarks>
    /// TODO: Возможно будет лучше если алгоритм будет выполняться полностью изолированно от
    ↪  Links на этапе сжатия.
    ///     А именно будет создаваться временный список пар необходимых для выполнения сжатия, в
    ↪  таком случае тип значения элемента массива может быть любым, как char так и ulong.
```

```
17      ///     Как только список/словарь пар был выявлен можно разом выполнить создание всех этих
        ↪  пар, а так же разом выполнить замену.
18      /// </remarks>
19      public class CompressingConverter<TLink> : LinksListToSequenceConverterBase<TLink>
20      {
21          private static readonly LinksConstants<TLink> _constants =
            ↪  Default<LinksConstants<TLink>>.Instance;
22          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪  EqualityComparer<TLink>.Default;
23          private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;
24
25          private static readonly TLink _zero = default;
26          private static readonly TLink _one = Arithmetic.Increment(_zero);
27
28          private readonly IConverter<IList<TLink>, TLink> _baseConverter;
29          private readonly LinkFrequenciesCache<TLink> _doubletFrequenciesCache;
30          private readonly TLink _minFrequencyToCompress;
31          private readonly bool _doInitialFrequenciesIncrement;
32          private Doublet<TLink> _maxDoublet;
33          private LinkFrequency<TLink> _maxDoubletData;
34
35          private struct HalfDoublet
36          {
37              public TLink Element;
38              public LinkFrequency<TLink> DoubletData;
39
40              [MethodImpl(MethodImplOptions.AggressiveInlining)]
41              public HalfDoublet(TLink element, LinkFrequency<TLink> doubletData)
42              {
43                  Element = element;
44                  DoubletData = doubletData;
45              }
46
47              public override string ToString() => $"{Element}: ({DoubletData})";
48          }
49
50          [MethodImpl(MethodImplOptions.AggressiveInlining)]
51          public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
            ↪  baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache)
52              : this(links, baseConverter, doubletFrequenciesCache, _one, true) { }
53
54          [MethodImpl(MethodImplOptions.AggressiveInlining)]
55          public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
            ↪  baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, bool
            ↪  doInitialFrequenciesIncrement)
56              : this(links, baseConverter, doubletFrequenciesCache, _one,
                ↪  doInitialFrequenciesIncrement) { }
57
58          [MethodImpl(MethodImplOptions.AggressiveInlining)]
59          public CompressingConverter(ILinks<TLink> links, IConverter<IList<TLink>, TLink>
            ↪  baseConverter, LinkFrequenciesCache<TLink> doubletFrequenciesCache, TLink
            ↪  minFrequencyToCompress, bool doInitialFrequenciesIncrement)
60              : base(links)
61          {
62              _baseConverter = baseConverter;
63              _doubletFrequenciesCache = doubletFrequenciesCache;
64              if (_comparer.Compare(minFrequencyToCompress, _one) < 0)
65              {
66                  minFrequencyToCompress = _one;
67              }
68              _minFrequencyToCompress = minFrequencyToCompress;
69              _doInitialFrequenciesIncrement = doInitialFrequenciesIncrement;
70              ResetMaxDoublet();
71          }
72
73          [MethodImpl(MethodImplOptions.AggressiveInlining)]
74          public override TLink Convert(IList<TLink> source) =>
            ↪  _baseConverter.Convert(Compress(source));
75
76          /// <remarks>
77          /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte_pair_encoding .
78          /// Faster version (doublets' frequencies dictionary is not recreated).
79          /// </remarks>
80          [MethodImpl(MethodImplOptions.AggressiveInlining)]
81          private IList<TLink> Compress(IList<TLink> sequence)
82          {
83              if (sequence.IsNullOrEmpty())
84              {
85                  return null;
86              }
```

```
            if (sequence.Count == 1)
            {
                return sequence;
            }
            if (sequence.Count == 2)
            {
                return new[] { _links.GetOrCreate(sequence[0], sequence[1]) };
            }
            // TODO: arraypool with min size (to improve cache locality) or stackallow with Sigil
            var copy = new HalfDoublet[sequence.Count];
            Doublet<TLink> doublet = default;
            for (var i = 1; i < sequence.Count; i++)
            {
                doublet = new Doublet<TLink>(sequence[i - 1], sequence[i]);
                LinkFrequency<TLink> data;
                if (_doInitialFrequenciesIncrement)
                {
                    data = _doubletFrequenciesCache.IncrementFrequency(ref doublet);
                }
                else
                {
                    data = _doubletFrequenciesCache.GetFrequency(ref doublet);
                    if (data == null)
                    {
                        throw new NotSupportedException("If you ask not to increment
                        ↪  frequencies, it is expected that all frequencies for the sequence
                        ↪  are prepared.");
                    }
                }
                copy[i - 1].Element = sequence[i - 1];
                copy[i - 1].DoubletData = data;
                UpdateMaxDoublet(ref doublet, data);
            }
            copy[sequence.Count - 1].Element = sequence[sequence.Count - 1];
            copy[sequence.Count - 1].DoubletData = new LinkFrequency<TLink>();
            if (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
            {
                var newLength = ReplaceDoublets(copy);
                sequence = new TLink[newLength];
                for (int i = 0; i < newLength; i++)
                {
                    sequence[i] = copy[i].Element;
                }
            }
            return sequence;
        }

        /// <remarks>
        /// Original algorithm idea: https://en.wikipedia.org/wiki/Byte_pair_encoding
        /// </remarks>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private int ReplaceDoublets(HalfDoublet[] copy)
        {
            var oldLength = copy.Length;
            var newLength = copy.Length;
            while (_comparer.Compare(_maxDoubletData.Frequency, default) > 0)
            {
                var maxDoubletSource = _maxDoublet.Source;
                var maxDoubletTarget = _maxDoublet.Target;
                if (_equalityComparer.Equals(_maxDoubletData.Link, _constants.Null))
                {
                    _maxDoubletData.Link = _links.GetOrCreate(maxDoubletSource,
                    ↪  maxDoubletTarget);
                }
                var maxDoubletReplacementLink = _maxDoubletData.Link;
                oldLength--;
                var oldLengthMinusTwo = oldLength - 1;
                // Substitute all usages
                int w = 0, r = 0; // (r == read, w == write)
                for (; r < oldLength; r++)
                {
                    if (_equalityComparer.Equals(copy[r].Element, maxDoubletSource) &&
                    ↪  _equalityComparer.Equals(copy[r + 1].Element, maxDoubletTarget))
                    {
                        if (r > 0)
                        {
                            var previous = copy[w - 1].Element;
                            copy[w - 1].DoubletData.DecrementFrequency();
```

```
                            copy[w - 1].DoubletData =
                            ↪  _doubletFrequenciesCache.IncrementFrequency(previous,
                            ↪  maxDoubletReplacementLink);
                        }
                        if (r < oldLengthMinusTwo)
                        {
                            var next = copy[r + 2].Element;
                            copy[r + 1].DoubletData.DecrementFrequency();
                            copy[w].DoubletData = _doubletFrequenciesCache.IncrementFrequency(ma
                            ↪  xDoubletReplacementLink,
                            ↪  next);
                        }
                        copy[w++].Element = maxDoubletReplacementLink;
                        r++;
                        newLength--;
                    }
                    else
                    {
                        copy[w++] = copy[r];
                    }
                }
                if (w < newLength)
                {
                    copy[w] = copy[r];
                }
                oldLength = newLength;
                ResetMaxDoublet();
                UpdateMaxDoublet(copy, newLength);
            }
            return newLength;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void ResetMaxDoublet()
        {
            _maxDoublet = new Doublet<TLink>();
            _maxDoubletData = new LinkFrequency<TLink>();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void UpdateMaxDoublet(HalfDoublet[] copy, int length)
        {
            Doublet<TLink> doublet = default;
            for (var i = 1; i < length; i++)
            {
                doublet = new Doublet<TLink>(copy[i - 1].Element, copy[i].Element);
                UpdateMaxDoublet(ref doublet, copy[i - 1].DoubletData);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void UpdateMaxDoublet(ref Doublet<TLink> doublet, LinkFrequency<TLink> data)
        {
            var frequency = data.Frequency;
            var maxFrequency = _maxDoubletData.Frequency;
            //if (frequency > _minFrequencyToCompress && (maxFrequency < frequency ||
            ↪  (maxFrequency == frequency && doublet.Source + doublet.Target < /* gives better
            ↪  compression string data (and gives collisions quickly) */ _maxDoublet.Source +
            ↪  _maxDoublet.Target)))
            if (_comparer.Compare(frequency, _minFrequencyToCompress) > 0 &&
               (_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 rundom
                ↪  numbers data (but gives collisions anyway) */
            {
                _maxDoublet = doublet;
                _maxDoubletData = data;
            }
        }
    }
}
```

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

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;
```

```

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Converters
{
    public abstract class LinksListToSequenceConverterBase<TLink> : LinksOperatorBase<TLink>,
    ↪  IConverter<IList<TLink>, TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected LinksListToSequenceConverterBase(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public abstract TLink Convert(IList<TLink> source);
    }
}
```

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

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Lists;
using Platform.Converters;
using Platform.Data.Doublets.Sequences.Frequencies.Cache;
using Platform.Data.Doublets.Sequences.Frequencies.Counters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Converters
{
    public class OptimalVariantConverter<TLink> : LinksListToSequenceConverterBase<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;
        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;

        private readonly IConverter<IList<TLink>> _sequenceToItsLocalElementLevelsConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public OptimalVariantConverter(ILinks<TLink> links, IConverter<IList<TLink>>
        ↪  sequenceToItsLocalElementLevelsConverter) : base(links)
            => _sequenceToItsLocalElementLevelsConverter =
            ↪  sequenceToItsLocalElementLevelsConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public OptimalVariantConverter(ILinks<TLink> links, LinkFrequenciesCache<TLink>
        ↪  linkFrequenciesCache)
            : this(links, new SequenceToItsLocalElementLevelsConverter<TLink>(links, new Frequen
            ↪  ciesCacheBasedLinkToItsFrequencyNumberConverter<TLink>(linkFrequenciesCache))) {
            ↪  }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public OptimalVariantConverter(ILinks<TLink> links)
            : this(links, new LinkFrequenciesCache<TLink>(links, new
            ↪  TotalSequenceSymbolFrequencyCounter<TLink>(links))) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Convert(IList<TLink> sequence)
        {
            var length = sequence.Count;
            if (length == 1)
            {
                return sequence[0];
            }
            if (length == 2)
            {
                return _links.GetOrCreate(sequence[0], sequence[1]);
            }
            sequence = sequence.ToArray();
            var levels = _sequenceToItsLocalElementLevelsConverter.Convert(sequence);
            while (length > 2)
            {
                var levelRepeat = 1;
                var currentLevel = levels[0];
                var previousLevel = levels[0];
                var skipOnce = false;
                var w = 0;
                for (var i = 1; i < length; i++)
                {
                    if (_equalityComparer.Equals(currentLevel, levels[i]))
                    {
                        levelRepeat++;
```

```
                        skipOnce = false;
                        if (levelRepeat == 2)
                        {
                            sequence[w] = _links.GetOrCreate(sequence[i - 1], sequence[i]);
                            var newLevel = i >= length - 1 ?
                                GetPreviousLowerThanCurrentOrCurrent(previousLevel,
                                ↪ currentLevel) :
                                i < 2 ?
                                GetNextLowerThanCurrentOrCurrent(currentLevel, levels[i + 1]) :
                                GetGreatestNeigbourLowerThanCurrentOrCurrent(previousLevel,
                                ↪ currentLevel, levels[i + 1]);
                            levels[w] = newLevel;
                            previousLevel = currentLevel;
                            w++;
                            levelRepeat = 0;
                            skipOnce = true;
                        }
                        else if (i == length - 1)
                        {
                            sequence[w] = sequence[i];
                            levels[w] = levels[i];
                            w++;
                        }
                    }
                    else
                    {
                        currentLevel = levels[i];
                        levelRepeat = 1;
                        if (skipOnce)
                        {
                            skipOnce = false;
                        }
                        else
                        {
                            sequence[w] = sequence[i - 1];
                            levels[w] = levels[i - 1];
                            previousLevel = levels[w];
                            w++;
                        }
                        if (i == length - 1)
                        {
                            sequence[w] = sequence[i];
                            levels[w] = levels[i];
                            w++;
                        }
                    }
                }
                length = w;
            }
            return _links.GetOrCreate(sequence[0], sequence[1]);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static TLink GetGreatestNeigbourLowerThanCurrentOrCurrent(TLink previous, TLink
        ↪ current, TLink next)
        {
            return _comparer.Compare(previous, next) > 0
                ? _comparer.Compare(previous, current) < 0 ? previous : current
                : _comparer.Compare(next, current) < 0 ? next : current;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static TLink GetNextLowerThanCurrentOrCurrent(TLink current, TLink next) =>
        ↪ _comparer.Compare(next, current) < 0 ? next : current;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static TLink GetPreviousLowerThanCurrentOrCurrent(TLink previous, TLink current)
        ↪ => _comparer.Compare(previous, current) < 0 ? previous : current;
    }
}
```

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

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Converters
```

```
{
    public class SequenceToItsLocalElementLevelsConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<IList<TLink>>
    {
        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;

        private readonly IConverter<Doublet<TLink>, TLink> _linkToItsFrequencyToNumberConveter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SequenceToItsLocalElementLevelsConverter(ILinks<TLink> links,
        ↪ IConverter<Doublet<TLink>, TLink> linkToItsFrequencyToNumberConveter) : base(links)
        ↪ => _linkToItsFrequencyToNumberConveter = linkToItsFrequencyToNumberConveter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public IList<TLink> Convert(IList<TLink> sequence)
        {
            var levels = new TLink[sequence.Count];
            levels[0] = GetFrequencyNumber(sequence[0], sequence[1]);
            for (var i = 1; i < sequence.Count - 1; i++)
            {
                var previous = GetFrequencyNumber(sequence[i - 1], sequence[i]);
                var next = GetFrequencyNumber(sequence[i], sequence[i + 1]);
                levels[i] = _comparer.Compare(previous, next) > 0 ? previous : next;
            }
            levels[levels.Length - 1] = GetFrequencyNumber(sequence[sequence.Count - 2],
            ↪ sequence[sequence.Count - 1]);
            return levels;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink GetFrequencyNumber(TLink source, TLink target) =>
        ↪ _linkToItsFrequencyToNumberConveter.Convert(new Doublet<TLink>(source, target));
    }
}
```

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

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.CriterionMatchers
{
    public class DefaultSequenceElementCriterionMatcher<TLink> : LinksOperatorBase<TLink>,
    ↪ ICriterionMatcher<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DefaultSequenceElementCriterionMatcher(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool IsMatched(TLink argument) => _links.IsPartialPoint(argument);
    }
}
```

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

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.CriterionMatchers
{
    public class MarkedSequenceCriterionMatcher<TLink> : ICriterionMatcher<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;

        private readonly ILinks<TLink> _links;
        private readonly TLink _sequenceMarkerLink;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public MarkedSequenceCriterionMatcher(ILinks<TLink> links, TLink sequenceMarkerLink)
        {
            _links = links;
            _sequenceMarkerLink = sequenceMarkerLink;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool IsMatched(TLink sequenceCandidate)
```

```
            => _equalityComparer.Equals(_links.GetSource(sequenceCandidate), _sequenceMarkerLink)
            || !_equalityComparer.Equals(_links.SearchOrDefault(_sequenceMarkerLink,
            ↪  sequenceCandidate), _links.Constants.Null);
    }
}
```

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

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Stacks;
using Platform.Data.Doublets.Sequences.HeightProviders;
using Platform.Data.Sequences;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    public class DefaultSequenceAppender<TLink> : LinksOperatorBase<TLink>,
    ↪  ISequenceAppender<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly IStack<TLink> _stack;
        private readonly ISequenceHeightProvider<TLink> _heightProvider;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DefaultSequenceAppender(ILinks<TLink> links, IStack<TLink> stack,
        ↪  ISequenceHeightProvider<TLink> heightProvider)
            : base(links)
        {
            _stack = stack;
            _heightProvider = heightProvider;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Append(TLink sequence, TLink appendant)
        {
            var cursor = sequence;
            var links = _links;
            while (!_equalityComparer.Equals(_heightProvider.Get(cursor), default))
            {
                var source = links.GetSource(cursor);
                var target = links.GetTarget(cursor);
                if (_equalityComparer.Equals(_heightProvider.Get(source),
                ↪  _heightProvider.Get(target)))
                {
                    break;
                }
                else
                {
                    _stack.Push(source);
                    cursor = target;
                }
            }
            var left = cursor;
            var right = appendant;
            while (!_equalityComparer.Equals(cursor = _stack.PopOrDefault(),
            ↪  links.Constants.Null))
            {
                right = links.GetOrCreate(left, right);
                left = cursor;
            }
            return links.GetOrCreate(left, right);
        }
    }
}
```

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

```
using System.Collections.Generic;
using System.Linq;
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    public class DuplicateSegmentsCounter<TLink> : ICounter<int>
    {
```

```
        private readonly IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
        ↪ _duplicateFragmentsProvider;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DuplicateSegmentsCounter(IProvider<IList<KeyValuePair<IList<TLink>,
        ↪ IList<TLink>>>> duplicateFragmentsProvider) => _duplicateFragmentsProvider =
        ↪ duplicateFragmentsProvider;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public int Count() => _duplicateFragmentsProvider.Get().Sum(x => x.Value.Count);
    }
}
```

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

```
using System;
using System.Linq;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Collections;
using Platform.Collections.Lists;
using Platform.Collections.Segments;
using Platform.Collections.Segments.Walkers;
using Platform.Singletons;
using Platform.Converters;
using Platform.Data.Doublets.Unicode;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    public class DuplicateSegmentsProvider<TLink> :
    ↪ DictionaryBasedDuplicateSegmentsWalkerBase<TLink>,
    ↪ IProvider<IList<KeyValuePair<IList<TLink>, IList<TLink>>>>
    {
        private static readonly UncheckedConverter<TLink, long> _addressToInt64Converter =
        ↪ UncheckedConverter<TLink, long>.Default;
        private static readonly UncheckedConverter<TLink, ulong> _addressToUInt64Converter =
        ↪ UncheckedConverter<TLink, ulong>.Default;
        private static readonly UncheckedConverter<ulong, TLink> _uInt64ToAddressConverter =
        ↪ UncheckedConverter<ulong, TLink>.Default;

        private readonly ILinks<TLink> _links;
        private readonly ILinks<TLink> _sequences;
        private HashSet<KeyValuePair<IList<TLink>, IList<TLink>>> _groups;
        private BitString _visited;

        private class ItemEquilityComparer : IEqualityComparer<KeyValuePair<IList<TLink>,
        ↪ IList<TLink>>>
        {
            private readonly IListEqualityComparer<TLink> _listComparer;

            public ItemEquilityComparer() => _listComparer =
            ↪ Default<IListEqualityComparer<TLink>>.Instance;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            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);

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public int GetHashCode(KeyValuePair<IList<TLink>, IList<TLink>> pair) =>
            ↪ (_listComparer.GetHashCode(pair.Key),
            ↪ _listComparer.GetHashCode(pair.Value)).GetHashCode();
        }

        private class ItemComparer : IComparer<KeyValuePair<IList<TLink>, IList<TLink>>>
        {
            private readonly IListComparer<TLink> _listComparer;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public ItemComparer() => _listComparer = Default<IListComparer<TLink>>.Instance;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public int Compare(KeyValuePair<IList<TLink>, IList<TLink>> left,
            ↪ KeyValuePair<IList<TLink>, IList<TLink>> right)
            {
                var intermediateResult = _listComparer.Compare(left.Key, right.Key);
                if (intermediateResult == 0)
```

```
                {
                    intermediateResult = _listComparer.Compare(left.Value, right.Value);
                }
                return intermediateResult;
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DuplicateSegmentsProvider(ILinks<TLink> links, ILinks<TLink> sequences)
            : base(minimumStringSegmentLength: 2)
        {
            _links = links;
            _sequences = sequences;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public IList<KeyValuePair<IList<TLink>, IList<TLink>>> Get()
        {
            _groups = new HashSet<KeyValuePair<IList<TLink>,
            ↪  IList<TLink>>>(Default<ItemEquilityComparer>.Instance);
            var links = _links;
            var count = links.Count();
            _visited = new BitString(_addressToInt64Converter.Convert(count) + 1L);
            links.Each(link =>
            {
                var linkIndex = links.GetIndex(link);
                var linkBitIndex = _addressToInt64Converter.Convert(linkIndex);
                var constants = links.Constants;
                if (!_visited.Get(linkBitIndex))
                {
                    var sequenceElements = new List<TLink>();
                    var filler = new ListFiller<TLink, TLink>(sequenceElements, constants.Break);
                    _sequences.Each(filler.AddSkipFirstAndReturnConstant, new
                    ↪  LinkAddress<TLink>(linkIndex));
                    if (sequenceElements.Count > 2)
                    {
                        WalkAll(sequenceElements);
                    }
                }
                return constants.Continue;
            });
            var resultList = _groups.ToList();
            var comparer = Default<ItemComparer>.Instance;
            resultList.Sort(comparer);
#if DEBUG
            foreach (var item in resultList)
            {
                PrintDuplicates(item);
            }
#endif
            return resultList;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override Segment<TLink> CreateSegment(IList<TLink> elements, int offset, int
        ↪  length) => new Segment<TLink>(elements, offset, length);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void OnDublicateFound(Segment<TLink> segment)
        {
            var duplicates = CollectDuplicatesForSegment(segment);
            if (duplicates.Count > 1)
            {
                _groups.Add(new KeyValuePair<IList<TLink>, IList<TLink>>(segment.ToArray(),
                ↪  duplicates));
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private List<TLink> CollectDuplicatesForSegment(Segment<TLink> segment)
        {
            var duplicates = new List<TLink>();
            var readAsElement = new HashSet<TLink>();
            var restrictions = segment.ShiftRight();
            var constants = _links.Constants;
            restrictions[0] = constants.Any;
            _sequences.Each(sequence =>
            {
                var sequenceIndex = sequence[constants.IndexPart];
```

```
                duplicates.Add(sequenceIndex);
                readAsElement.Add(sequenceIndex);
                return constants.Continue;
            }, restrictions);
            if (duplicates.Any(x => _visited.Get(_addressToInt64Converter.Convert(x))))
            {
                return new List<TLink>();
            }
            foreach (var duplicate in duplicates)
            {
                var duplicateBitIndex = _addressToInt64Converter.Convert(duplicate);
                _visited.Set(duplicateBitIndex);
            }
            if (_sequences is Sequences sequencesExperiments)
            {
                var partiallyMatched = sequencesExperiments.GetAllPartiallyMatchingSequences4((HashSet<ulong>)(object)readAsElement,
                (IList<ulong>)segment);
                foreach (var partiallyMatchedSequence in partiallyMatched)
                {
                    var sequenceIndex =
                    _uInt64ToAddressConverter.Convert(partiallyMatchedSequence);
                    duplicates.Add(sequenceIndex);
                }
            }
            duplicates.Sort();
            return duplicates;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void PrintDuplicates(KeyValuePair<IList<TLink>, IList<TLink>> duplicatesItem)
        {
            if (!(_links is ILinks<ulong> ulongLinks))
            {
                return;
            }
            var duplicatesKey = duplicatesItem.Key;
            var keyString = UnicodeMap.FromLinksToString((IList<ulong>)duplicatesKey);
            Console.WriteLine($"> {keyString} ({string.Join(", ", duplicatesKey)})");
            var duplicatesList = duplicatesItem.Value;
            for (int i = 0; i < duplicatesList.Count; i++)
            {
                var sequenceIndex = _addressToUInt64Converter.Convert(duplicatesList[i]);
                var formatedSequenceStructure = ulongLinks.FormatStructure(sequenceIndex, x =>
                Point<ulong>.IsPartialPoint(x), (sb, link) => _ =
                UnicodeMap.IsCharLink(link.Index) ?
                sb.Append(UnicodeMap.FromLinkToChar(link.Index)) : sb.Append(link.Index));
                Console.WriteLine(formatedSequenceStructure);
                var sequenceString = UnicodeMap.FromSequenceLinkToString(sequenceIndex,
                ulongLinks);
                Console.WriteLine(sequenceString);
            }
            Console.WriteLine();
        }
    }
}
```

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

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
{
    /// <remarks>
    /// Can be used to operate with many CompressingConverters (to keep global frequencies data
    between them).
    /// TODO: Extract interface to implement frequencies storage inside Links storage
    /// </remarks>
    public class LinkFrequenciesCache<TLink> : LinksOperatorBase<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        EqualityComparer<TLink>.Default;
        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;

```

```
20          private static readonly TLink _zero = default;
21          private static readonly TLink _one = Arithmetic.Increment(_zero);
22
23          private readonly Dictionary<Doublet<TLink>, LinkFrequency<TLink>> _doubletsCache;
24          private readonly ICounter<TLink, TLink> _frequencyCounter;
25
26          [MethodImpl(MethodImplOptions.AggressiveInlining)]
27          public LinkFrequenciesCache(ILinks<TLink> links, ICounter<TLink, TLink> frequencyCounter)
28              : base(links)
29          {
30              _doubletsCache = new Dictionary<Doublet<TLink>, LinkFrequency<TLink>>(4096,
                ↪  DoubletComparer<TLink>.Default);
31              _frequencyCounter = frequencyCounter;
32          }
33
34          [MethodImpl(MethodImplOptions.AggressiveInlining)]
35          public LinkFrequency<TLink> GetFrequency(TLink source, TLink target)
36          {
37              var doublet = new Doublet<TLink>(source, target);
38              return GetFrequency(ref doublet);
39          }
40
41          [MethodImpl(MethodImplOptions.AggressiveInlining)]
42          public LinkFrequency<TLink> GetFrequency(ref Doublet<TLink> doublet)
43          {
44              _doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data);
45              return data;
46          }
47
48          [MethodImpl(MethodImplOptions.AggressiveInlining)]
49          public void IncrementFrequencies(IList<TLink> sequence)
50          {
51              for (var i = 1; i < sequence.Count; i++)
52              {
53                  IncrementFrequency(sequence[i - 1], sequence[i]);
54              }
55          }
56
57          [MethodImpl(MethodImplOptions.AggressiveInlining)]
58          public LinkFrequency<TLink> IncrementFrequency(TLink source, TLink target)
59          {
60              var doublet = new Doublet<TLink>(source, target);
61              return IncrementFrequency(ref doublet);
62          }
63
64          [MethodImpl(MethodImplOptions.AggressiveInlining)]
65          public void PrintFrequencies(IList<TLink> sequence)
66          {
67              for (var i = 1; i < sequence.Count; i++)
68              {
69                  PrintFrequency(sequence[i - 1], sequence[i]);
70              }
71          }
72
73          [MethodImpl(MethodImplOptions.AggressiveInlining)]
74          public void PrintFrequency(TLink source, TLink target)
75          {
76              var number = GetFrequency(source, target).Frequency;
77              Console.WriteLine("({0},{1}) - {2}", source, target, number);
78          }
79
80          [MethodImpl(MethodImplOptions.AggressiveInlining)]
81          public LinkFrequency<TLink> IncrementFrequency(ref Doublet<TLink> doublet)
82          {
83              if (_doubletsCache.TryGetValue(doublet, out LinkFrequency<TLink> data))
84              {
85                  data.IncrementFrequency();
86              }
87              else
88              {
89                  var link = _links.SearchOrDefault(doublet.Source, doublet.Target);
90                  data = new LinkFrequency<TLink>(_one, link);
91                  if (!_equalityComparer.Equals(link, default))
92                  {
93                      data.Frequency = Arithmetic.Add(data.Frequency,
                        ↪  _frequencyCounter.Count(link));
94                  }
95                  _doubletsCache.Add(doublet, data);
96              }
```

```
            return data;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void ValidateFrequencies()
        {
            foreach (var entry in _doubletsCache)
            {
                var value = entry.Value;
                var linkIndex = value.Link;
                if (!_equalityComparer.Equals(linkIndex, default))
                {
                    var frequency = value.Frequency;
                    var count = _frequencyCounter.Count(linkIndex);
                    // TODO: Why `frequency` always greater than `count` by 1?
                    if (((_comparer.Compare(frequency, count) > 0) &&
                     ↪  (_comparer.Compare(Arithmetic.Subtract(frequency, count), _one) > 0))
                      || ((_comparer.Compare(count, frequency) > 0) &&
                       ↪  (_comparer.Compare(Arithmetic.Subtract(count, frequency), _one) > 0)))
                    {
                        throw new InvalidOperationException("Frequencies validation failed.");
                    }
                }
                //else
                //{
                //    if (value.Frequency > 0)
                //    {
                //        var frequency = value.Frequency;
                //        linkIndex = _createLink(entry.Key.Source, entry.Key.Target);
                //        var count = _countLinkFrequency(linkIndex);

                //        if ((frequency > count && frequency - count > 1) || (count > frequency
                 ↪  && count - frequency > 1))
                //            throw new InvalidOperationException("Frequencies validation
                 ↪  failed.");
                //    }
                //}
            }
        }
    }
}
```

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

```
using System.Runtime.CompilerServices;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
{
    public class LinkFrequency<TLink>
    {
        public TLink Frequency { get; set; }
        public TLink Link { get; set; }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkFrequency(TLink frequency, TLink link)
        {
            Frequency = frequency;
            Link = link;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkFrequency() { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void IncrementFrequency() => Frequency = Arithmetic<TLink>.Increment(Frequency);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void DecrementFrequency() => Frequency = Arithmetic<TLink>.Decrement(Frequency);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override string ToString() => $"F: {Frequency}, L: {Link}";
    }
}
```

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

```
using System.Runtime.CompilerServices;
using Platform.Converters;
```

```

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Cache
{
    public class FrequenciesCacheBasedLinkToItsFrequencyNumberConverter<TLink> :
    ↪ IConverter<Doublet<TLink>, TLink>
    {
        private readonly LinkFrequenciesCache<TLink> _cache;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public
        ↪ FrequenciesCacheBasedLinkToItsFrequencyNumberConverter(LinkFrequenciesCache<TLink>
        ↪ cache) => _cache = cache;

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

1.14 ./csharp/Platform.Data.Doublets.Sequences/Frequencies/Counters/MarkedSequenceSymbolFrequencyOneOf

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class MarkedSequenceSymbolFrequencyOneOffCounter<TLink> :
    ↪ SequenceSymbolFrequencyOneOffCounter<TLink>
    {
        private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public MarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
        ↪ ICriterionMatcher<TLink> markedSequenceMatcher, TLink sequenceLink, TLink symbol)
            : base(links, sequenceLink, symbol)
            => _markedSequenceMatcher = markedSequenceMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override TLink Count()
        {
            if (!_markedSequenceMatcher.IsMatched(_sequenceLink))
            {
                return default;
            }
            return base.Count();
        }
    }
}
```

1.15 ./csharp/Platform.Data.Doublets.Sequences/Frequencies/Counters/SequenceSymbolFrequencyOneOffCounte

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Numbers;
using Platform.Data.Sequences;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class SequenceSymbolFrequencyOneOffCounter<TLink> : ICounter<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;
        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;

        protected readonly ILinks<TLink> _links;
        protected readonly TLink _sequenceLink;
        protected readonly TLink _symbol;
        protected TLink _total;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink sequenceLink,
        ↪ TLink symbol)
        {
            _links = links;
            _sequenceLink = sequenceLink;
            _symbol = symbol;
```

```
            _total = default;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual TLink Count()
        {
            if (_comparer.Compare(_total, default) > 0)
            {
                return _total;
            }
            StopableSequenceWalker.WalkRight(_sequenceLink, _links.GetSource, _links.GetTarget,
            ↪  IsElement, VisitElement);
            return _total;
        }

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

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool VisitElement(TLink element)
        {
            if (_equalityComparer.Equals(element, _symbol))
            {
                _total = Arithmetic.Increment(_total);
            }
            return true;
        }
    }
}
```

1.16 ./csharp/Platform.Data.Doublets.Sequences/Frequencies/Counters/TotalMarkedSequenceSymbolFrequencyC

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class TotalMarkedSequenceSymbolFrequencyCounter<TLink> : ICounter<TLink, TLink>
    {
        private readonly ILinks<TLink> _links;
        private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TotalMarkedSequenceSymbolFrequencyCounter(ILinks<TLink> links,
        ↪  ICriterionMatcher<TLink> markedSequenceMatcher)
        {
            _links = links;
            _markedSequenceMatcher = markedSequenceMatcher;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Count(TLink argument) => new
        ↪  TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
        ↪  _markedSequenceMatcher, argument).Count();
    }
}
```

1.17 ./csharp/Platform.Data.Doublets.Sequences/Frequencies/Counters/TotalMarkedSequenceSymbolFrequencyO

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class TotalMarkedSequenceSymbolFrequencyOneOffCounter<TLink> :
    ↪  TotalSequenceSymbolFrequencyOneOffCounter<TLink>
    {
        private readonly ICriterionMatcher<TLink> _markedSequenceMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TotalMarkedSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links,
        ↪  ICriterionMatcher<TLink> markedSequenceMatcher, TLink symbol)
            : base(links, symbol)
            => _markedSequenceMatcher = markedSequenceMatcher;
```

```

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override void CountSequenceSymbolFrequency(TLink link)
        {
            var symbolFrequencyCounter = new
            ↪  MarkedSequenceSymbolFrequencyOneOffCounter<TLink>(_links,
            ↪  _markedSequenceMatcher, link, _symbol);
            _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
        }
    }
}
```

1.18 ./csharp/Platform.Data.Doublets.Sequences/Frequencies/Counters/TotalSequenceSymbolFrequencyCounter.

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class TotalSequenceSymbolFrequencyCounter<TLink> : ICounter<TLink, TLink>
    {
        private readonly ILinks<TLink> _links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TotalSequenceSymbolFrequencyCounter(ILinks<TLink> links) => _links = links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Count(TLink symbol) => new
        ↪  TotalSequenceSymbolFrequencyOneOffCounter<TLink>(_links, symbol).Count();
    }
}
```

1.19 ./csharp/Platform.Data.Doublets.Sequences/Frequencies/Counters/TotalSequenceSymbolFrequencyOneOffC

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Frequencies.Counters
{
    public class TotalSequenceSymbolFrequencyOneOffCounter<TLink> : ICounter<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;
        private static readonly Comparer<TLink> _comparer = Comparer<TLink>.Default;

        protected readonly ILinks<TLink> _links;
        protected readonly TLink _symbol;
        protected readonly HashSet<TLink> _visits;
        protected TLink _total;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TotalSequenceSymbolFrequencyOneOffCounter(ILinks<TLink> links, TLink symbol)
        {
            _links = links;
            _symbol = symbol;
            _visits = new HashSet<TLink>();
            _total = default;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Count()
        {
            if (_comparer.Compare(_total, default) > 0 || _visits.Count > 0)
            {
                return _total;
            }
            CountCore(_symbol);
            return _total;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void CountCore(TLink link)
        {
            var any = _links.Constants.Any;
            if (_equalityComparer.Equals(_links.Count(any, link), default))
            {
```

```
                CountSequenceSymbolFrequency(link);
            }
            else
            {
                _links.Each(EachElementHandler, any, link);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual void CountSequenceSymbolFrequency(TLink link)
        {
            var symbolFrequencyCounter = new SequenceSymbolFrequencyOneOffCounter<TLink>(_links,
            ↪  link, _symbol);
            _total = Arithmetic.Add(_total, symbolFrequencyCounter.Count());
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private TLink EachElementHandler(IList<TLink> doublet)
        {
            var constants = _links.Constants;
            var doubletIndex = doublet[constants.IndexPart];
            if (_visits.Add(doubletIndex))
            {
                CountCore(doubletIndex);
            }
            return constants.Continue;
        }
    }
}
```

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

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.HeightProviders
{
    public class CachedSequenceHeightProvider<TLink> : ISequenceHeightProvider<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly TLink _heightPropertyMarker;
        private readonly ISequenceHeightProvider<TLink> _baseHeightProvider;
        private readonly IConverter<TLink> _addressToUnaryNumberConverter;
        private readonly IConverter<TLink> _unaryNumberToAddressConverter;
        private readonly IProperties<TLink, TLink, TLink> _propertyOperator;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public CachedSequenceHeightProvider(
            ISequenceHeightProvider<TLink> baseHeightProvider,
            IConverter<TLink> addressToUnaryNumberConverter,
            IConverter<TLink> unaryNumberToAddressConverter,
            TLink heightPropertyMarker,
            IProperties<TLink, TLink, TLink> propertyOperator)
        {
            _heightPropertyMarker = heightPropertyMarker;
            _baseHeightProvider = baseHeightProvider;
            _addressToUnaryNumberConverter = addressToUnaryNumberConverter;
            _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
            _propertyOperator = propertyOperator;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Get(TLink sequence)
        {
            TLink height;
            var heightValue = _propertyOperator.GetValue(sequence, _heightPropertyMarker);
            if (_equalityComparer.Equals(heightValue, default))
            {
                height = _baseHeightProvider.Get(sequence);
                heightValue = _addressToUnaryNumberConverter.Convert(height);
                _propertyOperator.SetValue(sequence, _heightPropertyMarker, heightValue);
            }
            else
            {
                height = _unaryNumberToAddressConverter.Convert(heightValue);
```

```
            }
            return height;
        }
    }
}
```

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

```
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.HeightProviders
{
    public class DefaultSequenceRightHeightProvider<TLink> : LinksOperatorBase<TLink>,
    ↪ ISequenceHeightProvider<TLink>
    {
        private readonly ICriterionMatcher<TLink> _elementMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DefaultSequenceRightHeightProvider(ILinks<TLink> links, ICriterionMatcher<TLink>
        ↪ elementMatcher) : base(links) => _elementMatcher = elementMatcher;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Get(TLink sequence)
        {
            var height = default(TLink);
            var pairOrElement = sequence;
            while (!_elementMatcher.IsMatched(pairOrElement))
            {
                pairOrElement = _links.GetTarget(pairOrElement);
                height = Arithmetic.Increment(height);
            }
            return height;
        }
    }
}
```

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

```
using Platform.Interfaces;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.HeightProviders
{
    public interface ISequenceHeightProvider<TLink> : IProvider<TLink, TLink>
    {
    }
}
```

1.23 ./csharp/Platform.Data.Doublets.Sequences/Incrementers/FrequencyIncrementer.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Incrementers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Incrementers
{
    public class FrequencyIncrementer<TLink> : LinksOperatorBase<TLink>, IIncrementer<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;

        private readonly TLink _frequencyMarker;
        private readonly TLink _unaryOne;
        private readonly IIncrementer<TLink> _unaryNumberIncrementer;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public FrequencyIncrementer(ILinks<TLink> links, TLink frequencyMarker, TLink unaryOne,
        ↪ IIncrementer<TLink> unaryNumberIncrementer)
            : base(links)
        {
            _frequencyMarker = frequencyMarker;
            _unaryOne = unaryOne;
            _unaryNumberIncrementer = unaryNumberIncrementer;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
27          public TLink Increment(TLink frequency)
28          {
29              var links = _links;
30              if (_equalityComparer.Equals(frequency, default))
31              {
32                  return links.GetOrCreate(_unaryOne, _frequencyMarker);
33              }
34              var incrementedSource =
                ↪  _unaryNumberIncrementer.Increment(links.GetSource(frequency));
35              return links.GetOrCreate(incrementedSource, _frequencyMarker);
36          }
37      }
38  }
```

1.24 ./csharp/Platform.Data.Doublets.Sequences/Incrementers/UnaryNumberIncrementer.cs

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

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

```
1   using System.Collections.Generic;
2   using System.Runtime.CompilerServices;
3   using Platform.Data.Doublets.Sequences.Frequencies.Cache;
4
5   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7   namespace Platform.Data.Doublets.Sequences.Indexes
8   {
9       public class CachedFrequencyIncrementingSequenceIndex<TLink> : ISequenceIndex<TLink>
10      {
11          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪  EqualityComparer<TLink>.Default;
12
13          private readonly LinkFrequenciesCache<TLink> _cache;
14
15          [MethodImpl(MethodImplOptions.AggressiveInlining)]
16          public CachedFrequencyIncrementingSequenceIndex(LinkFrequenciesCache<TLink> cache) =>
            ↪  _cache = cache;
17
18          [MethodImpl(MethodImplOptions.AggressiveInlining)]
19          public bool Add(IList<TLink> sequence)
20          {
21              var indexed = true;
```

```
            var i = sequence.Count;
            while (--i >= 1 && (indexed = IsIndexedWithIncrement(sequence[i - 1], sequence[i])))
            ↪  { }
            for (; i >= 1; i--)
            {
                _cache.IncrementFrequency(sequence[i - 1], sequence[i]);
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool IsIndexedWithIncrement(TLink source, TLink target)
        {
            var frequency = _cache.GetFrequency(source, target);
            if (frequency == null)
            {
                return false;
            }
            var indexed = !_equalityComparer.Equals(frequency.Frequency, default);
            if (indexed)
            {
                _cache.IncrementFrequency(source, target);
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool MightContain(IList<TLink> sequence)
        {
            var indexed = true;
            var i = sequence.Count;
            while (--i >= 1 && (indexed = IsIndexed(sequence[i - 1], sequence[i]))) { }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool IsIndexed(TLink source, TLink target)
        {
            var frequency = _cache.GetFrequency(source, target);
            if (frequency == null)
            {
                return false;
            }
            return !_equalityComparer.Equals(frequency.Frequency, default);
        }
    }
}
```

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

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Incrementers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public class FrequencyIncrementingSequenceIndex<TLink> : SequenceIndex<TLink>,
    ↪  ISequenceIndex<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly IProperty<TLink, TLink> _frequencyPropertyOperator;
        private readonly IIncrementer<TLink> _frequencyIncrementer;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public FrequencyIncrementingSequenceIndex(ILinks<TLink> links, IProperty<TLink, TLink>
        ↪  frequencyPropertyOperator, IIncrementer<TLink> frequencyIncrementer)
            : base(links)
        {
            _frequencyPropertyOperator = frequencyPropertyOperator;
            _frequencyIncrementer = frequencyIncrementer;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public override bool Add(IList<TLink> sequence)
        {
            var indexed = true;
```

```
            var i = sequence.Count;
            while (--i >= 1 && (indexed = IsIndexedWithIncrement(sequence[i - 1], sequence[i])))
            ↪  { }
            for (; i >= 1; i--)
            {
                Increment(_links.GetOrCreate(sequence[i - 1], sequence[i]));
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool IsIndexedWithIncrement(TLink source, TLink target)
        {
            var link = _links.SearchOrDefault(source, target);
            var indexed = !_equalityComparer.Equals(link, default);
            if (indexed)
            {
                Increment(link);
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void Increment(TLink link)
        {
            var previousFrequency = _frequencyPropertyOperator.Get(link);
            var frequency = _frequencyIncrementer.Increment(previousFrequency);
            _frequencyPropertyOperator.Set(link, frequency);
        }
    }
}
```

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

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public interface ISequenceIndex<TLink>
    {
        /// <summary>
        /// Индексирует последовательность глобально, и возвращает значение,
        /// определяющие была ли запрошенная последовательность проиндексирована ранее.
        /// </summary>
        /// <param name="sequence">Последовательность для индексации.</param>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        bool Add(IList<TLink> sequence);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        bool MightContain(IList<TLink> sequence);
    }
}
```

1.28 ./csharp/Platform.Data.Doublets.Sequences/Indexes/SequenceIndex.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public class SequenceIndex<TLink> : LinksOperatorBase<TLink>, ISequenceIndex<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SequenceIndex(ILinks<TLink> links) : base(links) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual bool Add(IList<TLink> sequence)
        {
            var indexed = true;
            var i = sequence.Count;
            while (--i >= 1 && (indexed =
            ↪  !_equalityComparer.Equals(_links.SearchOrDefault(sequence[i - 1], sequence[i]),
            ↪  default))) { }
```

```
            for (; i >= 1; i--)
            {
                _links.GetOrCreate(sequence[i - 1], sequence[i]);
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual bool MightContain(IList<TLink> sequence)
        {
            var indexed = true;
            var i = sequence.Count;
            while (--i >= 1 && (indexed =
            ↪  !_equalityComparer.Equals(_links.SearchOrDefault(sequence[i - 1], sequence[i]),
            ↪  default))) { }
            return indexed;
        }
    }
}
```

1.29 ./csharp/Platform.Data.Doublets.Sequences/Indexes/SynchronizedSequenceIndex.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public class SynchronizedSequenceIndex<TLink> : ISequenceIndex<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly ISynchronizedLinks<TLink> _links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public SynchronizedSequenceIndex(ISynchronizedLinks<TLink> links) => _links = links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Add(IList<TLink> sequence)
        {
            var indexed = true;
            var i = sequence.Count;
            var links = _links.Unsync;
            _links.SyncRoot.ExecuteReadOperation(() =>
            {
                while (--i >= 1 && (indexed =
                ↪  !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
                ↪  sequence[i]), default))) { }
            });
            if (!indexed)
            {
                _links.SyncRoot.ExecuteWriteOperation(() =>
                {
                    for (; i >= 1; i--)
                    {
                        links.GetOrCreate(sequence[i - 1], sequence[i]);
                    }
                });
            }
            return indexed;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool MightContain(IList<TLink> sequence)
        {
            var links = _links.Unsync;
            return _links.SyncRoot.ExecuteReadOperation(() =>
            {
                var indexed = true;
                var i = sequence.Count;
                while (--i >= 1 && (indexed =
                ↪  !_equalityComparer.Equals(links.SearchOrDefault(sequence[i - 1],
                ↪  sequence[i]), default))) { }
                return indexed;
            });
        }
    }
}
```

1.30 ./csharp/Platform.Data.Doublets.Sequences/Indexes/Unindex.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Indexes
{
    public class Unindex<TLink> : ISequenceIndex<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual bool Add(IList<TLink> sequence) => false;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public virtual bool MightContain(IList<TLink> sequence) => true;
    }
}
```

1.31 ./csharp/Platform.Data.Doublets.Sequences/Numbers/Rational/DecimalToRationalConverter.cs

```
using System.Numerics;
using Platform.Converters;
using Platform.Data.Doublets.Decorators;
using System.Globalization;
using Platform.Data.Doublets.Numbers.Raw;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Rational
{
    public class DecimalToRationalConverter<TLink> : LinksDecoratorBase<TLink>,
    ↪  IConverter<decimal, TLink>
        where TLink: struct
    {
        public readonly BigIntegerToRawNumberSequenceConverter<TLink>
        ↪  BigIntegerToRawNumberSequenceConverter;

        public DecimalToRationalConverter(ILinks<TLink> links,
        ↪  BigIntegerToRawNumberSequenceConverter<TLink>
        ↪  bigIntegerToRawNumberSequenceConverter) : base(links)
        {
            BigIntegerToRawNumberSequenceConverter = bigIntegerToRawNumberSequenceConverter;
        }

        public TLink Convert(decimal @decimal)
        {
            var decimalAsString = @decimal.ToString(CultureInfo.InvariantCulture);
            var dotPosition = decimalAsString.IndexOf('.');
            var decimalWithoutDots = decimalAsString;
            int digitsAfterDot = 0;
            if (dotPosition != -1)
            {
                decimalWithoutDots = decimalWithoutDots.Remove(dotPosition, 1);
                digitsAfterDot = decimalAsString.Length - 1 - dotPosition;
            }
            BigInteger denominator = new(System.Math.Pow(10, digitsAfterDot));
            BigInteger numerator = BigInteger.Parse(decimalWithoutDots);
            BigInteger greatestCommonDivisor;
            do
            {
                greatestCommonDivisor = BigInteger.GreatestCommonDivisor(numerator, denominator);
                numerator /= greatestCommonDivisor;
                denominator /= greatestCommonDivisor;
            }
            while (greatestCommonDivisor > 1);
            var numeratorLink = BigIntegerToRawNumberSequenceConverter.Convert(numerator);
            var denominatorLink = BigIntegerToRawNumberSequenceConverter.Convert(denominator);
            return _links.GetOrCreate(numeratorLink, denominatorLink);
        }
    }
}
```

1.32 ./csharp/Platform.Data.Doublets.Sequences/Numbers/Rational/RationalToDecimalConverter.cs

```
using Platform.Converters;
using Platform.Data.Doublets.Decorators;
using Platform.Data.Doublets.Numbers.Raw;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Rational
{
```

```
    public class RationalToDecimalConverter<TLink> : LinksDecoratorBase<TLink>,
    ↪ IConverter<TLink, decimal>
        where TLink: struct
    {
        public readonly RawNumberSequenceToBigIntegerConverter<TLink>
        ↪ RawNumberSequenceToBigIntegerConverter;

        public RationalToDecimalConverter(ILinks<TLink> links,
        ↪ RawNumberSequenceToBigIntegerConverter<TLink>
        ↪ rawNumberSequenceToBigIntegerConverter) : base(links)
        {
            RawNumberSequenceToBigIntegerConverter = rawNumberSequenceToBigIntegerConverter;
        }

        public decimal Convert(TLink rationalNumber)
        {
            var numerator = (decimal)RawNumberSequenceToBigIntegerConverter.Convert(_links.GetSo
            ↪ urce(rationalNumber));
            var denominator = (decimal)RawNumberSequenceToBigIntegerConverter.Convert(_links.Get
            ↪ Target(rationalNumber));
            return numerator / denominator;
        }
    }
}
```

1.33 ./csharp/Platform.Data.Doublets.Sequences/Numbers/Raw/BigIntegerToRawNumberSequenceConverter.cs

```
using System.Collections.Generic;
using System.Numerics;
using Platform.Converters;
using Platform.Data.Doublets.Decorators;
using Platform.Numbers;
using Platform.Reflection;
using Platform.Unsafe;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Raw
{
    public class BigIntegerToRawNumberSequenceConverter<TLink> : LinksDecoratorBase<TLink>,
    ↪ IConverter<BigInteger, TLink>
        where TLink : struct
    {
        public static readonly TLink MaximumValue = NumericType<TLink>.MaxValue;
        public static readonly TLink BitMask = Bit.ShiftRight(MaximumValue, 1);
        public readonly IConverter<TLink> AddressToNumberConverter;
        public readonly IConverter<IList<TLink>, TLink> ListToSequenceConverter;
        public readonly TLink NegativeNumberMarker;

        public BigIntegerToRawNumberSequenceConverter(ILinks<TLink> links, IConverter<TLink>
        ↪ addressToNumberConverter, IConverter<IList<TLink>,TLink> listToSequenceConverter,
        ↪ TLink negativeNumberMarker) : base(links)
        {
            AddressToNumberConverter = addressToNumberConverter;
            ListToSequenceConverter = listToSequenceConverter;
            NegativeNumberMarker = negativeNumberMarker;
        }

        private List<TLink> GetRawNumberParts(BigInteger bigInteger)
        {
            List<TLink> rawNumbers = new();
            BigInteger currentBigInt = bigInteger;
            do
            {
                var bigIntBytes = currentBigInt.ToByteArray();
                var bigIntWithBitMask = Bit.And(bigIntBytes.ToStructure<TLink>(), BitMask);
                var rawNumber = AddressToNumberConverter.Convert(bigIntWithBitMask);
                rawNumbers.Add(rawNumber);
                currentBigInt >>= 63;
            }
            while (currentBigInt > 0);
            return rawNumbers;
        }

        public TLink Convert(BigInteger bigInteger)
        {
            var sign = bigInteger.Sign;
            var number = GetRawNumberParts(sign == -1 ? BigInteger.Negate(bigInteger) :
            ↪ bigInteger);
            var numberSequence = ListToSequenceConverter.Convert(number);
```

```
            return sign == -1 ? _links.GetOrCreate(NegativeNumberMarker, numberSequence) :
            ↪ numberSequence;
        }
    }
}
```

1.34 ./csharp/Platform.Data.Doublets.Sequences/Numbers/Raw/LongRawNumberSequenceToNumberConverter.c

```
using System.Runtime.CompilerServices;
using Platform.Collections.Stacks;
using Platform.Converters;
using Platform.Numbers;
using Platform.Reflection;
using Platform.Data.Doublets.Decorators;
using Platform.Data.Doublets.Sequences.Walkers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Raw
{
    public class LongRawNumberSequenceToNumberConverter<TSource, TTarget> :
    ↪ LinksDecoratorBase<TSource>, IConverter<TSource, TTarget>
    {
        private static readonly int _bitsPerRawNumber = NumericType<TSource>.BitsSize - 1;
        private static readonly UncheckedConverter<TSource, TTarget> _sourceToTargetConverter =
        ↪ UncheckedConverter<TSource, TTarget>.Default;

        private readonly IConverter<TSource> _numberToAddressConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LongRawNumberSequenceToNumberConverter(ILinks<TSource> links, IConverter<TSource>
        ↪ numberToAddressConverter) : base(links) => _numberToAddressConverter =
        ↪ numberToAddressConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TTarget Convert(TSource source)
        {
            var constants = Links.Constants;
            var externalReferencesRange = constants.ExternalReferencesRange;
            if (externalReferencesRange.HasValue &&
            ↪ externalReferencesRange.Value.Contains(source))
            {
                return
                ↪ _sourceToTargetConverter.Convert(_numberToAddressConverter.Convert(source));
            }
            else
            {
                var pair = Links.GetLink(source);
                var walker = new LeftSequenceWalker<TSource>(Links, new DefaultStack<TSource>(),
                ↪ (link) => externalReferencesRange.HasValue &&
                ↪ externalReferencesRange.Value.Contains(link));
                TTarget result = default;
                foreach (var element in walker.Walk(source))
                {
                    result = Bit.Or(Bit.ShiftLeft(result, _bitsPerRawNumber), Convert(element));
                }
                return result;
            }
        }
    }
}
```

1.35 ./csharp/Platform.Data.Doublets.Sequences/Numbers/Raw/NumberToLongRawNumberSequenceConverter.c

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;
using Platform.Numbers;
using Platform.Reflection;
using Platform.Data.Doublets.Decorators;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Raw
{
    public class NumberToLongRawNumberSequenceConverter<TSource, TTarget> :
    ↪ LinksDecoratorBase<TTarget>, IConverter<TSource, TTarget>
    {
        private static readonly Comparer<TSource> _comparer = Comparer<TSource>.Default;
        private static readonly TSource _maximumValue = NumericType<TSource>.MaxValue;
        private static readonly int _bitsPerRawNumber = NumericType<TTarget>.BitsSize - 1;
        private static readonly TSource _bitMask = Bit.ShiftRight(_maximumValue,
        ↪ NumericType<TTarget>.BitsSize + 1);
```

```
        private static readonly TSource _maximumConvertableAddress = CheckedConverter<TTarget,
        ↪  TSource>.Default.Convert(Arithmetic.Decrement(Hybrid<TTarget>.ExternalZero));
        private static readonly UncheckedConverter<TSource, TTarget> _sourceToTargetConverter =
        ↪  UncheckedConverter<TSource, TTarget>.Default;

        private readonly IConverter<TTarget> _addressToNumberConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public NumberToLongRawNumberSequenceConverter(ILinks<TTarget> links, IConverter<TTarget>
        ↪  addressToNumberConverter) : base(links) => _addressToNumberConverter =
        ↪  addressToNumberConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TTarget Convert(TSource source)
        {
            if (_comparer.Compare(source, _maximumConvertableAddress) > 0)
            {
                var numberPart = Bit.And(source, _bitMask);
                var convertedNumber = _addressToNumberConverter.Convert(_sourceToTargetConverter
                ↪  .Convert(numberPart));
                return Links.GetOrCreate(convertedNumber, Convert(Bit.ShiftRight(source,
                ↪  _bitsPerRawNumber)));
            }
            else
            {
                return
                ↪  _addressToNumberConverter.Convert(_sourceToTargetConverter.Convert(source));
            }
        }
    }
}
```

1.36 ./csharp/Platform.Data.Doublets.Sequences/Numbers/Raw/RawNumberSequenceToBigIntergerConverter.cs

```
using System;
using System.Collections.Generic;
using System.Numerics;
using Platform.Collections.Stacks;
using Platform.Converters;
using Platform.Data.Doublets.Decorators;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Unsafe;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Raw
{
    public class RawNumberSequenceToBigIntegerConverter<TLink> : LinksDecoratorBase<TLink>,
    ↪  IConverter<TLink, BigInteger>
        where TLink : struct
    {
        public readonly EqualityComparer<TLink> EqualityComparer =
        ↪  EqualityComparer<TLink>.Default;
        public readonly IConverter<TLink, TLink> NumberToAddressConverter;
        public readonly LeftSequenceWalker<TLink> LeftSequenceWalker;
        public readonly TLink NegativeNumberMarker;

        public RawNumberSequenceToBigIntegerConverter(ILinks<TLink> links, IConverter<TLink,
        ↪  TLink> numberToAddressConverter, TLink negativeNumberMarker) : base(links)
        {
            NumberToAddressConverter = numberToAddressConverter;
            LeftSequenceWalker = new(links, new DefaultStack<TLink>());
            NegativeNumberMarker = negativeNumberMarker;
        }

        public BigInteger Convert(TLink bigInteger)
        {
            var sign = 1;
            var bigIntegerSequence = bigInteger;
            if (EqualityComparer.Equals(_links.GetSource(bigIntegerSequence),
            ↪  NegativeNumberMarker))
            {
                sign = -1;
                bigIntegerSequence = _links.GetTarget(bigInteger);
            }
            using var enumerator = LeftSequenceWalker.Walk(bigIntegerSequence).GetEnumerator();
            if (!enumerator.MoveNext())
            {
                throw new Exception("Raw number sequence cannot be empty.");
            }
            var nextPart = NumberToAddressConverter.Convert(enumerator.Current);
```

```
            BigInteger currentBigInt = new(nextPart.ToBytes());
            while (enumerator.MoveNext())
            {
                currentBigInt <<= 63;
                nextPart = NumberToAddressConverter.Convert(enumerator.Current);
                currentBigInt |= new BigInteger(nextPart.ToBytes());
            }
            return sign == -1 ? BigInteger.Negate(currentBigInt) : currentBigInt;
        }
    }
}
```

1.37 ./csharp/Platform.Data.Doublets.Sequences/Numbers/Unary/AddressToUnaryNumberConverter.cs

```
using System.Collections.Generic;
using Platform.Reflection;
using Platform.Converters;
using Platform.Numbers;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Unary
{
    public class AddressToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;
        private static readonly TLink _zero = default;
        private static readonly TLink _one = Arithmetic.Increment(_zero);

        private readonly IConverter<int, TLink> _powerOf2ToUnaryNumberConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public AddressToUnaryNumberConverter(ILinks<TLink> links, IConverter<int, TLink>
        ↪ powerOf2ToUnaryNumberConverter) : base(links) => _powerOf2ToUnaryNumberConverter =
        ↪ powerOf2ToUnaryNumberConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(TLink number)
        {
            var links = _links;
            var nullConstant = links.Constants.Null;
            var target = nullConstant;
            for (var i = 0; !_equalityComparer.Equals(number, _zero) && i <
            ↪ NumericType<TLink>.BitsSize; i++)
            {
                if (_equalityComparer.Equals(Bit.And(number, _one), _one))
                {
                    target = _equalityComparer.Equals(target, nullConstant)
                        ? _powerOf2ToUnaryNumberConverter.Convert(i)
                        : links.GetOrCreate(_powerOf2ToUnaryNumberConverter.Convert(i), target);
                }
                number = Bit.ShiftRight(number, 1);
            }
            return target;
        }
    }
}
```

1.38 ./csharp/Platform.Data.Doublets.Sequences/Numbers/Unary/LinkToItsFrequencyNumberConveter.cs

```
using System;
using System.Collections.Generic;
using Platform.Interfaces;
using Platform.Converters;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Unary
{
    public class LinkToItsFrequencyNumberConveter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<Doublet<TLink>, TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;

        private readonly IProperty<TLink, TLink> _frequencyPropertyOperator;
        private readonly IConverter<TLink> _unaryNumberToAddressConverter;

```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LinkToItsFrequencyNumberConveter(
            ILinks<TLink> links,
            IProperty<TLink, TLink> frequencyPropertyOperator,
            IConverter<TLink> unaryNumberToAddressConverter)
            : base(links)
        {
            _frequencyPropertyOperator = frequencyPropertyOperator;
            _unaryNumberToAddressConverter = unaryNumberToAddressConverter;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(Doublet<TLink> doublet)
        {
            var links = _links;
            var link = links.SearchOrDefault(doublet.Source, doublet.Target);
            if (_equalityComparer.Equals(link, default))
            {
                throw new ArgumentException($"Link ({doublet}) not found.", nameof(doublet));
            }
            var frequency = _frequencyPropertyOperator.Get(link);
            if (_equalityComparer.Equals(frequency, default))
            {
                return default;
            }
            var frequencyNumber = links.GetSource(frequency);
            return _unaryNumberToAddressConverter.Convert(frequencyNumber);
        }
    }
}
```

1.39 ./csharp/Platform.Data.Doublets.Sequences/Numbers/Unary/PowerOf2ToUnaryNumberConverter.cs

```
using System.Collections.Generic;
using Platform.Exceptions;
using Platform.Ranges;
using Platform.Converters;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Unary
{
    public class PowerOf2ToUnaryNumberConverter<TLink> : LinksOperatorBase<TLink>,
    ↪  IConverter<int, TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly TLink[] _unaryNumberPowersOf2;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public PowerOf2ToUnaryNumberConverter(ILinks<TLink> links, TLink one) : base(links)
        {
            _unaryNumberPowersOf2 = new TLink[64];
            _unaryNumberPowersOf2[0] = one;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(int power)
        {
            Ensure.Always.ArgumentInRange(power, new Range<int>(0, _unaryNumberPowersOf2.Length
            ↪  - 1), nameof(power));
            if (!_equalityComparer.Equals(_unaryNumberPowersOf2[power], default))
            {
                return _unaryNumberPowersOf2[power];
            }
            var previousPowerOf2 = Convert(power - 1);
            var powerOf2 = _links.GetOrCreate(previousPowerOf2, previousPowerOf2);
            _unaryNumberPowersOf2[power] = powerOf2;
            return powerOf2;
        }
    }
}
```

1.40 ./csharp/Platform.Data.Doublets.Sequences/Numbers/Unary/UnaryNumberToAddressAddOperationConverte

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;
using Platform.Numbers;
```

```
5
6   #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
7
8   namespace Platform.Data.Doublets.Numbers.Unary
9   {
10      public class UnaryNumberToAddressAddOperationConverter<TLink> : LinksOperatorBase<TLink>,
        ↪  IConverter<TLink>
11      {
12          private static readonly EqualityComparer<TLink> _equalityComparer =
            ↪  EqualityComparer<TLink>.Default;
13          private static readonly UncheckedConverter<TLink, ulong> _addressToUInt64Converter =
            ↪  UncheckedConverter<TLink, ulong>.Default;
14          private static readonly UncheckedConverter<ulong, TLink> _uInt64ToAddressConverter =
            ↪  UncheckedConverter<ulong, TLink>.Default;
15          private static readonly TLink _zero = default;
16          private static readonly TLink _one = Arithmetic.Increment(_zero);
17
18          private readonly Dictionary<TLink, TLink> _unaryToUInt64;
19          private readonly TLink _unaryOne;
20
21          [MethodImpl(MethodImplOptions.AggressiveInlining)]
22          public UnaryNumberToAddressAddOperationConverter(ILinks<TLink> links, TLink unaryOne)
23              : base(links)
24          {
25              _unaryOne = unaryOne;
26              _unaryToUInt64 = CreateUnaryToUInt64Dictionary(links, unaryOne);
27          }
28
29          [MethodImpl(MethodImplOptions.AggressiveInlining)]
30          public TLink Convert(TLink unaryNumber)
31          {
32              if (_equalityComparer.Equals(unaryNumber, default))
33              {
34                  return default;
35              }
36              if (_equalityComparer.Equals(unaryNumber, _unaryOne))
37              {
38                  return _one;
39              }
40              var links = _links;
41              var source = links.GetSource(unaryNumber);
42              var target = links.GetTarget(unaryNumber);
43              if (_equalityComparer.Equals(source, target))
44              {
45                  return _unaryToUInt64[unaryNumber];
46              }
47              else
48              {
49                  var result = _unaryToUInt64[source];
50                  TLink lastValue;
51                  while (!_unaryToUInt64.TryGetValue(target, out lastValue))
52                  {
53                      source = links.GetSource(target);
54                      result = Arithmetic<TLink>.Add(result, _unaryToUInt64[source]);
55                      target = links.GetTarget(target);
56                  }
57                  result = Arithmetic<TLink>.Add(result, lastValue);
58                  return result;
59              }
60          }
61
62          [MethodImpl(MethodImplOptions.AggressiveInlining)]
63          private static Dictionary<TLink, TLink> CreateUnaryToUInt64Dictionary(ILinks<TLink>
            ↪  links, TLink unaryOne)
64          {
65              var unaryToUInt64 = new Dictionary<TLink, TLink>
66              {
67                  { unaryOne, _one }
68              };
69              var unary = unaryOne;
70              var number = _one;
71              for (var i = 1; i < 64; i++)
72              {
73                  unary = links.GetOrCreate(unary, unary);
74                  number = Double(number);
75                  unaryToUInt64.Add(unary, number);
76              }
77              return unaryToUInt64;
78          }
79
```

```
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static TLink Double(TLink number) =>
        ↪ _uInt64ToAddressConverter.Convert(_addressToUInt64Converter.Convert(number) * 2UL);
    }
}
```

1.41 ./csharp/Platform.Data.Doublets.Sequences/Numbers/Unary/UnaryNumberToAddressOrOperationConverter

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Reflection;
using Platform.Converters;
using Platform.Numbers;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Numbers.Unary
{
    public class UnaryNumberToAddressOrOperationConverter<TLink> : LinksOperatorBase<TLink>,
    ↪ IConverter<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪ EqualityComparer<TLink>.Default;
        private static readonly TLink _zero = default;
        private static readonly TLink _one = Arithmetic.Increment(_zero);

        private readonly IDictionary<TLink, int> _unaryNumberPowerOf2Indicies;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnaryNumberToAddressOrOperationConverter(ILinks<TLink> links, IConverter<int,
        ↪ TLink> powerOf2ToUnaryNumberConverter) : base(links) => _unaryNumberPowerOf2Indicies
        ↪ = CreateUnaryNumberPowerOf2IndiciesDictionary(powerOf2ToUnaryNumberConverter);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(TLink sourceNumber)
        {
            var links = _links;
            var nullConstant = links.Constants.Null;
            var source = sourceNumber;
            var target = nullConstant;
            if (!_equalityComparer.Equals(source, nullConstant))
            {
                while (true)
                {
                    if (_unaryNumberPowerOf2Indicies.TryGetValue(source, out int powerOf2Index))
                    {
                        SetBit(ref target, powerOf2Index);
                        break;
                    }
                    else
                    {
                        powerOf2Index = _unaryNumberPowerOf2Indicies[links.GetSource(source)];
                        SetBit(ref target, powerOf2Index);
                        source = links.GetTarget(source);
                    }
                }
            }
            return target;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static Dictionary<TLink, int>
        ↪ CreateUnaryNumberPowerOf2IndiciesDictionary(IConverter<int, TLink>
        ↪ powerOf2ToUnaryNumberConverter)
        {
            var unaryNumberPowerOf2Indicies = new Dictionary<TLink, int>();
            for (int i = 0; i < NumericType<TLink>.BitsSize; i++)
            {
                unaryNumberPowerOf2Indicies.Add(powerOf2ToUnaryNumberConverter.Convert(i), i);
            }
            return unaryNumberPowerOf2Indicies;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static void SetBit(ref TLink target, int powerOf2Index) => target =
        ↪ Bit.Or(target, Bit.ShiftLeft(_one, powerOf2Index));
    }
}
```

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

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using System.Linq;
using System.Text;
using Platform.Collections;
using Platform.Collections.Sets;
using Platform.Collections.Stacks;
using Platform.Data.Exceptions;
using Platform.Data.Sequences;
using Platform.Data.Doublets.Sequences.Frequencies.Counters;
using Platform.Data.Doublets.Sequences.Walkers;
using LinkIndex = System.UInt64;
using Stack = System.Collections.Generic.Stack<ulong>;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    partial class Sequences
    {
        #region Create All Variants (Not Practical)

        /// <remarks>
        /// Number of links that is needed to generate all variants for
        /// sequence of length N corresponds to https://oeis.org/A014143/list sequence.
        /// </remarks>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ulong[] CreateAllVariants2(ulong[] sequence)
        {
            return _sync.ExecuteWriteOperation(() =>
            {
                if (sequence.IsNullOrEmpty())
                {
                    return Array.Empty<ulong>();
                }
                Links.EnsureLinkExists(sequence);
                if (sequence.Length == 1)
                {
                    return sequence;
                }
                return CreateAllVariants2Core(sequence, 0, (ulong)sequence.Length - 1);
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private ulong[] CreateAllVariants2Core(ulong[] sequence, ulong startAt, ulong stopAt)
        {
            if ((stopAt - startAt) == 0)
            {
                return new[] { sequence[startAt] };
            }
            if ((stopAt - startAt) == 1)
            {
                return new[] { Links.Unsync.GetOrCreate(sequence[startAt], sequence[stopAt]) };
            }
            var variants = new ulong[Platform.Numbers.Math.Catalan(stopAt - startAt)];
            var last = 0;
            for (var splitter = startAt; splitter < stopAt; splitter++)
            {
                var left = CreateAllVariants2Core(sequence, startAt, splitter);
                var right = CreateAllVariants2Core(sequence, splitter + 1, stopAt);
                for (var i = 0; i < left.Length; i++)
                {
                    for (var j = 0; j < right.Length; j++)
                    {
                        var variant = Links.Unsync.GetOrCreate(left[i], right[j]);
                        if (variant == Constants.Null)
                        {
                            throw new NotImplementedException("Creation cancellation is not
                            ↪  implemented.");
                        }
                        variants[last++] = variant;
                    }
                }
            }
            return variants;
        }
```

```
78
79          [MethodImpl(MethodImplOptions.AggressiveInlining)]
80          public List<ulong> CreateAllVariants1(params ulong[] sequence)
81          {
82              return _sync.ExecuteWriteOperation(() =>
83              {
84                  if (sequence.IsNullOrEmpty())
85                  {
86                      return new List<ulong>();
87                  }
88                  Links.Unsync.EnsureLinkExists(sequence);
89                  if (sequence.Length == 1)
90                  {
91                      return new List<ulong> { sequence[0] };
92                  }
93                  var results = new
                    ↪  List<ulong>((int)Platform.Numbers.Math.Catalan((ulong)sequence.Length));
94                  return CreateAllVariants1Core(sequence, results);
95              });
96          }
97
98          [MethodImpl(MethodImplOptions.AggressiveInlining)]
99          private List<ulong> CreateAllVariants1Core(ulong[] sequence, List<ulong> results)
100         {
101             if (sequence.Length == 2)
102             {
103                 var link = Links.Unsync.GetOrCreate(sequence[0], sequence[1]);
104                 if (link == Constants.Null)
105                 {
106                     throw new NotImplementedException("Creation cancellation is not
                        ↪  implemented.");
107                 }
108                 results.Add(link);
109                 return results;
110             }
111             var innerSequenceLength = sequence.Length - 1;
112             var innerSequence = new ulong[innerSequenceLength];
113             for (var li = 0; li < innerSequenceLength; li++)
114             {
115                 var link = Links.Unsync.GetOrCreate(sequence[li], sequence[li + 1]);
116                 if (link == Constants.Null)
117                 {
118                     throw new NotImplementedException("Creation cancellation is not
                        ↪  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         [MethodImpl(MethodImplOptions.AggressiveInlining)]
137         public HashSet<ulong> Each1(params ulong[] sequence)
138         {
139             var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
140             Each1(link =>
141             {
142                 if (!visitedLinks.Contains(link))
143                 {
144                     visitedLinks.Add(link); // изучить почему случаются повторы
145                 }
146                 return true;
147             }, sequence);
148             return visitedLinks;
149         }
150
151         [MethodImpl(MethodImplOptions.AggressiveInlining)]
152         private void Each1(Func<ulong, bool> handler, params ulong[] sequence)
```

```
        {
            if (sequence.Length == 2)
            {
                Links.Unsync.Each(sequence[0], sequence[1], handler);
            }
            else
            {
                var innerSequenceLength = sequence.Length - 1;
                for (var li = 0; li < innerSequenceLength; li++)
                {
                    var left = sequence[li];
                    var right = sequence[li + 1];
                    if (left == 0 && right == 0)
                    {
                        continue;
                    }
                    var linkIndex = li;
                    ulong[] innerSequence = null;
                    Links.Unsync.Each(doublet =>
                    {
                        if (innerSequence == null)
                        {
                            innerSequence = new ulong[innerSequenceLength];
                            for (var isi = 0; isi < linkIndex; isi++)
                            {
                                innerSequence[isi] = sequence[isi];
                            }
                            for (var isi = linkIndex + 1; isi < innerSequenceLength; isi++)
                            {
                                innerSequence[isi] = sequence[isi + 1];
                            }
                        }
                        innerSequence[linkIndex] = doublet[Constants.IndexPart];
                        Each1(handler, innerSequence);
                        return Constants.Continue;
                    }, Constants.Any, left, right);
                }
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> EachPart(params ulong[] sequence)
        {
            var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
            EachPartCore(link =>
            {
                var linkIndex = link[Constants.IndexPart];
                if (!visitedLinks.Contains(linkIndex))
                {
                    visitedLinks.Add(linkIndex); // изучить почему случаются повторы
                }
                return Constants.Continue;
            }, sequence);
            return visitedLinks;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void EachPart(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[] sequence)
        {
            var visitedLinks = new HashSet<ulong>(); // Заменить на bitstring
            EachPartCore(link =>
            {
                var linkIndex = link[Constants.IndexPart];
                if (!visitedLinks.Contains(linkIndex))
                {
                    visitedLinks.Add(linkIndex); // изучить почему случаются повторы
                    return handler(new LinkAddress<LinkIndex>(linkIndex));
                }
                return Constants.Continue;
            }, sequence);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void EachPartCore(Func<IList<LinkIndex>, LinkIndex> handler, params ulong[]
        ↪  sequence)
        {
            if (sequence.IsNullOrEmpty())
            {
```

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

```
            var upStep = stepFrom;
            var firstSource = Links.Unsync.GetTarget(upStep);
            while (firstSource != right && firstSource != upStep)
            {
                upStep = firstSource;
                firstSource = Links.Unsync.GetSource(upStep);
            }
            if (firstSource == right)
            {
                handler(new LinkAddress<LinkIndex>(stepFrom));
            }
        }

        // TODO: Test
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void PartialStepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
        {
            Links.Unsync.Each(right, Constants.Any, doublet =>
            {
                StepLeft(handler, left, doublet);
                if (right != doublet)
                {
                    PartialStepLeft(handler, left, doublet);
                }
                return true;
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void StepLeft(Action<IList<LinkIndex>> handler, ulong left, ulong right)
        {
            Links.Unsync.Each(Constants.Any, right, leftStep =>
            {
                TryStepLeftUp(handler, left, leftStep);
                return true;
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void TryStepLeftUp(Action<IList<LinkIndex>> handler, ulong left, ulong stepFrom)
        {
            var upStep = stepFrom;
            var firstTarget = Links.Unsync.GetSource(upStep);
            while (firstTarget != left && firstTarget != upStep)
            {
                upStep = firstTarget;
                firstTarget = Links.Unsync.GetTarget(upStep);
            }
            if (firstTarget == left)
            {
                handler(new LinkAddress<LinkIndex>(stepFrom));
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool StartsWith(ulong sequence, ulong link)
        {
            var upStep = sequence;
            var firstSource = Links.Unsync.GetSource(upStep);
            while (firstSource != link && firstSource != upStep)
            {
                upStep = firstSource;
                firstSource = Links.Unsync.GetSource(upStep);
            }
            return firstSource == link;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool EndsWith(ulong sequence, ulong link)
        {
            var upStep = sequence;
            var lastTarget = Links.Unsync.GetTarget(upStep);
            while (lastTarget != link && lastTarget != upStep)
            {
                upStep = lastTarget;
                lastTarget = Links.Unsync.GetTarget(upStep);
            }
            return lastTarget == link;
        }
```

```
386
387         [MethodImpl(MethodImplOptions.AggressiveInlining)]
388         public List<ulong> GetAllMatchingSequences0(params ulong[] sequence)
389         {
390             return _sync.ExecuteReadOperation(() =>
391             {
392                 var results = new List<ulong>();
393                 if (sequence.Length > 0)
394                 {
395                     Links.EnsureLinkExists(sequence);
396                     var firstElement = sequence[0];
397                     if (sequence.Length == 1)
398                     {
399                         results.Add(firstElement);
400                         return results;
401                     }
402                     if (sequence.Length == 2)
403                     {
404                         var doublet = Links.SearchOrDefault(firstElement, sequence[1]);
405                         if (doublet != Constants.Null)
406                         {
407                             results.Add(doublet);
408                         }
409                         return results;
410                     }
411                     var linksInSequence = new HashSet<ulong>(sequence);
412                     void handler(IList<LinkIndex> result)
413                     {
414                         var resultIndex = result[Links.Constants.IndexPart];
415                         var filterPosition = 0;
416                         StopableSequenceWalker.WalkRight(resultIndex, Links.Unsync.GetSource,
                            ↪  Links.Unsync.GetTarget,
417                             x => linksInSequence.Contains(x) || Links.Unsync.GetTarget(x) == x,
                                ↪  x =>
418                             {
419                                 if (filterPosition == sequence.Length)
420                                 {
421                                     filterPosition = -2; // Длиннее чем нужно
422                                     return false;
423                                 }
424                                 if (x != sequence[filterPosition])
425                                 {
426                                     filterPosition = -1;
427                                     return false; // Начинается иначе
428                                 }
429                                 filterPosition++;
430
431                                 return true;
432                             });
433                         if (filterPosition == sequence.Length)
434                         {
435                             results.Add(resultIndex);
436                         }
437                     }
438                     if (sequence.Length >= 2)
439                     {
440                         StepRight(handler, sequence[0], sequence[1]);
441                     }
442                     var last = sequence.Length - 2;
443                     for (var i = 1; i < last; i++)
444                     {
445                         PartialStepRight(handler, sequence[i], sequence[i + 1]);
446                     }
447                     if (sequence.Length >= 3)
448                     {
449                         StepLeft(handler, sequence[sequence.Length - 2],
                            ↪  sequence[sequence.Length - 1]);
450                     }
451                 }
452                 return results;
453             });
454         }
455
456         [MethodImpl(MethodImplOptions.AggressiveInlining)]
457         public HashSet<ulong> GetAllMatchingSequences1(params ulong[] sequence)
458         {
459             return _sync.ExecuteReadOperation(() =>
460             {
```

```
                var results = new HashSet<ulong>();
                if (sequence.Length > 0)
                {
                    Links.EnsureLinkExists(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]);
                    }
                }
                return results;
            });
        }

        public const int MaxSequenceFormatSize = 200;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public string FormatSequence(LinkIndex sequenceLink, params LinkIndex[] knownElements)
        ↪  => FormatSequence(sequenceLink, (sb, x) => sb.Append(x), true, knownElements);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public string FormatSequence(LinkIndex sequenceLink, Action<StringBuilder, LinkIndex>
        ↪  elementToString, bool insertComma, params LinkIndex[] knownElements) =>
        ↪  Links.SyncRoot.ExecuteReadOperation(() => FormatSequence(Links.Unsync, sequenceLink,
        ↪  elementToString, insertComma, knownElements));

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private string FormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
        ↪  Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
        ↪  LinkIndex[] knownElements)
        {
            var linksInSequence = new HashSet<ulong>(knownElements);
            //var entered = new HashSet<ulong>();
            var sb = new StringBuilder();
            sb.Append('{');
            if (links.Exists(sequenceLink))
            {
                StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
                    x => linksInSequence.Contains(x) || links.IsPartialPoint(x), element => //
                    ↪  entered.AddAndReturnVoid, x => { }, entered.DoNotContains
                    {
                        if (insertComma && sb.Length > 1)
                        {
                            sb.Append(',');
                        }
                        //if (entered.Contains(element))
                        //{
                        //    sb.Append('{');
                        //    elementToString(sb, element);
                        //    sb.Append('}');
                        //}
                        //else
```

```
                    elementToString(sb, element);
                    if (sb.Length < MaxSequenceFormatSize)
                    {
                        return true;
                    }
                    sb.Append(insertComma ? ", ..." : "...");
                    return false;
                });
        }
        sb.Append('}');
        return sb.ToString();
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public string SafeFormatSequence(LinkIndex sequenceLink, params LinkIndex[]
    ↪  knownElements) => SafeFormatSequence(sequenceLink, (sb, x) => sb.Append(x), true,
    ↪  knownElements);

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public string SafeFormatSequence(LinkIndex sequenceLink, Action<StringBuilder,
    ↪  LinkIndex> elementToString, bool insertComma, params LinkIndex[] knownElements) =>
    ↪  Links.SyncRoot.ExecuteReadOperation(() => SafeFormatSequence(Links.Unsync,
    ↪  sequenceLink, elementToString, insertComma, knownElements));

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private string SafeFormatSequence(ILinks<LinkIndex> links, LinkIndex sequenceLink,
    ↪  Action<StringBuilder, LinkIndex> elementToString, bool insertComma, params
    ↪  LinkIndex[] knownElements)
    {
        var linksInSequence = new HashSet<ulong>(knownElements);
        var entered = new HashSet<ulong>();
        var sb = new StringBuilder();
        sb.Append('{');
        if (links.Exists(sequenceLink))
        {
            StopableSequenceWalker.WalkRight(sequenceLink, links.GetSource, links.GetTarget,
                x => linksInSequence.Contains(x) || links.IsFullPoint(x),
                ↪  entered.AddAndReturnVoid, x => { }, entered.DoNotContains, element =>
                {
                    if (insertComma && sb.Length > 1)
                    {
                        sb.Append(',');
                    }
                    if (entered.Contains(element))
                    {
                        sb.Append('{');
                        elementToString(sb, element);
                        sb.Append('}');
                    }
                    else
                    {
                        elementToString(sb, element);
                    }
                    if (sb.Length < MaxSequenceFormatSize)
                    {
                        return true;
                    }
                    sb.Append(insertComma ? ", ..." : "...");
                    return false;
                });
        }
        sb.Append('}');
        return sb.ToString();
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public List<ulong> GetAllPartiallyMatchingSequences0(params ulong[] sequence)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            if (sequence.Length > 0)
            {
                Links.EnsureLinkExists(sequence);
                var results = new HashSet<ulong>();
                for (var i = 0; i < sequence.Length; i++)
                {
                    AllUsagesCore(sequence[i], results);
                }
```

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

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public HashSet<ulong> GetAllPartiallyMatchingSequences1(params ulong[] sequence)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            if (sequence.Length > 0)
            {
                Links.EnsureLinkExists(sequence);
                var results = new HashSet<ulong>();
                for (var i = 0; i < sequence.Length; i++)
                {
                    AllUsagesCore(sequence[i], results);
                }
                var filteredResults = new HashSet<ulong>();
                var matcher = new Matcher(this, sequence, filteredResults, null);
                matcher.AddAllPartialMatchedToResults(results);
                return filteredResults;
            }
            return new HashSet<ulong>();
        });
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public bool GetAllPartiallyMatchingSequences2(Func<IList<LinkIndex>, LinkIndex> handler,
    ↪  params ulong[] sequence)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            if (sequence.Length > 0)
            {
                Links.EnsureLinkExists(sequence);

                var results = new HashSet<ulong>();
                var filteredResults = new HashSet<ulong>();
```

```
                    var matcher = new Matcher(this, sequence, filteredResults, handler);
                    for (var i = 0; i < sequence.Length; i++)
                    {
                        if (!AllUsagesCore1(sequence[i], results, matcher.HandlePartialMatched))
                        {
                            return false;
                        }
                    }
                    return true;
                }
                return true;
            });
        }

        //public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
        //{
        //    return Sync.ExecuteReadOperation(() =>
        //    {
        //        if (sequence.Length > 0)
        //        {
        //            _links.EnsureEachLinkIsAnyOrExists(sequence);

        //            var firstResults = new HashSet<ulong>();
        //            var lastResults = new HashSet<ulong>();

        //            var first = sequence.First(x => x != LinksConstants.Any);
        //            var last = sequence.Last(x => x != LinksConstants.Any);

        //            AllUsagesCore(first, firstResults);
        //            AllUsagesCore(last, lastResults);

        //            firstResults.IntersectWith(lastResults);

        //            //for (var i = 0; i < sequence.Length; i++)
        //            //    AllUsagesCore(sequence[i], results);

        //            var filteredResults = new HashSet<ulong>();
        //            var matcher = new Matcher(this, sequence, filteredResults, null);
        //            matcher.AddAllPartialMatchedToResults(firstResults);
        //            return filteredResults;
        //        }

        //        return new HashSet<ulong>();
        //    });
        //}

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> GetAllPartiallyMatchingSequences3(params ulong[] sequence)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                if (sequence.Length > 0)
                {
                    ILinksExtensions.EnsureLinkIsAnyOrExists(Links, sequence);
                    var firstResults = new HashSet<ulong>();
                    var lastResults = new HashSet<ulong>();
                    var first = sequence.First(x => x != Constants.Any);
                    var last = sequence.Last(x => x != Constants.Any);
                    AllUsagesCore(first, firstResults);
                    AllUsagesCore(last, lastResults);
                    firstResults.IntersectWith(lastResults);
                    //for (var i = 0; i < sequence.Length; i++)
                    //    AllUsagesCore(sequence[i], results);
                    var filteredResults = new HashSet<ulong>();
                    var matcher = new Matcher(this, sequence, filteredResults, null);
                    matcher.AddAllPartialMatchedToResults(firstResults);
                    return filteredResults;
                }
                return new HashSet<ulong>();
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> GetAllPartiallyMatchingSequences4(HashSet<ulong> readAsElements,
        ↪  IList<ulong> sequence)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                if (sequence.Count > 0)
```

```
                {
                    Links.EnsureLinkExists(sequence);
                    var results = new HashSet<LinkIndex>();
                    //var nextResults = new HashSet<ulong>();
                    //for (var i = 0; i < sequence.Length; i++)
                    //{
                    //    AllUsagesCore(sequence[i], nextResults);
                    //    if (results.IsNullOrEmpty())
                    //    {
                    //        results = nextResults;
                    //        nextResults = new HashSet<ulong>();
                    //    }
                    //    else
                    //    {
                    //        results.IntersectWith(nextResults);
                    //        nextResults.Clear();
                    //    }
                    //}
                    var collector1 = new AllUsagesCollector1(Links.Unsync, results);
                    collector1.Collect(Links.Unsync.GetLink(sequence[0]));
                    var next = new HashSet<ulong>();
                    for (var i = 1; i < sequence.Count; i++)
                    {
                        var collector = new AllUsagesCollector1(Links.Unsync, next);
                        collector.Collect(Links.Unsync.GetLink(sequence[i]));

                        results.IntersectWith(next);
                        next.Clear();
                    }
                    var filteredResults = new HashSet<ulong>();
                    var matcher = new Matcher(this, sequence, filteredResults, null,
                    ↪  readAsElements);
                    matcher.AddAllPartialMatchedToResultsAndReadAsElements(results.OrderBy(x =>
                    ↪  x)); // OrderBy is a Hack
                    return filteredResults;
                }
                return new HashSet<ulong>();
            });
        }

        // Does not work
        //public HashSet<ulong> GetAllPartiallyMatchingSequences5(HashSet<ulong> readAsElements,
        ↪  params ulong[] sequence)
        //{
        //    var visited = new HashSet<ulong>();
        //    var results = new HashSet<ulong>();
        //    var matcher = new Matcher(this, sequence, visited, x => { results.Add(x); return
        ↪  true; }, readAsElements);
        //    var last = sequence.Length - 1;
        //    for (var i = 0; i < last; i++)
        //    {
        //        PartialStepRight(matcher.PartialMatch, sequence[i], sequence[i + 1]);
        //    }
        //    return results;
        //}

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public List<ulong> GetAllPartiallyMatchingSequences(params ulong[] sequence)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                if (sequence.Length > 0)
                {
                    Links.EnsureLinkExists(sequence);
                    //var firstElement = sequence[0];
                    //if (sequence.Length == 1)
                    //{
                    //    //results.Add(firstElement);
                    //    return results;
                    //}
                    //if (sequence.Length == 2)
                    //{
                    //    //var doublet = _links.SearchCore(firstElement, sequence[1]);
                    //    //if (doublet != Doublets.Links.Null)
                    //    //    results.Add(doublet);
                    //    return results;
                    //}
                    //var lastElement = sequence[sequence.Length - 1];
```

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

```
            });
        }

        /// <remarks>
        /// TODO: Может потробоваться ограничение на уровень глубины рекурсии
        /// </remarks>
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> AllUsages(ulong link)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                var usages = new HashSet<ulong>();
                AllUsagesCore(link, usages);
                return usages;
            });
        }

        // При сборе всех использований (последовательностей) можно сохранять обратный путь к
        ↪  той связи с которой начинался поиск (STTTSSSTT),
        // причём достаточно одного бита для хранения перехода влево или вправо
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void AllUsagesCore(ulong link, HashSet<ulong> usages)
        {
            bool handler(ulong doublet)
            {
                if (usages.Add(doublet))
                {
                    AllUsagesCore(doublet, usages);
                }
                return true;
            }
            Links.Unsync.Each(link, Constants.Any, handler);
            Links.Unsync.Each(Constants.Any, link, handler);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> AllBottomUsages(ulong link)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                var visits = new HashSet<ulong>();
                var usages = new HashSet<ulong>();
                AllBottomUsagesCore(link, visits, usages);
                return usages;
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void AllBottomUsagesCore(ulong link, HashSet<ulong> visits, HashSet<ulong>
        ↪  usages)
        {
            bool handler(ulong doublet)
            {
                if (visits.Add(doublet))
                {
                    AllBottomUsagesCore(doublet, visits, usages);
                }
                return true;
            }
            if (Links.Unsync.Count(Constants.Any, link) == 0)
            {
                usages.Add(link);
            }
            else
            {
                Links.Unsync.Each(link, Constants.Any, handler);
                Links.Unsync.Each(Constants.Any, link, handler);
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ulong CalculateTotalSymbolFrequencyCore(ulong symbol)
        {
            if (Options.UseSequenceMarker)
            {
                var counter = new TotalMarkedSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
                ↪  Options.MarkedSequenceMatcher, symbol);
                return counter.Count();
```

```
            }
            else
            {
                var counter = new TotalSequenceSymbolFrequencyOneOffCounter<ulong>(Links,
                ↪  symbol);
                return counter.Count();
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool AllUsagesCore1(ulong link, HashSet<ulong> usages, Func<IList<LinkIndex>,
        ↪  LinkIndex> outerHandler)
        {
            bool handler(ulong doublet)
            {
                if (usages.Add(doublet))
                {
                    if (outerHandler(new LinkAddress<LinkIndex>(doublet)) != Constants.Continue)
                    {
                        return false;
                    }
                    if (!AllUsagesCore1(doublet, usages, outerHandler))
                    {
                        return false;
                    }
                }
                return true;
            }
            return Links.Unsync.Each(link, Constants.Any, handler)
                && Links.Unsync.Each(Constants.Any, link, handler);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void CalculateAllUsages(ulong[] totals)
        {
            var calculator = new AllUsagesCalculator(Links, totals);
            calculator.Calculate();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void CalculateAllUsages2(ulong[] totals)
        {
            var calculator = new AllUsagesCalculator2(Links, totals);
            calculator.Calculate();
        }

        private class AllUsagesCalculator
        {
            private readonly SynchronizedLinks<ulong> _links;
            private readonly ulong[] _totals;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public AllUsagesCalculator(SynchronizedLinks<ulong> links, ulong[] totals)
            {
                _links = links;
                _totals = totals;
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
            ↪  CalculateCore);

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            private bool CalculateCore(ulong link)
            {
                if (_totals[link] == 0)
                {
                    var total = 1UL;
                    _totals[link] = total;
                    var visitedChildren = new HashSet<ulong>();
                    bool linkCalculator(ulong child)
                    {
                        if (link != child && visitedChildren.Add(child))
                        {
                            total += _totals[child] == 0 ? 1 : _totals[child];
                        }
                        return true;
                    }
                    _links.Unsync.Each(link, _links.Constants.Any, linkCalculator);
```

```
                _links.Unsync.Each(_links.Constants.Any, link, linkCalculator);
                _totals[link] = total;
            }
            return true;
        }
    }

    private class AllUsagesCalculator2
    {
        private readonly SynchronizedLinks<ulong> _links;
        private readonly ulong[] _totals;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public AllUsagesCalculator2(SynchronizedLinks<ulong> links, ulong[] totals)
        {
            _links = links;
            _totals = totals;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Calculate() => _links.Each(_links.Constants.Any, _links.Constants.Any,
        ↪  CalculateCore);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool IsElement(ulong link)
        {
            //_linksInSequence.Contains(link) ||
            return _links.Unsync.GetTarget(link) == link || _links.Unsync.GetSource(link) ==
            ↪  link;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private bool CalculateCore(ulong link)
        {
            // TODO: Проработать защиту от зацикливания
            // Основано на SequenceWalker.WalkLeft
            Func<ulong, ulong> getSource = _links.Unsync.GetSource;
            Func<ulong, ulong> getTarget = _links.Unsync.GetTarget;
            Func<ulong, bool> isElement = IsElement;
            void visitLeaf(ulong parent)
            {
                if (link != parent)
                {
                    _totals[parent]++;
                }
            }
            void visitNode(ulong parent)
            {
                if (link != parent)
                {
                    _totals[parent]++;
                }
            }
            var stack = new Stack();
            var element = link;
            if (isElement(element))
            {
                visitLeaf(element);
            }
            else
            {
                while (true)
                {
                    if (isElement(element))
                    {
                        if (stack.Count == 0)
                        {
                            break;
                        }
                        element = stack.Pop();
                        var source = getSource(element);
                        var target = getTarget(element);
                        // Обработка элемента
                        if (isElement(target))
                        {
                            visitLeaf(target);
                        }
                        if (isElement(source))
                        {
```

```
                            visitLeaf(source);
                        }
                        element = source;
                    }
                    else
                    {
                        stack.Push(element);
                        visitNode(element);
                        element = getTarget(element);
                    }
                }
            }
            _totals[link]++;
            return true;
        }
    }

    private class AllUsagesCollector
    {
        private readonly ILinks<ulong> _links;
        private readonly HashSet<ulong> _usages;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public AllUsagesCollector(ILinks<ulong> links, HashSet<ulong> usages)
        {
            _links = links;
            _usages = usages;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool Collect(ulong link)
        {
            if (_usages.Add(link))
            {
                _links.Each(link, _links.Constants.Any, Collect);
                _links.Each(_links.Constants.Any, link, Collect);
            }
            return true;
        }
    }

    private class AllUsagesCollector1
    {
        private readonly ILinks<ulong> _links;
        private readonly HashSet<ulong> _usages;
        private readonly ulong _continue;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public AllUsagesCollector1(ILinks<ulong> links, HashSet<ulong> usages)
        {
            _links = links;
            _usages = usages;
            _continue = _links.Constants.Continue;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public ulong Collect(IList<ulong> link)
        {
            var linkIndex = _links.GetIndex(link);
            if (_usages.Add(linkIndex))
            {
                _links.Each(Collect, _links.Constants.Any, linkIndex);
            }
            return _continue;
        }
    }

    private class AllUsagesCollector2
    {
        private readonly ILinks<ulong> _links;
        private readonly BitString _usages;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public AllUsagesCollector2(ILinks<ulong> links, BitString usages)
        {
            _links = links;
            _usages = usages;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
            public bool Collect(ulong link)
            {
                if (_usages.Add((long)link))
                {
                    _links.Each(link, _links.Constants.Any, Collect);
                    _links.Each(_links.Constants.Any, link, Collect);
                }
                return true;
            }
        }

        private class AllUsagesIntersectingCollector
        {
            private readonly SynchronizedLinks<ulong> _links;
            private readonly HashSet<ulong> _intersectWith;
            private readonly HashSet<ulong> _usages;
            private readonly HashSet<ulong> _enter;

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public AllUsagesIntersectingCollector(SynchronizedLinks<ulong> links, HashSet<ulong>
            ↪  intersectWith, HashSet<ulong> usages)
            {
                _links = links;
                _intersectWith = intersectWith;
                _usages = usages;
                _enter = new HashSet<ulong>(); // защита от зацикливания
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public bool Collect(ulong link)
            {
                if (_enter.Add(link))
                {
                    if (_intersectWith.Contains(link))
                    {
                        _usages.Add(link);
                    }
                    _links.Unsync.Each(link, _links.Constants.Any, Collect);
                    _links.Unsync.Each(_links.Constants.Any, link, Collect);
                }
                return true;
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void CloseInnerConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
        ↪  right)
        {
            TryStepLeftUp(handler, left, right);
            TryStepRightUp(handler, right, left);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void AllCloseConnections(Action<IList<LinkIndex>> handler, ulong left, ulong
        ↪  right)
        {
            // Direct
            if (left == right)
            {
                handler(new LinkAddress<LinkIndex>(left));
            }
            var doublet = Links.Unsync.SearchOrDefault(left, right);
            if (doublet != Constants.Null)
            {
                handler(new LinkAddress<LinkIndex>(doublet));
            }
            // Inner
            CloseInnerConnections(handler, left, right);
            // Outer
            StepLeft(handler, left, right);
            StepRight(handler, left, right);
            PartialStepRight(handler, left, right);
            PartialStepLeft(handler, left, right);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private HashSet<ulong> GetAllPartiallyMatchingSequencesCore(ulong[] sequence,
        ↪  HashSet<ulong> previousMatchings, long startAt)
        {
```

```
            if (startAt >= sequence.Length) // ?
            {
                return previousMatchings;
            }
            var secondLinkUsages = new HashSet<ulong>();
            AllUsagesCore(sequence[startAt], secondLinkUsages);
            secondLinkUsages.Add(sequence[startAt]);
            var matchings = new HashSet<ulong>();
            var filler = new SetFiller<LinkIndex, LinkIndex>(matchings, Constants.Continue);
            //for (var i = 0; i < previousMatchings.Count; i++)
            foreach (var secondLinkUsage in secondLinkUsages)
            {
                foreach (var previousMatching in previousMatchings)
                {
                    //AllCloseConnections(matchings.AddAndReturnVoid, previousMatching,
                    ↪  secondLinkUsage);
                    StepRight(filler.AddFirstAndReturnConstant, previousMatching,
                    ↪  secondLinkUsage);
                    TryStepRightUp(filler.AddFirstAndReturnConstant, secondLinkUsage,
                    ↪  previousMatching);
                    //PartialStepRight(matchings.AddAndReturnVoid, secondLinkUsage,
                    ↪  sequence[startAt]); // почему-то эта ошибочная запись приводит к
                    ↪  желаемым результам.
                    PartialStepRight(filler.AddFirstAndReturnConstant, previousMatching,
                    ↪  secondLinkUsage);
                }
            }
            if (matchings.Count == 0)
            {
                return matchings;
            }
            return GetAllPartiallyMatchingSequencesCore(sequence, matchings, startAt + 1); // ??
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static void EnsureEachLinkIsAnyOrZeroOrManyOrExists(SynchronizedLinks<ulong>
        ↪  links, params ulong[] sequence)
        {
            if (sequence == null)
            {
                return;
            }
            for (var i = 0; i < sequence.Length; i++)
            {
                if (sequence[i] != links.Constants.Any && sequence[i] != ZeroOrMany &&
                ↪  !links.Exists(sequence[i]))
                {
                    throw new ArgumentLinkDoesNotExistsException<ulong>(sequence[i],
                    ↪  $"patternSequence[{i}]");
                }
            }
        }

        // Pattern Matching -> Key To Triggers
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public HashSet<ulong> MatchPattern(params ulong[] patternSequence)
        {
            return _sync.ExecuteReadOperation(() =>
            {
                patternSequence = Simplify(patternSequence);
                if (patternSequence.Length > 0)
                {
                    EnsureEachLinkIsAnyOrZeroOrManyOrExists(Links, patternSequence);
                    var uniqueSequenceElements = new HashSet<ulong>();
                    for (var i = 0; i < patternSequence.Length; i++)
                    {
                        if (patternSequence[i] != Constants.Any && patternSequence[i] !=
                        ↪  ZeroOrMany)
                        {
                            uniqueSequenceElements.Add(patternSequence[i]);
                        }
                    }
                    var results = new HashSet<ulong>();
                    foreach (var uniqueSequenceElement in uniqueSequenceElements)
                    {
                        AllUsagesCore(uniqueSequenceElement, results);
                    }
```

```
                var filteredResults = new HashSet<ulong>();
                var matcher = new PatternMatcher(this, patternSequence, filteredResults);
                matcher.AddAllPatternMatchedToResults(results);
                return filteredResults;
            }
            return new HashSet<ulong>();
        });
    }

    // Найти все возможные связи между указанным списком связей.
    // Находит связи между всеми указанными связями в любом порядке.
    // TODO: решить что делать с повторами (когда одни и те же элементы встречаются несколько раз в последовательности)
    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public HashSet<ulong> GetAllConnections(params ulong[] linksToConnect)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            var results = new HashSet<ulong>();
            if (linksToConnect.Length > 0)
            {
                Links.EnsureLinkExists(linksToConnect);
                AllUsagesCore(linksToConnect[0], results);
                for (var i = 1; i < linksToConnect.Length; i++)
                {
                    var next = new HashSet<ulong>();
                    AllUsagesCore(linksToConnect[i], next);
                    results.IntersectWith(next);
                }
            }
            return results;
        });
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public HashSet<ulong> GetAllConnections1(params ulong[] linksToConnect)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            var results = new HashSet<ulong>();
            if (linksToConnect.Length > 0)
            {
                Links.EnsureLinkExists(linksToConnect);
                var collector1 = new AllUsagesCollector(Links.Unsync, results);
                collector1.Collect(linksToConnect[0]);
                var next = new HashSet<ulong>();
                for (var i = 1; i < linksToConnect.Length; i++)
                {
                    var collector = new AllUsagesCollector(Links.Unsync, next);
                    collector.Collect(linksToConnect[i]);
                    results.IntersectWith(next);
                    next.Clear();
                }
            }
            return results;
        });
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public HashSet<ulong> GetAllConnections2(params ulong[] linksToConnect)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            var results = new HashSet<ulong>();
            if (linksToConnect.Length > 0)
            {
                Links.EnsureLinkExists(linksToConnect);
                var collector1 = new AllUsagesCollector(Links, results);
                collector1.Collect(linksToConnect[0]);
                //AllUsagesCore(linksToConnect[0], results);
                for (var i = 1; i < linksToConnect.Length; i++)
                {
                    var next = new HashSet<ulong>();
                    var collector = new AllUsagesIntersectingCollector(Links, results, next);
                    collector.Collect(linksToConnect[i]);
                    //AllUsagesCore(linksToConnect[i], next);
                    //results.IntersectWith(next);
                    results = next;
```

```
                }
            }
            return results;
        });
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public List<ulong> GetAllConnections3(params ulong[] linksToConnect)
    {
        return _sync.ExecuteReadOperation(() =>
        {
            var results = new BitString((long)Links.Unsync.Count() + 1); // new
            ↪  BitArray((int)_links.Total + 1);
            if (linksToConnect.Length > 0)
            {
                Links.EnsureLinkExists(linksToConnect);
                var collector1 = new AllUsagesCollector2(Links.Unsync, results);
                collector1.Collect(linksToConnect[0]);
                for (var i = 1; i < linksToConnect.Length; i++)
                {
                    var next = new BitString((long)Links.Unsync.Count() + 1); //new
                    ↪  BitArray((int)_links.Total + 1);
                    var collector = new AllUsagesCollector2(Links.Unsync, next);
                    collector.Collect(linksToConnect[i]);
                    results = results.And(next);
                }
            }
            return results.GetSetUInt64Indices();
        });
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    private static ulong[] Simplify(ulong[] sequence)
    {
        // Считаем новый размер последовательности
        long newLength = 0;
        var zeroOrManyStepped = false;
        for (var i = 0; i < sequence.Length; i++)
        {
            if (sequence[i] == ZeroOrMany)
            {
                if (zeroOrManyStepped)
                {
                    continue;
                }
                zeroOrManyStepped = true;
            }
            else
            {
                //if (zeroOrManyStepped) Is it efficient?
                zeroOrManyStepped = false;
            }
            newLength++;
        }
        // Строим новую последовательность
        zeroOrManyStepped = false;
        var newSequence = new ulong[newLength];
        long j = 0;
        for (var i = 0; i < sequence.Length; i++)
        {
            //var current = zeroOrManyStepped;
            //zeroOrManyStepped = patternSequence[i] == zeroOrMany;
            //if (current && zeroOrManyStepped)
            //    continue;
            //var newZeroOrManyStepped = patternSequence[i] == zeroOrMany;
            //if (zeroOrManyStepped && newZeroOrManyStepped)
            //    continue;
            //zeroOrManyStepped = newZeroOrManyStepped;
            if (sequence[i] == ZeroOrMany)
            {
                if (zeroOrManyStepped)
                {
                    continue;
                }
                zeroOrManyStepped = true;
            }
            else
            {
                //if (zeroOrManyStepped) Is it efficient?
```

```
                    zeroOrManyStepped = false;
                }
                newSequence[j++] = sequence[i];
            }
            return newSequence;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static void TestSimplify()
        {
            var sequence = new ulong[] { ZeroOrMany, ZeroOrMany, 2, 3, 4, ZeroOrMany,
            ↪  ZeroOrMany, ZeroOrMany, 4, ZeroOrMany, ZeroOrMany, ZeroOrMany };
            var simplifiedSequence = Simplify(sequence);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public List<ulong> GetSimilarSequences() => new List<ulong>();

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Prediction()
        {
            //_links
            //sequences
        }

        #region From Triplets

        //public static void DeleteSequence(Link sequence)
        //{
        //}

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public List<ulong> CollectMatchingSequences(ulong[] links)
        {
            if (links.Length == 1)
            {
                throw new InvalidOperationException("Подпоследовательности с одним элементом не
                ↪  поддерживаются.");
            }
            var leftBound = 0;
            var rightBound = links.Length - 1;
            var left = links[leftBound++];
            var right = links[rightBound--];
            var results = new List<ulong>();
            CollectMatchingSequences(left, leftBound, links, right, rightBound, ref results);
            return results;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void CollectMatchingSequences(ulong leftLink, int leftBound, ulong[]
        ↪  middleLinks, ulong rightLink, int rightBound, ref List<ulong> results)
        {
            var leftLinkTotalReferers = Links.Unsync.Count(leftLink);
            var rightLinkTotalReferers = Links.Unsync.Count(rightLink);
            if (leftLinkTotalReferers <= rightLinkTotalReferers)
            {
                var nextLeftLink = middleLinks[leftBound];
                var elements = GetRightElements(leftLink, nextLeftLink);
                if (leftBound <= rightBound)
                {
                    for (var i = elements.Length - 1; i >= 0; i--)
                    {
                        var element = elements[i];
                        if (element != 0)
                        {
                            CollectMatchingSequences(element, leftBound + 1, middleLinks,
                            ↪  rightLink, rightBound, ref results);
                        }
                    }
                }
                else
                {
                    for (var i = elements.Length - 1; i >= 0; i--)
                    {
                        var element = elements[i];
                        if (element != 0)
                        {
                            results.Add(element);
```

```
                    }
                }
            }
        }
        else
        {
            var nextRightLink = middleLinks[rightBound];
            var elements = GetLeftElements(rightLink, nextRightLink);
            if (leftBound <= rightBound)
            {
                for (var i = elements.Length - 1; i >= 0; i--)
                {
                    var element = elements[i];
                    if (element != 0)
                    {
                        CollectMatchingSequences(leftLink, leftBound, middleLinks,
                        ↪  elements[i], rightBound - 1, ref results);
                    }
                }
            }
            else
            {
                for (var i = elements.Length - 1; i >= 0; i--)
                {
                    var element = elements[i];
                    if (element != 0)
                    {
                        results.Add(element);
                    }
                }
            }
        }
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public ulong[] GetRightElements(ulong startLink, ulong rightLink)
    {
        var result = new ulong[5];
        TryStepRight(startLink, rightLink, result, 0);
        Links.Each(Constants.Any, startLink, couple =>
        {
            if (couple != startLink)
            {
                if (TryStepRight(couple, rightLink, result, 2))
                {
                    return false;
                }
            }
            return true;
        });
        if (Links.GetTarget(Links.GetTarget(startLink)) == rightLink)
        {
            result[4] = startLink;
        }
        return result;
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public bool TryStepRight(ulong startLink, ulong rightLink, ulong[] result, int offset)
    {
        var added = 0;
        Links.Each(startLink, Constants.Any, couple =>
        {
            if (couple != startLink)
            {
                var coupleTarget = Links.GetTarget(couple);
                if (coupleTarget == rightLink)
                {
                    result[offset] = couple;
                    if (++added == 2)
                    {
                        return false;
                    }
                }
                else if (Links.GetSource(coupleTarget) == rightLink) // coupleTarget.Linker
                ↪  == Net.And &&
                {
                    result[offset + 1] = couple;
```

```
                    if (++added == 2)
                    {
                        return false;
                    }
                }
            }
            return true;
        });
        return added > 0;
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public ulong[] GetLeftElements(ulong startLink, ulong leftLink)
    {
        var result = new ulong[5];
        TryStepLeft(startLink, leftLink, result, 0);
        Links.Each(startLink, Constants.Any, couple =>
        {
            if (couple != startLink)
            {
                if (TryStepLeft(couple, leftLink, result, 2))
                {
                    return false;
                }
            }
            return true;
        });
        if (Links.GetSource(Links.GetSource(leftLink)) == startLink)
        {
            result[4] = leftLink;
        }
        return result;
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public bool TryStepLeft(ulong startLink, ulong leftLink, ulong[] result, int offset)
    {
        var added = 0;
        Links.Each(Constants.Any, startLink, couple =>
        {
            if (couple != startLink)
            {
                var coupleSource = Links.GetSource(couple);
                if (coupleSource == leftLink)
                {
                    result[offset] = couple;
                    if (++added == 2)
                    {
                        return false;
                    }
                }
                else if (Links.GetTarget(coupleSource) == leftLink) // coupleSource.Linker
                ↪  == Net.And &&
                {
                    result[offset + 1] = couple;
                    if (++added == 2)
                    {
                        return false;
                    }
                }
            }
            return true;
        });
        return added > 0;
    }

    #endregion

    #region Walkers

    public class PatternMatcher : RightSequenceWalker<ulong>
    {
        private readonly Sequences _sequences;
        private readonly ulong[] _patternSequence;
        private readonly HashSet<LinkIndex> _linksInSequence;
        private readonly HashSet<LinkIndex> _results;

        #region Pattern Match

        enum PatternBlockType
```

```
        {
            Undefined,
            Gap,
            Elements
        }

        struct PatternBlock
        {
            public PatternBlockType Type;
            public long Start;
            public long Stop;
        }

        private readonly List<PatternBlock> _pattern;
        private int _patternPosition;
        private long _sequencePosition;

        #endregion

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public PatternMatcher(Sequences sequences, LinkIndex[] patternSequence,
        ↪  HashSet<LinkIndex> results)
            : base(sequences.Links.Unsync, new DefaultStack<ulong>())
        {
            _sequences = sequences;
            _patternSequence = patternSequence;
            _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
            ↪  _sequences.Constants.Any && x != ZeroOrMany));
            _results = results;
            _pattern = CreateDetailedPattern();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override bool IsElement(ulong link) => _linksInSequence.Contains(link) ||
        ↪  base.IsElement(link);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public bool PatternMatch(LinkIndex sequenceToMatch)
        {
            _patternPosition = 0;
            _sequencePosition = 0;
            foreach (var part in Walk(sequenceToMatch))
            {
                if (!PatternMatchCore(part))
                {
                    break;
                }
            }
            return _patternPosition == _pattern.Count || (_patternPosition == _pattern.Count
            ↪  - 1 && _pattern[_patternPosition].Start == 0);
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private List<PatternBlock> CreateDetailedPattern()
        {
            var pattern = new List<PatternBlock>();
            var patternBlock = new PatternBlock();
            for (var i = 0; i < _patternSequence.Length; i++)
            {
                if (patternBlock.Type == PatternBlockType.Undefined)
                {
                    if (_patternSequence[i] == _sequences.Constants.Any)
                    {
                        patternBlock.Type = PatternBlockType.Gap;
                        patternBlock.Start = 1;
                        patternBlock.Stop = 1;
                    }
                    else if (_patternSequence[i] == ZeroOrMany)
                    {
                        patternBlock.Type = PatternBlockType.Gap;
                        patternBlock.Start = 0;
                        patternBlock.Stop = long.MaxValue;
                    }
                    else
                    {
                        patternBlock.Type = PatternBlockType.Elements;
                        patternBlock.Start = i;
                        patternBlock.Stop = i;
                    }
                }
```

```
                else if (patternBlock.Type == PatternBlockType.Elements)
                {
                    if (_patternSequence[i] == _sequences.Constants.Any)
                    {
                        pattern.Add(patternBlock);
                        patternBlock = new PatternBlock
                        {
                            Type = PatternBlockType.Gap,
                            Start = 1,
                            Stop = 1
                        };
                    }
                    else if (_patternSequence[i] == ZeroOrMany)
                    {
                        pattern.Add(patternBlock);
                        patternBlock = new PatternBlock
                        {
                            Type = PatternBlockType.Gap,
                            Start = 0,
                            Stop = long.MaxValue
                        };
                    }
                    else
                    {
                        patternBlock.Stop = i;
                    }
                }
                else // patternBlock.Type == PatternBlockType.Gap
                {
                    if (_patternSequence[i] == _sequences.Constants.Any)
                    {
                        patternBlock.Start++;
                        if (patternBlock.Stop < patternBlock.Start)
                        {
                            patternBlock.Stop = patternBlock.Start;
                        }
                    }
                    else if (_patternSequence[i] == ZeroOrMany)
                    {
                        patternBlock.Stop = long.MaxValue;
                    }
                    else
                    {
                        pattern.Add(patternBlock);
                        patternBlock = new PatternBlock
                        {
                            Type = PatternBlockType.Elements,
                            Start = i,
                            Stop = i
                        };
                    }
                }
            }
            if (patternBlock.Type != PatternBlockType.Undefined)
            {
                pattern.Add(patternBlock);
            }
            return pattern;
        }

        // match: search for regexp anywhere in text
        //int match(char* regexp, char* text)
        //{
        //    do
        //    {
        //    } while (*text++ != '\0');
        //    return 0;
        //}

        // matchhere: search for regexp at beginning of text
        //int matchhere(char* regexp, char* text)
        //{
        //    if (regexp[0] == '\0')
        //        return 1;
        //    if (regexp[1] == '*')
        //        return matchstar(regexp[0], regexp + 2, text);
        //    if (regexp[0] == '$' && regexp[1] == '\0')
        //        return *text == '\0';
        //    if (*text != '\0' && (regexp[0] == '.' || regexp[0] == *text))
```

```
//        return matchhere(regexp + 1, text + 1);
//    return 0;
//}

// matchstar: search for c*regexp at beginning of text
//int matchstar(int c, char* regexp, char* text)
//{
//    do
//    {    /* a * matches zero or more instances */
//        if (matchhere(regexp, text))
//            return 1;
//    } while (*text != '\0' && (*text++ == c || c == '.'));
//    return 0;
//}

//private void GetNextPatternElement(out LinkIndex element, out long mininumGap, out long maximumGap)
//{
//    mininumGap = 0;
//    maximumGap = 0;
//    element = 0;
//    for (; _patternPosition < _patternSequence.Length; _patternPosition++)
//    {
//        if (_patternSequence[_patternPosition] == Doublets.Links.Null)
//            mininumGap++;
//        else if (_patternSequence[_patternPosition] == ZeroOrMany)
//            maximumGap = long.MaxValue;
//        else
//            break;
//    }

//    if (maximumGap < mininumGap)
//        maximumGap = mininumGap;
//}

[MethodImpl(MethodImplOptions.AggressiveInlining)]
private bool PatternMatchCore(LinkIndex element)
{
    if (_patternPosition >= _pattern.Count)
    {
        _patternPosition = -2;
        return false;
    }
    var currentPatternBlock = _pattern[_patternPosition];
    if (currentPatternBlock.Type == PatternBlockType.Gap)
    {
        //var currentMatchingBlockLength = (_sequencePosition - _lastMatchedBlockPosition);
        if (_sequencePosition < currentPatternBlock.Start)
        {
            _sequencePosition++;
            return true; // Двигаемся дальше
        }
        // Это последний блок
        if (_pattern.Count == _patternPosition + 1)
        {
            _patternPosition++;
            _sequencePosition = 0;
            return false; // Полное соответствие
        }
        else
        {
            if (_sequencePosition > currentPatternBlock.Stop)
            {
                return false; // Соответствие невозможно
            }
            var nextPatternBlock = _pattern[_patternPosition + 1];
            if (_patternSequence[nextPatternBlock.Start] == element)
            {
                if (nextPatternBlock.Start < nextPatternBlock.Stop)
                {
                    _patternPosition++;
                    _sequencePosition = 1;
                }
                else
                {
                    _patternPosition += 2;
                    _sequencePosition = 0;
                }
```

```
                        }
                    }
                }
                else // currentPatternBlock.Type == PatternBlockType.Elements
                {
                    var patternElementPosition = currentPatternBlock.Start + _sequencePosition;
                    if (_patternSequence[patternElementPosition] != element)
                    {
                        return false; // Соответствие невозможно
                    }
                    if (patternElementPosition == currentPatternBlock.Stop)
                    {
                        _patternPosition++;
                        _sequencePosition = 0;
                    }
                    else
                    {
                        _sequencePosition++;
                    }
                }
                return true;
                //if (_patternSequence[_patternPosition] != element)
                //    return false;
                //else
                //{
                //    _sequencePosition++;
                //    _patternPosition++;
                //    return true;
                //}
                ////////
                //if (_filterPosition == _patternSequence.Length)
                //{
                //    _filterPosition = -2; // Длиннее чем нужно
                //    return false;
                //}
                //if (element != _patternSequence[_filterPosition])
                //{
                //    _filterPosition = -1;
                //    return false; // Начинается иначе
                //}
                //_filterPosition++;
                //if (_filterPosition == (_patternSequence.Length - 1))
                //    return false;
                //if (_filterPosition >= 0)
                //{
                //    if (element == _patternSequence[_filterPosition + 1])
                //        _filterPosition++;
                //    else
                //        return false;
                //}
                //if (_filterPosition < 0)
                //{
                //    if (element == _patternSequence[0])
                //        _filterPosition = 0;
                //}
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public void AddAllPatternMatchedToResults(IEnumerable<ulong> sequencesToMatch)
            {
                foreach (var sequenceToMatch in sequencesToMatch)
                {
                    if (PatternMatch(sequenceToMatch))
                    {
                        _results.Add(sequenceToMatch);
                    }
                }
            }
        }

        #endregion
    }
}
```

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

```
using System;
using System.Collections.Generic;
using System.Linq;
using System.Runtime.CompilerServices;
```

```
using Platform.Collections;
using Platform.Collections.Lists;
using Platform.Collections.Stacks;
using Platform.Threading.Synchronization;
using Platform.Data.Doublets.Sequences.Walkers;
using LinkIndex = System.UInt64;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    /// <summary>
    /// Представляет коллекцию последовательностей связей.
    /// </summary>
    /// <remarks>
    /// Обязательно реализовать атомарность каждого публичного метода.
    ///
    /// TODO:
    ///
    /// !!! Повышение вероятности повторного использования групп (подпоследовательностей),
    /// через естественную группировку по unicode типам, все whitespace вместе, все символы вместе, все числа вместе и т.п.
    /// + использовать ровно сбалансированный вариант, чтобы уменьшать вложенность (глубину графа)
    ///
    /// x*y - найти все связи между, в последовательностях любой формы, если не стоит ограничитель на то, что является последовательностью, а что нет,
    /// то находятся любые структуры связей, которые содержат эти элементы именно в таком порядке.
    ///
    /// Рост последовательности слева и справа.
    /// Поиск со звёздочкой.
    /// URL, PURL - реестр используемых во вне ссылок на ресурсы,
    /// так же проблема может быть решена при реализации дистанционных триггеров.
    /// Нужны ли уникальные указатели вообще?
    /// Что если обращение к информации будет происходить через содержимое всегда?
    ///
    /// Писать тесты.
    ///
    ///
    /// Можно убрать зависимость от конкретной реализации Links,
    /// на зависимость от абстрактного элемента, который может быть представлен несколькими способами.
    ///
    /// Можно ли как-то сделать один общий интерфейс
    ///
    ///
    /// Блокчейн и/или гит для распределённой записи транзакций.
    ///
    /// </remarks>
    public partial class Sequences : ILinks<LinkIndex> // IList<string>, IList<LinkIndex[]>
    (после завершения реализации Sequences)
    {
        /// <summary>Возвращает значение LinkIndex, обозначающее любое количество связей.</summary>
        public const LinkIndex ZeroOrMany = LinkIndex.MaxValue;

        public SequencesOptions<LinkIndex> Options { get; }
        public SynchronizedLinks<LinkIndex> Links { get; }
        private readonly ISynchronization _sync;

        public LinksConstants<LinkIndex> Constants { get; }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public Sequences(SynchronizedLinks<LinkIndex> links, SequencesOptions<LinkIndex> options)
        {
            Links = links;
            _sync = links.SyncRoot;
            Options = options;
            Options.ValidateOptions();
            Options.InitOptions(Links);
            Constants = links.Constants;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public Sequences(SynchronizedLinks<LinkIndex> links) : this(links, new SequencesOptions<LinkIndex>()) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
76          public bool IsSequence(LinkIndex sequence)
77          {
78              return _sync.ExecuteReadOperation(() =>
79              {
80                  if (Options.UseSequenceMarker)
81                  {
82                      return Options.MarkedSequenceMatcher.IsMatched(sequence);
83                  }
84                  return !Links.Unsync.IsPartialPoint(sequence);
85              });
86          }
87
88          [MethodImpl(MethodImplOptions.AggressiveInlining)]
89          private LinkIndex GetSequenceByElements(LinkIndex sequence)
90          {
91              if (Options.UseSequenceMarker)
92              {
93                  return Links.SearchOrDefault(Options.SequenceMarkerLink, sequence);
94              }
95              return sequence;
96          }
97
98          [MethodImpl(MethodImplOptions.AggressiveInlining)]
99          private LinkIndex GetSequenceElements(LinkIndex sequence)
100         {
101             if (Options.UseSequenceMarker)
102             {
103                 var linkContents = new Link<ulong>(Links.GetLink(sequence));
104                 if (linkContents.Source == Options.SequenceMarkerLink)
105                 {
106                     return linkContents.Target;
107                 }
108                 if (linkContents.Target == Options.SequenceMarkerLink)
109                 {
110                     return linkContents.Source;
111                 }
112             }
113             return sequence;
114         }
115
116         #region Count
117
118         [MethodImpl(MethodImplOptions.AggressiveInlining)]
119         public LinkIndex Count(IList<LinkIndex> restrictions)
120         {
121             if (restrictions.IsNullOrEmpty())
122             {
123                 return Links.Count(Constants.Any, Options.SequenceMarkerLink, Constants.Any);
124             }
125             if (restrictions.Count == 1) // Первая связь это адрес
126             {
127                 var sequenceIndex = restrictions[0];
128                 if (sequenceIndex == Constants.Null)
129                 {
130                     return 0;
131                 }
132                 if (sequenceIndex == Constants.Any)
133                 {
134                     return Count(null);
135                 }
136                 if (Options.UseSequenceMarker)
137                 {
138                     return Links.Count(Constants.Any, Options.SequenceMarkerLink, sequenceIndex);
139                 }
140                 return Links.Exists(sequenceIndex) ? 1UL : 0;
141             }
142             throw new NotImplementedException();
143         }
144
145         [MethodImpl(MethodImplOptions.AggressiveInlining)]
146         private LinkIndex CountUsages(params LinkIndex[] restrictions)
147         {
148             if (restrictions.Length == 0)
149             {
150                 return 0;
151             }
152             if (restrictions.Length == 1) // Первая связь это адрес
153             {
154                 if (restrictions[0] == Constants.Null)
```

```
155                 {
156                     return 0;
157                 }
158                 var any = Constants.Any;
159                 if (Options.UseSequenceMarker)
160                 {
161                     var elementsLink = GetSequenceElements(restrictions[0]);
162                     var sequenceLink = GetSequenceByElements(elementsLink);
163                     if (sequenceLink != Constants.Null)
164                     {
165                         return Links.Count(any, sequenceLink) + Links.Count(any, elementsLink) -
                            ↪ 1;
166                     }
167                     return Links.Count(any, elementsLink);
168                 }
169                 return Links.Count(any, restrictions[0]);
170             }
171             throw new NotImplementedException();
172         }
173 
174         #endregion
175 
176         #region Create
177 
178         [MethodImpl(MethodImplOptions.AggressiveInlining)]
179         public LinkIndex Create(IList<LinkIndex> restrictions)
180         {
181             return _sync.ExecuteWriteOperation(() =>
182             {
183                 if (restrictions.IsNullOrEmpty())
184                 {
185                     return Constants.Null;
186                 }
187                 Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
188                 return CreateCore(restrictions);
189             });
190         }
191 
192         [MethodImpl(MethodImplOptions.AggressiveInlining)]
193         private LinkIndex CreateCore(IList<LinkIndex> restrictions)
194         {
195             LinkIndex[] sequence = restrictions.SkipFirst();
196             if (Options.UseIndex)
197             {
198                 Options.Index.Add(sequence);
199             }
200             var sequenceRoot = default(LinkIndex);
201             if (Options.EnforceSingleSequenceVersionOnWriteBasedOnExisting)
202             {
203                 var matches = Each(restrictions);
204                 if (matches.Count > 0)
205                 {
206                     sequenceRoot = matches[0];
207                 }
208             }
209             else if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew)
210             {
211                 return CompactCore(sequence);
212             }
213             if (sequenceRoot == default)
214             {
215                 sequenceRoot = Options.LinksToSequenceConverter.Convert(sequence);
216             }
217             if (Options.UseSequenceMarker)
218             {
219                 return Links.Unsync.GetOrCreate(Options.SequenceMarkerLink, sequenceRoot);
220             }
221             return sequenceRoot; // Возвращаем корень последовательности (т.е. сами элементы)
222         }
223 
224         #endregion
225 
226         #region Each
227 
228         [MethodImpl(MethodImplOptions.AggressiveInlining)]
229         public List<LinkIndex> Each(IList<LinkIndex> sequence)
230         {
231             var results = new List<LinkIndex>();
232             var filler = new ListFiller<LinkIndex, LinkIndex>(results, Constants.Continue);
```

```
233             Each(filler.AddFirstAndReturnConstant, sequence);
234             return results;
235         }
236 
237         [MethodImpl(MethodImplOptions.AggressiveInlining)]
238         public LinkIndex Each(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
            ↪ restrictions)
239         {
240             return _sync.ExecuteReadOperation(() =>
241             {
242                 if (restrictions.IsNullOrEmpty())
243                 {
244                     return Constants.Continue;
245                 }
246                 Links.EnsureInnerReferenceExists(restrictions, nameof(restrictions));
247                 if (restrictions.Count == 1)
248                 {
249                     var link = restrictions[0];
250                     var any = Constants.Any;
251                     if (link == any)
252                     {
253                         if (Options.UseSequenceMarker)
254                         {
255                             return Links.Unsync.Each(handler, new Link<LinkIndex>(any,
                                ↪ Options.SequenceMarkerLink, any));
256                         }
257                         else
258                         {
259                             return Links.Unsync.Each(handler, new Link<LinkIndex>(any, any,
                                ↪ any));
260                         }
261                     }
262                     if (Options.UseSequenceMarker)
263                     {
264                         var sequenceLinkValues = Links.Unsync.GetLink(link);
265                         if (sequenceLinkValues[Constants.SourcePart] ==
                            ↪ Options.SequenceMarkerLink)
266                         {
267                             link = sequenceLinkValues[Constants.TargetPart];
268                         }
269                     }
270                     var sequence = Options.Walker.Walk(link).ToArray().ShiftRight();
271                     sequence[0] = link;
272                     return handler(sequence);
273                 }
274                 else if (restrictions.Count == 2)
275                 {
276                     throw new NotImplementedException();
277                 }
278                 else if (restrictions.Count == 3)
279                 {
280                     return Links.Unsync.Each(handler, restrictions);
281                 }
282                 else
283                 {
284                     var sequence = restrictions.SkipFirst();
285                     if (Options.UseIndex && !Options.Index.MightContain(sequence))
286                     {
287                         return Constants.Break;
288                     }
289                     return EachCore(handler, sequence);
290                 }
291             });
292         }
293 
294         [MethodImpl(MethodImplOptions.AggressiveInlining)]
295         private LinkIndex EachCore(Func<IList<LinkIndex>, LinkIndex> handler, IList<LinkIndex>
            ↪ values)
296         {
297             var matcher = new Matcher(this, values, new HashSet<LinkIndex>(), handler);
298             // TODO: Find out why matcher.HandleFullMatched executed twice for the same sequence
                ↪ Id.
299             Func<IList<LinkIndex>, LinkIndex> innerHandler = Options.UseSequenceMarker ?
                ↪ (Func<IList<LinkIndex>, LinkIndex>)matcher.HandleFullMatchedSequence :
                ↪ matcher.HandleFullMatched;
300             //if (sequence.Length >= 2)
301             if (StepRight(innerHandler, values[0], values[1]) != Constants.Continue)
302             {
```

```
303                 return Constants.Break;
304             }
305             var last = values.Count - 2;
306             for (var i = 1; i < last; i++)
307             {
308                 if (PartialStepRight(innerHandler, values[i], values[i + 1]) !=
                    ↪  Constants.Continue)
309                 {
310                     return Constants.Break;
311                 }
312             }
313             if (values.Count >= 3)
314             {
315                 if (StepLeft(innerHandler, values[values.Count - 2], values[values.Count - 1])
                    ↪  != Constants.Continue)
316                 {
317                     return Constants.Break;
318                 }
319             }
320             return Constants.Continue;
321         }
322
323         [MethodImpl(MethodImplOptions.AggressiveInlining)]
324         private LinkIndex PartialStepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
            ↪  left, LinkIndex right)
325         {
326             return Links.Unsync.Each(doublet =>
327             {
328                 var doubletIndex = doublet[Constants.IndexPart];
329                 if (StepRight(handler, doubletIndex, right) != Constants.Continue)
330                 {
331                     return Constants.Break;
332                 }
333                 if (left != doubletIndex)
334                 {
335                     return PartialStepRight(handler, doubletIndex, right);
336                 }
337                 return Constants.Continue;
338             }, new Link<LinkIndex>(Constants.Any, Constants.Any, left));
339         }
340
341         [MethodImpl(MethodImplOptions.AggressiveInlining)]
342         private LinkIndex StepRight(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex left,
            ↪  LinkIndex right) => Links.Unsync.Each(rightStep => TryStepRightUp(handler, right,
            ↪  rightStep[Constants.IndexPart]), new Link<LinkIndex>(Constants.Any, left,
            ↪  Constants.Any));
343
344         [MethodImpl(MethodImplOptions.AggressiveInlining)]
345         private LinkIndex TryStepRightUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
            ↪  right, LinkIndex stepFrom)
346         {
347             var upStep = stepFrom;
348             var firstSource = Links.Unsync.GetTarget(upStep);
349             while (firstSource != right && firstSource != upStep)
350             {
351                 upStep = firstSource;
352                 firstSource = Links.Unsync.GetSource(upStep);
353             }
354             if (firstSource == right)
355             {
356                 return handler(new LinkAddress<LinkIndex>(stepFrom));
357             }
358             return Constants.Continue;
359         }
360
361         [MethodImpl(MethodImplOptions.AggressiveInlining)]
362         private LinkIndex StepLeft(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex left,
            ↪  LinkIndex right) => Links.Unsync.Each(leftStep => TryStepLeftUp(handler, left,
            ↪  leftStep[Constants.IndexPart]), new Link<LinkIndex>(Constants.Any, Constants.Any,
            ↪  right));
363
364         [MethodImpl(MethodImplOptions.AggressiveInlining)]
365         private LinkIndex TryStepLeftUp(Func<IList<LinkIndex>, LinkIndex> handler, LinkIndex
            ↪  left, LinkIndex stepFrom)
366         {
367             var upStep = stepFrom;
368             var firstTarget = Links.Unsync.GetSource(upStep);
369             while (firstTarget != left && firstTarget != upStep)
```

```
370             {
371                 upStep = firstTarget;
372                 firstTarget = Links.Unsync.GetTarget(upStep);
373             }
374             if (firstTarget == left)
375             {
376                 return handler(new LinkAddress<LinkIndex>(stepFrom));
377             }
378             return Constants.Continue;
379         }
380 
381         #endregion
382 
383         #region Update
384 
385         [MethodImpl(MethodImplOptions.AggressiveInlining)]
386         public LinkIndex Update(IList<LinkIndex> restrictions, IList<LinkIndex> substitution)
387         {
388             var sequence = restrictions.SkipFirst();
389             var newSequence = substitution.SkipFirst();
390             if (sequence.IsNullOrEmpty() && newSequence.IsNullOrEmpty())
391             {
392                 return Constants.Null;
393             }
394             if (sequence.IsNullOrEmpty())
395             {
396                 return Create(substitution);
397             }
398             if (newSequence.IsNullOrEmpty())
399             {
400                 Delete(restrictions);
401                 return Constants.Null;
402             }
403             return _sync.ExecuteWriteOperation((Func<ulong>)(() =>
404             {
405                 ILinksExtensions.EnsureLinkIsAnyOrExists<ulong>(Links, (IList<ulong>)sequence);
406                 Links.EnsureLinkExists(newSequence);
407                 return UpdateCore(sequence, newSequence);
408             }));
409         }
410 
411         [MethodImpl(MethodImplOptions.AggressiveInlining)]
412         private LinkIndex UpdateCore(IList<LinkIndex> sequence, IList<LinkIndex> newSequence)
413         {
414             LinkIndex bestVariant;
415             if (Options.EnforceSingleSequenceVersionOnWriteBasedOnNew &&
                 ↪  !sequence.EqualTo(newSequence))
416             {
417                 bestVariant = CompactCore(newSequence);
418             }
419             else
420             {
421                 bestVariant = CreateCore(newSequence);
422             }
423             // TODO: Check all options only ones before loop execution
424             // Возможно нужно две версии Each, возвращающий фактические последовательности и с
                 ↪  маркером,
425             // или возможно даже возвращать и тот и тот вариант. С другой стороны все варианты
                 ↪  можно получить имея только фактические последовательности.
426             foreach (var variant in Each(sequence))
427             {
428                 if (variant != bestVariant)
429                 {
430                     UpdateOneCore(variant, bestVariant);
431                 }
432             }
433             return bestVariant;
434         }
435 
436         [MethodImpl(MethodImplOptions.AggressiveInlining)]
437         private void UpdateOneCore(LinkIndex sequence, LinkIndex newSequence)
438         {
439             if (Options.UseGarbageCollection)
440             {
441                 var sequenceElements = GetSequenceElements(sequence);
442                 var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
443                 var sequenceLink = GetSequenceByElements(sequenceElements);
444                 var newSequenceElements = GetSequenceElements(newSequence);
445                 var newSequenceLink = GetSequenceByElements(newSequenceElements);
```

```
                if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
                {
                    if (sequenceLink != Constants.Null)
                    {
                        Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
                    }
                    Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
                }
                ClearGarbage(sequenceElementsContents.Source);
                ClearGarbage(sequenceElementsContents.Target);
            }
            else
            {
                if (Options.UseSequenceMarker)
                {
                    var sequenceElements = GetSequenceElements(sequence);
                    var sequenceLink = GetSequenceByElements(sequenceElements);
                    var newSequenceElements = GetSequenceElements(newSequence);
                    var newSequenceLink = GetSequenceByElements(newSequenceElements);
                    if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
                    {
                        if (sequenceLink != Constants.Null)
                        {
                            Links.Unsync.MergeAndDelete(sequenceLink, newSequenceLink);
                        }
                        Links.Unsync.MergeAndDelete(sequenceElements, newSequenceElements);
                    }
                }
                else
                {
                    if (Options.UseCascadeUpdate || CountUsages(sequence) == 0)
                    {
                        Links.Unsync.MergeAndDelete(sequence, newSequence);
                    }
                }
            }
        }

        #endregion

        #region Delete

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Delete(IList<LinkIndex> restrictions)
        {
            _sync.ExecuteWriteOperation(() =>
            {
                var sequence = restrictions.SkipFirst();
                // TODO: Check all options only ones before loop execution
                foreach (var linkToDelete in Each(sequence))
                {
                    DeleteOneCore(linkToDelete);
                }
            });
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private void DeleteOneCore(LinkIndex link)
        {
            if (Options.UseGarbageCollection)
            {
                var sequenceElements = GetSequenceElements(link);
                var sequenceElementsContents = new Link<ulong>(Links.GetLink(sequenceElements));
                var sequenceLink = GetSequenceByElements(sequenceElements);
                if (Options.UseCascadeDelete || CountUsages(link) == 0)
                {
                    if (sequenceLink != Constants.Null)
                    {
                        Links.Unsync.Delete(sequenceLink);
                    }
                    Links.Unsync.Delete(link);
                }
                ClearGarbage(sequenceElementsContents.Source);
                ClearGarbage(sequenceElementsContents.Target);
            }
            else
            {
                if (Options.UseSequenceMarker)
```

```
524                 {
525                     var sequenceElements = GetSequenceElements(link);
526                     var sequenceLink = GetSequenceByElements(sequenceElements);
527                     if (Options.UseCascadeDelete || CountUsages(link) == 0)
528                     {
529                         if (sequenceLink != Constants.Null)
530                         {
531                             Links.Unsync.Delete(sequenceLink);
532                         }
533                         Links.Unsync.Delete(link);
534                     }
535                 }
536                 else
537                 {
538                     if (Options.UseCascadeDelete || CountUsages(link) == 0)
539                     {
540                         Links.Unsync.Delete(link);
541                     }
542                 }
543             }
544         }
545 
546         #endregion
547 
548         #region Compactification
549 
550         [MethodImpl(MethodImplOptions.AggressiveInlining)]
551         public void CompactAll()
552         {
553             _sync.ExecuteWriteOperation(() =>
554             {
555                 var sequences = Each((LinkAddress<LinkIndex>)Constants.Any);
556                 for (int i = 0; i < sequences.Count; i++)
557                 {
558                     var sequence = this.ToList(sequences[i]);
559                     Compact(sequence.ShiftRight());
560                 }
561             });
562         }
563 
564         /// <remarks>
565         /// bestVariant можно выбирать по максимальному числу использований,
566         /// но балансированный позволяет гарантировать уникальность (если есть возможность,
567         /// гарантировать его использование в других местах).
568         ///
569         /// Получается этот метод должен игнорировать Options.EnforceSingleSequenceVersionOnWrite
570         /// </remarks>
571         [MethodImpl(MethodImplOptions.AggressiveInlining)]
572         public LinkIndex Compact(IList<LinkIndex> sequence)
573         {
574             return _sync.ExecuteWriteOperation(() =>
575             {
576                 if (sequence.IsNullOrEmpty())
577                 {
578                     return Constants.Null;
579                 }
580                 Links.EnsureInnerReferenceExists(sequence, nameof(sequence));
581                 return CompactCore(sequence);
582             });
583         }
584 
585         [MethodImpl(MethodImplOptions.AggressiveInlining)]
586         private LinkIndex CompactCore(IList<LinkIndex> sequence) => UpdateCore(sequence,
            ↪ sequence);
587 
588         #endregion
589 
590         #region Garbage Collection
591 
592         /// <remarks>
593         /// TODO: Добавить дополнительный обработчик / событие CanBeDeleted которое можно
            ↪ определить извне или в унаследованном классе
594         /// </remarks>
595         [MethodImpl(MethodImplOptions.AggressiveInlining)]
596         private bool IsGarbage(LinkIndex link) => link != Options.SequenceMarkerLink &&
            ↪ !Links.Unsync.IsPartialPoint(link) && Links.Count(Constants.Any, link) == 0;
597 
598         [MethodImpl(MethodImplOptions.AggressiveInlining)]
599         private void ClearGarbage(LinkIndex link)
```

```
600         {
601             if (IsGarbage(link))
602             {
603                 var contents = new Link<ulong>(Links.GetLink(link));
604                 Links.Unsync.Delete(link);
605                 ClearGarbage(contents.Source);
606                 ClearGarbage(contents.Target);
607             }
608         }
609 
610         #endregion
611 
612         #region Walkers
613 
614         [MethodImpl(MethodImplOptions.AggressiveInlining)]
615         public bool EachPart(Func<LinkIndex, bool> handler, LinkIndex sequence)
616         {
617             return _sync.ExecuteReadOperation(() =>
618             {
619                 var links = Links.Unsync;
620                 foreach (var part in Options.Walker.Walk(sequence))
621                 {
622                     if (!handler(part))
623                     {
624                         return false;
625                     }
626                 }
627                 return true;
628             });
629         }
630 
631         public class Matcher : RightSequenceWalker<LinkIndex>
632         {
633             private readonly Sequences _sequences;
634             private readonly IList<LinkIndex> _patternSequence;
635             private readonly HashSet<LinkIndex> _linksInSequence;
636             private readonly HashSet<LinkIndex> _results;
637             private readonly Func<IList<LinkIndex>, LinkIndex> _stopableHandler;
638             private readonly HashSet<LinkIndex> _readAsElements;
639             private int _filterPosition;
640 
641             [MethodImpl(MethodImplOptions.AggressiveInlining)]
642             public Matcher(Sequences sequences, IList<LinkIndex> patternSequence,
                ↪  HashSet<LinkIndex> results, Func<IList<LinkIndex>, LinkIndex> stopableHandler,
                ↪  HashSet<LinkIndex> readAsElements = null)
643                 : base(sequences.Links.Unsync, new DefaultStack<LinkIndex>())
644             {
645                 _sequences = sequences;
646                 _patternSequence = patternSequence;
647                 _linksInSequence = new HashSet<LinkIndex>(patternSequence.Where(x => x !=
                    ↪  _links.Constants.Any && x != ZeroOrMany));
648                 _results = results;
649                 _stopableHandler = stopableHandler;
650                 _readAsElements = readAsElements;
651             }
652 
653             [MethodImpl(MethodImplOptions.AggressiveInlining)]
654             protected override bool IsElement(LinkIndex link) => base.IsElement(link) ||
                ↪  (_readAsElements != null && _readAsElements.Contains(link)) ||
                ↪  _linksInSequence.Contains(link);
655 
656             [MethodImpl(MethodImplOptions.AggressiveInlining)]
657             public bool FullMatch(LinkIndex sequenceToMatch)
658             {
659                 _filterPosition = 0;
660                 foreach (var part in Walk(sequenceToMatch))
661                 {
662                     if (!FullMatchCore(part))
663                     {
664                         break;
665                     }
666                 }
667                 return _filterPosition == _patternSequence.Count;
668             }
669 
670             [MethodImpl(MethodImplOptions.AggressiveInlining)]
671             private bool FullMatchCore(LinkIndex element)
672             {
673                 if (_filterPosition == _patternSequence.Count)
674                 {
```

```
675                     _filterPosition = -2; // Длиннее чем нужно
676                     return false;
677                 }
678                 if (_patternSequence[_filterPosition] != _links.Constants.Any
679                  && element != _patternSequence[_filterPosition])
680                 {
681                     _filterPosition = -1;
682                     return false; // Начинается/Продолжается иначе
683                 }
684                 _filterPosition++;
685                 return true;
686             }
687 
688             [MethodImpl(MethodImplOptions.AggressiveInlining)]
689             public void AddFullMatchedToResults(IList<LinkIndex> restrictions)
690             {
691                 var sequenceToMatch = restrictions[_links.Constants.IndexPart];
692                 if (FullMatch(sequenceToMatch))
693                 {
694                     _results.Add(sequenceToMatch);
695                 }
696             }
697 
698             [MethodImpl(MethodImplOptions.AggressiveInlining)]
699             public LinkIndex HandleFullMatched(IList<LinkIndex> restrictions)
700             {
701                 var sequenceToMatch = restrictions[_links.Constants.IndexPart];
702                 if (FullMatch(sequenceToMatch) && _results.Add(sequenceToMatch))
703                 {
704                     return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
705                 }
706                 return _links.Constants.Continue;
707             }
708 
709             [MethodImpl(MethodImplOptions.AggressiveInlining)]
710             public LinkIndex HandleFullMatchedSequence(IList<LinkIndex> restrictions)
711             {
712                 var sequenceToMatch = restrictions[_links.Constants.IndexPart];
713                 var sequence = _sequences.GetSequenceByElements(sequenceToMatch);
714                 if (sequence != _links.Constants.Null && FullMatch(sequenceToMatch) &&
                    ↪ _results.Add(sequenceToMatch))
715                 {
716                     return _stopableHandler(new LinkAddress<LinkIndex>(sequence));
717                 }
718                 return _links.Constants.Continue;
719             }
720 
721             /// <remarks>
722             /// TODO: Add support for LinksConstants.Any
723             /// </remarks>
724             [MethodImpl(MethodImplOptions.AggressiveInlining)]
725             public bool PartialMatch(LinkIndex sequenceToMatch)
726             {
727                 _filterPosition = -1;
728                 foreach (var part in Walk(sequenceToMatch))
729                 {
730                     if (!PartialMatchCore(part))
731                     {
732                         break;
733                     }
734                 }
735                 return _filterPosition == _patternSequence.Count - 1;
736             }
737 
738             [MethodImpl(MethodImplOptions.AggressiveInlining)]
739             private bool PartialMatchCore(LinkIndex element)
740             {
741                 if (_filterPosition == (_patternSequence.Count - 1))
742                 {
743                     return false; // Нашлось
744                 }
745                 if (_filterPosition >= 0)
746                 {
747                     if (element == _patternSequence[_filterPosition + 1])
748                     {
749                         _filterPosition++;
750                     }
751                     else
752                     {
```

```
                        _filterPosition = -1;
                    }
                }
                if (_filterPosition < 0)
                {
                    if (element == _patternSequence[0])
                    {
                        _filterPosition = 0;
                    }
                }
                return true; // Ищем дальше
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public void AddPartialMatchedToResults(LinkIndex sequenceToMatch)
            {
                if (PartialMatch(sequenceToMatch))
                {
                    _results.Add(sequenceToMatch);
                }
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public LinkIndex HandlePartialMatched(IList<LinkIndex> restrictions)
            {
                var sequenceToMatch = restrictions[_links.Constants.IndexPart];
                if (PartialMatch(sequenceToMatch))
                {
                    return _stopableHandler(new LinkAddress<LinkIndex>(sequenceToMatch));
                }
                return _links.Constants.Continue;
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public void AddAllPartialMatchedToResults(IEnumerable<LinkIndex> sequencesToMatch)
            {
                foreach (var sequenceToMatch in sequencesToMatch)
                {
                    if (PartialMatch(sequenceToMatch))
                    {
                        _results.Add(sequenceToMatch);
                    }
                }
            }

            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            public void AddAllPartialMatchedToResultsAndReadAsElements(IEnumerable<LinkIndex>
            ↪  sequencesToMatch)
            {
                foreach (var sequenceToMatch in sequencesToMatch)
                {
                    if (PartialMatch(sequenceToMatch))
                    {
                        _readAsElements.Add(sequenceToMatch);
                        _results.Add(sequenceToMatch);
                    }
                }
            }
        }

        #endregion
    }
}
```

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

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Lists;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    public static class SequencesExtensions
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static TLink Create<TLink>(this ILinks<TLink> sequences, IList<TLink[]>
        ↪  groupedSequence)
        {
```

```
            var finalSequence = new TLink[groupedSequence.Count];
            for (var i = 0; i < finalSequence.Length; i++)
            {
                var part = groupedSequence[i];
                finalSequence[i] = part.Length == 1 ? part[0] :
                ↪  sequences.Create(part.ShiftRight());
            }
            return sequences.Create(finalSequence.ShiftRight());
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static IList<TLink> ToList<TLink>(this ILinks<TLink> sequences, TLink sequence)
        {
            var list = new List<TLink>();
            var filler = new ListFiller<TLink, TLink>(list, sequences.Constants.Break);
            sequences.Each(filler.AddSkipFirstAndReturnConstant, new
            ↪  LinkAddress<TLink>(sequence));
            return list;
        }
    }
}
```

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

```
using System;
using System.Collections.Generic;
using Platform.Interfaces;
using Platform.Collections.Stacks;
using Platform.Converters;
using Platform.Data.Doublets.Sequences.Frequencies.Cache;
using Platform.Data.Doublets.Sequences.Frequencies.Counters;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Data.Doublets.Sequences.Indexes;
using Platform.Data.Doublets.Sequences.CriterionMatchers;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences
{
    public class SequencesOptions<TLink> // TODO: To use type parameter <TLink> the
    ↪  ILinks<TLink> must contain GetConstants function.
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        public TLink SequenceMarkerLink
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool UseCascadeUpdate
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool UseCascadeDelete
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool UseIndex
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        } // TODO: Update Index on sequence update/delete.

        public bool UseSequenceMarker
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool UseCompression
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool UseGarbageCollection
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool EnforceSingleSequenceVersionOnWriteBasedOnExisting
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool EnforceSingleSequenceVersionOnWriteBasedOnNew
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public MarkedSequenceCriterionMatcher<TLink> MarkedSequenceMatcher
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public IConverter<IList<TLink>, TLink> LinksToSequenceConverter
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public ISequenceIndex<TLink> Index
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public ISequenceWalker<TLink> Walker
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        public bool ReadFullSequence
        {
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            get;
            [MethodImpl(MethodImplOptions.AggressiveInlining)]
            set;
        }

        // TODO: Реализовать компактификацию при чтении
        //public bool EnforceSingleSequenceVersionOnRead { get; set; }
        //public bool UseRequestMarker { get; set; }
        //public bool StoreRequestResults { get; set; }
```

```
138
139         [MethodImpl(MethodImplOptions.AggressiveInlining)]
140         public void InitOptions(ISynchronizedLinks<TLink> links)
141         {
142             if (UseSequenceMarker)
143             {
144                 if (_equalityComparer.Equals(SequenceMarkerLink, links.Constants.Null))
145                 {
146                     SequenceMarkerLink = links.CreatePoint();
147                 }
148                 else
149                 {
150                     if (!links.Exists(SequenceMarkerLink))
151                     {
152                         var link = links.CreatePoint();
153                         if (!_equalityComparer.Equals(link, SequenceMarkerLink))
154                         {
155                             throw new InvalidOperationException("Cannot recreate sequence marker
                                ↪  link.");
156                         }
157                     }
158                 }
159                 if (MarkedSequenceMatcher == null)
160                 {
161                     MarkedSequenceMatcher = new MarkedSequenceCriterionMatcher<TLink>(links,
                        ↪  SequenceMarkerLink);
162                 }
163             }
164             var balancedVariantConverter = new BalancedVariantConverter<TLink>(links);
165             if (UseCompression)
166             {
167                 if (LinksToSequenceConverter == null)
168                 {
169                     ICounter<TLink, TLink> totalSequenceSymbolFrequencyCounter;
170                     if (UseSequenceMarker)
171                     {
172                         totalSequenceSymbolFrequencyCounter = new
                            ↪  TotalMarkedSequenceSymbolFrequencyCounter<TLink>(links,
                            ↪  MarkedSequenceMatcher);
173                     }
174                     else
175                     {
176                         totalSequenceSymbolFrequencyCounter = new
                            ↪  TotalSequenceSymbolFrequencyCounter<TLink>(links);
177                     }
178                     var doubletFrequenciesCache = new LinkFrequenciesCache<TLink>(links,
                        ↪  totalSequenceSymbolFrequencyCounter);
179                     var compressingConverter = new CompressingConverter<TLink>(links,
                        ↪  balancedVariantConverter, doubletFrequenciesCache);
180                     LinksToSequenceConverter = compressingConverter;
181                 }
182             }
183             else
184             {
185                 if (LinksToSequenceConverter == null)
186                 {
187                     LinksToSequenceConverter = balancedVariantConverter;
188                 }
189             }
190             if (UseIndex && Index == null)
191             {
192                 Index = new SequenceIndex<TLink>(links);
193             }
194             if (Walker == null)
195             {
196                 Walker = new RightSequenceWalker<TLink>(links, new DefaultStack<TLink>());
197             }
198         }
199
200         [MethodImpl(MethodImplOptions.AggressiveInlining)]
201         public void ValidateOptions()
202         {
203             if (UseGarbageCollection && !UseSequenceMarker)
204             {
205                 throw new NotSupportedException("To use garbage collection UseSequenceMarker
                    ↪  option must be on.");
206             }
207         }
```

```
    }
}
```

1.46 ./csharp/Platform.Data.Doublets.Sequences/Time/DateTimeToLongRawNumberSequenceConverter.cs

```
using System;
using System.Runtime.CompilerServices;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Time
{
    public class DateTimeToLongRawNumberSequenceConverter<TLink> : IConverter<DateTime, TLink>
    {
        private readonly IConverter<long, TLink> _int64ToLongRawNumberConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DateTimeToLongRawNumberSequenceConverter(IConverter<long, TLink>
        ↪  int64ToLongRawNumberConverter) => _int64ToLongRawNumberConverter =
        ↪  int64ToLongRawNumberConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(DateTime source) =>
        ↪  _int64ToLongRawNumberConverter.Convert(source.ToFileTimeUtc());
    }
}
```

1.47 ./csharp/Platform.Data.Doublets.Sequences/Time/LongRawNumberSequenceToDateTimeConverter.cs

```
using System;
using System.Runtime.CompilerServices;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Time
{
    public class LongRawNumberSequenceToDateTimeConverter<TLink> : IConverter<TLink, DateTime>
    {
        private readonly IConverter<TLink, long> _longRawNumberConverterToInt64;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LongRawNumberSequenceToDateTimeConverter(IConverter<TLink, long>
        ↪  longRawNumberConverterToInt64) => _longRawNumberConverterToInt64 =
        ↪  longRawNumberConverterToInt64;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public DateTime Convert(TLink source) =>
        ↪  DateTime.FromFileTimeUtc(_longRawNumberConverterToInt64.Convert(source));
    }
}
```

1.48 ./csharp/Platform.Data.Doublets.Sequences/UInt64LinksExtensions.cs

```
using System;
using System.Text;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Singletons;
using Platform.Data.Doublets.Unicode;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets
{
    public static class UInt64LinksExtensions
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static void UseUnicode(this ILinks<ulong> links) => UnicodeMap.InitNew(links);
    }
}
```

1.49 ./csharp/Platform.Data.Doublets.Sequences/Unicode/CharToUnicodeSymbolConverter.cs

```
using System.Runtime.CompilerServices;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class CharToUnicodeSymbolConverter<TLink> : LinksOperatorBase<TLink>,
    ↪  IConverter<char, TLink>
```

```
    {
        private static readonly UncheckedConverter<char, TLink> _charToAddressConverter =
        ↪  UncheckedConverter<char, TLink>.Default;

        private readonly IConverter<TLink> _addressToNumberConverter;
        private readonly TLink _unicodeSymbolMarker;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public CharToUnicodeSymbolConverter(ILinks<TLink> links, IConverter<TLink>
        ↪  addressToNumberConverter, TLink unicodeSymbolMarker) : base(links)
        {
            _addressToNumberConverter = addressToNumberConverter;
            _unicodeSymbolMarker = unicodeSymbolMarker;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(char source)
        {
            var unaryNumber =
            ↪  _addressToNumberConverter.Convert(_charToAddressConverter.Convert(source));
            return _links.GetOrCreate(unaryNumber, _unicodeSymbolMarker);
        }
    }
}
```

1.50 ./csharp/Platform.Data.Doublets.Sequences/Unicode/StringToUnicodeSequenceConverter.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;
using Platform.Data.Doublets.Sequences.Indexes;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class StringToUnicodeSequenceConverter<TLink> : LinksOperatorBase<TLink>,
    ↪  IConverter<string, TLink>
    {
        private readonly IConverter<string, IList<TLink>> _stringToUnicodeSymbolListConverter;
        private readonly IConverter<IList<TLink>, TLink> _unicodeSymbolListToSequenceConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<string,
        ↪  IList<TLink>> stringToUnicodeSymbolListConverter, IConverter<IList<TLink>, TLink>
        ↪  unicodeSymbolListToSequenceConverter) : base(links)
        {
            _stringToUnicodeSymbolListConverter = stringToUnicodeSymbolListConverter;
            _unicodeSymbolListToSequenceConverter = unicodeSymbolListToSequenceConverter;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<string,
        ↪  IList<TLink>> stringToUnicodeSymbolListConverter, ISequenceIndex<TLink> index,
        ↪  IConverter<IList<TLink>, TLink> listToSequenceLinkConverter, TLink
        ↪  unicodeSequenceMarker)
            : this(links, stringToUnicodeSymbolListConverter, new
            ↪  UnicodeSymbolsListToUnicodeSequenceConverter<TLink>(links, index,
            ↪  listToSequenceLinkConverter, unicodeSequenceMarker)) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<char, TLink>
        ↪  charToUnicodeSymbolConverter, ISequenceIndex<TLink> index, IConverter<IList<TLink>,
        ↪  TLink> listToSequenceLinkConverter, TLink unicodeSequenceMarker)
            : this(links, new
            ↪  StringToUnicodeSymbolsListConverter<TLink>(charToUnicodeSymbolConverter), index,
            ↪  listToSequenceLinkConverter, unicodeSequenceMarker) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<char, TLink>
        ↪  charToUnicodeSymbolConverter, IConverter<IList<TLink>, TLink>
        ↪  listToSequenceLinkConverter, TLink unicodeSequenceMarker)
            : this(links, charToUnicodeSymbolConverter, new Unindex<TLink>(),
            ↪  listToSequenceLinkConverter, unicodeSequenceMarker) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public StringToUnicodeSequenceConverter(ILinks<TLink> links, IConverter<string,
        ↪  IList<TLink>> stringToUnicodeSymbolListConverter, IConverter<IList<TLink>, TLink>
        ↪  listToSequenceLinkConverter, TLink unicodeSequenceMarker)
```

```
            : this(links, stringToUnicodeSymbolListConverter, new Unindex<TLink>(),
            ↪  listToSequenceLinkConverter, unicodeSequenceMarker) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(string source)
        {
            var elements = _stringToUnicodeSymbolListConverter.Convert(source);
            return _unicodeSymbolListToSequenceConverter.Convert(elements);
        }
    }
}
```

1.51 ./csharp/Platform.Data.Doublets.Sequences/Unicode/StringToUnicodeSymbolsListConverter.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class StringToUnicodeSymbolsListConverter<TLink> : IConverter<string, IList<TLink>>
    {
        private readonly IConverter<char, TLink> _charToUnicodeSymbolConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public StringToUnicodeSymbolsListConverter(IConverter<char, TLink>
        ↪  charToUnicodeSymbolConverter) => _charToUnicodeSymbolConverter =
        ↪  charToUnicodeSymbolConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public IList<TLink> Convert(string source)
        {
            var elements = new TLink[source.Length];
            for (var i = 0; i < elements.Length; i++)
            {
                elements[i] = _charToUnicodeSymbolConverter.Convert(source[i]);
            }
            return elements;
        }
    }
}
```

1.52 ./csharp/Platform.Data.Doublets.Sequences/Unicode/UnicodeMap.cs

```
using System;
using System.Collections.Generic;
using System.Globalization;
using System.Runtime.CompilerServices;
using System.Text;
using Platform.Data.Sequences;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class UnicodeMap
    {
        public static readonly ulong FirstCharLink = 1;
        public static readonly ulong LastCharLink = FirstCharLink + char.MaxValue;
        public static readonly ulong MapSize = 1 + char.MaxValue;

        private readonly ILinks<ulong> _links;
        private bool _initialized;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnicodeMap(ILinks<ulong> links) => _links = links;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static UnicodeMap InitNew(ILinks<ulong> links)
        {
            var map = new UnicodeMap(links);
            map.Init();
            return map;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public void Init()
        {
            if (_initialized)
            {
```

```
                return;
            }
            _initialized = true;
            var firstLink = _links.CreatePoint();
            if (firstLink != FirstCharLink)
            {
                _links.Delete(firstLink);
            }
            else
            {
                for (var i = FirstCharLink + 1; i <= LastCharLink; i++)
                {
                    // From NIL to It (NIL -> Character) transformation meaning, (or infinite amount of NIL characters before actual Character)
                    var createdLink = _links.CreatePoint();
                    _links.Update(createdLink, firstLink, createdLink);
                    if (createdLink != i)
                    {
                        throw new InvalidOperationException("Unable to initialize UTF 16 table.");
                    }
                }
            }
        }

        // 0 - null link
        // 1 - nil character (0 character)
        // ...
        // 65536 (0(1) + 65535 = 65536 possible values)

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static ulong FromCharToLink(char character) => (ulong)character + 1;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static char FromLinkToChar(ulong link) => (char)(link - 1);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static bool IsCharLink(ulong link) => link <= MapSize;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static string FromLinksToString(IList<ulong> linksList)
        {
            var sb = new StringBuilder();
            for (int i = 0; i < linksList.Count; i++)
            {
                sb.Append(FromLinkToChar(linksList[i]));
            }
            return sb.ToString();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static string FromSequenceLinkToString(ulong link, ILinks<ulong> links)
        {
            var sb = new StringBuilder();
            if (links.Exists(link))
            {
                StopableSequenceWalker.WalkRight(link, links.GetSource, links.GetTarget,
                    x => x <= MapSize || links.GetSource(x) == x || links.GetTarget(x) == x,
                    element =>
                    {
                        sb.Append(FromLinkToChar(element));
                        return true;
                    });
            }
            return sb.ToString();
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static ulong[] FromCharsToLinkArray(char[] chars) => FromCharsToLinkArray(chars, chars.Length);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public static ulong[] FromCharsToLinkArray(char[] chars, int count)
        {
            // char array to ulong array
            var linksSequence = new ulong[count];
            for (var i = 0; i < count; i++)
            {
```

```
            linksSequence[i] = FromCharToLink(chars[i]);
        }
        return linksSequence;
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public static ulong[] FromStringToLinkArray(string sequence)
    {
        // char array to ulong array
        var linksSequence = new ulong[sequence.Length];
        for (var i = 0; i < sequence.Length; i++)
        {
            linksSequence[i] = FromCharToLink(sequence[i]);
        }
        return linksSequence;
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public static List<ulong[]> FromStringToLinkArrayGroups(string sequence)
    {
        var result = new List<ulong[]>();
        var offset = 0;
        while (offset < sequence.Length)
        {
            var currentCategory = CharUnicodeInfo.GetUnicodeCategory(sequence[offset]);
            var relativeLength = 1;
            var absoluteLength = offset + relativeLength;
            while (absoluteLength < sequence.Length &&
                   currentCategory ==
                    ↪ CharUnicodeInfo.GetUnicodeCategory(sequence[absoluteLength]))
            {
                relativeLength++;
                absoluteLength++;
            }
            // char array to ulong array
            var innerSequence = new ulong[relativeLength];
            var maxLength = offset + relativeLength;
            for (var i = offset; i < maxLength; i++)
            {
                innerSequence[i - offset] = FromCharToLink(sequence[i]);
            }
            result.Add(innerSequence);
            offset += relativeLength;
        }
        return result;
    }

    [MethodImpl(MethodImplOptions.AggressiveInlining)]
    public static List<ulong[]> FromLinkArrayToLinkArrayGroups(ulong[] array)
    {
        var result = new List<ulong[]>();
        var offset = 0;
        while (offset < array.Length)
        {
            var relativeLength = 1;
            if (array[offset] <= LastCharLink)
            {
                var currentCategory =
                ↪ CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(array[offset]));
                var absoluteLength = offset + relativeLength;
                while (absoluteLength < array.Length &&
                       array[absoluteLength] <= LastCharLink &&
                       currentCategory == CharUnicodeInfo.GetUnicodeCategory(FromLinkToChar(
                        ↪ array[absoluteLength])))
                {
                    relativeLength++;
                    absoluteLength++;
                }
            }
            else
            {
                var absoluteLength = offset + relativeLength;
                while (absoluteLength < array.Length && array[absoluteLength] > LastCharLink)
                {
                    relativeLength++;
                    absoluteLength++;
                }
            }
            // copy array
```

```
                var innerSequence = new ulong[relativeLength];
                var maxLength = offset + relativeLength;
                for (var i = offset; i < maxLength; i++)
                {
                    innerSequence[i - offset] = array[i];
                }
                result.Add(innerSequence);
                offset += relativeLength;
            }
            return result;
        }
    }
}
```

1.53 ./csharp/Platform.Data.Doublets.Sequences/Unicode/UnicodeSequenceToStringConverter.cs

```
using System;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Converters;
using Platform.Data.Doublets.Sequences.Walkers;
using System.Text;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class UnicodeSequenceToStringConverter<TLink> : LinksOperatorBase<TLink>,
    ↪  IConverter<TLink, string>
    {
        private readonly ICriterionMatcher<TLink> _unicodeSequenceCriterionMatcher;
        private readonly ISequenceWalker<TLink> _sequenceWalker;
        private readonly IConverter<TLink, char> _unicodeSymbolToCharConverter;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnicodeSequenceToStringConverter(ILinks<TLink> links, ICriterionMatcher<TLink>
        ↪  unicodeSequenceCriterionMatcher, ISequenceWalker<TLink> sequenceWalker,
        ↪  IConverter<TLink, char> unicodeSymbolToCharConverter) : base(links)
        {
            _unicodeSequenceCriterionMatcher = unicodeSequenceCriterionMatcher;
            _sequenceWalker = sequenceWalker;
            _unicodeSymbolToCharConverter = unicodeSymbolToCharConverter;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public string Convert(TLink source)
        {
            if (!_unicodeSequenceCriterionMatcher.IsMatched(source))
            {
                throw new ArgumentOutOfRangeException(nameof(source), source, "Specified link is
                ↪  not a unicode sequence.");
            }
            var sequence = _links.GetSource(source);
            var sb = new StringBuilder();
            foreach(var character in _sequenceWalker.Walk(sequence))
            {
                sb.Append(_unicodeSymbolToCharConverter.Convert(character));
            }
            return sb.ToString();
        }
    }
}
```

1.54 ./csharp/Platform.Data.Doublets.Sequences/Unicode/UnicodeSymbolToCharConverter.cs

```
using System;
using System.Runtime.CompilerServices;
using Platform.Interfaces;
using Platform.Converters;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class UnicodeSymbolToCharConverter<TLink> : LinksOperatorBase<TLink>,
    ↪  IConverter<TLink, char>
    {
        private static readonly UncheckedConverter<TLink, char> _addressToCharConverter =
        ↪  UncheckedConverter<TLink, char>.Default;

        private readonly IConverter<TLink> _numberToAddressConverter;
        private readonly ICriterionMatcher<TLink> _unicodeSymbolCriterionMatcher;
```

```

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnicodeSymbolToCharConverter(ILinks<TLink> links, IConverter<TLink>
        ↪  numberToAddressConverter, ICriterionMatcher<TLink> unicodeSymbolCriterionMatcher) :
        ↪  base(links)
        {
            _numberToAddressConverter = numberToAddressConverter;
            _unicodeSymbolCriterionMatcher = unicodeSymbolCriterionMatcher;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public char Convert(TLink source)
        {
            if (!_unicodeSymbolCriterionMatcher.IsMatched(source))
            {
                throw new ArgumentOutOfRangeException(nameof(source), source, "Specified link is
                ↪  not a unicode symbol.");
            }
            return _addressToCharConverter.Convert(_numberToAddressConverter.Convert(_links.GetS
            ↪  ource(source)));
        }
    }
}
```

1.55 ./csharp/Platform.Data.Doublets.Sequences/Unicode/UnicodeSymbolsListToUnicodeSequenceConverter.cs

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Converters;
using Platform.Data.Doublets.Sequences.Indexes;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Unicode
{
    public class UnicodeSymbolsListToUnicodeSequenceConverter<TLink> : LinksOperatorBase<TLink>,
    ↪  IConverter<IList<TLink>, TLink>
    {
        private readonly ISequenceIndex<TLink> _index;
        private readonly IConverter<IList<TLink>, TLink> _listToSequenceLinkConverter;
        private readonly TLink _unicodeSequenceMarker;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnicodeSymbolsListToUnicodeSequenceConverter(ILinks<TLink> links,
        ↪  ISequenceIndex<TLink> index, IConverter<IList<TLink>, TLink>
        ↪  listToSequenceLinkConverter, TLink unicodeSequenceMarker) : base(links)
        {
            _index = index;
            _listToSequenceLinkConverter = listToSequenceLinkConverter;
            _unicodeSequenceMarker = unicodeSequenceMarker;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public UnicodeSymbolsListToUnicodeSequenceConverter(ILinks<TLink> links,
        ↪  IConverter<IList<TLink>, TLink> listToSequenceLinkConverter, TLink
        ↪  unicodeSequenceMarker)
            : this(links, new Unindex<TLink>(), listToSequenceLinkConverter,
            ↪  unicodeSequenceMarker) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public TLink Convert(IList<TLink> list)
        {
            _index.Add(list);
            var sequence = _listToSequenceLinkConverter.Convert(list);
            return _links.GetOrCreate(sequence, _unicodeSequenceMarker);
        }
    }
}
```

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

```
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Walkers
{
    public interface ISequenceWalker<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

```
        IEnumerable<TLink> Walk(TLink sequence);
    }
}
```

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

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Stacks;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Walkers
{
    public class LeftSequenceWalker<TLink> : SequenceWalkerBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LeftSequenceWalker(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
        ↪  isElement) : base(links, stack, isElement) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LeftSequenceWalker(ILinks<TLink> links, IStack<TLink> stack) : base(links, stack,
        ↪  links.IsPartialPoint) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetNextElementAfterPop(TLink element) =>
        ↪  _links.GetSource(element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetNextElementAfterPush(TLink element) =>
        ↪  _links.GetTarget(element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override IEnumerable<TLink> WalkContents(TLink element)
        {
            var links = _links;
            var parts = links.GetLink(element);
            var start = links.Constants.SourcePart;
            for (var i = parts.Count - 1; i >= start; i--)
            {
                var part = parts[i];
                if (IsElement(part))
                {
                    yield return part;
                }
            }
        }
    }
}
```

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

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

//#define USEARRAYPOOL
#if USEARRAYPOOL
using Platform.Collections;
#endif

namespace Platform.Data.Doublets.Sequences.Walkers
{
    public class LeveledSequenceWalker<TLink> : LinksOperatorBase<TLink>, ISequenceWalker<TLink>
    {
        private static readonly EqualityComparer<TLink> _equalityComparer =
        ↪  EqualityComparer<TLink>.Default;

        private readonly Func<TLink, bool> _isElement;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LeveledSequenceWalker(ILinks<TLink> links, Func<TLink, bool> isElement) :
        ↪  base(links) => _isElement = isElement;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public LeveledSequenceWalker(ILinks<TLink> links) : base(links) => _isElement =
        ↪  _links.IsPartialPoint;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
```

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

```
            }
#if USEARRAYPOOL
                ArrayPool.Free(array);
#endif
            return finalArray;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        private static int CountFilledElements(TLink[] array)
        {
            var count = 0;
            for (var i = 0; i < array.Length; i++)
            {
                if (!_equalityComparer.Equals(array[i], default))
                {
                    count++;
                }
            }
            return count;
        }
    }
}
```

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

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Stacks;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Walkers
{
    public class RightSequenceWalker<TLink> : SequenceWalkerBase<TLink>
    {
        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public RightSequenceWalker(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
        ↪  isElement) : base(links, stack, isElement) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public RightSequenceWalker(ILinks<TLink> links, IStack<TLink> stack) : base(links,
        ↪  stack, links.IsPartialPoint) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetNextElementAfterPop(TLink element) =>
        ↪  _links.GetTarget(element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override TLink GetNextElementAfterPush(TLink element) =>
        ↪  _links.GetSource(element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected override IEnumerable<TLink> WalkContents(TLink element)
        {
            var parts = _links.GetLink(element);
            for (var i = _links.Constants.SourcePart; i < parts.Count; i++)
            {
                var part = parts[i];
                if (IsElement(part))
                {
                    yield return part;
                }
            }
        }
    }
}
```

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

```
using System;
using System.Collections.Generic;
using System.Runtime.CompilerServices;
using Platform.Collections.Stacks;

#pragma warning disable CS1591 // Missing XML comment for publicly visible type or member

namespace Platform.Data.Doublets.Sequences.Walkers
{
    public abstract class SequenceWalkerBase<TLink> : LinksOperatorBase<TLink>,
    ↪  ISequenceWalker<TLink>
```

```
    {
        private readonly IStack<TLink> _stack;
        private readonly Func<TLink, bool> _isElement;

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack, Func<TLink, bool>
        ↪  isElement) : base(links)
        {
            _stack = stack;
            _isElement = isElement;
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected SequenceWalkerBase(ILinks<TLink> links, IStack<TLink> stack) : this(links,
        ↪  stack, links.IsPartialPoint) { }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        public IEnumerable<TLink> Walk(TLink sequence)
        {
            _stack.Clear();
            var element = sequence;
            if (IsElement(element))
            {
                yield return element;
            }
            else
            {
                while (true)
                {
                    if (IsElement(element))
                    {
                        if (_stack.IsEmpty)
                        {
                            break;
                        }
                        element = _stack.Pop();
                        foreach (var output in WalkContents(element))
                        {
                            yield return output;
                        }
                        element = GetNextElementAfterPop(element);
                    }
                    else
                    {
                        _stack.Push(element);
                        element = GetNextElementAfterPush(element);
                    }
                }
            }
        }

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected virtual bool IsElement(TLink elementLink) => _isElement(elementLink);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract TLink GetNextElementAfterPop(TLink element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract TLink GetNextElementAfterPush(TLink element);

        [MethodImpl(MethodImplOptions.AggressiveInlining)]
        protected abstract IEnumerable<TLink> WalkContents(TLink element);
    }
}
```

1.61 ./csharp/Platform.Data.Doublets.Sequences.Tests/BigIntegerConvertersTests.cs

```
using System.Collections.Generic;
using System.Numerics;
using Platform.Data.Doublets.Memory;
using Platform.Data.Doublets.Memory.United.Generic;
using Platform.Data.Doublets.Numbers.Raw;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Numbers.Raw;
using Platform.Memory;
using Xunit;
using TLink = System.UInt64;

namespace Platform.Data.Doublets.Sequences.Tests
{
    public class BigIntegerConvertersTests
```

```
    {
        public ILinks<TLink> CreateLinks() => CreateLinks<TLink>(new IO.TemporaryFile());

        public ILinks<TLink> CreateLinks<TLink>(string dataDbFilename)
        {
            var linksConstants = new LinksConstants<TLink>(enableExternalReferencesSupport:
            ↪ true);
            return new UnitedMemoryLinks<TLink>(new
            ↪ FileMappedResizableDirectMemory(dataDbFilename),
            ↪ UnitedMemoryLinks<TLink>.DefaultLinksSizeStep, linksConstants,
            ↪ IndexTreeType.Default);
        }

        [Fact]
        public void DecimalMaxValueTest()
        {
            var links = CreateLinks();
            BigInteger bigInteger = new(decimal.MaxValue);
            TLink negativeNumberMarker = links.Create();
            AddressToRawNumberConverter<TLink> addressToRawNumberConverter = new();
            RawNumberToAddressConverter<TLink> numberToAddressConverter = new();
            BalancedVariantConverter<TLink> listToSequenceConverter = new(links);
            BigIntegerToRawNumberSequenceConverter<TLink> bigIntegerToRawNumberSequenceConverter
            ↪ = new(links, addressToRawNumberConverter, listToSequenceConverter,
            ↪ negativeNumberMarker);
            RawNumberSequenceToBigIntegerConverter<TLink> rawNumberSequenceToBigIntegerConverter
            ↪ = new(links, numberToAddressConverter, negativeNumberMarker);
            var bigIntSequence = bigIntegerToRawNumberSequenceConverter.Convert(bigInteger);
            var bigIntFromSequence =
            ↪ rawNumberSequenceToBigIntegerConverter.Convert(bigIntSequence);
            Assert.Equal(bigInteger, bigIntFromSequence);
        }

        [Fact]
        public void DecimalMinValueTest()
        {
            var links = CreateLinks();
            BigInteger bigInteger = new(decimal.MinValue);
            TLink negativeNumberMarker = links.Create();
            AddressToRawNumberConverter<TLink> addressToRawNumberConverter = new();
            RawNumberToAddressConverter<TLink> numberToAddressConverter = new();
            BalancedVariantConverter<TLink> listToSequenceConverter = new(links);
            BigIntegerToRawNumberSequenceConverter<TLink> bigIntegerToRawNumberSequenceConverter
            ↪ = new(links, addressToRawNumberConverter, listToSequenceConverter,
            ↪ negativeNumberMarker);
            RawNumberSequenceToBigIntegerConverter<TLink> rawNumberSequenceToBigIntegerConverter
            ↪ = new(links, numberToAddressConverter, negativeNumberMarker);
            var bigIntSequence = bigIntegerToRawNumberSequenceConverter.Convert(bigInteger);
            var bigIntFromSequence =
            ↪ rawNumberSequenceToBigIntegerConverter.Convert(bigIntSequence);
            Assert.Equal(bigInteger, bigIntFromSequence);
        }

        [Fact]
        public void ZeroValueTest()
        {
            var links = CreateLinks();
            BigInteger bigInteger = new(0);
            TLink negativeNumberMarker = links.Create();
            AddressToRawNumberConverter<TLink> addressToRawNumberConverter = new();
            RawNumberToAddressConverter<TLink> numberToAddressConverter = new();
            BalancedVariantConverter<TLink> listToSequenceConverter = new(links);
            BigIntegerToRawNumberSequenceConverter<TLink> bigIntegerToRawNumberSequenceConverter
            ↪ = new(links, addressToRawNumberConverter, listToSequenceConverter,
            ↪ negativeNumberMarker);
            RawNumberSequenceToBigIntegerConverter<TLink> rawNumberSequenceToBigIntegerConverter
            ↪ = new(links, numberToAddressConverter, negativeNumberMarker);
            var bigIntSequence = bigIntegerToRawNumberSequenceConverter.Convert(bigInteger);
            var bigIntFromSequence =
            ↪ rawNumberSequenceToBigIntegerConverter.Convert(bigIntSequence);
            Assert.Equal(bigInteger, bigIntFromSequence);
        }

        [Fact]
        public void OneValueTest()
        {
            var links = CreateLinks();
            BigInteger bigInteger = new(1);
```

```
77              TLink negativeNumberMarker = links.Create();
78              AddressToRawNumberConverter<TLink> addressToRawNumberConverter = new();
79              RawNumberToAddressConverter<TLink> numberToAddressConverter = new();
80              BalancedVariantConverter<TLink> listToSequenceConverter = new(links);
81              BigIntegerToRawNumberSequenceConverter<TLink> bigIntegerToRawNumberSequenceConverter
                ↪  = new(links, addressToRawNumberConverter, listToSequenceConverter,
                ↪  negativeNumberMarker);
82              RawNumberSequenceToBigIntegerConverter<TLink> rawNumberSequenceToBigIntegerConverter
                ↪  = new(links, numberToAddressConverter, negativeNumberMarker);
83              var bigIntSequence = bigIntegerToRawNumberSequenceConverter.Convert(bigInteger);
84              var bigIntFromSequence =
                ↪  rawNumberSequenceToBigIntegerConverter.Convert(bigIntSequence);
85              Assert.Equal(bigInteger, bigIntFromSequence);
86          }
87      }
88  }
```

1.62 ./csharp/Platform.Data.Doublets.Sequences.Tests/DefaultSequenceAppenderTests.cs

```
1   using System.Collections.Generic;
2   using Platform.Collections.Stacks;
3   using Platform.Data.Doublets.Memory;
4   using Platform.Data.Doublets.Memory.United.Generic;
5   using Platform.Data.Doublets.Sequences;
6   using Platform.Data.Doublets.Sequences.HeightProviders;
7   using Platform.Data.Numbers.Raw;
8   using Platform.Interfaces;
9   using Platform.Memory;
10  using Platform.Numbers;
11  using Xunit;
12  using Xunit.Abstractions;
13  using TLink = System.UInt64;
14
15  namespace Platform.Data.Doublets.Sequences.Tests
16  {
17      public class DefaultSequenceAppenderTests
18      {
19          private readonly ITestOutputHelper _output;
20
21          public DefaultSequenceAppenderTests(ITestOutputHelper output)
22          {
23              _output = output;
24          }
25          public static ILinks<TLink> CreateLinks() => CreateLinks<TLink>(new IO.TemporaryFile());
26
27          public static ILinks<TLink> CreateLinks<TLink>(string dataDBFilename)
28          {
29              var linksConstants = new LinksConstants<TLink>(enableExternalReferencesSupport:
                ↪  true);
30              return new UnitedMemoryLinks<TLink>(new
                ↪  FileMappedResizableDirectMemory(dataDBFilename),
                ↪  UnitedMemoryLinks<TLink>.DefaultLinksSizeStep, linksConstants,
                ↪  IndexTreeType.Default);
31          }
32
33          public class ValueCriterionMatcher<TLink> : ICriterionMatcher<TLink>
34          {
35              public readonly ILinks<TLink> Links;
36              public readonly TLink Marker;
37              public ValueCriterionMatcher(ILinks<TLink> links, TLink marker)
38              {
39                  Links = links;
40                  Marker = marker;
41              }
42
43              public bool IsMatched(TLink link) =>
                ↪  EqualityComparer<TLink>.Default.Equals(Links.GetSource(link), Marker);
44          }
45
46          [Fact]
47          public void AppendArrayBug()
48          {
49              ILinks<TLink> links = CreateLinks();
50              TLink zero = default;
51              var markerIndex = Arithmetic.Increment(zero);
52              var meaningRoot = links.GetOrCreate(markerIndex, markerIndex);
53              var sequence = links.Create();
54              sequence = links.Update(sequence, meaningRoot, sequence);
55              var appendant = links.Create();
56              appendant = links.Update(appendant, meaningRoot, appendant);
57              ValueCriterionMatcher<TLink> valueCriterionMatcher = new(links, meaningRoot);
```

```
            DefaultSequenceRightHeightProvider<ulong> defaultSequenceRightHeightProvider =
            ↪ new(links, valueCriterionMatcher);
            DefaultSequenceAppender<TLink> defaultSequenceAppender = new(links, new
            ↪ DefaultStack<ulong>(), defaultSequenceRightHeightProvider);
            var newArray = defaultSequenceAppender.Append(sequence, appendant);
            var output = links.FormatStructure(newArray, link => link.IsFullPoint(), true);
            Assert.Equal("(4:(2:1 2) (3:1 3))", output);
        }
    }
}
```

1.63 ./csharp/Platform.Data.Doublets.Sequences.Tests/ILinksExtensionsTests.cs

```
using Xunit;

namespace Platform.Data.Doublets.Sequences.Tests
{
    public class ILinksExtensionsTests
    {
        [Fact]
        public void FormatTest()
        {
            using (var scope = new TempLinksTestScope())
            {
                var links = scope.Links;
                var link = links.Create();
                var linkString = links.Format(link);
                Assert.Equal("(1: 1 1)", linkString);
            }
        }
    }
}
```

1.64 ./csharp/Platform.Data.Doublets.Sequences.Tests/OptimalVariantSequenceTests.cs

```
using System;
using System.Linq;
using Xunit;
using Platform.Collections.Stacks;
using Platform.Collections.Arrays;
using Platform.Memory;
using Platform.Data.Numbers.Raw;
using Platform.Data.Doublets.Sequences;
using Platform.Data.Doublets.Sequences.Frequencies.Cache;
using Platform.Data.Doublets.Sequences.Frequencies.Counters;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Doublets.PropertyOperators;
using Platform.Data.Doublets.Incrementers;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Data.Doublets.Sequences.Indexes;
using Platform.Data.Doublets.Unicode;
using Platform.Data.Doublets.Numbers.Unary;
using Platform.Data.Doublets.Decorators;
using Platform.Data.Doublets.Memory.United.Specific;
using Platform.Data.Doublets.Memory;

namespace Platform.Data.Doublets.Sequences.Tests
{
    public static class OptimalVariantSequenceTests
    {
        private static readonly string _sequenceExample = "зеленела зелёная зелень";
        private static readonly string _loremIpsumExample = @"Lorem ipsum dolor sit amet,
        ↪ consectetur adipiscing elit, sed do eiusmod tempor incididunt ut labore et dolore
        ↪ magna aliqua.
Facilisi nullam vehicula ipsum a arcu cursus vitae congue mauris.
Et malesuada fames ac turpis egestas sed.
Eget velit aliquet sagittis id consectetur purus.
Dignissim cras tincidunt lobortis feugiat vivamus.
Vitae aliquet nec ullamcorper sit.
Lectus quam id leo in vitae.
Tortor dignissim convallis aenean et tortor at risus viverra adipiscing.
Sed risus ultricies tristique nulla aliquet enim tortor at auctor.
Integer eget aliquet nibh praesent tristique.
Vitae congue eu consequat ac felis donec et odio.
Tristique et egestas quis ipsum suspendisse.
Suspendisse potenti nullam ac tortor vitae purus faucibus ornare.
Nulla facilisi etiam dignissim diam quis enim lobortis scelerisque.
Imperdiet proin fermentum leo vel orci.
In ante metus dictum at tempor commodo.
Nisi lacus sed viverra tellus in.
Quam vulputate dignissim suspendisse in.
Elit scelerisque mauris pellentesque pulvinar pellentesque habitant morbi tristique senectus.
Gravida cum sociis natoque penatibus et magnis dis parturient.
```

```
Risus quis varius quam quisque id diam.
Congue nisi vitae suscipit tellus mauris a diam maecenas.
Eget nunc scelerisque viverra mauris in aliquam sem fringilla.
Pharetra vel turpis nunc eget lorem dolor sed viverra.
Mattis pellentesque id nibh tortor id aliquet.
Purus non enim praesent elementum facilisis leo vel.
Etiam sit amet nisl purus in mollis nunc sed.
Tortor at auctor urna nunc id cursus metus aliquam.
Volutpat odio facilisis mauris sit amet.
Turpis egestas pretium aenean pharetra magna ac placerat.
Fermentum dui faucibus in ornare quam viverra orci sagittis eu.
Porttitor leo a diam sollicitudin tempor id eu.
Volutpat sed cras ornare arcu dui.
Ut aliquam purus sit amet luctus venenatis lectus magna.
Aliquet risus feugiat in ante metus dictum at.
Mattis nunc sed blandit libero.
Elit pellentesque habitant morbi tristique senectus et netus.
Nibh sit amet commodo nulla facilisi nullam vehicula ipsum a.
Enim sit amet venenatis urna cursus eget nunc scelerisque viverra.
Amet venenatis urna cursus eget nunc scelerisque viverra mauris in.
Diam donec adipiscing tristique risus nec feugiat.
Pulvinar mattis nunc sed blandit libero volutpat.
Cras fermentum odio eu feugiat pretium nibh ipsum.
In nulla posuere sollicitudin aliquam ultrices sagittis orci a.
Mauris pellentesque pulvinar pellentesque habitant morbi tristique senectus et.
A iaculis at erat pellentesque.
Morbi blandit cursus risus at ultrices mi tempus imperdiet nulla.
Eget lorem dolor sed viverra ipsum nunc.
Leo a diam sollicitudin tempor id eu.
Interdum consectetur libero id faucibus nisl tincidunt eget nullam non.";

        [Fact]
        public static void LinksBasedFrequencyStoredOptimalVariantSequenceTest()
        {
            using (var scope = new TempLinksTestScope(useSequences: false))
            {
                var links = scope.Links;
                var constants = links.Constants;

                links.UseUnicode();

                var sequence = UnicodeMap.FromStringToLinkArray(_sequenceExample);

                var meaningRoot = links.CreatePoint();
                var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
                var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
                var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
                    constants.Itself);

                var unaryNumberToAddressConverter = new
                    UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
                var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
                var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
                    frequencyMarker, unaryOne, unaryNumberIncrementer);
                var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
                    frequencyPropertyMarker, frequencyMarker);
                var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
                    frequencyPropertyOperator, frequencyIncrementer);
                var linkToItsFrequencyNumberConverter = new
                    LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
                    unaryNumberToAddressConverter);
                var sequenceToItsLocalElementLevelsConverter = new
                    SequenceToItsLocalElementLevelsConverter<ulong>(links,
                    linkToItsFrequencyNumberConverter);
                var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                    sequenceToItsLocalElementLevelsConverter);

                var sequences = new Sequences(links, new SequencesOptions<ulong>() { Walker =
                    new LeveledSequenceWalker<ulong>(links) });

                ExecuteTest(sequences, sequence, sequenceToItsLocalElementLevelsConverter,
                    index, optimalVariantConverter);
            }
        }

        [Fact]
        public static void DictionaryBasedFrequencyStoredOptimalVariantSequenceTest()
        {
            using (var scope = new TempLinksTestScope(useSequences: false))
            {
```

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

```
                var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                ↪  sequenceToItsLocalElementLevelsConverter);

                var walker = new RightSequenceWalker<ulong>(links, new DefaultStack<ulong>(),
                ↪  (link) => constants.IsExternalReference(link) || links.IsPartialPoint(link));

                var unicodeSequencesOptions = new SequencesOptions<ulong>()
                {
                    UseSequenceMarker = true,
                    SequenceMarkerLink = unicodeSequenceMarker,
                    UseIndex = true,
                    Index = index,
                    LinksToSequenceConverter = optimalVariantConverter,
                    Walker = walker,
                    UseGarbageCollection = true
                };

                var unicodeSequences = new Sequences(new SynchronizedLinks<ulong>(links),
                ↪  unicodeSequencesOptions);

                // Create some sequences
                var strings = _loremIpsumExample.Split(new[] { '\n', '\r' },
                ↪  StringSplitOptions.RemoveEmptyEntries);
                var arrays = strings.Select(x => x.Select(y =>
                ↪  addressToNumberConverter.Convert(y)).ToArray()).ToArray();
                for (int i = 0; i < arrays.Length; i++)
                {
                    unicodeSequences.Create(arrays[i].ShiftRight());
                }

                var linksCountAfterCreation = links.Count();

                // get list of sequences links
                // for each sequence link
                //   create new sequence version
                //   if new sequence is not the same as sequence link
                //     delete sequence link
                //     collect garbadge
                unicodeSequences.CompactAll();

                var linksCountAfterCompactification = links.Count();

                Assert.True(linksCountAfterCompactification < linksCountAfterCreation);
            }
        }
    }
}
```

1.65 ./csharp/Platform.Data.Doublets.Sequences.Tests/RationalNumbersTests.cs

```
using Platform.Data.Doublets.Memory;
using Platform.Data.Doublets.Memory.United.Generic;
using Platform.Data.Doublets.Numbers.Rational;
using Platform.Data.Doublets.Numbers.Raw;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Numbers.Raw;
using Platform.Memory;
using Xunit;
using TLink = System.UInt64;

namespace Platform.Data.Doublets.Sequences.Tests
{
    public class RationalNumbersTests
    {
        public ILinks<TLink> CreateLinks() => CreateLinks<TLink>(new IO.TemporaryFile());

        public ILinks<TLink> CreateLinks<TLink>(string dataDbFilename)
        {
            var linksConstants = new LinksConstants<TLink>(enableExternalReferencesSupport:
            ↪  true);
            return new UnitedMemoryLinks<TLink>(new
            ↪  FileMappedResizableDirectMemory(dataDbFilename),
            ↪  UnitedMemoryLinks<TLink>.DefaultLinksSizeStep, linksConstants,
            ↪  IndexTreeType.Default);
        }

        [Fact]
        public void DecimalMinValueTest()
        {
            const decimal @decimal = decimal.MinValue;
            var links = CreateLinks();
```

```
28              TLink negativeNumberMarker = links.Create();
29              AddressToRawNumberConverter<TLink> addressToRawNumberConverter = new();
30              RawNumberToAddressConverter<TLink> numberToAddressConverter = new();
31              BalancedVariantConverter<TLink> balancedVariantConverter = new(links);
32              BigIntegerToRawNumberSequenceConverter<TLink> bigIntegerToRawNumberSequenceConverter
                ↪  = new(links, addressToRawNumberConverter, balancedVariantConverter,
                ↪  negativeNumberMarker);
33              RawNumberSequenceToBigIntegerConverter<TLink> rawNumberSequenceToBigIntegerConverter
                ↪  = new(links, numberToAddressConverter, negativeNumberMarker);
34              DecimalToRationalConverter<TLink> decimalToRationalConverter = new(links,
                ↪  bigIntegerToRawNumberSequenceConverter);
35              RationalToDecimalConverter<TLink> rationalToDecimalConverter = new(links,
                ↪  rawNumberSequenceToBigIntegerConverter);
36              var rationalNumber = decimalToRationalConverter.Convert(@decimal);
37              var decimalFromRational = rationalToDecimalConverter.Convert(rationalNumber);
38             Assert.Equal(@decimal, decimalFromRational);
39          }
40
41          [Fact]
42          public void DecimalMaxValueTest()
43          {
44              const decimal @decimal = decimal.MaxValue;
45              var links = CreateLinks();
46              TLink negativeNumberMarker = links.Create();
47              AddressToRawNumberConverter<TLink> addressToRawNumberConverter = new();
48              RawNumberToAddressConverter<TLink> numberToAddressConverter = new();
49              BalancedVariantConverter<TLink> balancedVariantConverter = new(links);
50              BigIntegerToRawNumberSequenceConverter<TLink> bigIntegerToRawNumberSequenceConverter
                ↪  = new(links, addressToRawNumberConverter, balancedVariantConverter,
                ↪  negativeNumberMarker);
51              RawNumberSequenceToBigIntegerConverter<TLink> rawNumberSequenceToBigIntegerConverter
                ↪  = new(links, numberToAddressConverter, negativeNumberMarker);
52              DecimalToRationalConverter<TLink> decimalToRationalConverter = new(links,
                ↪  bigIntegerToRawNumberSequenceConverter);
53              RationalToDecimalConverter<TLink> rationalToDecimalConverter = new(links,
                ↪  rawNumberSequenceToBigIntegerConverter);
54              var rationalNumber = decimalToRationalConverter.Convert(@decimal);
55              var decimalFromRational = rationalToDecimalConverter.Convert(rationalNumber);
56              Assert.Equal(@decimal, decimalFromRational);
57          }
58
59          [Fact]
60          public void DecimalPositiveHalfTest()
61          {
62              const decimal @decimal = 0.5M;
63              var links = CreateLinks();
64              TLink negativeNumberMarker = links.Create();
65              AddressToRawNumberConverter<TLink> addressToRawNumberConverter = new();
66              RawNumberToAddressConverter<TLink> numberToAddressConverter = new();
67              BalancedVariantConverter<TLink> balancedVariantConverter = new(links);
68              BigIntegerToRawNumberSequenceConverter<TLink> bigIntegerToRawNumberSequenceConverter
                ↪  = new(links, addressToRawNumberConverter, balancedVariantConverter,
                ↪  negativeNumberMarker);
69              RawNumberSequenceToBigIntegerConverter<TLink> rawNumberSequenceToBigIntegerConverter
                ↪  = new(links, numberToAddressConverter, negativeNumberMarker);
70              DecimalToRationalConverter<TLink> decimalToRationalConverter = new(links,
                ↪  bigIntegerToRawNumberSequenceConverter);
71              RationalToDecimalConverter<TLink> rationalToDecimalConverter = new(links,
                ↪  rawNumberSequenceToBigIntegerConverter);
72              var rationalNumber = decimalToRationalConverter.Convert(@decimal);
73              var decimalFromRational = rationalToDecimalConverter.Convert(rationalNumber);
74              Assert.Equal(@decimal, decimalFromRational);
75          }
76
77          [Fact]
78          public void DecimalNegativeHalfTest()
79          {
80              const decimal @decimal = -0.5M;
81              var links = CreateLinks();
82              TLink negativeNumberMarker = links.Create();
83              AddressToRawNumberConverter<TLink> addressToRawNumberConverter = new();
84              RawNumberToAddressConverter<TLink> numberToAddressConverter = new();
85              BalancedVariantConverter<TLink> balancedVariantConverter = new(links);
86              BigIntegerToRawNumberSequenceConverter<TLink> bigIntegerToRawNumberSequenceConverter
                ↪  = new(links, addressToRawNumberConverter, balancedVariantConverter,
                ↪  negativeNumberMarker);
87              RawNumberSequenceToBigIntegerConverter<TLink> rawNumberSequenceToBigIntegerConverter
                ↪  = new(links, numberToAddressConverter, negativeNumberMarker);
```

```
            DecimalToRationalConverter<TLink> decimalToRationalConverter = new(links,
            ↪  bigIntegerToRawNumberSequenceConverter);
            RationalToDecimalConverter<TLink> rationalToDecimalConverter = new(links,
            ↪  rawNumberSequenceToBigIntegerConverter);
            var rationalNumber = decimalToRationalConverter.Convert(@decimal);
            var decimalFromRational = rationalToDecimalConverter.Convert(rationalNumber);
            Assert.Equal(@decimal, decimalFromRational);
        }

        [Fact]
        public void DecimalOneTest()
        {
            const decimal @decimal = 1;
            var links = CreateLinks();
            TLink negativeNumberMarker = links.Create();
            AddressToRawNumberConverter<TLink> addressToRawNumberConverter = new();
            RawNumberToAddressConverter<TLink> numberToAddressConverter = new();
            BalancedVariantConverter<TLink> balancedVariantConverter = new(links);
            BigIntegerToRawNumberSequenceConverter<TLink> bigIntegerToRawNumberSequenceConverter
            ↪  = new(links, addressToRawNumberConverter, balancedVariantConverter,
            ↪  negativeNumberMarker);
            RawNumberSequenceToBigIntegerConverter<TLink> rawNumberSequenceToBigIntegerConverter
            ↪  = new(links, numberToAddressConverter, negativeNumberMarker);
            DecimalToRationalConverter<TLink> decimalToRationalConverter = new(links,
            ↪  bigIntegerToRawNumberSequenceConverter);
            RationalToDecimalConverter<TLink> rationalToDecimalConverter = new(links,
            ↪  rawNumberSequenceToBigIntegerConverter);
            var rationalNumber = decimalToRationalConverter.Convert(@decimal);
            var decimalFromRational = rationalToDecimalConverter.Convert(rationalNumber);
            Assert.Equal(@decimal, decimalFromRational);
        }

        [Fact]
        public void DecimalMinusOneTest()
        {
            const decimal @decimal = -1;
            var links = CreateLinks();
            TLink negativeNumberMarker = links.Create();
            AddressToRawNumberConverter<TLink> addressToRawNumberConverter = new();
            RawNumberToAddressConverter<TLink> numberToAddressConverter = new();
            BalancedVariantConverter<TLink> balancedVariantConverter = new(links);
            BigIntegerToRawNumberSequenceConverter<TLink> bigIntegerToRawNumberSequenceConverter
            ↪  = new(links, addressToRawNumberConverter, balancedVariantConverter,
            ↪  negativeNumberMarker);
            RawNumberSequenceToBigIntegerConverter<TLink> rawNumberSequenceToBigIntegerConverter
            ↪  = new(links, numberToAddressConverter, negativeNumberMarker);
            DecimalToRationalConverter<TLink> decimalToRationalConverter = new(links,
            ↪  bigIntegerToRawNumberSequenceConverter);
            RationalToDecimalConverter<TLink> rationalToDecimalConverter = new(links,
            ↪  rawNumberSequenceToBigIntegerConverter);
            var rationalNumber = decimalToRationalConverter.Convert(@decimal);
            var decimalFromRational = rationalToDecimalConverter.Convert(rationalNumber);
            Assert.Equal(@decimal, decimalFromRational);
        }
    }
}
```

1.66 ./csharp/Platform.Data.Doublets.Sequences.Tests/ReadSequenceTests.cs

```
using System;
using System.Collections.Generic;
using System.Diagnostics;
using System.Linq;
using Xunit;
using Platform.Data.Sequences;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Data.Doublets.Sequences;

namespace Platform.Data.Doublets.Sequences.Tests
{
    public static class ReadSequenceTests
    {
        [Fact]
        public static void ReadSequenceTest()
        {
            const long sequenceLength = 2000;

            using (var scope = new TempLinksTestScope(useSequences: false))
            {
```

```
                var links = scope.Links;
                var sequences = new Sequences(links, new SequencesOptions<ulong> { Walker = new
                ↪  LeveledSequenceWalker<ulong>(links) });

                var sequence = new ulong[sequenceLength];
                for (var i = 0; i < sequenceLength; i++)
                {
                    sequence[i] = links.Create();
                }

                var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);

                var sw1 = Stopwatch.StartNew();
                var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();

                var sw2 = Stopwatch.StartNew();
                var readSequence1 = sequences.ToList(balancedVariant); sw2.Stop();

                var sw3 = Stopwatch.StartNew();
                var readSequence2 = new List<ulong>();
                SequenceWalker.WalkRight(balancedVariant,
                                         links.GetSource,
                                         links.GetTarget,
                                         links.IsPartialPoint,
                                         readSequence2.Add);
                sw3.Stop();

                Assert.True(sequence.SequenceEqual(readSequence1));

                Assert.True(sequence.SequenceEqual(readSequence2));

                // Assert.True(sw2.Elapsed < sw3.Elapsed);

                Console.WriteLine($"Stack-based walker: {sw3.Elapsed}, Level-based reader:
                ↪  {sw2.Elapsed}");

                for (var i = 0; i < sequenceLength; i++)
                {
                    links.Delete(sequence[i]);
                }
            }
        }
    }
}
```

1.67 ./csharp/Platform.Data.Doublets.Sequences.Tests/SequencesTests.cs

```
using System;
using System.Collections.Generic;
using System.Diagnostics;
using System.Linq;
using Xunit;
using Platform.Collections;
using Platform.Collections.Arrays;
using Platform.Random;
using Platform.IO;
using Platform.Singletons;
using Platform.Data.Doublets.Sequences;
using Platform.Data.Doublets.Sequences.Frequencies.Cache;
using Platform.Data.Doublets.Sequences.Frequencies.Counters;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Doublets.Unicode;

namespace Platform.Data.Doublets.Sequences.Tests
{
    public static class SequencesTests
    {
        private static readonly LinksConstants<ulong> _constants =
        ↪  Default<LinksConstants<ulong>>.Instance;

        static SequencesTests()
        {
            // Trigger static constructor to not mess with perfomance measurements
            _ = BitString.GetBitMaskFromIndex(1);
        }

        [Fact]
        public static void CreateAllVariantsTest()
        {
            const long sequenceLength = 8;

            using (var scope = new TempLinksTestScope(useSequences: true))
```

```
35              {
36                  var links = scope.Links;
37                  var sequences = scope.Sequences;
38
39                  var sequence = new ulong[sequenceLength];
40                  for (var i = 0; i < sequenceLength; i++)
41                  {
42                      sequence[i] = links.Create();
43                  }
44
45                  var sw1 = Stopwatch.StartNew();
46                  var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
47
48                  var sw2 = Stopwatch.StartNew();
49                  var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();
50
51                  Assert.True(results1.Count > results2.Length);
52                  Assert.True(sw1.Elapsed > sw2.Elapsed);
53
54                  for (var i = 0; i < sequenceLength; i++)
55                  {
56                      links.Delete(sequence[i]);
57                  }
58
59                  Assert.True(links.Count() == 0);
60              }
61          }
62
63          //[Fact]
64          //public void CUDTest()
65          //{
66          //    var tempFilename = Path.GetTempFileName();
67
68          //    const long sequenceLength = 8;
69
70          //    const ulong itself = LinksConstants.Itself;
71
72          //    using (var memoryAdapter = new ResizableDirectMemoryLinks(tempFilename,
    ↪  DefaultLinksSizeStep))
73          //    using (var links = new Links(memoryAdapter))
74          //    {
75          //        var sequence = new ulong[sequenceLength];
76          //        for (var i = 0; i < sequenceLength; i++)
77          //            sequence[i] = links.Create(itself, itself);
78
79          //        SequencesOptions o = new SequencesOptions();
80
81          // TODO: Из числа в bool значения o.UseSequenceMarker = ((value & 1) != 0)
82          //        o.
83
84          //        var sequences = new Sequences(links);
85
86          //        var sw1 = Stopwatch.StartNew();
87          //        var results1 = sequences.CreateAllVariants1(sequence); sw1.Stop();
88
89          //        var sw2 = Stopwatch.StartNew();
90          //        var results2 = sequences.CreateAllVariants2(sequence); sw2.Stop();
91
92          //        Assert.True(results1.Count > results2.Length);
93          //        Assert.True(sw1.Elapsed > sw2.Elapsed);
94
95          //        for (var i = 0; i < sequenceLength; i++)
96          //            links.Delete(sequence[i]);
97          //    }
98
99          //    File.Delete(tempFilename);
100         //}
101
102         [Fact]
103         public static void AllVariantsSearchTest()
104         {
105             const long sequenceLength = 8;
106
107             using (var scope = new TempLinksTestScope(useSequences: true))
108             {
109                 var links = scope.Links;
110                 var sequences = scope.Sequences;
111
112                 var sequence = new ulong[sequenceLength];
113                 for (var i = 0; i < sequenceLength; i++)
```

```
114                 {
115                     sequence[i] = links.Create();
116                 }
117 
118                 var createResults = sequences.CreateAllVariants2(sequence).Distinct().ToArray();
119 
120                 //for (int i = 0; i < createResults.Length; i++)
121                 //    sequences.Create(createResults[i]);
122 
123                 var sw0 = Stopwatch.StartNew();
124                 var searchResults0 = sequences.GetAllMatchingSequences0(sequence); sw0.Stop();
125 
126                 var sw1 = Stopwatch.StartNew();
127                 var searchResults1 = sequences.GetAllMatchingSequences1(sequence); sw1.Stop();
128 
129                 var sw2 = Stopwatch.StartNew();
130                 var searchResults2 = sequences.Each1(sequence); sw2.Stop();
131 
132                 var sw3 = Stopwatch.StartNew();
133                 var searchResults3 = sequences.Each(sequence.ShiftRight()); sw3.Stop();
134 
135                 var intersection0 = createResults.Intersect(searchResults0).ToList();
136                 Assert.True(intersection0.Count == searchResults0.Count);
137                 Assert.True(intersection0.Count == createResults.Length);
138 
139                 var intersection1 = createResults.Intersect(searchResults1).ToList();
140                 Assert.True(intersection1.Count == searchResults1.Count);
141                 Assert.True(intersection1.Count == createResults.Length);
142 
143                 var intersection2 = createResults.Intersect(searchResults2).ToList();
144                 Assert.True(intersection2.Count == searchResults2.Count);
145                 Assert.True(intersection2.Count == createResults.Length);
146 
147                 var intersection3 = createResults.Intersect(searchResults3).ToList();
148                 Assert.True(intersection3.Count == searchResults3.Count);
149                 Assert.True(intersection3.Count == createResults.Length);
150 
151                 for (var i = 0; i < sequenceLength; i++)
152                 {
153                     links.Delete(sequence[i]);
154                 }
155             }
156         }
157 
158         [Fact]
159         public static void BalancedVariantSearchTest()
160         {
161             const long sequenceLength = 200;
162 
163             using (var scope = new TempLinksTestScope(useSequences: true))
164             {
165                 var links = scope.Links;
166                 var sequences = scope.Sequences;
167 
168                 var sequence = new ulong[sequenceLength];
169                 for (var i = 0; i < sequenceLength; i++)
170                 {
171                     sequence[i] = links.Create();
172                 }
173 
174                 var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);
175 
176                 var sw1 = Stopwatch.StartNew();
177                 var balancedVariant = balancedVariantConverter.Convert(sequence); sw1.Stop();
178 
179                 var sw2 = Stopwatch.StartNew();
180                 var searchResults2 = sequences.GetAllMatchingSequences0(sequence); sw2.Stop();
181 
182                 var sw3 = Stopwatch.StartNew();
183                 var searchResults3 = sequences.GetAllMatchingSequences1(sequence); sw3.Stop();
184 
185                 // На количестве в 200 элементов это будет занимать вечность
186                 //var sw4 = Stopwatch.StartNew();
187                 //var searchResults4 = sequences.Each(sequence); sw4.Stop();
188 
189                 Assert.True(searchResults2.Count == 1 && balancedVariant == searchResults2[0]);
190 
191                 Assert.True(searchResults3.Count == 1 && balancedVariant ==
                    ↪ searchResults3.First());
192 
```

```
193                 //Assert.True(sw1.Elapsed < sw2.Elapsed);
194
195                 for (var i = 0; i < sequenceLength; i++)
196                 {
197                     links.Delete(sequence[i]);
198                 }
199             }
200         }
201
202         [Fact]
203         public static void AllPartialVariantsSearchTest()
204         {
205             const long sequenceLength = 8;
206
207             using (var scope = new TempLinksTestScope(useSequences: true))
208             {
209                 var links = scope.Links;
210                 var sequences = scope.Sequences;
211
212                 var sequence = new ulong[sequenceLength];
213                 for (var i = 0; i < sequenceLength; i++)
214                 {
215                     sequence[i] = links.Create();
216                 }
217
218                 var createResults = sequences.CreateAllVariants2(sequence);
219
220                 //var createResultsStrings = createResults.Select(x => x + ": " +
                    ↪ sequences.FormatSequence(x)).ToList();
221                 //Global.Trash = createResultsStrings;
222
223                 var partialSequence = new ulong[sequenceLength - 2];
224
225                 Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);
226
227                 var sw1 = Stopwatch.StartNew();
228                 var searchResults1 =
                    ↪ sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();
229
230                 var sw2 = Stopwatch.StartNew();
231                 var searchResults2 =
                    ↪ sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();
232
233                 //var sw3 = Stopwatch.StartNew();
234                 //var searchResults3 =
                    ↪ sequences.GetAllPartiallyMatchingSequences2(partialSequence); sw3.Stop();
235
236                 var sw4 = Stopwatch.StartNew();
237                 var searchResults4 =
                    ↪ sequences.GetAllPartiallyMatchingSequences3(partialSequence); sw4.Stop();
238
239                 //Global.Trash = searchResults3;
240
241                 //var searchResults1Strings = searchResults1.Select(x => x + ": " +
                    ↪ sequences.FormatSequence(x)).ToList();
242                 //Global.Trash = searchResults1Strings;
243
244                 var intersection1 = createResults.Intersect(searchResults1).ToList();
245                 Assert.True(intersection1.Count == createResults.Length);
246
247                 var intersection2 = createResults.Intersect(searchResults2).ToList();
248                 Assert.True(intersection2.Count == createResults.Length);
249
250                 var intersection4 = createResults.Intersect(searchResults4).ToList();
251                 Assert.True(intersection4.Count == createResults.Length);
252
253                 for (var i = 0; i < sequenceLength; i++)
254                 {
255                     links.Delete(sequence[i]);
256                 }
257             }
258         }
259
260         [Fact]
261         public static void BalancedPartialVariantsSearchTest()
262         {
263             const long sequenceLength = 200;
264
265             using (var scope = new TempLinksTestScope(useSequences: true))
```

```
        {
            var links = scope.Links;
            var sequences = scope.Sequences;

            var sequence = new ulong[sequenceLength];
            for (var i = 0; i < sequenceLength; i++)
            {
                sequence[i] = links.Create();
            }

            var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);

            var balancedVariant = balancedVariantConverter.Convert(sequence);

            var partialSequence = new ulong[sequenceLength - 2];

            Array.Copy(sequence, 1, partialSequence, 0, (int)sequenceLength - 2);

            var sw1 = Stopwatch.StartNew();
            var searchResults1 =
            ↪  sequences.GetAllPartiallyMatchingSequences0(partialSequence); sw1.Stop();

            var sw2 = Stopwatch.StartNew();
            var searchResults2 =
            ↪  sequences.GetAllPartiallyMatchingSequences1(partialSequence); sw2.Stop();

            Assert.True(searchResults1.Count == 1 && balancedVariant == searchResults1[0]);

            Assert.True(searchResults2.Count == 1 && balancedVariant ==
            ↪  searchResults2.First());

            for (var i = 0; i < sequenceLength; i++)
            {
                links.Delete(sequence[i]);
            }
        }
    }

    [Fact(Skip = "Correct implementation is pending")]
    public static void PatternMatchTest()
    {
        var zeroOrMany = Sequences.ZeroOrMany;

        using (var scope = new TempLinksTestScope(useSequences: true))
        {
            var links = scope.Links;
            var sequences = scope.Sequences;

            var e1 = links.Create();
            var e2 = links.Create();

            var sequence = new[]
            {
                e1, e2, e1, e2 // mama / papa
            };

            var balancedVariantConverter = new BalancedVariantConverter<ulong>(links);

            var balancedVariant = balancedVariantConverter.Convert(sequence);

            // 1: [1]
            // 2: [2]
            // 3: [1,2]
            // 4: [1,2,1,2]

            var doublet = links.GetSource(balancedVariant);

            var matchedSequences1 = sequences.MatchPattern(e2, e1, zeroOrMany);

            Assert.True(matchedSequences1.Count == 0);

            var matchedSequences2 = sequences.MatchPattern(zeroOrMany, e2, e1);

            Assert.True(matchedSequences2.Count == 0);

            var matchedSequences3 = sequences.MatchPattern(e1, zeroOrMany, e1);

            Assert.True(matchedSequences3.Count == 0);

            var matchedSequences4 = sequences.MatchPattern(e1, zeroOrMany, e2);
```

```
343
344                 Assert.Contains(doublet, matchedSequences4);
345                 Assert.Contains(balancedVariant, matchedSequences4);
346
347                 for (var i = 0; i < sequence.Length; i++)
348                 {
349                     links.Delete(sequence[i]);
350                 }
351             }
352         }
353
354         [Fact]
355         public static void IndexTest()
356         {
357             using (var scope = new TempLinksTestScope(new SequencesOptions<ulong> { UseIndex =
                ↪ true }, useSequences: true))
358             {
359                 var links = scope.Links;
360                 var sequences = scope.Sequences;
361                 var index = sequences.Options.Index;
362
363                 var e1 = links.Create();
364                 var e2 = links.Create();
365
366                 var sequence = new[]
367                 {
368                     e1, e2, e1, e2 // mama / papa
369                 };
370
371                 Assert.False(index.MightContain(sequence));
372
373                 index.Add(sequence);
374
375                 Assert.True(index.MightContain(sequence));
376             }
377         }
378
379         /// <summary>Imported from https://raw.githubusercontent.com/wiki/Konard/LinksPlatform/%
            ↪ D0%9E-%D1%82%D0%BE%D0%BC%2C-%D0%BA%D0%B0%D0%BA-%D0%B2%D1%81%D1%91-%D0%BD%D0%B0%D1%87
            ↪ %D0%B8%D0%BD%D0%B0%D0%BB%D0%BE%D1%81%D1%8C.md</summary>
380         private static readonly string _exampleText =
381             @"([english
                ↪ version](https://github.com/Konard/LinksPlatform/wiki/About-the-beginning))
382
383 Обозначение пустоты, какое оно? Темнота ли это? Там где отсутствие света, отсутствие фотонов
    ↪ (носителей света)? Или это то, что полностью отражает свет? Пустой белый лист бумаги? Там
    ↪ где есть место для нового начала? Разве пустота это не характеристика пространства?
    ↪ Пространство это то, что можно чем-то наполнить?
384
385 [![чёрное пространство, белое
    ↪ пространство](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/1.png
    ↪ ""чёрное пространство, белое пространство"")](https://raw.githubusercontent.com/Konard/Links
    ↪ Platform/master/doc/Intro/1.png)
386
387 Что может быть минимальным рисунком, образом, графикой? Может быть это точка? Это ли простейшая
    ↪ форма? Но есть ли у точки размер? Цвет? Масса? Координаты? Время существования?
388
389 [![чёрное пространство, чёрная
    ↪ точка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/2.png
    ↪ ""чёрное пространство, чёрная
    ↪ точка"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/2.png)
390
391 А что если повторить? Сделать копию? Создать дубликат? Из одного сделать два? Может это быть
    ↪ так? Инверсия? Отражение? Сумма?
392
393 [![белая точка, чёрная
    ↪ точка](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/3.png ""белая
    ↪ точка, чёрная
    ↪ точка"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/3.png)
394
395 А что если мы вообразим движение? Нужно ли время? Каким самым коротким будет путь? Что будет
    ↪ если этот путь зафиксировать? Запомнить след? Как две точки становятся линией? Чертой?
    ↪ Гранью? Разделителем? Единицей?
396
397 [![две белые точки, чёрная вертикальная
    ↪ линия](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/4.png ""две
    ↪ белые точки, чёрная вертикальная
    ↪ линия"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/4.png)
398
```

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)

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?

[![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)

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?

[![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)

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?

[![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)

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?

[![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)

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?

[![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)

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

[![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)

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

```
[![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)

...

[![анимация](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro-animation-500.gif ""анимация"")](https://raw.githubusercontent.com/Konard/LinksPlatform/master/doc/Intro/intro-animation-500.gif)";

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

        [Fact]
        public static void CompressionTest()
        {
            using (var scope = new TempLinksTestScope(useSequences: true))
            {
                var links = scope.Links;
                var sequences = scope.Sequences;

                var e1 = links.Create();
                var e2 = links.Create();

                var sequence = new[]
                {
                    e1, e2, e1, e2 // mama / papa / template [(m/p), a] { [1] [2] [1] [2] }
                };

                var balancedVariantConverter = new BalancedVariantConverter<ulong>(links.Unsync);
                var totalSequenceSymbolFrequencyCounter = new TotalSequenceSymbolFrequencyCounter<ulong>(links.Unsync);
                var doubletFrequenciesCache = new LinkFrequenciesCache<ulong>(links.Unsync, totalSequenceSymbolFrequencyCounter);
                var compressingConverter = new CompressingConverter<ulong>(links.Unsync, balancedVariantConverter, doubletFrequenciesCache);

                var compressedVariant = compressingConverter.Convert(sequence);

                // 1: [1]       (1->1) point
                // 2: [2]       (2->2) point
                // 3: [1,2]     (1->2) doublet
                // 4: [1,2,1,2] (3->3) doublet

                Assert.True(links.GetSource(links.GetSource(compressedVariant)) == sequence[0]);
                Assert.True(links.GetTarget(links.GetSource(compressedVariant)) == sequence[1]);
                Assert.True(links.GetSource(links.GetTarget(compressedVariant)) == sequence[2]);
                Assert.True(links.GetTarget(links.GetTarget(compressedVariant)) == sequence[3]);

                var source = _constants.SourcePart;
                var target = _constants.TargetPart;

                Assert.True(links.GetByKeys(compressedVariant, source, source) == sequence[0]);
                Assert.True(links.GetByKeys(compressedVariant, source, target) == sequence[1]);
                Assert.True(links.GetByKeys(compressedVariant, target, source) == sequence[2]);
                Assert.True(links.GetByKeys(compressedVariant, target, target) == sequence[3]);

                // 4 - length of sequence
                Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 0) == sequence[0]);
                Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 1) == sequence[1]);
                Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 2) == sequence[2]);
                Assert.True(links.GetSquareMatrixSequenceElementByIndex(compressedVariant, 4, 3) == sequence[3]);
            }
        }

        [Fact]
        public static void CompressionEfficiencyTest()
```

```
490         {
491             var strings = _exampleLoremIpsumText.Split(new[] { '\n', '\r' },
                ↪  StringSplitOptions.RemoveEmptyEntries);
492             var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
493             var totalCharacters = arrays.Select(x => x.Length).Sum();
494 
495             using (var scope1 = new TempLinksTestScope(useSequences: true))
496             using (var scope2 = new TempLinksTestScope(useSequences: true))
497             using (var scope3 = new TempLinksTestScope(useSequences: true))
498             {
499                 scope1.Links.Unsync.UseUnicode();
500                 scope2.Links.Unsync.UseUnicode();
501                 scope3.Links.Unsync.UseUnicode();
502 
503                 var balancedVariantConverter1 = new
                    ↪  BalancedVariantConverter<ulong>(scope1.Links.Unsync);
504                 var totalSequenceSymbolFrequencyCounter = new
                    ↪  TotalSequenceSymbolFrequencyCounter<ulong>(scope1.Links.Unsync);
505                 var linkFrequenciesCache1 = new LinkFrequenciesCache<ulong>(scope1.Links.Unsync,
                    ↪  totalSequenceSymbolFrequencyCounter);
506                 var compressor1 = new CompressingConverter<ulong>(scope1.Links.Unsync,
                    ↪  balancedVariantConverter1, linkFrequenciesCache1,
                    ↪  doInitialFrequenciesIncrement: false);
507 
508                 //var compressor2 = scope2.Sequences;
509                 var compressor3 = scope3.Sequences;
510 
511                 var constants = Default<LinksConstants<ulong>>.Instance;
512 
513                 var sequences = compressor3;
514                 //var meaningRoot = links.CreatePoint();
515                 //var unaryOne = links.CreateAndUpdate(meaningRoot, constants.Itself);
516                 //var frequencyMarker = links.CreateAndUpdate(meaningRoot, constants.Itself);
517                 //var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot,
                    ↪  constants.Itself);
518 
519                 //var unaryNumberToAddressConverter = new
                    ↪  UnaryNumberToAddressAddOperationConverter<ulong>(links, unaryOne);
520                 //var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links,
                    ↪  unaryOne);
521                 //var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
                    ↪  frequencyMarker, unaryOne, unaryNumberIncrementer);
522                 //var frequencyPropertyOperator = new FrequencyPropertyOperator<ulong>(links,
                    ↪  frequencyPropertyMarker, frequencyMarker);
523                 //var linkFrequencyIncrementer = new LinkFrequencyIncrementer<ulong>(links,
                    ↪  frequencyPropertyOperator, frequencyIncrementer);
524                 //var linkToItsFrequencyNumberConverter = new
                    ↪  LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
                    ↪  unaryNumberToAddressConverter);
525 
526                 var linkFrequenciesCache3 = new LinkFrequenciesCache<ulong>(scope3.Links.Unsync,
                    ↪  totalSequenceSymbolFrequencyCounter);
527 
528                 var linkToItsFrequencyNumberConverter = new FrequenciesCacheBasedLinkToItsFreque
                    ↪  ncyNumberConverter<ulong>(linkFrequenciesCache3);
529 
530                 var sequenceToItsLocalElementLevelsConverter = new
                    ↪  SequenceToItsLocalElementLevelsConverter<ulong>(scope3.Links.Unsync,
                    ↪  linkToItsFrequencyNumberConverter);
531                 var optimalVariantConverter = new
                    ↪  OptimalVariantConverter<ulong>(scope3.Links.Unsync,
                    ↪  sequenceToItsLocalElementLevelsConverter);
532 
533                 var compressed1 = new ulong[arrays.Length];
534                 var compressed2 = new ulong[arrays.Length];
535                 var compressed3 = new ulong[arrays.Length];
536 
537                 var START = 0;
538                 var END = arrays.Length;
539 
540                 //for (int i = START; i < END; i++)
541                 //    linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
542 
543                 var initialCount1 = scope2.Links.Unsync.Count();
544 
545                 var sw1 = Stopwatch.StartNew();
546 
547                 for (int i = START; i < END; i++)
```

```
548                 {
549                     linkFrequenciesCache1.IncrementFrequencies(arrays[i]);
550                     compressed1[i] = compressor1.Convert(arrays[i]);
551                 }
552 
553                 var elapsed1 = sw1.Elapsed;
554 
555                 var balancedVariantConverter2 = new
                    ↪  BalancedVariantConverter<ulong>(scope2.Links.Unsync);
556 
557                 var initialCount2 = scope2.Links.Unsync.Count();
558 
559                 var sw2 = Stopwatch.StartNew();
560 
561                 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},
                    ↪  Optimal variant: {elapsed3}");
586 
587                 // Assert.True(elapsed1 > elapsed2);
588 
589                 // Checks
590                 for (int i = START; i < END; i++)
591                 {
592                     var sequence1 = compressed1[i];
593                     var sequence2 = compressed2[i];
594                     var sequence3 = compressed3[i];
595 
596                     var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
                        ↪  scope1.Links.Unsync);
597 
598                     var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
                        ↪  scope2.Links.Unsync);
599 
600                     var decompress3 = UnicodeMap.FromSequenceLinkToString(sequence3,
                        ↪  scope3.Links.Unsync);
601 
602                     var structure1 = scope1.Links.Unsync.FormatStructure(sequence1, link =>
                        ↪  link.IsPartialPoint());
603                     var structure2 = scope2.Links.Unsync.FormatStructure(sequence2, link =>
                        ↪  link.IsPartialPoint());
604                     var structure3 = scope3.Links.Unsync.FormatStructure(sequence3, link =>
                        ↪  link.IsPartialPoint());
605 
606                     //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
                        ↪  arrays[i].Length > 3)
607                     //    Assert.False(structure1 == structure2);
608                     //if (sequence3 != Constants.Null && sequence2 != Constants.Null &&
                        ↪  arrays[i].Length > 3)
609                     //    Assert.False(structure3 == structure2);
610 
611                     Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
612                     Assert.True(strings[i] == decompress3 && decompress3 == decompress2);
613                 }
614 
615                 Assert.True((int)(scope1.Links.Unsync.Count() - initialCount1) <
                    ↪  totalCharacters);
```

```
616                 Assert.True((int)(scope2.Links.Unsync.Count() - initialCount2) <
                    ↪ totalCharacters);
617                 Assert.True((int)(scope3.Links.Unsync.Count() - initialCount3) <
                    ↪ totalCharacters);
618
619                 Console.WriteLine($"{(double)(scope1.Links.Unsync.Count() - initialCount1) /
                    ↪ totalCharacters} | {(double)(scope2.Links.Unsync.Count() - initialCount2) /
                    ↪ totalCharacters} | {(double)(scope3.Links.Unsync.Count() - initialCount3) /
                    ↪ totalCharacters}");
620
621                 Assert.True(scope1.Links.Unsync.Count() - initialCount1 <
                    ↪ scope2.Links.Unsync.Count() - initialCount2);
622                 Assert.True(scope3.Links.Unsync.Count() - initialCount3 <
                    ↪ scope2.Links.Unsync.Count() - initialCount2);
623
624                 var duplicateProvider1 = new
                    ↪ DuplicateSegmentsProvider<ulong>(scope1.Links.Unsync, scope1.Sequences);
625                 var duplicateProvider2 = new
                    ↪ DuplicateSegmentsProvider<ulong>(scope2.Links.Unsync, scope2.Sequences);
626                 var duplicateProvider3 = new
                    ↪ DuplicateSegmentsProvider<ulong>(scope3.Links.Unsync, scope3.Sequences);
627
628                 var duplicateCounter1 = new DuplicateSegmentsCounter<ulong>(duplicateProvider1);
629                 var duplicateCounter2 = new DuplicateSegmentsCounter<ulong>(duplicateProvider2);
630                 var duplicateCounter3 = new DuplicateSegmentsCounter<ulong>(duplicateProvider3);
631
632                 var duplicates1 = duplicateCounter1.Count();
633
634                 ConsoleHelpers.Debug("------");
635
636                 var duplicates2 = duplicateCounter2.Count();
637
638                 ConsoleHelpers.Debug("------");
639
640                 var duplicates3 = duplicateCounter3.Count();
641
642                 Console.WriteLine($"{duplicates1} | {duplicates2} | {duplicates3}");
643
644                 linkFrequenciesCache1.ValidateFrequencies();
645                 linkFrequenciesCache3.ValidateFrequencies();
646             }
647         }
648
649         [Fact]
650         public static void CompressionStabilityTest()
651         {
652             // TODO: Fix bug (do a separate test)
653             //const ulong minNumbers = 0;
654             //const ulong maxNumbers = 1000;
655
656             const ulong minNumbers = 10000;
657             const ulong maxNumbers = 12500;
658
659             var strings = new List<string>();
660
661             for (ulong i = minNumbers; i < maxNumbers; i++)
662             {
663                 strings.Add(i.ToString());
664             }
665
666             var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
667             var totalCharacters = arrays.Select(x => x.Length).Sum();
668
669             using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
                    ↪ SequencesOptions<ulong> { UseCompression = true,
                    ↪ EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
670             using (var scope2 = new TempLinksTestScope(useSequences: true))
671             {
672                 scope1.Links.UseUnicode();
673                 scope2.Links.UseUnicode();
674
675                 //var compressor1 = new Compressor(scope1.Links.Unsync, scope1.Sequences);
676                 var compressor1 = scope1.Sequences;
677                 var compressor2 = scope2.Sequences;
678
679                 var compressed1 = new ulong[arrays.Length];
680                 var compressed2 = new ulong[arrays.Length];
681
682                 var sw1 = Stopwatch.StartNew();
```

```
683
684                 var START = 0;
685                 var END = arrays.Length;
686
687                 // Collisions proved (cannot be solved by max doublet comparison, no stable rule)
688                 // Stability issue starts at 10001 or 11000
689                 //for (int i = START; i < END; i++)
690                 //{
691                 //    var first = compressor1.Compress(arrays[i]);
692                 //    var second = compressor1.Compress(arrays[i]);
693
694                 //    if (first == second)
695                 //        compressed1[i] = first;
696                 //    else
697                 //    {
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].ShiftRight());
705                     var second = compressor1.Create(arrays[i].ShiftRight());
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:
                    {elapsed2}");
737
738                 Assert.True(elapsed1 > elapsed2);
739
740                 // Checks
741                 for (int i = START; i < END; i++)
742                 {
743                     var sequence1 = compressed1[i];
744                     var sequence2 = compressed2[i];
745
746                     if (sequence1 != _constants.Null && sequence2 != _constants.Null)
747                     {
748                         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
                            scope1.Links);
749
750                         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
                            scope2.Links);
751
752                         //var structure1 = scope1.Links.FormatStructure(sequence1, link =>
                            link.IsPartialPoint());
753                         //var structure2 = scope2.Links.FormatStructure(sequence2, link =>
                            link.IsPartialPoint());
754
755                         //if (sequence1 != Constants.Null && sequence2 != Constants.Null &&
                            arrays[i].Length > 3)
```

```
                    //    Assert.False(structure1 == structure2);

                    Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
                }
            }

            Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
            Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);

            Debug.WriteLine($"{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
            ↪  totalCharacters} | {(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
            ↪  totalCharacters}");

            Assert.True(scope1.Links.Count() <= scope2.Links.Count());

            //compressor1.ValidateFrequencies();
        }
    }

    [Fact]
    public static void RundomNumbersCompressionQualityTest()
    {
        const ulong N = 500;

        //const ulong minNumbers = 10000;
        //const ulong maxNumbers = 20000;

        //var strings = new List<string>();

        //for (ulong i = 0; i < N; i++)
        //    strings.Add(RandomHelpers.DefaultFactory.NextUInt64(minNumbers,
        ↪  maxNumbers).ToString());

        var strings = new List<string>();

        for (ulong i = 0; i < N; i++)
        {
            strings.Add(RandomHelpers.Default.NextUInt64().ToString());
        }

        strings = strings.Distinct().ToList();

        var arrays = strings.Select(UnicodeMap.FromStringToLinkArray).ToArray();
        var totalCharacters = arrays.Select(x => x.Length).Sum();

        using (var scope1 = new TempLinksTestScope(useSequences: true, sequencesOptions: new
        ↪  SequencesOptions<ulong> { UseCompression = true,
        ↪  EnforceSingleSequenceVersionOnWriteBasedOnExisting = true }))
        using (var scope2 = new TempLinksTestScope(useSequences: true))
        {
            scope1.Links.UseUnicode();
            scope2.Links.UseUnicode();

            var compressor1 = scope1.Sequences;
            var compressor2 = scope2.Sequences;

            var compressed1 = new ulong[arrays.Length];
            var compressed2 = new ulong[arrays.Length];

            var sw1 = Stopwatch.StartNew();

            var START = 0;
            var END = arrays.Length;

            for (int i = START; i < END; i++)
            {
                compressed1[i] = compressor1.Create(arrays[i].ShiftRight());
            }

            var elapsed1 = sw1.Elapsed;

            var balancedVariantConverter = new BalancedVariantConverter<ulong>(scope2.Links);

            var sw2 = Stopwatch.StartNew();

            for (int i = START; i < END; i++)
            {
                compressed2[i] = balancedVariantConverter.Convert(arrays[i]);
            }

```

```
831                 var elapsed2 = sw2.Elapsed;
832
833                 Debug.WriteLine($"Compressor: {elapsed1}, Balanced sequence creator:
                    ↪ {elapsed2}");
834
835                 Assert.True(elapsed1 > elapsed2);
836
837                 // Checks
838                 for (int i = START; i < END; i++)
839                 {
840                     var sequence1 = compressed1[i];
841                     var sequence2 = compressed2[i];
842
843                     if (sequence1 != _constants.Null && sequence2 != _constants.Null)
844                     {
845                         var decompress1 = UnicodeMap.FromSequenceLinkToString(sequence1,
                            ↪ scope1.Links);
846
847                         var decompress2 = UnicodeMap.FromSequenceLinkToString(sequence2,
                            ↪ scope2.Links);
848
849                         Assert.True(strings[i] == decompress1 && decompress1 == decompress2);
850                     }
851                 }
852
853                 Assert.True((int)(scope1.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
854                 Assert.True((int)(scope2.Links.Count() - UnicodeMap.MapSize) < totalCharacters);
855
856                 Debug.WriteLine($"{(double)(scope1.Links.Count() - UnicodeMap.MapSize) /
                    ↪ totalCharacters} | {(double)(scope2.Links.Count() - UnicodeMap.MapSize) /
                    ↪ totalCharacters}");
857
858                 // Can be worse than balanced variant
859                 //Assert.True(scope1.Links.Count() <= scope2.Links.Count());
860
861                 //compressor1.ValidateFrequencies();
862             }
863         }
864
865         [Fact]
866         public static void AllTreeBreakDownAtSequencesCreationBugTest()
867         {
868             // Made out of AllPossibleConnectionsTest test.
869
870             //const long sequenceLength = 5; //100% bug
871             const long sequenceLength = 4; //100% bug
872             //const long sequenceLength = 3; //100% _no_bug (ok)
873
874             using (var scope = new TempLinksTestScope(useSequences: true))
875             {
876                 var links = scope.Links;
877                 var sequences = scope.Sequences;
878
879                 var sequence = new ulong[sequenceLength];
880                 for (var i = 0; i < sequenceLength; i++)
881                 {
882                     sequence[i] = links.Create();
883                 }
884
885                 var createResults = sequences.CreateAllVariants2(sequence);
886
887                 Global.Trash = createResults;
888
889                 for (var i = 0; i < sequenceLength; i++)
890                 {
891                     links.Delete(sequence[i]);
892                 }
893             }
894         }
895
896         [Fact]
897         public static void AllPossibleConnectionsTest()
898         {
899             const long sequenceLength = 5;
900
901             using (var scope = new TempLinksTestScope(useSequences: true))
902             {
903                 var links = scope.Links;
904                 var sequences = scope.Sequences;
```

```
905
906                 var sequence = new ulong[sequenceLength];
907                 for (var i = 0; i < sequenceLength; i++)
908                 {
909                     sequence[i] = links.Create();
910                 }
911
912                 var createResults = sequences.CreateAllVariants2(sequence);
913                 var reverseResults = sequences.CreateAllVariants2(sequence.Reverse().ToArray());
914
915                 for (var i = 0; i < 1; i++)
916                 {
917                     var sw1 = Stopwatch.StartNew();
918                     var searchResults1 = sequences.GetAllConnections(sequence); sw1.Stop();
919
920                     var sw2 = Stopwatch.StartNew();
921                     var searchResults2 = sequences.GetAllConnections1(sequence); sw2.Stop();
922
923                     var sw3 = Stopwatch.StartNew();
924                     var searchResults3 = sequences.GetAllConnections2(sequence); sw3.Stop();
925
926                     var sw4 = Stopwatch.StartNew();
927                     var searchResults4 = sequences.GetAllConnections3(sequence); sw4.Stop();
928
929                     Global.Trash = searchResults3;
930                     Global.Trash = searchResults4; //-V3008
931
932                     var intersection1 = createResults.Intersect(searchResults1).ToList();
933                     Assert.True(intersection1.Count == createResults.Length);
934
935                     var intersection2 = reverseResults.Intersect(searchResults1).ToList();
936                     Assert.True(intersection2.Count == reverseResults.Length);
937
938                     var intersection0 = searchResults1.Intersect(searchResults2).ToList();
939                     Assert.True(intersection0.Count == searchResults2.Count);
940
941                     var intersection3 = searchResults2.Intersect(searchResults3).ToList();
942                     Assert.True(intersection3.Count == searchResults3.Count);
943
944                     var intersection4 = searchResults3.Intersect(searchResults4).ToList();
945                     Assert.True(intersection4.Count == searchResults4.Count);
946                 }
947
948                 for (var i = 0; i < sequenceLength; i++)
949                 {
950                     links.Delete(sequence[i]);
951                 }
952             }
953         }
954
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 =
                 ↪  sequences.CreateAllVariants2(sequence.Reverse().ToArray());
974
975                 for (var i = 0; i < 1; i++)
976                 {
977                     var linksTotalUsages1 = new ulong[links.Count() + 1];
978
979                     sequences.CalculateAllUsages(linksTotalUsages1);
980
981                     var linksTotalUsages2 = new ulong[links.Count() + 1];
982
983                     sequences.CalculateAllUsages2(linksTotalUsages2);
```

```
984
985                     var intersection1 = linksTotalUsages1.Intersect(linksTotalUsages2).ToList();
986                     Assert.True(intersection1.Count == linksTotalUsages2.Length);
987                 }
988
989                 for (var i = 0; i < sequenceLength; i++)
990                 {
991                     links.Delete(sequence[i]);
992                 }
993             }
994         }
995     }
996 }
```

1.68 ./csharp/Platform.Data.Doublets.Sequences.Tests/TempLinksTestScope.cs

```
1  using System.IO;
2  using Platform.Disposables;
3  using Platform.Data.Doublets.Sequences;
4  using Platform.Data.Doublets.Decorators;
5  using Platform.Data.Doublets.Memory.United.Specific;
6  using Platform.Data.Doublets.Memory.Split.Specific;
7  using Platform.Memory;
8
9  namespace Platform.Data.Doublets.Sequences.Tests
10 {
11     public class TempLinksTestScope : DisposableBase
12     {
13         public ILinks<ulong> MemoryAdapter { get; }
14         public SynchronizedLinks<ulong> Links { get; }
15         public Sequences Sequences { get; }
16         public string TempFilename { get; }
17         public string TempTransactionLogFilename { get; }
18         private readonly bool _deleteFiles;
19
20         public TempLinksTestScope(bool deleteFiles = true, bool useSequences = false, bool
           ↪  useLog = false) : this(new SequencesOptions<ulong>(), deleteFiles, useSequences,
           ↪  useLog) { }
21
22         public TempLinksTestScope(SequencesOptions<ulong> sequencesOptions, bool deleteFiles =
           ↪  true, bool useSequences = false, bool useLog = false)
23         {
24             _deleteFiles = deleteFiles;
25             TempFilename = Path.GetTempFileName();
26             TempTransactionLogFilename = Path.GetTempFileName();
27             //var coreMemoryAdapter = new UInt64UnitedMemoryLinks(TempFilename);
28             var coreMemoryAdapter = new UInt64SplitMemoryLinks(new
                   ↪  FileMappedResizableDirectMemory(TempFilename), new
                   ↪  FileMappedResizableDirectMemory(Path.ChangeExtension(TempFilename, "indexes")),
                   ↪  UInt64SplitMemoryLinks.DefaultLinksSizeStep, new LinksConstants<ulong>(),
                   ↪  Memory.IndexTreeType.Default, useLinkedList: true);
29             MemoryAdapter = useLog ? (ILinks<ulong>)new
                   ↪  UInt64LinksTransactionsLayer(coreMemoryAdapter, TempTransactionLogFilename) :
                   ↪  coreMemoryAdapter;
30             Links = new SynchronizedLinks<ulong>(new UInt64Links(MemoryAdapter));
31             if (useSequences)
32             {
33                 Sequences = new Sequences(Links, sequencesOptions);
34             }
35         }
36
37         protected override void Dispose(bool manual, bool wasDisposed)
38         {
39             if (!wasDisposed)
40             {
41                 Links.Unsync.DisposeIfPossible();
42                 if (_deleteFiles)
43                 {
44                     DeleteFiles();
45                 }
46             }
47         }
48
49         public void DeleteFiles()
50         {
51             File.Delete(TempFilename);
52             File.Delete(TempTransactionLogFilename);
53         }
54     }
55 }
```

1.69 ./csharp/Platform.Data.Doublets.Sequences.Tests/TestExtensions.cs

```
using System.Collections.Generic;
using Xunit;
using Platform.Ranges;
using Platform.Numbers;
using Platform.Random;
using Platform.Setters;
using Platform.Converters;

namespace Platform.Data.Doublets.Sequences.Tests
{
    public static class TestExtensions
    {
        public static void TestCRUDOperations<T>(this ILinks<T> links)
        {
            var constants = links.Constants;

            var equalityComparer = EqualityComparer<T>.Default;

            var zero = default(T);
            var one = Arithmetic.Increment(zero);

            // Create Link
            Assert.True(equalityComparer.Equals(links.Count(), zero));

            var setter = new Setter<T>(constants.Null);
            links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);

            Assert.True(equalityComparer.Equals(setter.Result, constants.Null));

            var linkAddress = links.Create();

            var link = new Link<T>(links.GetLink(linkAddress));

            Assert.True(link.Count == 3);
            Assert.True(equalityComparer.Equals(link.Index, linkAddress));
            Assert.True(equalityComparer.Equals(link.Source, constants.Null));
            Assert.True(equalityComparer.Equals(link.Target, constants.Null));

            Assert.True(equalityComparer.Equals(links.Count(), one));

            // Get first link
            setter = new Setter<T>(constants.Null);
            links.Each(constants.Any, constants.Any, setter.SetAndReturnFalse);

            Assert.True(equalityComparer.Equals(setter.Result, linkAddress));

            // Update link to reference itself
            links.Update(linkAddress, linkAddress, linkAddress);

            link = new Link<T>(links.GetLink(linkAddress));

            Assert.True(equalityComparer.Equals(link.Source, linkAddress));
            Assert.True(equalityComparer.Equals(link.Target, linkAddress));

            // Update link to reference null (prepare for delete)
            var updated = links.Update(linkAddress, constants.Null, constants.Null);

            Assert.True(equalityComparer.Equals(updated, linkAddress));

            link = new Link<T>(links.GetLink(linkAddress));

            Assert.True(equalityComparer.Equals(link.Source, constants.Null));
            Assert.True(equalityComparer.Equals(link.Target, constants.Null));

            // Delete link
            links.Delete(linkAddress);

            Assert.True(equalityComparer.Equals(links.Count(), zero));

            setter = new Setter<T>(constants.Null);
            links.Each(constants.Any, constants.Any, setter.SetAndReturnTrue);

            Assert.True(equalityComparer.Equals(setter.Result, constants.Null));
        }

        public static void TestRawNumbersCRUDOperations<T>(this ILinks<T> links)
        {
            // Constants
            var constants = links.Constants;
            var equalityComparer = EqualityComparer<T>.Default;
```

```
81
82              var zero = default(T);
83              var one = Arithmetic.Increment(zero);
84              var two = Arithmetic.Increment(one);
85
86              var h106E = new Hybrid<T>(106L, isExternal: true);
87              var h107E = new Hybrid<T>(-char.ConvertFromUtf32(107)[0]);
88              var h108E = new Hybrid<T>(-108L);
89
90              Assert.Equal(106L, h106E.AbsoluteValue);
91              Assert.Equal(107L, h107E.AbsoluteValue);
92              Assert.Equal(108L, h108E.AbsoluteValue);
93
94              // Create Link (External -> External)
95              var linkAddress1 = links.Create();
96
97              links.Update(linkAddress1, h106E, h108E);
98
99              var link1 = new Link<T>(links.GetLink(linkAddress1));
100
101             Assert.True(equalityComparer.Equals(link1.Source, h106E));
102             Assert.True(equalityComparer.Equals(link1.Target, h108E));
103
104             // Create Link (Internal -> External)
105             var linkAddress2 = links.Create();
106
107             links.Update(linkAddress2, linkAddress1, h108E);
108
109             var link2 = new Link<T>(links.GetLink(linkAddress2));
110
111             Assert.True(equalityComparer.Equals(link2.Source, linkAddress1));
112             Assert.True(equalityComparer.Equals(link2.Target, h108E));
113
114             // Create Link (Internal -> Internal)
115             var linkAddress3 = links.Create();
116
117             links.Update(linkAddress3, linkAddress1, linkAddress2);
118
119             var link3 = new Link<T>(links.GetLink(linkAddress3));
120
121             Assert.True(equalityComparer.Equals(link3.Source, linkAddress1));
122             Assert.True(equalityComparer.Equals(link3.Target, linkAddress2));
123
124             // Search for created link
125             var setter1 = new Setter<T>(constants.Null);
126             links.Each(h106E, h108E, setter1.SetAndReturnFalse);
127
128             Assert.True(equalityComparer.Equals(setter1.Result, linkAddress1));
129
130             // Search for nonexistent link
131             var setter2 = new Setter<T>(constants.Null);
132             links.Each(h106E, h107E, setter2.SetAndReturnFalse);
133
134             Assert.True(equalityComparer.Equals(setter2.Result, constants.Null));
135
136             // Update link to reference null (prepare for delete)
137             var updated = links.Update(linkAddress3, constants.Null, constants.Null);
138
139             Assert.True(equalityComparer.Equals(updated, linkAddress3));
140
141             link3 = new Link<T>(links.GetLink(linkAddress3));
142
143             Assert.True(equalityComparer.Equals(link3.Source, constants.Null));
144             Assert.True(equalityComparer.Equals(link3.Target, constants.Null));
145
146             // Delete link
147             links.Delete(linkAddress3);
148
149             Assert.True(equalityComparer.Equals(links.Count(), two));
150
151             var setter3 = new Setter<T>(constants.Null);
152             links.Each(constants.Any, constants.Any, setter3.SetAndReturnTrue);
153
154             Assert.True(equalityComparer.Equals(setter3.Result, linkAddress2));
155         }
156
157         public static void TestMultipleRandomCreationsAndDeletions<TLink>(this ILinks<TLink>
            ↪ links, int maximumOperationsPerCycle)
158         {
159             var comparer = Comparer<TLink>.Default;
```

```
            var addressToUInt64Converter = CheckedConverter<TLink, ulong>.Default;
            var uInt64ToAddressConverter = CheckedConverter<ulong, TLink>.Default;
            for (var N = 1; N < maximumOperationsPerCycle; N++)
            {
                var random = new System.Random(N);
                var created = 0UL;
                var deleted = 0UL;
                for (var i = 0; i < N; i++)
                {
                    var linksCount = addressToUInt64Converter.Convert(links.Count());
                    var createPoint = random.NextBoolean();
                    if (linksCount >= 2 && createPoint)
                    {
                        var linksAddressRange = new Range<ulong>(1, linksCount);
                        TLink source = uInt64ToAddressConverter.Convert(random.NextUInt64(linksA
                        ↪  ddressRange));
                        TLink target = uInt64ToAddressConverter.Convert(random.NextUInt64(linksA
                        ↪  ddressRange));
                        ↪  //-V3086
                        var resultLink = links.GetOrCreate(source, target);
                        if (comparer.Compare(resultLink,
                        ↪  uInt64ToAddressConverter.Convert(linksCount)) > 0)
                        {
                            created++;
                        }
                    }
                    else
                    {
                        links.Create();
                        created++;
                    }
                }
                Assert.True(created == addressToUInt64Converter.Convert(links.Count()));
                for (var i = 0; i < N; i++)
                {
                    TLink link = uInt64ToAddressConverter.Convert((ulong)i + 1UL);
                    if (links.Exists(link))
                    {
                        links.Delete(link);
                        deleted++;
                    }
                }
                Assert.True(addressToUInt64Converter.Convert(links.Count()) == 0L);
            }
        }
    }
}
```

1.70 ./csharp/Platform.Data.Doublets.Sequences.Tests/UInt64LinksTests.cs

```
using System;
using System.Collections.Generic;
using System.Diagnostics;
using System.IO;
using System.Text;
using System.Threading;
using System.Threading.Tasks;
using Xunit;
using Platform.Disposables;
using Platform.Ranges;
using Platform.Random;
using Platform.Timestamps;
using Platform.Reflection;
using Platform.Singletons;
using Platform.Scopes;
using Platform.Counters;
using Platform.Diagnostics;
using Platform.IO;
using Platform.Memory;
using Platform.Data.Doublets.Decorators;
using Platform.Data.Doublets.Memory.United.Specific;

namespace Platform.Data.Doublets.Sequences.Tests
{
    public static class UInt64LinksTests
    {
        private static readonly LinksConstants<ulong> _constants =
        ↪  Default<LinksConstants<ulong>>.Instance;

        private const long Iterations = 10 * 1024;

```

```
        #region Concept

        [Fact]
        public static void MultipleCreateAndDeleteTest()
        {
            using (var scope = new Scope<Types<HeapResizableDirectMemory,
            ↪  UInt64UnitedMemoryLinks>>())
            {
                new UInt64Links(scope.Use<ILinks<ulong>>()).TestMultipleRandomCreationsAndDeleti
                ↪  ons(100);
            }
        }

        [Fact]
        public static void CascadeUpdateTest()
        {
            var itself = _constants.Itself;
            using (var scope = new TempLinksTestScope(useLog: true))
            {
                var links = scope.Links;

                var l1 = links.Create();
                var l2 = links.Create();

                l2 = links.Update(l2, l2, l1, l2);

                links.CreateAndUpdate(l2, itself);
                links.CreateAndUpdate(l2, itself);

                l2 = links.Update(l2, l1);

                links.Delete(l2);

                Global.Trash = links.Count();

                links.Unsync.DisposeIfPossible(); // Close links to access log

                Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scop
                ↪  e.TempTransactionLogFilename);
            }
        }

        [Fact]
        public static void BasicTransactionLogTest()
        {
            using (var scope = new TempLinksTestScope(useLog: true))
            {
                var links = scope.Links;
                var l1 = links.Create();
                var l2 = links.Create();

                Global.Trash = links.Update(l2, l2, l1, l2);

                links.Delete(l1);

                links.Unsync.DisposeIfPossible(); // Close links to access log

                Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(scop
                ↪  e.TempTransactionLogFilename);
            }
        }

        [Fact]
        public static void TransactionAutoRevertedTest()
        {
            // Auto Reverted (Because no commit at transaction)
            using (var scope = new TempLinksTestScope(useLog: true))
            {
                var links = scope.Links;
                var transactionsLayer = (UInt64LinksTransactionsLayer)scope.MemoryAdapter;
                using (var transaction = transactionsLayer.BeginTransaction())
                {
                    var l1 = links.Create();
                    var l2 = links.Create();

                    links.Update(l2, l2, l1, l2);
                }

                Assert.Equal(0UL, links.Count());
```

```
106
107                 links.Unsync.DisposeIfPossible();
108
109                 var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(s
                    ↪  cope.TempTransactionLogFilename);
110                 Assert.Single(transitions);
111             }
112         }
113
114         [Fact]
115         public static void TransactionUserCodeErrorNoDataSavedTest()
116         {
117             // User Code Error (Autoreverted), no data saved
118             var itself = _constants.Itself;
119
120             TempLinksTestScope lastScope = null;
121             try
122             {
123                 using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
                    ↪  useLog: true))
124                 {
125                     var links = scope.Links;
126                     var transactionsLayer = (UInt64LinksTransactionsLayer)((LinksDisposableDecor
                        ↪  atorBase<ulong>)links.Unsync).Links;
127                     using (var transaction = transactionsLayer.BeginTransaction())
128                     {
129                         var l1 = links.CreateAndUpdate(itself, itself);
130                         var l2 = links.CreateAndUpdate(itself, itself);
131
132                         l2 = links.Update(l2, l2, l1, l2);
133
134                         links.CreateAndUpdate(l2, itself);
135                         links.CreateAndUpdate(l2, itself);
136
137                         //Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transi
                            ↪  tion>(scope.TempTransactionLogFilename);
138
139                         l2 = links.Update(l2, l1);
140
141                         links.Delete(l2);
142
143                         ExceptionThrower();
144
145                         transaction.Commit();
146                     }
147
148                     Global.Trash = links.Count();
149                 }
150             }
151             catch
152             {
153                 Assert.False(lastScope == null);
154
155                 var transitions = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(l
                    ↪  astScope.TempTransactionLogFilename);
156
157                 Assert.True(transitions.Length == 1 && transitions[0].Before.IsNull() &&
                    ↪  transitions[0].After.IsNull());
158
159                 lastScope.DeleteFiles();
160             }
161         }
162
163         [Fact]
164         public static void TransactionUserCodeErrorSomeDataSavedTest()
165         {
166             // User Code Error (Autoreverted), some data saved
167             var itself = _constants.Itself;
168
169             TempLinksTestScope lastScope = null;
170             try
171             {
172                 ulong l1;
173                 ulong l2;
174
175                 using (var scope = new TempLinksTestScope(useLog: true))
176                 {
177                     var links = scope.Links;
178                     l1 = links.CreateAndUpdate(itself, itself);
```

```
                    l2 = links.CreateAndUpdate(itself, itself);

                    l2 = links.Update(l2, l2, l1, l2);

                    links.CreateAndUpdate(l2, itself);
                    links.CreateAndUpdate(l2, itself);

                    links.Unsync.DisposeIfPossible();

                    Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(
                        scope.TempTransactionLogFilename);
                }

                using (var scope = lastScope = new TempLinksTestScope(deleteFiles: false,
                    useLog: true))
                {
                    var links = scope.Links;
                    var transactionsLayer = (UInt64LinksTransactionsLayer)links.Unsync;
                    using (var transaction = transactionsLayer.BeginTransaction())
                    {
                        l2 = links.Update(l2, l1);

                        links.Delete(l2);

                        ExceptionThrower();

                        transaction.Commit();
                    }

                    Global.Trash = links.Count();
                }
            }
            catch
            {
                Assert.False(lastScope == null);

                Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(last
                    Scope.TempTransactionLogFilename);

                lastScope.DeleteFiles();
            }
        }

        [Fact]
        public static void TransactionCommit()
        {
            var itself = _constants.Itself;

            var tempDatabaseFilename = Path.GetTempFileName();
            var tempTransactionLogFilename = Path.GetTempFileName();

            // Commit
            using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
                UInt64UnitedMemoryLinks(tempDatabaseFilename), tempTransactionLogFilename))
            using (var links = new UInt64Links(memoryAdapter))
            {
                using (var transaction = memoryAdapter.BeginTransaction())
                {
                    var l1 = links.CreateAndUpdate(itself, itself);
                    var l2 = links.CreateAndUpdate(itself, itself);

                    Global.Trash = links.Update(l2, l2, l1, l2);

                    links.Delete(l1);

                    transaction.Commit();
                }

                Global.Trash = links.Count();
            }

            Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
                sactionLogFilename);
        }

        [Fact]
        public static void TransactionDamage()
        {
            var itself = _constants.Itself;
```

```
253
254             var tempDatabaseFilename = Path.GetTempFileName();
255             var tempTransactionLogFilename = Path.GetTempFileName();
256
257             // Commit
258             using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
                ↪ UInt64UnitedMemoryLinks(tempDatabaseFilename), tempTransactionLogFilename))
259             using (var links = new UInt64Links(memoryAdapter))
260             {
261                 using (var transaction = memoryAdapter.BeginTransaction())
262                 {
263                     var l1 = links.CreateAndUpdate(itself, itself);
264                     var l2 = links.CreateAndUpdate(itself, itself);
265
266                     Global.Trash = links.Update(l2, l2, l1, l2);
267
268                     links.Delete(l1);
269
270                     transaction.Commit();
271                 }
272
273                 Global.Trash = links.Count();
274             }
275
276             Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
                ↪ sactionLogFilename);
277
278             // Damage database
279
280             FileHelpers.WriteFirst(tempTransactionLogFilename, new
                ↪ UInt64LinksTransactionsLayer.Transition(new UniqueTimestampFactory(), 555));
281
282             // Try load damaged database
283             try
284             {
285                 // TODO: Fix
286                 using (var memoryAdapter = new UInt64LinksTransactionsLayer(new
                    ↪ UInt64UnitedMemoryLinks(tempDatabaseFilename), tempTransactionLogFilename))
287                 using (var links = new UInt64Links(memoryAdapter))
288                 {
289                     Global.Trash = links.Count();
290                 }
291             }
292             catch (NotSupportedException ex)
293             {
294                 Assert.True(ex.Message == "Database is damaged, autorecovery is not supported
                    ↪ yet.");
295             }
296
297             Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(tempTran
                ↪ sactionLogFilename);
298
299             File.Delete(tempDatabaseFilename);
300             File.Delete(tempTransactionLogFilename);
301         }
302
303         [Fact]
304         public static void Bug1Test()
305         {
306             var tempDatabaseFilename = Path.GetTempFileName();
307             var tempTransactionLogFilename = Path.GetTempFileName();
308
309             var itself = _constants.Itself;
310
311             // User Code Error (Autoreverted), some data saved
312             try
313             {
314                 ulong l1;
315                 ulong l2;
316
317                 using (var memory = new UInt64UnitedMemoryLinks(tempDatabaseFilename))
318                 using (var memoryAdapter = new UInt64LinksTransactionsLayer(memory,
                    ↪ tempTransactionLogFilename))
319                 using (var links = new UInt64Links(memoryAdapter))
320                 {
321                     l1 = links.CreateAndUpdate(itself, itself);
322                     l2 = links.CreateAndUpdate(itself, itself);
323
324                     l2 = links.Update(l2, l2, l1, l2);
```

```
325
326                     links.CreateAndUpdate(l2, itself);
327                     links.CreateAndUpdate(l2, itself);
328                 }
329
330                 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
                    ↪ TransactionLogFilename);
331
332                 using (var memory = new UInt64UnitedMemoryLinks(tempDatabaseFilename))
333                 using (var memoryAdapter = new UInt64LinksTransactionsLayer(memory,
                    ↪ tempTransactionLogFilename))
334                 using (var links = new UInt64Links(memoryAdapter))
335                 {
336                     using (var transaction = memoryAdapter.BeginTransaction())
337                     {
338                         l2 = links.Update(l2, l1);
339
340                         links.Delete(l2);
341
342                         ExceptionThrower();
343
344                         transaction.Commit();
345                     }
346
347                     Global.Trash = links.Count();
348                 }
349             }
350             catch
351             {
352                 Global.Trash = FileHelpers.ReadAll<UInt64LinksTransactionsLayer.Transition>(temp
                    ↪ TransactionLogFilename);
353             }
354
355             File.Delete(tempDatabaseFilename);
356             File.Delete(tempTransactionLogFilename);
357         }
358
359         private static void ExceptionThrower() => throw new InvalidOperationException();
360
361         [Fact]
362         public static void PathsTest()
363         {
364             var source = _constants.SourcePart;
365             var target = _constants.TargetPart;
366
367             using (var scope = new TempLinksTestScope())
368             {
369                 var links = scope.Links;
370                 var l1 = links.CreatePoint();
371                 var l2 = links.CreatePoint();
372
373                 var r1 = links.GetByKeys(l1, source, target, source);
374                 var r2 = links.CheckPathExistance(l2, l2, l2, l2);
375             }
376         }
377
378         [Fact]
379         public static void RecursiveStringFormattingTest()
380         {
381             using (var scope = new TempLinksTestScope(useSequences: true))
382             {
383                 var links = scope.Links;
384                 var sequences = scope.Sequences; // TODO: Auto use sequences on Sequences getter.
385
386                 var a = links.CreatePoint();
387                 var b = links.CreatePoint();
388                 var c = links.CreatePoint();
389
390                 var ab = links.GetOrCreate(a, b);
391                 var cb = links.GetOrCreate(c, b);
392                 var ac = links.GetOrCreate(a, c);
393
394                 a = links.Update(a, c, b);
395                 b = links.Update(b, a, c);
396                 c = links.Update(c, a, b);
397
398                 Debug.WriteLine(links.FormatStructure(ab, link => link.IsFullPoint(), true));
399                 Debug.WriteLine(links.FormatStructure(cb, link => link.IsFullPoint(), true));
400                 Debug.WriteLine(links.FormatStructure(ac, link => link.IsFullPoint(), true));
```

```
401
402                 Assert.True(links.FormatStructure(cb, link => link.IsFullPoint(), true) ==
                    ↪  "(5:(4:5 (6:5 4)) 6)");
403                 Assert.True(links.FormatStructure(ac, link => link.IsFullPoint(), true) ==
                    ↪  "(6:(5:(4:5 6) 6) 4)");
404                 Assert.True(links.FormatStructure(ab, link => link.IsFullPoint(), true) ==
                    ↪  "(4:(5:4 (6:5 4)) 6)");
405
406                 // TODO: Think how to build balanced syntax tree while formatting structure (eg.
                    ↪  "(4:(5:4 6) (6:5 4)") instead of "(4:(5:4 (6:5 4)) 6)"
407
408                 Assert.True(sequences.SafeFormatSequence(cb, DefaultFormatter, false) ==
                    ↪  "{{5}{5}{4}{6}}");
409                 Assert.True(sequences.SafeFormatSequence(ac, DefaultFormatter, false) ==
                    ↪  "{{5}{6}{6}{4}}");
410                 Assert.True(sequences.SafeFormatSequence(ab, DefaultFormatter, false) ==
                    ↪  "{{4}{5}{4}{6}}");
411             }
412         }
413
414         private static void DefaultFormatter(StringBuilder sb, ulong link)
415         {
416             sb.Append(link.ToString());
417         }
418
419         #endregion
420
421         #region Performance
422
423         /*
424        public static void RunAllPerformanceTests()
425        {
426             try
427             {
428                 links.TestLinksInSteps();
429             }
430             catch (Exception ex)
431             {
432                 ex.WriteToConsole();
433             }
434
435             return;
436
437             try
438             {
439                 //ThreadPool.SetMaxThreads(2, 2);
440
441                 // Запускаем все тесты дважды, чтобы первоначальная инициализация не повлияла на
    ↪  результат
442                 // Также это дополнительно помогает в отладке
443                 // Увеличивает вероятность попадания информации в кэши
444                 for (var i = 0; i < 10; i++)
445                 {
446                     //0 - 10 ГБ
447                     //Каждые 100 МБ срез цифр
448
449                     //links.TestGetSourceFunction();
450                     //links.TestGetSourceFunctionInParallel();
451                     //links.TestGetTargetFunction();
452                     //links.TestGetTargetFunctionInParallel();
453                     links.Create64BillionLinks();
454
455                     links.TestRandomSearchFixed();
456                     //links.Create64BillionLinksInParallel();
457                     links.TestEachFunction();
458                     //links.TestForeach();
459                     //links.TestParallelForeach();
460                 }
461
462                 links.TestDeletionOfAllLinks();
463
464             }
465             catch (Exception ex)
466             {
467                 ex.WriteToConsole();
468             }
469         }*/
470
471         /*
```

```
472         public static void TestLinksInSteps()
473         {
474             const long gibibyte = 1024 * 1024 * 1024;
475             const long mebibyte = 1024 * 1024;
476 
477             var totalLinksToCreate = gibibyte /
    ↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
478             var linksStep = 102 * mebibyte /
    ↪ Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;
479 
480             var creationMeasurements = new List<TimeSpan>();
481             var searchMeasuremets = new List<TimeSpan>();
482             var deletionMeasurements = new List<TimeSpan>();
483 
484             GetBaseRandomLoopOverhead(linksStep);
485             GetBaseRandomLoopOverhead(linksStep);
486 
487             var stepLoopOverhead = GetBaseRandomLoopOverhead(linksStep);
488 
489             ConsoleHelpers.Debug("Step loop overhead: {0}.", stepLoopOverhead);
490 
491             var loops = totalLinksToCreate / linksStep;
492 
493             for (int i = 0; i < loops; i++)
494             {
495                 creationMeasurements.Add(Measure(() => links.RunRandomCreations(linksStep)));
496                 searchMeasuremets.Add(Measure(() => links.RunRandomSearches(linksStep)));
497 
498                 Console.Write("\rC + S {0}/{1}", i + 1, loops);
499             }
500 
501             ConsoleHelpers.Debug();
502 
503             for (int i = 0; i < loops; i++)
504             {
505                 deletionMeasurements.Add(Measure(() => links.RunRandomDeletions(linksStep)));
506 
507                 Console.Write("\rD {0}/{1}", i + 1, loops);
508             }
509 
510             ConsoleHelpers.Debug();
511 
512             ConsoleHelpers.Debug("C S D");
513 
514             for (int i = 0; i < loops; i++)
515             {
516                 ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i],
    ↪ searchMeasuremets[i], deletionMeasurements[i]);
517             }
518 
519             ConsoleHelpers.Debug("C S D (no overhead)");
520 
521             for (int i = 0; i < loops; i++)
522             {
523                 ConsoleHelpers.Debug("{0} {1} {2}", creationMeasurements[i] - stepLoopOverhead,
    ↪ searchMeasuremets[i] - stepLoopOverhead, deletionMeasurements[i] - stepLoopOverhead);
524             }
525 
526             ConsoleHelpers.Debug("All tests done. Total links left in database: {0}.",
    ↪ links.Total);
527         }
528 
529         private static void CreatePoints(this Platform.Links.Data.Core.Doublets.Links links, long
    ↪ amountToCreate)
530         {
531             for (long i = 0; i < amountToCreate; i++)
532                 links.Create(0, 0);
533         }
534 
535          private static TimeSpan GetBaseRandomLoopOverhead(long loops)
536          {
537              return Measure(() =>
538              {
539                  ulong maxValue = RandomHelpers.DefaultFactory.NextUInt64();
540                  ulong result = 0;
541                  for (long i = 0; i < loops; i++)
542                  {
543                      var source = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
544                      var target = RandomHelpers.DefaultFactory.NextUInt64(maxValue);
```

```
545
546                     result += maxValue + source + target;
547                 }
548                 Global.Trash = result;
549             });
550         }
551          */
552
553         [Fact(Skip = "performance test")]
554         public static void GetSourceTest()
555         {
556             using (var scope = new TempLinksTestScope())
557             {
558                 var links = scope.Links;
559                 ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations.",
                    ↪  Iterations);
560
561                 ulong counter = 0;
562
563                 //var firstLink = links.First();
564                 // Создаём одну связь, из которой будет производить считывание
565                 var firstLink = links.Create();
566
567                 var sw = Stopwatch.StartNew();
568
569                 // Тестируем саму функцию
570                 for (ulong i = 0; i < Iterations; i++)
571                 {
572                     counter += links.GetSource(firstLink);
573                 }
574
575                 var elapsedTime = sw.Elapsed;
576
577                 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
578
579                 // Удаляем связь, из которой производилось считывание
580                 links.Delete(firstLink);
581
582                 ConsoleHelpers.Debug(
583                     "{0} Iterations of GetSource function done in {1} ({2} Iterations per
                        ↪  second), counter result: {3}",
584                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
585             }
586         }
587
588         [Fact(Skip = "performance test")]
589         public static void GetSourceInParallel()
590         {
591             using (var scope = new TempLinksTestScope())
592             {
593                 var links = scope.Links;
594                 ConsoleHelpers.Debug("Testing GetSource function with {0} Iterations in
                    ↪  parallel.", Iterations);
595
596                 long counter = 0;
597
598                 //var firstLink = links.First();
599                 var firstLink = links.Create();
600
601                 var sw = Stopwatch.StartNew();
602
603                 // Тестируем саму функцию
604                 Parallel.For(0, Iterations, x =>
605                 {
606                     Interlocked.Add(ref counter, (long)links.GetSource(firstLink));
607                     //Interlocked.Increment(ref counter);
608                 });
609
610                 var elapsedTime = sw.Elapsed;
611
612                 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
613
614                 links.Delete(firstLink);
615
616                 ConsoleHelpers.Debug(
617                     "{0} Iterations of GetSource function done in {1} ({2} Iterations per
                        ↪  second), counter result: {3}",
618                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
619             }
```

```
620         }
621
622         [Fact(Skip = "performance test")]
623         public static void TestGetTarget()
624         {
625             using (var scope = new TempLinksTestScope())
626             {
627                 var links = scope.Links;
628                 ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations.",
                    ↪  Iterations);
629
630                 ulong counter = 0;
631
632                 //var firstLink = links.First();
633                 var firstLink = links.Create();
634
635                 var sw = Stopwatch.StartNew();
636
637                 for (ulong i = 0; i < Iterations; i++)
638                 {
639                     counter += links.GetTarget(firstLink);
640                 }
641
642                 var elapsedTime = sw.Elapsed;
643
644                 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
645
646                 links.Delete(firstLink);
647
648                 ConsoleHelpers.Debug(
649                     "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
                        ↪  second), counter result: {3}",
650                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
651             }
652         }
653
654         [Fact(Skip = "performance test")]
655         public static void TestGetTargetInParallel()
656         {
657             using (var scope = new TempLinksTestScope())
658             {
659                 var links = scope.Links;
660                 ConsoleHelpers.Debug("Testing GetTarget function with {0} Iterations in
                    ↪  parallel.", Iterations);
661
662                 long counter = 0;
663
664                 //var firstLink = links.First();
665                 var firstLink = links.Create();
666
667                 var sw = Stopwatch.StartNew();
668
669                 Parallel.For(0, Iterations, x =>
670                 {
671                     Interlocked.Add(ref counter, (long)links.GetTarget(firstLink));
672                     //Interlocked.Increment(ref counter);
673                 });
674
675                 var elapsedTime = sw.Elapsed;
676
677                 var iterationsPerSecond = Iterations / elapsedTime.TotalSeconds;
678
679                 links.Delete(firstLink);
680
681                 ConsoleHelpers.Debug(
682                     "{0} Iterations of GetTarget function done in {1} ({2} Iterations per
                        ↪  second), counter result: {3}",
683                     Iterations, elapsedTime, (long)iterationsPerSecond, counter);
684             }
685         }
686
687         // TODO: Заполнить базу данных перед тестом
688         /*
689         [Fact]
690         public void TestRandomSearchFixed()
691         {
692             var tempFilename = Path.GetTempFileName();
693
694             using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
    ↪  DefaultLinksSizeStep))
```

```
            {
                long iterations = 64 * 1024 * 1024 /
    ↪  Platform.Links.Data.Core.Doublets.Links.LinkSizeInBytes;

                ulong counter = 0;
                var maxLink = links.Total;

                ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.", iterations);

                var sw = Stopwatch.StartNew();

                for (var i = iterations; i > 0; i--)
                {
                    var source =
    ↪  RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);
                    var target =
    ↪  RandomHelpers.DefaultFactory.NextUInt64(LinksConstants.MinPossibleIndex, maxLink);

                    counter += links.Search(source, target);
                }

                var elapsedTime = sw.Elapsed;

                var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;

                ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
    ↪  Iterations per second), c: {3}", iterations, elapsedTime, (long)iterationsPerSecond,
    ↪  counter);
            }

            File.Delete(tempFilename);
        }*/

        [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
        public static void TestRandomSearchAll()
        {
            using (var scope = new TempLinksTestScope())
            {
                var links = scope.Links;
                ulong counter = 0;

                var maxLink = links.Count();

                var iterations = links.Count();

                ConsoleHelpers.Debug("Testing Random Search with {0} Iterations.",
                ↪  links.Count());

                var sw = Stopwatch.StartNew();

                for (var i = iterations; i > 0; i--)
                {
                    var linksAddressRange = new
                    ↪  Range<ulong>(_constants.InternalReferencesRange.Minimum, maxLink);

                    var source = RandomHelpers.Default.NextUInt64(linksAddressRange);
                    var target = RandomHelpers.Default.NextUInt64(linksAddressRange);

                    counter += links.SearchOrDefault(source, target);
                }

                var elapsedTime = sw.Elapsed;

                var iterationsPerSecond = iterations / elapsedTime.TotalSeconds;

                ConsoleHelpers.Debug("{0} Iterations of Random Search done in {1} ({2}
                ↪  Iterations per second), c: {3}",
                     iterations, elapsedTime, (long)iterationsPerSecond, counter);
            }
        }

        [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
        public static void TestEach()
        {
            using (var scope = new TempLinksTestScope())
            {
                var links = scope.Links;

                var counter = new Counter<IList<ulong>, ulong>(links.Constants.Continue);

```

```
767                 ConsoleHelpers.Debug("Testing Each function.");
768
769                 var sw = Stopwatch.StartNew();
770
771                 links.Each(counter.IncrementAndReturnTrue);
772
773                 var elapsedTime = sw.Elapsed;
774
775                 var linksPerSecond = counter.Count / elapsedTime.TotalSeconds;
776
777                 ConsoleHelpers.Debug("{0} Iterations of Each's handler function done in {1} ({2}
                    ↪  links per second)",
778                     counter, elapsedTime, (long)linksPerSecond);
779             }
780         }
781
782         /*
783         [Fact]
784         public static void TestForeach()
785         {
786             var tempFilename = Path.GetTempFileName();
787
788             using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
    ↪  DefaultLinksSizeStep))
789             {
790                 ulong counter = 0;
791
792                 ConsoleHelpers.Debug("Testing foreach through links.");
793
794                 var sw = Stopwatch.StartNew();
795
796                 //foreach (var link in links)
797                 //{
798                 //    counter++;
799                 //}
800
801                 var elapsedTime = sw.Elapsed;
802
803                 var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
804
805                 ConsoleHelpers.Debug("{0} Iterations of Foreach's handler block done in {1} ({2}
    ↪  links per second)", counter, elapsedTime, (long)linksPerSecond);
806             }
807
808             File.Delete(tempFilename);
809         }
810         */
811
812         /*
813         [Fact]
814         public static void TestParallelForeach()
815         {
816             var tempFilename = Path.GetTempFileName();
817
818             using (var links = new Platform.Links.Data.Core.Doublets.Links(tempFilename,
    ↪  DefaultLinksSizeStep))
819             {
820
821                 long counter = 0;
822
823                 ConsoleHelpers.Debug("Testing parallel foreach through links.");
824
825                 var sw = Stopwatch.StartNew();
826
827                 //Parallel.ForEach((IEnumerable<ulong>)links, x =>
828                 //{
829                 //    Interlocked.Increment(ref counter);
830                 //});
831
832                 var elapsedTime = sw.Elapsed;
833
834                 var linksPerSecond = (double)counter / elapsedTime.TotalSeconds;
835
836                 ConsoleHelpers.Debug("{0} Iterations of Parallel Foreach's handler block done in
    ↪  {1} ({2} links per second)", counter, elapsedTime, (long)linksPerSecond);
837             }
838
839             File.Delete(tempFilename);
840         }
841         */
```

```
842
843         [Fact(Skip = "performance test")]
844         public static void Create64BillionLinks()
845         {
846             using (var scope = new TempLinksTestScope())
847             {
848                 var links = scope.Links;
849                 var linksBeforeTest = links.Count();
850
851                 long linksToCreate = 64 * 1024 * 1024 / UInt64UnitedMemoryLinks.LinkSizeInBytes;
852
853                 ConsoleHelpers.Debug("Creating {0} links.", linksToCreate);
854
855                 var elapsedTime = Performance.Measure(() =>
856                 {
857                     for (long i = 0; i < linksToCreate; i++)
858                     {
859                         links.Create();
860                     }
861                 });
862
863                 var linksCreated = links.Count() - linksBeforeTest;
864                 var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
865
866                 ConsoleHelpers.Debug("Current links count: {0}.", links.Count());
867
868                 ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
                    ↪  linksCreated, elapsedTime,
869                     (long)linksPerSecond);
870             }
871         }
872
873         [Fact(Skip = "performance test")]
874         public static void Create64BillionLinksInParallel()
875         {
876             using (var scope = new TempLinksTestScope())
877             {
878                 var links = scope.Links;
879                 var linksBeforeTest = links.Count();
880
881                 var sw = Stopwatch.StartNew();
882
883                 long linksToCreate = 64 * 1024 * 1024 / UInt64UnitedMemoryLinks.LinkSizeInBytes;
884
885                 ConsoleHelpers.Debug("Creating {0} links in parallel.", linksToCreate);
886
887                 Parallel.For(0, linksToCreate, x => links.Create());
888
889                 var elapsedTime = sw.Elapsed;
890
891                 var linksCreated = links.Count() - linksBeforeTest;
892                 var linksPerSecond = linksCreated / elapsedTime.TotalSeconds;
893
894                 ConsoleHelpers.Debug("{0} links created in {1} ({2} links per second)",
                    ↪  linksCreated, elapsedTime,
895                     (long)linksPerSecond);
896             }
897         }
898
899         [Fact(Skip = "useless: 0(0), was dependent on creation tests")]
900         public static void TestDeletionOfAllLinks()
901         {
902             using (var scope = new TempLinksTestScope())
903             {
904                 var links = scope.Links;
905                 var linksBeforeTest = links.Count();
906
907                 ConsoleHelpers.Debug("Deleting all links");
908
909                 var elapsedTime = Performance.Measure(links.DeleteAll);
910
911                 var linksDeleted = linksBeforeTest - links.Count();
912                 var linksPerSecond = linksDeleted / elapsedTime.TotalSeconds;
913
914                 ConsoleHelpers.Debug("{0} links deleted in {1} ({2} links per second)",
                    ↪  linksDeleted, elapsedTime,
915                     (long)linksPerSecond);
916             }
917         }
918
```

```
919             #endregion
920         }
921     }
```

1.71 ./csharp/Platform.Data.Doublets.Sequences.Tests/Uint64LinksExtensionsTests.cs

```
1   using Platform.Data.Doublets.Memory;
2   using Platform.Data.Doublets.Memory.United.Generic;
3   using Platform.Data.Numbers.Raw;
4   using Platform.Memory;
5   using Platform.Numbers;
6   using Xunit;
7   using Xunit.Abstractions;
8   using TLink = System.UInt64;
9
10  namespace Platform.Data.Doublets.Sequences.Tests
11  {
12      public class Uint64LinksExtensionsTests
13      {
14          public static ILinks<TLink> CreateLinks() => CreateLinks<TLink>(new
            ↪  Platform.IO.TemporaryFile());
15
16          public static ILinks<TLink> CreateLinks<TLink>(string dataDBFilename)
17          {
18              var linksConstants = new LinksConstants<TLink>(enableExternalReferencesSupport:
                ↪  true);
19              return new UnitedMemoryLinks<TLink>(new
                ↪  FileMappedResizableDirectMemory(dataDBFilename),
                ↪  UnitedMemoryLinks<TLink>.DefaultLinksSizeStep, linksConstants,
                ↪  IndexTreeType.Default);
20          }
21          [Fact]
22          public void FormatStructureWithExternalReferenceTest()
23          {
24              ILinks<TLink> links = CreateLinks();
25              TLink zero = default;
26              var one = Arithmetic.Increment(zero);
27              var markerIndex = one;
28              var meaningRoot = links.GetOrCreate(markerIndex, markerIndex);
29              var numberMarker = links.GetOrCreate(meaningRoot, Arithmetic.Increment(ref
                ↪  markerIndex));
30              AddressToRawNumberConverter<TLink> addressToNumberConverter = new();
31              var numberAddress = addressToNumberConverter.Convert(1);
32              var numberLink = links.GetOrCreate(numberMarker, numberAddress);
33              var linkNotation = links.FormatStructure(numberLink, link => link.IsFullPoint(),
                ↪  true);
34              Assert.Equal("(3:(2:1 2) 18446744073709551615)", linkNotation);
35          }
36      }
37  }
```

1.72 ./csharp/Platform.Data.Doublets.Sequences.Tests/UnaryNumberConvertersTests.cs

```
1   using Xunit;
2   using Platform.Random;
3   using Platform.Data.Doublets.Numbers.Unary;
4
5   namespace Platform.Data.Doublets.Sequences.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]);
```

```
                }
                var fromUnaryNumberConverterUsingOrOperation = new
                ↪  UnaryNumberToAddressOrOperationConverter<ulong>(links,
                ↪  powerOf2ToUnaryNumberConverter);
                var fromUnaryNumberConverterUsingAddOperation = new
                ↪  UnaryNumberToAddressAddOperationConverter<ulong>(links, one);
                for (int i = 0; i < N; i++)
                {
                    Assert.Equal(numbers[i],
                    ↪  fromUnaryNumberConverterUsingOrOperation.Convert(unaryNumbers[i]));
                    Assert.Equal(numbers[i],
                    ↪  fromUnaryNumberConverterUsingAddOperation.Convert(unaryNumbers[i]));
                }
            }
        }
    }
}
```

1.73 ./csharp/Platform.Data.Doublets.Sequences.Tests/UnicodeConvertersTests.cs

```
using Xunit;
using Platform.Converters;
using Platform.Memory;
using Platform.Reflection;
using Platform.Scopes;
using Platform.Data.Numbers.Raw;
using Platform.Data.Doublets.Incrementers;
using Platform.Data.Doublets.Numbers.Unary;
using Platform.Data.Doublets.PropertyOperators;
using Platform.Data.Doublets.Sequences.Converters;
using Platform.Data.Doublets.Sequences.Indexes;
using Platform.Data.Doublets.Sequences.Walkers;
using Platform.Data.Doublets.Unicode;
using Platform.Data.Doublets.Memory.United.Generic;
using Platform.Data.Doublets.CriterionMatchers;

namespace Platform.Data.Doublets.Sequences.Tests
{
    public static class UnicodeConvertersTests
    {
        [Fact]
        public static void CharAndUnaryNumberUnicodeSymbolConvertersTest()
        {
            using (var scope = new TempLinksTestScope())
            {
                var links = scope.Links;
                var meaningRoot = links.CreatePoint();
                var one = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
                var powerOf2ToUnaryNumberConverter = new
                ↪  PowerOf2ToUnaryNumberConverter<ulong>(links, one);
                var addressToUnaryNumberConverter = new
                ↪  AddressToUnaryNumberConverter<ulong>(links, powerOf2ToUnaryNumberConverter);
                var unaryNumberToAddressConverter = new
                ↪  UnaryNumberToAddressOrOperationConverter<ulong>(links,
                ↪  powerOf2ToUnaryNumberConverter);
                TestCharAndUnicodeSymbolConverters(links, meaningRoot,
                ↪  addressToUnaryNumberConverter, unaryNumberToAddressConverter);
            }
        }

        [Fact]
        public static void CharAndRawNumberUnicodeSymbolConvertersTest()
        {
            using (var scope = new Scope<Types<HeapResizableDirectMemory,
            ↪  UnitedMemoryLinks<ulong>>>())
            {
                var links = scope.Use<ILinks<ulong>>();
                var meaningRoot = links.CreatePoint();
                var addressToRawNumberConverter = new AddressToRawNumberConverter<ulong>();
                var rawNumberToAddressConverter = new RawNumberToAddressConverter<ulong>();
                TestCharAndUnicodeSymbolConverters(links, meaningRoot,
                ↪  addressToRawNumberConverter, rawNumberToAddressConverter);
            }
        }

        private static void TestCharAndUnicodeSymbolConverters(ILinks<ulong> links, ulong
        ↪  meaningRoot, IConverter<ulong> addressToNumberConverter, IConverter<ulong>
        ↪  numberToAddressConverter)
        {
            var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, links.Constants.Itself);
```

```
52              var charToUnicodeSymbolConverter = new CharToUnicodeSymbolConverter<ulong>(links,
                ↪  addressToNumberConverter, unicodeSymbolMarker);
53              var originalCharacter = 'H';
54              var characterLink = charToUnicodeSymbolConverter.Convert(originalCharacter);
55              var unicodeSymbolCriterionMatcher = new TargetMatcher<ulong>(links,
                ↪  unicodeSymbolMarker);
56              var unicodeSymbolToCharConverter = new UnicodeSymbolToCharConverter<ulong>(links,
                ↪  numberToAddressConverter, unicodeSymbolCriterionMatcher);
57              var resultingCharacter = unicodeSymbolToCharConverter.Convert(characterLink);
58              Assert.Equal(originalCharacter, resultingCharacter);
59          }
60
61          [Fact]
62          public static void StringAndUnicodeSequenceConvertersTest()
63          {
64              using (var scope = new TempLinksTestScope())
65              {
66                  var links = scope.Links;
67
68                  var itself = links.Constants.Itself;
69
70                  var meaningRoot = links.CreatePoint();
71                  var unaryOne = links.CreateAndUpdate(meaningRoot, itself);
72                  var unicodeSymbolMarker = links.CreateAndUpdate(meaningRoot, itself);
73                  var unicodeSequenceMarker = links.CreateAndUpdate(meaningRoot, itself);
74                  var frequencyMarker = links.CreateAndUpdate(meaningRoot, itself);
75                  var frequencyPropertyMarker = links.CreateAndUpdate(meaningRoot, itself);
76
77                  var powerOf2ToUnaryNumberConverter = new
                    ↪  PowerOf2ToUnaryNumberConverter<ulong>(links, unaryOne);
78                  var addressToUnaryNumberConverter = new
                    ↪  AddressToUnaryNumberConverter<ulong>(links, powerOf2ToUnaryNumberConverter);
79                  var charToUnicodeSymbolConverter = new
                    ↪  CharToUnicodeSymbolConverter<ulong>(links, addressToUnaryNumberConverter,
                    ↪  unicodeSymbolMarker);
80
81                  var unaryNumberToAddressConverter = new
                    ↪  UnaryNumberToAddressOrOperationConverter<ulong>(links,
                    ↪  powerOf2ToUnaryNumberConverter);
82                  var unaryNumberIncrementer = new UnaryNumberIncrementer<ulong>(links, unaryOne);
83                  var frequencyIncrementer = new FrequencyIncrementer<ulong>(links,
                    ↪  frequencyMarker, unaryOne, unaryNumberIncrementer);
84                  var frequencyPropertyOperator = new PropertyOperator<ulong>(links,
                    ↪  frequencyPropertyMarker, frequencyMarker);
85                  var index = new FrequencyIncrementingSequenceIndex<ulong>(links,
                    ↪  frequencyPropertyOperator, frequencyIncrementer);
86                  var linkToItsFrequencyNumberConverter = new
                    ↪  LinkToItsFrequencyNumberConveter<ulong>(links, frequencyPropertyOperator,
                    ↪  unaryNumberToAddressConverter);
87                  var sequenceToItsLocalElementLevelsConverter = new
                    ↪  SequenceToItsLocalElementLevelsConverter<ulong>(links,
                    ↪  linkToItsFrequencyNumberConverter);
88                  var optimalVariantConverter = new OptimalVariantConverter<ulong>(links,
                    ↪  sequenceToItsLocalElementLevelsConverter);
89
90                  var stringToUnicodeSequenceConverter = new
                    ↪  StringToUnicodeSequenceConverter<ulong>(links, charToUnicodeSymbolConverter,
                    ↪  index, optimalVariantConverter, unicodeSequenceMarker);
91
92                  var originalString = "Hello";
93
94                  var unicodeSequenceLink =
                    ↪  stringToUnicodeSequenceConverter.Convert(originalString);
95
96                  var unicodeSymbolCriterionMatcher = new TargetMatcher<ulong>(links,
                    ↪  unicodeSymbolMarker);
97                  var unicodeSymbolToCharConverter = new
                    ↪  UnicodeSymbolToCharConverter<ulong>(links, unaryNumberToAddressConverter,
                    ↪  unicodeSymbolCriterionMatcher);
98
99                  var unicodeSequenceCriterionMatcher = new TargetMatcher<ulong>(links,
                    ↪  unicodeSequenceMarker);
100
101                 var sequenceWalker = new LeveledSequenceWalker<ulong>(links,
                    ↪  unicodeSymbolCriterionMatcher.IsMatched);
102
```

```
                    var unicodeSequenceToStringConverter = new
                    ↪  UnicodeSequenceToStringConverter<ulong>(links,
                    ↪  unicodeSequenceCriterionMatcher, sequenceWalker,
                    ↪  unicodeSymbolToCharConverter);

                    var resultingString =
                    ↪  unicodeSequenceToStringConverter.Convert(unicodeSequenceLink);

                    Assert.Equal(originalString, resultingString);
                }
            }
        }
    }
```

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