

LinksPlatform's Platform.Collections.Methods Class Library

1.1 ./csharp/Platform.Collections.Methods/GenericCollectionMethodsBase.cs

```
1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3 using Platform.Numbers;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Collections.Methods
8 {
9     /// <summary>
10    /// <para>Represents a base implementation of methods for a collection of elements of type
11    ↪ TElement.</para>
12    /// <para>Представляет базовую реализацию методов коллекции элементов типа TElement.</para>
13    /// </summary>
14    public abstract class GenericCollectionMethodsBase<TElement>
15    {
16        /// <summary>
17        /// <para>Presents the Range in readable format.</para>
18        /// <para>Представляет диапазон в удобном для чтения формате.</para>
19        /// </summary>
20        /// <returns><para>String representation of the Range.</para><para>Строковое
21        ↪ представление диапазона.</para></returns>
22        [MethodImpl(MethodImplOptions.AggressiveInlining)]
23        protected virtual TElement GetZero() => default;
24
25        /// <summary>
26        /// <para>Presents the Range in readable format.</para>
27        /// <para>Представляет диапазон в удобном для чтения формате.</para>
28        /// </summary>
29        /// <returns><para>String representation of the Range.</para><para>Строковое
30        ↪ представление диапазона.</para></returns>
31        [MethodImpl(MethodImplOptions.AggressiveInlining)]
32        protected virtual bool EqualToZero(TElement value) => EqualityComparer.Equals(value,
33        ↪ Zero);
34
35        /// <summary>
36        /// <para>Presents the Range in readable format.</para>
37        /// <para>Представляет диапазон в удобном для чтения формате.</para>
38        /// </summary>
39        /// <returns><para>String representation of the Range.</para><para>Строковое
40        ↪ представление диапазона.</para></returns>
41        [MethodImpl(MethodImplOptions.AggressiveInlining)]
42        protected virtual bool AreEqual(TElement first, TElement second) =>
43        ↪ EqualityComparer.Equals(first, second);
44
45        /// <summary>
46        /// <para>Presents the Range in readable format.</para>
47        /// <para>Представляет диапазон в удобном для чтения формате.</para>
48        /// </summary>
49        /// <returns><para>String representation of the Range.</para><para>Строковое
50        ↪ представление диапазона.</para></returns>
51        [MethodImpl(MethodImplOptions.AggressiveInlining)]
52        protected virtual bool GreaterThanZero(TElement value) => Comparer.Compare(value, Zero)
53        ↪ > 0;
54
55        /// <summary>
56        /// <para>Presents the Range in readable format.</para>
57        /// <para>Представляет диапазон в удобном для чтения формате.</para>
58        /// </summary>
59        /// <returns><para>String representation of the Range.</para><para>Строковое
60        ↪ представление диапазона.</para></returns>
61        [MethodImpl(MethodImplOptions.AggressiveInlining)]
62        protected virtual bool GreaterThan(TElement first, TElement second) =>
63        ↪ Comparer.Compare(first, second) > 0;
64
65        /// <summary>
66        /// <para>Presents the Range in readable format.</para>
67        /// <para>Представляет диапазон в удобном для чтения формате.</para>
68        /// </summary>
69        /// <returns><para>String representation of the Range.</para><para>Строковое
70        ↪ представление диапазона.</para></returns>
71        [MethodImpl(MethodImplOptions.AggressiveInlining)]
72        protected virtual bool GreaterOrEqualThanZero(TElement value) => Comparer.Compare(value,
73        ↪ Zero) >= 0;
74
75        /// <summary>
```

```

64    /// <para>Presents the Range in readable format.</para>
65    /// <para>Представляет диапазон в удобном для чтения формате.</para>
66    /// </summary>
67    /// <returns><para>String representation of the Range.</para><para>Строковое
    ↳ представление диапазона.</para></returns>
68    [MethodImpl(MethodImplOptions.AggressiveInlining)]
69    protected virtual bool GreaterOrEqualThan(TElement first, TElement second) =>
    ↳ Comparer.Compare(first, second) >= 0;
70
71    /// <summary>
72    /// <para>Presents the Range in readable format.</para>
73    /// <para>Представляет диапазон в удобном для чтения формате.</para>
74    /// </summary>
75    /// <returns><para>String representation of the Range.</para><para>Строковое
    ↳ представление диапазона.</para></returns>
76    [MethodImpl(MethodImplOptions.AggressiveInlining)]
77    protected virtual bool LessOrEqualThanZero(TElement value) => Comparer.Compare(value,
    ↳ Zero) <= 0;
78
79    /// <summary>
80    /// <para>Presents the Range in readable format.</para>
81    /// <para>Представляет диапазон в удобном для чтения формате.</para>
82    /// </summary>
83    /// <returns><para>String representation of the Range.</para><para>Строковое
    ↳ представление диапазона.</para></returns>
84    [MethodImpl(MethodImplOptions.AggressiveInlining)]
85    protected virtual bool LessOrEqualThan(TElement first, TElement second) =>
    ↳ Comparer.Compare(first, second) <= 0;
86
87    /// <summary>
88    /// <para>Presents the Range in readable format.</para>
89    /// <para>Представляет диапазон в удобном для чтения формате.</para>
90    /// </summary>
91    /// <returns><para>String representation of the Range.</para><para>Строковое
    ↳ представление диапазона.</para></returns>
92    [MethodImpl(MethodImplOptions.AggressiveInlining)]
93    protected virtual bool LessThanZero(TElement value) => Comparer.Compare(value, Zero) < 0;
94
95    /// <summary>
96    /// <para>Presents the Range in readable format.</para>
97    /// <para>Представляет диапазон в удобном для чтения формате.</para>
98    /// </summary>
99    /// <returns><para>String representation of the Range.</para><para>Строковое
    ↳ представление диапазона.</para></returns>
100   [MethodImpl(MethodImplOptions.AggressiveInlining)]
101   protected virtual bool LessThan(TElement first, TElement second) =>
    ↳ Comparer.Compare(first, second) < 0;
102
103   /// <summary>
104   /// <para>Presents the Range in readable format.</para>
105   /// <para>Представляет диапазон в удобном для чтения формате.</para>
106   /// </summary>
107   /// <returns><para>String representation of the Range.</para><para>Строковое
    ↳ представление диапазона.</para></returns>
108   [MethodImpl(MethodImplOptions.AggressiveInlining)]
109   protected virtual TElement Increment(TElement value) =>
    ↳ Arithmetic<TElement>.Increment(value);
110
111   /// <summary>
112   /// <para>Presents the Range in readable format.</para>
113   /// <para>Представляет диапазон в удобном для чтения формате.</para>
114   /// </summary>
115   /// <returns><para>String representation of the Range.</para><para>Строковое
    ↳ представление диапазона.</para></returns>
116   [MethodImpl(MethodImplOptions.AggressiveInlining)]
117   protected virtual TElement Decrement(TElement value) =>
    ↳ Arithmetic<TElement>.Decrement(value);
118
119   /// <summary>
120   /// <para>Presents the Range in readable format.</para>
121   /// <para>Представляет диапазон в удобном для чтения формате.</para>
122   /// </summary>
123   /// <returns><para>String representation of the Range.</para><para>Строковое
    ↳ представление диапазона.</para></returns>
124   [MethodImpl(MethodImplOptions.AggressiveInlining)]
125   protected virtual TElement Add(TElement first, TElement second) =>
    ↳ Arithmetic<TElement>.Add(first, second);

```

```

126
127 /// <summary>
128 /// <para>Presents the Range in readable format.</para>
129 /// <para>Представляет диапазон в удобном для чтения формате.</para>
130 /// </summary>
131 /// <returns><para>String representation of the Range.</para><para>Строковое
    ↳ представление диапазона.</para></returns>
132 [MethodImpl(MethodImplOptions.AggressiveInlining)]
133 protected virtual TElement Subtract(TElement first, TElement second) =>
    ↳ Arithmetic<TElement>.Subtract(first, second);
134
135 /// <summary>
136 /// <para>Returns minimum value of the range.</para>
137 /// <para>Возвращает минимальное значение диапазона.</para>
138 /// </summary>
139 protected readonly TElement Zero;
140
141 /// <summary>
142 /// <para>Returns minimum value of the range.</para>
143 /// <para>Возвращает минимальное значение диапазона.</para>
144 /// </summary>
145 protected readonly TElement One;
146
147 /// <summary>
148 /// <para>Returns minimum value of the range.</para>
149 /// <para>Возвращает минимальное значение диапазона.</para>
150 /// </summary>
151 protected readonly TElement Two;
152
153 /// <summary>
154 /// <para>Returns minimum value of the range.</para>
155 /// <para>Возвращает минимальное значение диапазона.</para>
156 /// </summary>
157 protected readonly EqualityComparer<TElement> EqualityComparer;
158
159 /// <summary>
160 /// <para>Returns minimum value of the range.</para>
161 /// <para>Возвращает минимальное значение диапазона.</para>
162 /// </summary>
163 protected readonly Comparer<TElement> Comparer;
164
165 /// <summary>
166 /// <para>Presents the Range in readable format.</para>
167 /// <para>Представляет диапазон в удобном для чтения формате.</para>
168 /// </summary>
169 /// <returns><para>String representation of the Range.</para><para>Строковое
    ↳ представление диапазона.</para></returns>
170 protected GenericCollectionMethodsBase()
171 {
172     EqualityComparer = EqualityComparer<TElement>.Default;
173     Comparer = Comparer<TElement>.Default;
174     Zero = GetZero(); //-V3068
175     One = Increment(Zero); //-V3068
176     Two = Increment(One); //-V3068
177 }
178 }
179 }

```

1.2 ./csharp/Platform.Collections.Methods/Lists/AbsoluteCircularDoublyLinkedListMethods.cs

```

1 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3 namespace Platform.Collections.Methods.Lists
4 {
5     public abstract class AbsoluteCircularDoublyLinkedListMethods<TElement> :
        ↳ AbsoluteDoublyLinkedListMethodsBase<TElement>
6     {
7         public void AttachBefore(TElement baseElement, TElement newElement)
8         {
9             var baseElementPrevious = GetPrevious(baseElement);
10             SetPrevious(newElement, baseElementPrevious);
11             SetNext(newElement, baseElement);
12             if (AreEqual(baseElement, GetFirst()))
13             {
14                 SetFirst(newElement);
15             }
16             SetNext(baseElementPrevious, newElement);
17             SetPrevious(baseElement, newElement);
18             IncrementSize();
19         }
20     }
21 }

```

```

20
21 public void AttachAfter(TElement baseElement, TElement newElement)
22 {
23     var baseElementNext = GetNext(baseElement);
24     SetPrevious(newElement, baseElement);
25     SetNext(newElement, baseElementNext);
26     if (AreEqual(baseElement, GetLast()))
27     {
28         SetLast(newElement);
29     }
30     SetPrevious(baseElementNext, newElement);
31     SetNext(baseElement, newElement);
32     IncrementSize();
33 }
34
35 public void AttachAsFirst(TElement element)
36 {
37     var first = GetFirst();
38     if (EqualToZero(first))
39     {
40         SetFirst(element);
41         SetLast(element);
42         SetPrevious(element, element);
43         SetNext(element, element);
44         IncrementSize();
45     }
46     else
47     {
48         AttachBefore(first, element);
49     }
50 }
51
52 public void AttachAsLast(TElement element)
53 {
54     var last = GetLast();
55     if (EqualToZero(last))
56     {
57         AttachAsFirst(element);
58     }
59     else
60     {
61         AttachAfter(last, element);
62     }
63 }
64
65 public void Detach(TElement element)
66 {
67     var elementPrevious = GetPrevious(element);
68     var elementNext = GetNext(element);
69     if (AreEqual(elementNext, element))
70     {
71         SetFirst(Zero);
72         SetLast(Zero);
73     }
74     else
75     {
76         SetNext(elementPrevious, elementNext);
77         SetPrevious(elementNext, elementPrevious);
78         if (AreEqual(element, GetFirst()))
79         {
80             SetFirst(elementNext);
81         }
82         if (AreEqual(element, GetLast()))
83         {
84             SetLast(elementPrevious);
85         }
86     }
87     SetPrevious(element, Zero);
88     SetNext(element, Zero);
89     DecrementSize();
90 }
91 }
92 }

```

1.3 ./csharp/Platform.Collections.Methods/Lists/AbsoluteDoublyLinkedListMethodsBase.cs

```

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

```

```

4
5 namespace Platform.Collections.Methods.Lists
6 {
7     public abstract class AbsoluteDoublyLinkedListMethodsBase<TElement> :
8         ↳ DoublyLinkedListMethodsBase<TElement>
9     {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         protected abstract TElement GetFirst();
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         protected abstract TElement GetLast();
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         protected abstract TElement GetSize();
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         protected abstract void SetFirst(TElement element);
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected abstract void SetLast(TElement element);
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected abstract void SetSize(TElement size);
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected void IncrementSize() => SetSize(Increment(GetSize()));
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected void DecrementSize() => SetSize(Decrement(GetSize()));
33     }

```

1.4 ./csharp/Platform.Collections.Methods.Lists/AbsoluteOpenDoublyLinkedListMethods.cs

```

1 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3 namespace Platform.Collections.Methods.Lists
4 {
5     public abstract class AbsoluteOpenDoublyLinkedListMethods<TElement> :
6         ↳ AbsoluteDoublyLinkedListMethodsBase<TElement>
7     {
8         public void AttachBefore(TElement baseElement, TElement newElement)
9         {
10             var baseElementPrevious = GetPrevious(baseElement);
11             SetPrevious(newElement, baseElementPrevious);
12             SetNext(newElement, baseElement);
13             if (EqualToZero(baseElementPrevious))
14             {
15                 SetFirst(newElement);
16             }
17             else
18             {
19                 SetNext(baseElementPrevious, newElement);
20             }
21             SetPrevious(baseElement, newElement);
22             IncrementSize();
23         }
24
25         public void AttachAfter(TElement baseElement, TElement newElement)
26         {
27             var baseElementNext = GetNext(baseElement);
28             SetPrevious(newElement, baseElement);
29             SetNext(newElement, baseElementNext);
30             if (EqualToZero(baseElementNext))
31             {
32                 SetLast(newElement);
33             }
34             else
35             {
36                 SetPrevious(baseElementNext, newElement);
37             }
38             SetNext(baseElement, newElement);
39             IncrementSize();
40         }
41
42         public void AttachAsFirst(TElement element)
43         {
44             var first = GetFirst();
45             if (EqualToZero(first))

```

```

46         SetFirst(element);
47         SetLast(element);
48         SetPrevious(element, Zero);
49         SetNext(element, Zero);
50         IncrementSize();
51     }
52     else
53     {
54         AttachBefore(first, element);
55     }
56 }
57
58 public void AttachAsLast(TElement element)
59 {
60     var last = GetLast();
61     if (EqualToZero(last))
62     {
63         AttachAsFirst(element);
64     }
65     else
66     {
67         AttachAfter(last, element);
68     }
69 }
70
71 public void Detach(TElement element)
72 {
73     var elementPrevious = GetPrevious(element);
74     var elementNext = GetNext(element);
75     if (EqualToZero(elementPrevious))
76     {
77         SetFirst(elementNext);
78     }
79     else
80     {
81         SetNext(elementPrevious, elementNext);
82     }
83     if (EqualToZero(elementNext))
84     {
85         SetLast(elementPrevious);
86     }
87     else
88     {
89         SetPrevious(elementNext, elementPrevious);
90     }
91     SetPrevious(element, Zero);
92     SetNext(element, Zero);
93     DecrementSize();
94 }
95 }
96 }

```

1.5 ./csharp/Platform.Collections.Methods/Lists/DoublyLinkedListMethodsBase.cs

```

1 using System.Runtime.CompilerServices;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Collections.Methods.Lists
6 {
7     /// <remarks>
8     /// Based on <a href="https://en.wikipedia.org/wiki/Doubly_linked_list">doubly linked
9     /// list</a> implementation.
10    /// </remarks>
11    public abstract class DoublyLinkedListMethodsBase<TElement> :
12        GenericCollectionMethodsBase<TElement>
13    {
14        [MethodImpl(MethodImplOptions.AggressiveInlining)]
15        protected abstract TElement GetPrevious(TElement element);
16
17        [MethodImpl(MethodImplOptions.AggressiveInlining)]
18        protected abstract TElement GetNext(TElement element);
19
20        [MethodImpl(MethodImplOptions.AggressiveInlining)]
21        protected abstract void SetPrevious(TElement element, TElement previous);
22
23        [MethodImpl(MethodImplOptions.AggressiveInlining)]
24        protected abstract void SetNext(TElement element, TElement next);
25    }
26 }

```

1.6 ./csharp/Platform.Collections.Methods/Lists/RelativeCircularDoublyLinkedListMethods.cs

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  namespace Platform.Collections.Methods.Lists
4  {
5      public abstract class RelativeCircularDoublyLinkedListMethods<TElement> :
        ↳ RelativeDoublyLinkedListMethodsBase<TElement>
6      {
7          public void AttachBefore(TElement headElement, TElement baseElement, TElement newElement)
8          {
9              var baseElementPrevious = GetPrevious(baseElement);
10             SetPrevious(newElement, baseElementPrevious);
11             SetNext(newElement, baseElement);
12             if (AreEqual(baseElement, GetFirst(headElement)))
13             {
14                 SetFirst(headElement, newElement);
15             }
16             SetNext(baseElementPrevious, newElement);
17             SetPrevious(baseElement, newElement);
18             IncrementSize(headElement);
19         }
20
21         public void AttachAfter(TElement headElement, TElement baseElement, TElement newElement)
22         {
23             var baseElementNext = GetNext(baseElement);
24             SetPrevious(newElement, baseElement);
25             SetNext(newElement, baseElementNext);
26             if (AreEqual(baseElement, GetLast(headElement)))
27             {
28                 SetLast(headElement, newElement);
29             }
30             SetPrevious(baseElementNext, newElement);
31             SetNext(baseElement, newElement);
32             IncrementSize(headElement);
33         }
34
35         public void AttachAsFirst(TElement headElement, TElement element)
36         {
37             var first = GetFirst(headElement);
38             if (EqualToZero(first))
39             {
40                 SetFirst(headElement, element);
41                 SetLast(headElement, element);
42                 SetPrevious(element, element);
43                 SetNext(element, element);
44                 IncrementSize(headElement);
45             }
46             else
47             {
48                 AttachBefore(headElement, first, element);
49             }
50         }
51
52         public void AttachAsLast(TElement headElement, TElement element)
53         {
54             var last = GetLast(headElement);
55             if (EqualToZero(last))
56             {
57                 AttachAsFirst(headElement, element);
58             }
59             else
60             {
61                 AttachAfter(headElement, last, element);
62             }
63         }
64
65         public void Detach(TElement headElement, TElement element)
66         {
67             var elementPrevious = GetPrevious(element);
68             var elementNext = GetNext(element);
69             if (AreEqual(elementNext, element))
70             {
71                 SetFirst(headElement, Zero);
72                 SetLast(headElement, Zero);
73             }
74             else
75             {
76                 SetNext(elementPrevious, elementNext);

```

```

77         SetPrevious(elementNext, elementPrevious);
78         if (AreEqual(element, GetFirst(headElement)))
79         {
80             SetFirst(headElement, elementNext);
81         }
82         if (AreEqual(element, GetLast(headElement)))
83         {
84             SetLast(headElement, elementPrevious);
85         }
86     }
87     SetPrevious(element, Zero);
88     SetNext(element, Zero);
89     DecrementSize(headElement);
90 }
91 }
92 }

```

1.7 ./csharp/Platform.Collections.Methods/Lists/RelativeDoublyLinkedListMethodsBase.cs

```

1  using System.Runtime.CompilerServices;
2
3  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5  namespace Platform.Collections.Methods.Lists
6  {
7      public abstract class RelativeDoublyLinkedListMethodsBase<TElement> :
8          ↳ DoublyLinkedListMethodsBase<TElement>
9      {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         protected abstract TElement GetFirst(TElement headElement);
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         protected abstract TElement GetLast(TElement headElement);
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         protected abstract TElement GetSize(TElement headElement);
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         protected abstract void SetFirst(TElement headElement, TElement element);
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected abstract void SetLast(TElement headElement, TElement element);
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected abstract void SetSize(TElement headElement, TElement size);
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected void IncrementSize(TElement headElement) => SetSize(headElement,
30             ↳ Increment(GetSize(headElement)));
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected void DecrementSize(TElement headElement) => SetSize(headElement,
34             ↳ Decrement(GetSize(headElement)));
35     }
36 }

```

1.8 ./csharp/Platform.Collections.Methods/Lists/RelativeOpenDoublyLinkedListMethods.cs

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  namespace Platform.Collections.Methods.Lists
4  {
5      public abstract class RelativeOpenDoublyLinkedListMethods<TElement> :
6          ↳ RelativeDoublyLinkedListMethodsBase<TElement>
7      {
8         public void AttachBefore(TElement headElement, TElement baseElement, TElement newElement)
9         {
10             var baseElementPrevious = GetPrevious(baseElement);
11             SetPrevious(newElement, baseElementPrevious);
12             SetNext(newElement, baseElement);
13             if (EqualToZero(baseElementPrevious))
14             {
15                 SetFirst(headElement, newElement);
16             }
17             else
18             {
19                 SetNext(baseElementPrevious, newElement);
20             }
21             SetPrevious(baseElement, newElement);
22             IncrementSize(headElement);
23         }
24     }
25 }

```



```

22     }
23
24     public void AttachAfter(TElement headElement, TElement baseElement, TElement newElement)
25     {
26         var baseElementNext = GetNext(baseElement);
27         SetPrevious(newElement, baseElement);
28         SetNext(newElement, baseElementNext);
29         if (EqualToZero(baseElementNext))
30         {
31             SetLast(headElement, newElement);
32         }
33         else
34         {
35             SetPrevious(baseElementNext, newElement);
36         }
37         SetNext(baseElement, newElement);
38         IncrementSize(headElement);
39     }
40
41     public void AttachAsFirst(TElement headElement, TElement element)
42     {
43         var first = GetFirst(headElement);
44         if (EqualToZero(first))
45         {
46             SetFirst(headElement, element);
47             SetLast(headElement, element);
48             SetPrevious(element, Zero);
49             SetNext(element, Zero);
50             IncrementSize(headElement);
51         }
52         else
53         {
54             AttachBefore(headElement, first, element);
55         }
56     }
57
58     public void AttachAsLast(TElement headElement, TElement element)
59     {
60         var last = GetLast(headElement);
61         if (EqualToZero(last))
62         {
63             AttachAsFirst(headElement, element);
64         }
65         else
66         {
67             AttachAfter(headElement, last, element);
68         }
69     }
70
71     public void Detach(TElement headElement, TElement element)
72     {
73         var elementPrevious = GetPrevious(element);
74         var elementNext = GetNext(element);
75         if (EqualToZero(elementPrevious))
76         {
77             SetFirst(headElement, elementNext);
78         }
79         else
80         {
81             SetNext(elementPrevious, elementNext);
82         }
83         if (EqualToZero(elementNext))
84         {
85             SetLast(headElement, elementPrevious);
86         }
87         else
88         {
89             SetPrevious(elementNext, elementPrevious);
90         }
91         SetPrevious(element, Zero);
92         SetNext(element, Zero);
93         DecrementSize(headElement);
94     }
95 }
96

```

1.9 ./csharp/Platform.Collections.Methods/Trees/RecursionlessSizeBalancedTreeMethods.cs

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2

```

```

3 namespace Platform.Collections.Methods.Trees
4 {
5     public abstract class RecursionlessSizeBalancedTreeMethods<TElement> :
        ↳ SizedBinaryTreeMethodsBase<TElement>
6     {
7         protected override void AttachCore(ref TElement root, TElement node)
8         {
9             while (true)
10            {
11                ref var left = ref GetLeftReference(root);
12                var leftSize = GetSizeOrZero(left);
13                ref var right = ref GetRightReference(root);
14                var rightSize = GetSizeOrZero(right);
15                if (FirstIsToTheLeftOfSecond(node, root)) // node.Key less than root.Key
16                {
17                    if (EqualToZero(left))
18                    {
19                        IncrementSize(root);
20                        SetSize(node, One);
21                        left = node;
22                        return;
23                    }
24                    if (FirstIsToTheLeftOfSecond(node, left)) // node.Key less than left.Key
25                    {
26                        if (GreaterThan(Increment(leftSize), rightSize))
27                        {
28                            RightRotate(ref root);
29                        }
30                        else
31                        {
32                            IncrementSize(root);
33                            root = ref left;
34                        }
35                    }
36                    else // node.Key greater than left.Key
37                    {
38                        var leftRightSize = GetSizeOrZero(GetRight(left));
39                        if (GreaterThan(Increment(leftRightSize), rightSize))
40                        {
41                            if (EqualToZero(leftRightSize) && EqualToZero(rightSize))
42                            {
43                                SetLeft(node, left);
44                                SetRight(node, root);
45                                SetSize(node, Add(leftSize, Two)); // Two (2) - node the size of
                                    ↳ root and a node itself
46                                SetLeft(root, Zero);
47                                SetSize(root, One);
48                                root = node;
49                                return;
50                            }
51                            LeftRotate(ref left);
52                            RightRotate(ref root);
53                        }
54                        else
55                        {
56                            IncrementSize(root);
57                            root = ref left;
58                        }
59                    }
60                }
61                else // node.Key greater than root.Key
62                {
63                    if (EqualToZero(right))
64                    {
65                        IncrementSize(root);
66                        SetSize(node, One);
67                        right = node;
68                        return;
69                    }
70                    if (FirstIsToTheRightOfSecond(node, right)) // node.Key greater than
                        ↳ right.Key
71                    {
72                        if (GreaterThan(Increment(rightSize), leftSize))
73                        {
74                            LeftRotate(ref root);
75                        }
76                        else
77                        {
78                            IncrementSize(root);

```

```

79         root = ref right;
80     }
81 }
82 else // node.Key less than right.Key
83 {
84     var rightLeftSize = GetSizeOrZero(GetLeft(right));
85     if (GreaterThan(Increment(rightLeftSize), leftSize))
86     {
87         if (EqualToZero(rightLeftSize) && EqualToZero(leftSize))
88         {
89             SetLeft(node, root);
90             SetRight(node, right);
91             SetSize(node, Add(rightSize, Two)); // Two (2) - node the size
92             ↳ of root and a node itself
93             SetRight(root, Zero);
94             SetSize(root, One);
95             root = node;
96             return;
97         }
98         RightRotate(ref right);
99         LeftRotate(ref root);
100     }
101     else
102     {
103         IncrementSize(root);
104         root = ref right;
105     }
106 }
107 }
108 }
109
110 protected override void DetachCore(ref TElement root, TElement node)
111 {
112     while (true)
113     {
114         ref var left = ref GetLeftReference(root);
115         var leftSize = GetSizeOrZero(left);
116         ref var right = ref GetRightReference(root);
117         var rightSize = GetSizeOrZero(right);
118         if (FirstIsToTheLeftOfSecond(node, root)) // node.Key less than root.Key
119         {
120             var decrementedLeftSize = Decrement(leftSize);
121             if (GreaterThan(GetSizeOrZero(GetRightOrDefault(right)),
122                 ↳ decrementedLeftSize))
123             {
124                 LeftRotate(ref root);
125             }
126             else if (GreaterThan(GetSizeOrZero(GetLeftOrDefault(right)),
127                 ↳ decrementedLeftSize))
128             {
129                 RightRotate(ref right);
130                 LeftRotate(ref root);
131             }
132             else
133             {
134                 DecrementSize(root);
135                 root = ref left;
136             }
137         }
138         else if (FirstIsToTheRightOfSecond(node, root)) // node.Key greater than root.Key
139         {
140             var decrementedRightSize = Decrement(rightSize);
141             if (GreaterThan(GetSizeOrZero(GetLeftOrDefault(left)), decrementedRightSize))
142             {
143                 RightRotate(ref root);
144             }
145             else if (GreaterThan(GetSizeOrZero(GetRightOrDefault(left)),
146                 ↳ decrementedRightSize))
147             {
148                 LeftRotate(ref left);
149                 RightRotate(ref root);
150             }
151             else
152             {
153                 DecrementSize(root);
154                 root = ref right;
155             }
156         }
157     }
158 }

```

```

153     }
154     else // key equals to root.Key
155     {
156         if (GreaterThanZero(leftSize) && GreaterThanZero(rightSize))
157         {
158             TElement replacement;
159             if (GreaterThan(leftSize, rightSize))
160             {
161                 replacement = GetRighttest(left);
162                 DetachCore(ref left, replacement);
163             }
164             else
165             {
166                 replacement = GetLefttest(right);
167                 DetachCore(ref right, replacement);
168             }
169             SetLeft(replacement, left);
170             SetRight(replacement, right);
171             SetSize(replacement, Add(leftSize, rightSize));
172             root = replacement;
173         }
174         else if (GreaterThanZero(leftSize))
175         {
176             root = left;
177         }
178         else if (GreaterThanZero(rightSize))
179         {
180             root = right;
181         }
182         else
183         {
184             root = Zero;
185         }
186         ClearNode(node);
187         return;
188     }
189 }
190 }
191 }
192 }

```

1.10 ./csharp/Platform.Collections.Methods/Trees/SizeBalancedTreeMethods.cs

```

1 using System;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Collections.Methods.Trees
6 {
7     public abstract class SizeBalancedTreeMethods<TElement> :
8         ↳ SizedBinaryTreeMethodsBase<TElement>
9     {
10         protected override void AttachCore(ref TElement root, TElement node)
11         {
12             if (EqualToZero(root))
13             {
14                 root = node;
15                 IncrementSize(root);
16             }
17             else
18             {
19                 IncrementSize(root);
20                 if (FirstIsToTheLeftOfSecond(node, root))
21                 {
22                     AttachCore(ref GetLeftReference(root), node);
23                     LeftMaintain(ref root);
24                 }
25                 else
26                 {
27                     AttachCore(ref GetRightReference(root), node);
28                     RightMaintain(ref root);
29                 }
30             }
31         }
32
33         protected override void DetachCore(ref TElement root, TElement nodeToDetach)
34         {
35             ref var currentNode = ref root;
36             ref var parent = ref root;
37             var replacementNode = Zero;

```

```

37 while (!AreEqual(currentNode, nodeToDetach))
38 {
39     DecrementSize(currentNode);
40     if (FirstIsToTheLeftOfSecond(nodeToDetach, currentNode))
41     {
42         parent = ref currentNode;
43         currentNode = ref GetLeftReference(currentNode);
44     }
45     else if (FirstIsToTheRightOfSecond(nodeToDetach, currentNode))
46     {
47         parent = ref currentNode;
48         currentNode = ref GetRightReference(currentNode);
49     }
50     else
51     {
52         throw new InvalidOperationException("Duplicate link found in the tree.");
53     }
54 }
55 var nodeToDetachLeft = GetLeft(nodeToDetach);
56 var node = GetRight(nodeToDetach);
57 if (!EqualToZero(nodeToDetachLeft) && !EqualToZero(node))
58 {
59     var lefttestNode = GetLefttest(node);
60     DetachCore(ref GetRightReference(nodeToDetach), lefttestNode);
61     SetLeft(lefttestNode, nodeToDetachLeft);
62     node = GetRight(nodeToDetach);
63     if (!EqualToZero(node))
64     {
65         SetRight(lefttestNode, node);
66         SetSize(lefttestNode, Increment(Add(GetSize(nodeToDetachLeft),
67             ↪ GetSize(node))));
68     }
69     else
70     {
71         SetSize(lefttestNode, Increment(GetSize(nodeToDetachLeft)));
72     }
73     replacementNode = lefttestNode;
74 }
75 else if (!EqualToZero(nodeToDetachLeft))
76 {
77     replacementNode = nodeToDetachLeft;
78 }
79 else if (!EqualToZero(node))
80 {
81     replacementNode = node;
82 }
83 if (AreEqual(root, nodeToDetach))
84 {
85     root = replacementNode;
86 }
87 else if (AreEqual(GetLeft(parent), nodeToDetach))
88 {
89     SetLeft(parent, replacementNode);
90 }
91 else if (AreEqual(GetRight(parent), nodeToDetach))
92 {
93     SetRight(parent, replacementNode);
94 }
95 ClearNode(nodeToDetach);
96 }
97 private void LeftMaintain(ref TElement root)
98 {
99     if (!EqualToZero(root))
100     {
101         var rootLeftNode = GetLeft(root);
102         if (!EqualToZero(rootLeftNode))
103         {
104             var rootRightNode = GetRight(root);
105             var rootRightNodeSize = GetSize(rootRightNode);
106             var rootLeftNodeLeftNode = GetLeft(rootLeftNode);
107             if (!EqualToZero(rootLeftNodeLeftNode) &&
108                 (EqualToZero(rootRightNode) ||
109                 ↪ GreaterThan(GetSize(rootLeftNodeLeftNode), rootRightNodeSize)))
110             {
111                 RightRotate(ref root);
112             }
113             else

```

```

113     {
114         var rootLeftNodeRightNode = GetRight(rootLeftNode);
115         if (!EqualToZero(rootLeftNodeRightNode) &&
116             (EqualToZero(rootRightNode) ||
117              ⇨ GreaterThan(GetSize(rootLeftNodeRightNode), rootRightNodeSize)))
118         {
119             LeftRotate(ref GetLeftReference(root));
120             RightRotate(ref root);
121         }
122         else
123         {
124             return;
125         }
126     }
127     LeftMaintain(ref GetLeftReference(root));
128     RightMaintain(ref GetRightReference(root));
129     LeftMaintain(ref root);
130     RightMaintain(ref root);
131 }
132 }
133 }
134 private void RightMaintain(ref TElement root)
135 {
136     if (!EqualToZero(root))
137     {
138         var rootRightNode = GetRight(root);
139         if (!EqualToZero(rootRightNode))
140         {
141             var rootLeftNode = GetLeft(root);
142             var rootLeftNodeSize = GetSize(rootLeftNode);
143             var rootRightNodeRightNode = GetRight(rootRightNode);
144             if (!EqualToZero(rootRightNodeRightNode) &&
145                 (EqualToZero(rootLeftNode) ||
146                  ⇨ GreaterThan(GetSize(rootRightNodeRightNode), rootLeftNodeSize)))
147             {
148                 LeftRotate(ref root);
149             }
150             else
151             {
152                 var rootRightNodeLeftNode = GetLeft(rootRightNode);
153                 if (!EqualToZero(rootRightNodeLeftNode) &&
154                     (EqualToZero(rootLeftNode) ||
155                      ⇨ GreaterThan(GetSize(rootRightNodeLeftNode), rootLeftNodeSize)))
156                 {
157                     RightRotate(ref GetRightReference(root));
158                     LeftRotate(ref root);
159                 }
160                 else
161                 {
162                     return;
163                 }
164             }
165             LeftMaintain(ref GetLeftReference(root));
166             RightMaintain(ref GetRightReference(root));
167             LeftMaintain(ref root);
168             RightMaintain(ref root);
169         }
170     }
171 }

```

1.11 ./csharp/Platform.Collections.Methods/Trees/SizedAndThreadedAVLBalancedTreeMethods.cs

```

1 using System;
2 using System.Runtime.CompilerServices;
3 using System.Text;
4 #if USEARRAYPOOL
5 using Platform.Collections;
6 #endif
7 using Platform.Reflection;
8
9 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
10
11 namespace Platform.Collections.Methods.Trees
12 {
13     /// <summary>
14     /// Combination of Size, Height (AVL), and threads.
15     /// </summary>

```

```

16  /// <remarks>
17  /// Based on: <a href="https://github.com/programatom/TreeLib/blob/master/TreeLib/TreeLib/G_
    ↳ enerated/AVLTreeList.cs">TreeLib.AVLTreeList</a>.
18  /// Which itself based on: <a
    ↳ href="https://github.com/GNOME/glib/blob/master/glib/gtree.c">GNOME/glib/gtree</a>.
19  /// </remarks>
20  public abstract class SizedAndThreadedAVLBalancedTreeMethods<TElement> :
    ↳ SizedBinaryTreeMethodsBase<TElement>
21  {
22      private static readonly int _maxPath = 11 * NumericType<TElement>.BytesSize + 4;
23
24      [MethodImpl(MethodImplOptions.AggressiveInlining)]
25      protected override TElement GetRighttest(TElement current)
26      {
27          var currentRight = GetRightOrDefault(current);
28          while (!EqualToZero(currentRight))
29          {
30              current = currentRight;
31              currentRight = GetRightOrDefault(current);
32          }
33          return current;
34      }
35
36      [MethodImpl(MethodImplOptions.AggressiveInlining)]
37      protected override TElement GetLefttest(TElement current)
38      {
39          var currentLeft = GetLeftOrDefault(current);
40          while (!EqualToZero(currentLeft))
41          {
42              current = currentLeft;
43              currentLeft = GetLeftOrDefault(current);
44          }
45          return current;
46      }
47
48      public override bool Contains(TElement node, TElement root)
49      {
50          while (!EqualToZero(root))
51          {
52              if (FirstIsToTheLeftOfSecond(node, root)) // node.Key < root.Key
53              {
54                  root = GetLeftOrDefault(root);
55              }
56              else if (FirstIsToTheRightOfSecond(node, root)) // node.Key > root.Key
57              {
58                  root = GetRightOrDefault(root);
59              }
60              else // node.Key == root.Key
61              {
62                  return true;
63              }
64          }
65          return false;
66      }
67
68      protected override void PrintNode(TElement node, StringBuilder sb, int level)
69      {
70          base.PrintNode(node, sb, level);
71          sb.Append(' ');
72          sb.Append(GetLeftIsChild(node) ? 'l' : 'L');
73          sb.Append(GetRightIsChild(node) ? 'r' : 'R');
74          sb.Append(' ');
75          sb.Append(GetBalance(node));
76      }
77
78      [MethodImpl(MethodImplOptions.AggressiveInlining)]
79      protected void IncrementBalance(TElement node) => SetBalance(node,
    ↳ (sbyte)(GetBalance(node) + 1));
80
81      [MethodImpl(MethodImplOptions.AggressiveInlining)]
82      protected void DecrementBalance(TElement node) => SetBalance(node,
    ↳ (sbyte)(GetBalance(node) - 1));
83
84      [MethodImpl(MethodImplOptions.AggressiveInlining)]
85      protected override TElement GetLeftOrDefault(TElement node) => GetLeftIsChild(node) ?
    ↳ GetLeft(node) : default;
86
87      [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

88     protected override TElement GetRightOrDefault(TElement node) => GetRightIsChild(node) ?
      ↪ GetRight(node) : default;
89
90     [MethodImpl(MethodImplOptions.AggressiveInlining)]
91     protected abstract bool GetLeftIsChild(TElement node);
92
93     [MethodImpl(MethodImplOptions.AggressiveInlining)]
94     protected abstract void SetLeftIsChild(TElement node, bool value);
95
96     [MethodImpl(MethodImplOptions.AggressiveInlining)]
97     protected abstract bool GetRightIsChild(TElement node);
98
99     [MethodImpl(MethodImplOptions.AggressiveInlining)]
100    protected abstract void SetRightIsChild(TElement node, bool value);
101
102    [MethodImpl(MethodImplOptions.AggressiveInlining)]
103    protected abstract sbyte GetBalance(TElement node);
104
105    [MethodImpl(MethodImplOptions.AggressiveInlining)]
106    protected abstract void SetBalance(TElement node, sbyte value);
107
108    protected override void AttachCore(ref TElement root, TElement node)
109    {
110        unchecked
111        {
112            // TODO: Check what is faster to use simple array or array from array pool
113            // TODO: Try to use stackalloc as an optimization (requires code generation,
            ↪ because of generics)
114
115            #if USEARRAYPOOL
116                var path = ArrayPool.Allocate<TElement>(MaxPath);
117                var pathPosition = 0;
118                path[pathPosition++] = default;
119            #else
120                var path = new TElement[_maxPath];
121                var pathPosition = 1;
122            #endif
123
124            var currentNode = root;
125            while (true)
126            {
127                if (FirstIsToTheLeftOfSecond(node, currentNode))
128                {
129                    if (GetLeftIsChild(currentNode))
130                    {
131                        IncrementSize(currentNode);
132                        path[pathPosition++] = currentNode;
133                        currentNode = GetLeft(currentNode);
134                    }
135                    else
136                    {
137                        // Threads
138                        SetLeft(node, GetLeft(currentNode));
139                        SetRight(node, currentNode);
140                        SetLeft(currentNode, node);
141                        SetLeftIsChild(currentNode, true);
142                        DecrementBalance(currentNode);
143                        SetSize(node, One);
144                        FixSize(currentNode); // Should be incremented already
145                        break;
146                    }
147                }
148                else if (FirstIsToTheRightOfSecond(node, currentNode))
149                {
150                    if (GetRightIsChild(currentNode))
151                    {
152                        IncrementSize(currentNode);
153                        path[pathPosition++] = currentNode;
154                        currentNode = GetRight(currentNode);
155                    }
156                    else
157                    {
158                        // Threads
159                        SetRight(node, GetRight(currentNode));
160                        SetLeft(node, currentNode);
161                        SetRight(currentNode, node);
162                        SetRightIsChild(currentNode, true);
163                        IncrementBalance(currentNode);
164                        SetSize(node, One);
165                        FixSize(currentNode); // Should be incremented already
166                        break;

```



```

165     }
166 }
167 else
168 {
169     throw new InvalidOperationException("Node with the same key already
170     ↳ attached to a tree.");
171 }
172 // Restore balance. This is the goodness of a non-recursive
173 // implementation, when we are done with balancing we 'break'
174 // the loop and we are done.
175 while (true)
176 {
177     var parent = path[--pathPosition];
178     var isLeftNode = !AreEqual(parent, default) && AreEqual(currentNode,
179     ↳ GetLeft(parent));
180     var currentNodeBalance = GetBalance(currentNode);
181     if (currentNodeBalance < -1 || currentNodeBalance > 1)
182     {
183         currentNode = Balance(currentNode);
184         if (AreEqual(parent, default))
185         {
186             root = currentNode;
187         }
188         else if (isLeftNode)
189         {
190             SetLeft(parent, currentNode);
191             FixSize(parent);
192         }
193         else
194         {
195             SetRight(parent, currentNode);
196             FixSize(parent);
197         }
198     }
199     currentNodeBalance = GetBalance(currentNode);
200     if (currentNodeBalance == 0 || AreEqual(parent, default))
201     {
202         break;
203     }
204     if (isLeftNode)
205     {
206         DecrementBalance(parent);
207     }
208     else
209     {
210         IncrementBalance(parent);
211     }
212     currentNode = parent;
213 }
214 #if USEARRAYPOOL
215     ArrayPool.Free(path);
216 #endif
217 }
218
219 private TElement Balance(TElement node)
220 {
221     unchecked
222     {
223         var rootBalance = GetBalance(node);
224         if (rootBalance < -1)
225         {
226             var left = GetLeft(node);
227             if (GetBalance(left) > 0)
228             {
229                 SetLeft(node, LeftRotateWithBalance(left));
230                 FixSize(node);
231             }
232             node = RightRotateWithBalance(node);
233         }
234         else if (rootBalance > 1)
235         {
236             var right = GetRight(node);
237             if (GetBalance(right) < 0)
238             {
239                 SetRight(node, RightRotateWithBalance(right));
240                 FixSize(node);

```

```

241     }
242     node = LeftRotateWithBalance(node);
243 }
244 return node;
245 }
246 }
247
248 protected TElement LeftRotateWithBalance(TElement node)
249 {
250     unchecked
251     {
252         var right = GetRight(node);
253         if (GetLeftIsChild(right))
254         {
255             SetRight(node, GetLeft(right));
256         }
257         else
258         {
259             SetRightIsChild(node, false);
260             SetLeftIsChild(right, true);
261         }
262         SetLeft(right, node);
263         // Fix size
264         SetSize(right, GetSize(node));
265         FixSize(node);
266         // Fix balance
267         var rootBalance = GetBalance(node);
268         var rightBalance = GetBalance(right);
269         if (rightBalance <= 0)
270         {
271             if (rootBalance >= 1)
272             {
273                 SetBalance(right, (sbyte)(rightBalance - 1));
274             }
275             else
276             {
277                 SetBalance(right, (sbyte)(rootBalance + rightBalance - 2));
278             }
279             SetBalance(node, (sbyte)(rootBalance - 1));
280         }
281         else
282         {
283             if (rootBalance <= rightBalance)
284             {
285                 SetBalance(right, (sbyte)(rootBalance - 2));
286             }
287             else
288             {
289                 SetBalance(right, (sbyte)(rightBalance - 1));
290             }
291             SetBalance(node, (sbyte)(rootBalance - rightBalance - 1));
292         }
293         return right;
294     }
295 }
296
297 protected TElement RightRotateWithBalance(TElement node)
298 {
299     unchecked
300     {
301         var left = GetLeft(node);
302         if (GetRightIsChild(left))
303         {
304             SetLeft(node, GetRight(left));
305         }
306         else
307         {
308             SetLeftIsChild(node, false);
309             SetRightIsChild(left, true);
310         }
311         SetRight(left, node);
312         // Fix size
313         SetSize(left, GetSize(node));
314         FixSize(node);
315         // Fix balance
316         var rootBalance = GetBalance(node);
317         var leftBalance = GetBalance(left);
318         if (leftBalance <= 0)

```

```

319     {
320         if (leftBalance > rootBalance)
321         {
322             SetBalance(left, (sbyte)(leftBalance + 1));
323         }
324         else
325         {
326             SetBalance(left, (sbyte)(rootBalance + 2));
327         }
328         SetBalance(node, (sbyte)(rootBalance - leftBalance + 1));
329     }
330     else
331     {
332         if (rootBalance <= -1)
333         {
334             SetBalance(left, (sbyte)(leftBalance + 1));
335         }
336         else
337         {
338             SetBalance(left, (sbyte)(rootBalance + leftBalance + 2));
339         }
340         SetBalance(node, (sbyte)(rootBalance + 1));
341     }
342     return left;
343 }
344
345 [MethodImpl(MethodImplOptions.AggressiveInlining)]
346 protected override TElement GetNext(TElement node)
347 {
348     var current = GetRight(node);
349     if (GetRightIsChild(node))
350     {
351         return GetLefttest(current);
352     }
353     return current;
354 }
355
356 [MethodImpl(MethodImplOptions.AggressiveInlining)]
357 protected override TElement GetPrevious(TElement node)
358 {
359     var current = GetLeft(node);
360     if (GetLeftIsChild(node))
361     {
362         return GetRighttest(current);
363     }
364     return current;
365 }
366
367 protected override void DetachCore(ref TElement root, TElement node)
368 {
369     unchecked
370     {
371         #if USEARRAYPOOL
372             var path = ArrayPool.Allocate<TElement>(MaxPath);
373             var pathPosition = 0;
374             path[pathPosition++] = default;
375         #else
376             var path = new TElement[_maxPath];
377             var pathPosition = 1;
378         #endif
379         var currentNode = root;
380         while (true)
381         {
382             if (FirstIsToTheLeftOfSecond(node, currentNode))
383             {
384                 if (!GetLeftIsChild(currentNode))
385                 {
386                     throw new InvalidOperationException("Cannot find a node.");
387                 }
388                 DecrementSize(currentNode);
389                 path[pathPosition++] = currentNode;
390                 currentNode = GetLeft(currentNode);
391             }
392             else if (FirstIsToTheRightOfSecond(node, currentNode))
393             {
394                 if (!GetRightIsChild(currentNode))
395                 {
396                     throw new InvalidOperationException("Cannot find a node.");
397

```

```

398     }
399     DecrementSize(currentNode);
400     path[pathPosition++] = currentNode;
401     currentNode = GetRight(currentNode);
402 }
403 else
404 {
405     break;
406 }
407 }
408 var parent = path[--pathPosition];
409 var balanceNode = parent;
410 var isLeftNode = !AreEqual(parent, default) && AreEqual(currentNode,
    ↪ GetLeft(parent));
411 if (!GetLeftIsChild(currentNode))
412 {
413     if (!GetRightIsChild(currentNode)) // node has no children
414     {
415         if (AreEqual(parent, default))
416         {
417             root = Zero;
418         }
419         else if (isLeftNode)
420         {
421             SetLeftIsChild(parent, false);
422             SetLeft(parent, GetLeft(currentNode));
423             IncrementBalance(parent);
424         }
425         else
426         {
427             SetRightIsChild(parent, false);
428             SetRight(parent, GetRight(currentNode));
429             DecrementBalance(parent);
430         }
431     }
432     else // node has a right child
433     {
434         var successor = GetNext(currentNode);
435         SetLeft(successor, GetLeft(currentNode));
436         var right = GetRight(currentNode);
437         if (AreEqual(parent, default))
438         {
439             root = right;
440         }
441         else if (isLeftNode)
442         {
443             SetLeft(parent, right);
444             IncrementBalance(parent);
445         }
446         else
447         {
448             SetRight(parent, right);
449             DecrementBalance(parent);
450         }
451     }
452 }
453 else // node has a left child
454 {
455     if (!GetRightIsChild(currentNode))
456     {
457         var predecessor = GetPrevious(currentNode);
458         SetRight(predecessor, GetRight(currentNode));
459         var leftValue = GetLeft(currentNode);
460         if (AreEqual(parent, default))
461         {
462             root = leftValue;
463         }
464         else if (isLeftNode)
465         {
466             SetLeft(parent, leftValue);
467             IncrementBalance(parent);
468         }
469         else
470         {
471             SetRight(parent, leftValue);
472             DecrementBalance(parent);
473         }
474     }

```

```

475 else // node has a both children (left and right)
476 {
477     var predecessor = GetLeft(currentNode);
478     var successor = GetRight(currentNode);
479     var successorParent = currentNode;
480     int previousPathPosition = ++pathPosition;
481     // find the immediately next node (and its parent)
482     while (GetLeftIsChild(successor))
483     {
484         path[++pathPosition] = successorParent = successor;
485         successor = GetLeft(successor);
486         if (!AreEqual(successorParent, currentNode))
487         {
488             DecrementSize(successorParent);
489         }
490     }
491     path[previousPathPosition] = successor;
492     balanceNode = path[pathPosition];
493     // remove 'successor' from the tree
494     if (!AreEqual(successorParent, currentNode))
495     {
496         if (!GetRightIsChild(successor))
497         {
498             SetLeftIsChild(successorParent, false);
499         }
500         else
501         {
502             SetLeft(successorParent, GetRight(successor));
503         }
504         IncrementBalance(successorParent);
505         SetRightIsChild(successor, true);
506         SetRight(successor, GetRight(currentNode));
507     }
508     else
509     {
510         DecrementBalance(currentNode);
511     }
512     // set the predecessor's successor link to point to the right place
513     while (GetRightIsChild(predecessor))
514     {
515         predecessor = GetRight(predecessor);
516     }
517     SetRight(predecessor, successor);
518     // prepare 'successor' to replace 'node'
519     var left = GetLeft(currentNode);
520     SetLeftIsChild(successor, true);
521     SetLeft(successor, left);
522     SetBalance(successor, GetBalance(currentNode));
523     FixSize(successor);
524     if (AreEqual(parent, default))
525     {
526         root = successor;
527     }
528     else if (isLeftNode)
529     {
530         SetLeft(parent, successor);
531     }
532     else
533     {
534         SetRight(parent, successor);
535     }
536 }
537 }
538 // restore balance
539 if (!AreEqual(balanceNode, default))
540 {
541     while (true)
542     {
543         var balanceParent = path[--pathPosition];
544         isLeftNode = !AreEqual(balanceParent, default) && AreEqual(balanceNode,
545             ↪ GetLeft(balanceParent));
546         var currentNodeBalance = GetBalance(balanceNode);
547         if (currentNodeBalance < -1 || currentNodeBalance > 1)
548         {
549             balanceNode = Balance(balanceNode);
550             if (AreEqual(balanceParent, default))
551             {
552                 root = balanceNode;

```

```

552     }
553     else if (isLeftNode)
554     {
555         SetLeft(balanceParent, balanceNode);
556     }
557     else
558     {
559         SetRight(balanceParent, balanceNode);
560     }
561 }
562 currentNodeBalance = GetBalance(balanceNode);
563 if (currentNodeBalance != 0 || AreEqual(balanceParent, default))
564 {
565     break;
566 }
567 if (isLeftNode)
568 {
569     IncrementBalance(balanceParent);
570 }
571 else
572 {
573     DecrementBalance(balanceParent);
574 }
575 balanceNode = balanceParent;
576 }
577 }
578 ClearNode(node);
579 #if USEARRAYPOOL
580     ArrayPool.Free(path);
581 #endif
582 }
583 }
584
585 [MethodImpl(MethodImplOptions.AggressiveInlining)]
586 protected override void ClearNode(TElement node)
587 {
588     SetLeft(node, Zero);
589     SetRight(node, Zero);
590     SetSize(node, Zero);
591     SetLeftIsChild(node, false);
592     SetRightIsChild(node, false);
593     SetBalance(node, 0);
594 }
595 }
596 }

```

1.12 ./csharp/Platform.Collections.Methods/Trees/SizedBinaryTreeMethodsBase.cs

```

1  // #define ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
2
3  using System;
4  using System.Diagnostics;
5  using System.Runtime.CompilerServices;
6  using System.Text;
7  using Platform.Numbers;
8
9  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
10
11 namespace Platform.Collections.Methods.Trees
12 {
13     public abstract class SizedBinaryTreeMethodsBase<TElement> :
14         ↳ GenericCollectionMethodsBase<TElement>
15     {
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         protected abstract ref TElement GetLeftReference(TElement node);
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         protected abstract ref TElement GetRightReference(TElement node);
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected abstract TElement GetLeft(TElement node);
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected abstract TElement GetRight(TElement node);
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected abstract TElement GetSize(TElement node);
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected abstract void SetLeft(TElement node, TElement left);
33     }

```

```

33 [MethodImpl(MethodImplOptions.AggressiveInlining)]
34 protected abstract void SetRight(TElement node, TElement right);
35
36 [MethodImpl(MethodImplOptions.AggressiveInlining)]
37 protected abstract void SetSize(TElement node, TElement size);
38
39 [MethodImpl(MethodImplOptions.AggressiveInlining)]
40 protected abstract bool FirstIsToTheLeftOfSecond(TElement first, TElement second);
41
42 [MethodImpl(MethodImplOptions.AggressiveInlining)]
43 protected abstract bool FirstIsToTheRightOfSecond(TElement first, TElement second);
44
45 [MethodImpl(MethodImplOptions.AggressiveInlining)]
46 protected virtual TElement GetLeftOrDefault(TElement node) => AreEqual(node, default) ?
    ↳ default : GetLeft(node);
47
48 [MethodImpl(MethodImplOptions.AggressiveInlining)]
49 protected virtual TElement GetRightOrDefault(TElement node) => AreEqual(node, default) ?
    ↳ default : GetRight(node);
50
51 [MethodImpl(MethodImplOptions.AggressiveInlining)]
52 protected void IncrementSize(TElement node) => SetSize(node, Increment(GetSize(node)));
53
54 [MethodImpl(MethodImplOptions.AggressiveInlining)]
55 protected void DecrementSize(TElement node) => SetSize(node, Decrement(GetSize(node)));
56
57 [MethodImpl(MethodImplOptions.AggressiveInlining)]
58 protected TElement GetLeftSize(TElement node) => GetSizeOrZero(GetLeftOrDefault(node));
59
60 [MethodImpl(MethodImplOptions.AggressiveInlining)]
61 protected TElement GetRightSize(TElement node) => GetSizeOrZero(GetRightOrDefault(node));
62
63 [MethodImpl(MethodImplOptions.AggressiveInlining)]
64 protected TElement GetSizeOrZero(TElement node) => EqualToZero(node) ? Zero :
    ↳ GetSize(node);
65
66 [MethodImpl(MethodImplOptions.AggressiveInlining)]
67 protected void FixSize(TElement node) => SetSize(node, Increment(Add(GetLeftSize(node),
    ↳ GetRightSize(node))));
68
69 [MethodImpl(MethodImplOptions.AggressiveInlining)]
70 protected void LeftRotate(ref TElement root) => root = LeftRotate(root);
71
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 protected TElement LeftRotate(TElement root)
74 {
75     var right = GetRight(root);
76     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
77     if (EqualToZero(right))
78     {
79         throw new InvalidOperationException("Right is null.");
80     }
81     #endif
82     SetRight(root, GetLeft(right));
83     SetLeft(right, root);
84     SetSize(right, GetSize(root));
85     FixSize(root);
86     return right;
87 }
88
89 [MethodImpl(MethodImplOptions.AggressiveInlining)]
90 protected void RightRotate(ref TElement root) => root = RightRotate(root);
91
92 [MethodImpl(MethodImplOptions.AggressiveInlining)]
93 protected TElement RightRotate(TElement root)
94 {
95     var left = GetLeft(root);
96     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
97     if (EqualToZero(left))
98     {
99         throw new InvalidOperationException("Left is null.");
100     }
101     #endif
102     SetLeft(root, GetRight(left));
103     SetRight(left, root);
104     SetSize(left, GetSize(root));
105     FixSize(root);
106     return left;
107 }

```

```

108 [MethodImpl(MethodImplOptions.AggressiveInlining)]
109 protected virtual TElement GetRightest(TElement current)
110 {
111     var currentRight = GetRight(current);
112     while (!EqualToZero(currentRight))
113     {
114         current = currentRight;
115         currentRight = GetRight(current);
116     }
117     return current;
118 }
119
120 [MethodImpl(MethodImplOptions.AggressiveInlining)]
121 protected virtual TElement GetLeftest(TElement current)
122 {
123     var currentLeft = GetLeft(current);
124     while (!EqualToZero(currentLeft))
125     {
126         current = currentLeft;
127         currentLeft = GetLeft(current);
128     }
129     return current;
130 }
131
132 [MethodImpl(MethodImplOptions.AggressiveInlining)]
133 protected virtual TElement GetNext(TElement node) => GetLeftest(GetRight(node));
134
135 [MethodImpl(MethodImplOptions.AggressiveInlining)]
136 protected virtual TElement GetPrevious(TElement node) => GetRightest(GetLeft(node));
137
138 [MethodImpl(MethodImplOptions.AggressiveInlining)]
139 public virtual bool Contains(TElement node, TElement root)
140 {
141     while (!EqualToZero(root))
142     {
143         if (FirstIsToTheLeftOfSecond(node, root)) // node.Key < root.Key
144         {
145             root = GetLeft(root);
146         }
147         else if (FirstIsToTheRightOfSecond(node, root)) // node.Key > root.Key
148         {
149             root = GetRight(root);
150         }
151         else // node.Key == root.Key
152         {
153             return true;
154         }
155     }
156     return false;
157 }
158
159 [MethodImpl(MethodImplOptions.AggressiveInlining)]
160 protected virtual void ClearNode(TElement node)
161 {
162     SetLeft(node, Zero);
163     SetRight(node, Zero);
164     SetSize(node, Zero);
165 }
166
167 [MethodImpl(MethodImplOptions.AggressiveInlining)]
168 public void Attach(ref TElement root, TElement node)
169 {
170     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
171         ValidateSizes(root);
172         Debug.WriteLine("--BeforeAttach--");
173         Debug.WriteLine(PrintNodes(root));
174         Debug.WriteLine("-----");
175         var sizeBefore = GetSize(root);
176     #endif
177     if (EqualToZero(root))
178     {
179         SetSize(node, One);
180         root = node;
181         return;
182     }
183     AttachCore(ref root, node);
184     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
185         Debug.WriteLine("--AfterAttach--");
186     #endif

```



```

187         Debug.WriteLine(PrintNodes(root));
188         Debug.WriteLine("-----");
189         ValidateSizes(root);
190         var sizeAfter = GetSize(root);
191         if (!AreEqual(Arithmetic.Increment(sizeBefore), sizeAfter))
192         {
193             throw new InvalidOperationException("Tree was broken after attach.");
194         }
195     #endif
196 }
197
198     protected abstract void AttachCore(ref TElement root, TElement node);
199
200     [MethodImpl(MethodImplOptions.AggressiveInlining)]
201     public void Detach(ref TElement root, TElement node)
202     {
203     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
204         ValidateSizes(root);
205         Debug.WriteLine("--BeforeDetach--");
206         Debug.WriteLine(PrintNodes(root));
207         Debug.WriteLine("-----");
208         var sizeBefore = GetSize(root);
209         if (EqualToZero(root))
210         {
211             throw new InvalidOperationException($"Элемент с {node} не содержится в
212             ↳ дереве.");
213         }
214     #endif
215     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
216         DetachCore(ref root, node);
217         Debug.WriteLine("--AfterDetach--");
218         Debug.WriteLine(PrintNodes(root));
219         Debug.WriteLine("-----");
220         ValidateSizes(root);
221         var sizeAfter = GetSize(root);
222         if (!AreEqual(Arithmetic.Decrement(sizeBefore), sizeAfter))
223         {
224             throw new InvalidOperationException("Tree was broken after detach.");
225         }
226     #endif
227 }
228
229     protected abstract void DetachCore(ref TElement root, TElement node);
230
231     public void FixSizes(TElement node)
232     {
233         if (AreEqual(node, default))
234         {
235             return;
236         }
237         FixSizes(GetLeft(node));
238         FixSizes(GetRight(node));
239         FixSize(node);
240     }
241
242     public void ValidateSizes(TElement node)
243     {
244         if (AreEqual(node, default))
245         {
246             return;
247         }
248         var size = GetSize(node);
249         var leftSize = GetLeftSize(node);
250         var rightSize = GetRightSize(node);
251         var expectedSize = Arithmetic.Increment(Arithmetic.Add(leftSize, rightSize));
252         if (!AreEqual(size, expectedSize))
253         {
254             throw new InvalidOperationException($"Size of {node} is not valid. Expected
255             ↳ size: {expectedSize}, actual size: {size}.");
256         }
257         ValidateSizes(GetLeft(node));
258         ValidateSizes(GetRight(node));
259     }
260
261     public void ValidateSize(TElement node)
262     {
263         var size = GetSize(node);
264         var leftSize = GetLeftSize(node);

```

```

263     var rightSize = GetRightSize(node);
264     var expectedSize = Arithmetic.Increment(Arithmetic.Add(leftSize, rightSize));
265     if (!AreEqual(size, expectedSize))
266     {
267         throw new InvalidOperationException($"Size of {node} is not valid. Expected
        ↳ size: {expectedSize}, actual size: {size}.");
268     }
269 }
270
271 public string PrintNodes(TElement node)
272 {
273     var sb = new StringBuilder();
274     PrintNodes(node, sb);
275     return sb.ToString();
276 }
277
278 [MethodImpl(MethodImplOptions.AggressiveInlining)]
279 public void PrintNodes(TElement node, StringBuilder sb) => PrintNodes(node, sb, 0);
280
281 public void PrintNodes(TElement node, StringBuilder sb, int level)
282 {
283     if (AreEqual(node, default))
284     {
285         return;
286     }
287     PrintNodes(GetLeft(node), sb, level + 1);
288     PrintNode(node, sb, level);
289     sb.AppendLine();
290     PrintNodes(GetRight(node), sb, level + 1);
291 }
292
293 public string PrintNode(TElement node)
294 {
295     var sb = new StringBuilder();
296     PrintNode(node, sb);
297     return sb.ToString();
298 }
299
300 [MethodImpl(MethodImplOptions.AggressiveInlining)]
301 protected void PrintNode(TElement node, StringBuilder sb) => PrintNode(node, sb, 0);
302
303 protected virtual void PrintNode(TElement node, StringBuilder sb, int level)
304 {
305     sb.Append('\t', level);
306     sb.Append(node);
307     PrintNodeValue(node, sb);
308     sb.Append(' ');
309     sb.Append('s');
310     sb.Append(GetSize(node));
311 }
312
313 protected abstract void PrintNodeValue(TElement node, StringBuilder sb);
314 }
315 }

```

1.13 ./csharp/Platform.Collections.Methods.Tests/RecursionlessSizeBalancedTree.cs

```

1  using System;
2  using System.Collections.Generic;
3  using System.Text;
4  using Platform.Numbers;
5  using Platform.Collections.Methods.Trees;
6  using Platform.Converters;
7
8  namespace Platform.Collections.Methods.Tests
9  {
10     public class RecursionlessSizeBalancedTree<TElement> :
        ↳ RecursionlessSizeBalancedTreeMethods<TElement>
11     {
12         private struct TreeElement
13         {
14             public TElement Size;
15             public TElement Left;
16             public TElement Right;
17         }
18
19         private readonly TreeElement[] _elements;
20         private TElement _allocated;
21
22         public TElement Root;
23

```

```

24     public TElement Count => GetSizeOrZero(Root);
25
26     public RecursionlessSizeBalancedTree(int capacity) => (_elements, _allocated) = (new
    ↪ TreeElement[capacity], One);
27
28     public TElement Allocate()
29     {
30         var newNode = _allocated;
31         if (IsEmpty(newNode))
32         {
33             _allocated = Arithmetic.Increment(_allocated);
34             return newNode;
35         }
36         else
37         {
38             throw new InvalidOperationException("Allocated tree element is not empty.");
39         }
40     }
41
42     public void Free(TElement node)
43     {
44         while (!EqualityComparer.Equals(_allocated, One) && IsEmpty(node))
45         {
46             var lastNode = Arithmetic.Decrement(_allocated);
47             if (EqualityComparer.Equals(lastNode, node))
48             {
49                 _allocated = lastNode;
50                 node = Arithmetic.Decrement(node);
51             }
52             else
53             {
54                 return;
55             }
56         }
57     }
58
59     public bool IsEmpty(TElement node) =>
    ↪ EqualityComparer<TreeElement>.Default.Equals(GetElement(node), default);
60
61     protected override bool FirstIsToTheLeftOfSecond(TElement first, TElement second) =>
    ↪ Comparer.Compare(first, second) < 0;
62
63     protected override bool FirstIsToTheRightOfSecond(TElement first, TElement second) =>
    ↪ Comparer.Compare(first, second) > 0;
64
65     protected override ref TElement GetLeftReference(TElement node) => ref
    ↪ GetElement(node).Left;
66
67     protected override TElement GetLeft(TElement node) => GetElement(node).Left;
68
69     protected override ref TElement GetRightReference(TElement node) => ref
    ↪ GetElement(node).Right;
70
71     protected override TElement GetRight(TElement node) => GetElement(node).Right;
72
73     protected override TElement GetSize(TElement node) => GetElement(node).Size;
74
75     protected override void PrintNodeValue(TElement node, StringBuilder sb) =>
    ↪ sb.Append(node);
76
77     protected override void SetLeft(TElement node, TElement left) => GetElement(node).Left =
    ↪ left;
78
79     protected override void SetRight(TElement node, TElement right) =>
    ↪ GetElement(node).Right = right;
80
81     protected override void SetSize(TElement node, TElement size) => GetElement(node).Size =
    ↪ size;
82
83     private ref TreeElement GetElement(TElement node) => ref
    ↪ _elements[UncheckedConverter<TElement, long>.Default.Convert(node)];
84 }
85 }

```

1.14 ./csharp/Platform.Collections.Methods.Tests/SizeBalancedTree.cs

```

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

```

```

5  using Platform.Collections.Methods.Trees;
6  using Platform.Converters;
7
8  namespace Platform.Collections.Methods.Tests
9  {
10     public class SizeBalancedTree<TElement> : SizeBalancedTreeMethods<TElement>
11     {
12         private struct TreeElement
13         {
14             public TElement Size;
15             public TElement Left;
16             public TElement Right;
17         }
18
19         private readonly TreeElement[] _elements;
20         private TElement _allocated;
21
22         public TElement Root;
23
24         public TElement Count => GetSizeOrZero(Root);
25
26         public SizeBalancedTree(int capacity) => (_elements, _allocated) = (new
            ↪ TreeElement[capacity], One);
27
28         public TElement Allocate()
29         {
30             var newNode = _allocated;
31             if (IsEmpty(newNode))
32             {
33                 _allocated = Arithmetic.Increment(_allocated);
34                 return newNode;
35             }
36             else
37             {
38                 throw new InvalidOperationException("Allocated tree element is not empty.");
39             }
40         }
41
42         public void Free(TElement node)
43         {
44             while (!EqualityComparer.Equals(_allocated, One) && IsEmpty(node))
45             {
46                 var lastNode = Arithmetic.Decrement(_allocated);
47                 if (EqualityComparer.Equals(lastNode, node))
48                 {
49                     _allocated = lastNode;
50                     node = Arithmetic.Decrement(node);
51                 }
52                 else
53                 {
54                     return;
55                 }
56             }
57         }
58
59         public bool IsEmpty(TElement node) =>
            ↪ EqualityComparer<TreeElement>.Default.Equals(GetElement(node), default);
60
61         protected override bool FirstIsToTheLeftOfSecond(TElement first, TElement second) =>
            ↪ Comparer.Compare(first, second) < 0;
62
63         protected override bool FirstIsToTheRightOfSecond(TElement first, TElement second) =>
            ↪ Comparer.Compare(first, second) > 0;
64
65         protected override ref TElement GetLeftReference(TElement node) => ref
            ↪ GetElement(node).Left;
66
67         protected override TElement GetLeft(TElement node) => GetElement(node).Left;
68
69         protected override ref TElement GetRightReference(TElement node) => ref
            ↪ GetElement(node).Right;
70
71         protected override TElement GetRight(TElement node) => GetElement(node).Right;
72
73         protected override TElement GetSize(TElement node) => GetElement(node).Size;
74
75         protected override void PrintNodeValue(TElement node, StringBuilder sb) =>
            ↪ sb.Append(node);
76

```

```

77     protected override void SetLeft(TElement node, TElement left) => GetElement(node).Left =
78         ↳ left;
79     protected override void SetRight(TElement node, TElement right) =>
80         ↳ GetElement(node).Right = right;
81     protected override void SetSize(TElement node, TElement size) => GetElement(node).Size =
82         ↳ size;
83     private ref TreeElement GetElement(TElement node) => ref
84         ↳ _elements[UncheckedConverter<TElement, long>.Default.Convert(node)];
85 }

```

1.15 ./csharp/Platform.Collections.Methods.Tests/SizedAndThreadedAVLBalancedTree.cs

```

1  using System;
2  using System.Collections.Generic;
3  using System.Text;
4  using Platform.Numbers;
5  using Platform.Collections.Methods.Trees;
6  using Platform.Converters;
7
8  namespace Platform.Collections.Methods.Tests
9  {
10     public class SizedAndThreadedAVLBalancedTree<TElement> :
11         ↳ SizedAndThreadedAVLBalancedTreeMethods<TElement>
12     {
13         private struct TreeElement
14         {
15             public TElement Size;
16             public TElement Left;
17             public TElement Right;
18             public sbyte Balance;
19             public bool LeftIsChild;
20             public bool RightIsChild;
21         }
22
23         private readonly TreeElement[] _elements;
24         private TElement _allocated;
25
26         public TElement Root;
27
28         public TElement Count => GetSizeOrZero(Root);
29
30         public SizedAndThreadedAVLBalancedTree(int capacity) => (_elements, _allocated) = (new
31             ↳ TreeElement[capacity], One);
32
33         public TElement Allocate()
34         {
35             var newNode = _allocated;
36             if (IsEmpty(newNode))
37             {
38                 _allocated = Arithmetic.Increment(_allocated);
39                 return newNode;
40             }
41             else
42             {
43                 throw new InvalidOperationException("Allocated tree element is not empty.");
44             }
45         }
46
47         public void Free(TElement node)
48         {
49             while (!EqualityComparer.Equals(_allocated, One) && IsEmpty(node))
50             {
51                 var lastNode = Arithmetic.Decrement(_allocated);
52                 if (EqualityComparer.Equals(lastNode, node))
53                 {
54                     _allocated = lastNode;
55                     node = Arithmetic.Decrement(node);
56                 }
57                 else
58                 {
59                     return;
60                 }
61             }
62
63             public bool IsEmpty(TElement node) =>
64                 ↳ EqualityComparer<TreeElement>.Default.Equals(GetElement(node), default);

```

```

63
64     protected override bool FirstIsToTheLeftOfSecond(TElement first, TElement second) =>
        ↳ Comparer.Compare(first, second) < 0;
65
66     protected override bool FirstIsToTheRightOfSecond(TElement first, TElement second) =>
        ↳ Comparer.Compare(first, second) > 0;
67
68     protected override sbyte GetBalance(TElement node) => GetElement(node).Balance;
69
70     protected override bool GetLeftIsChild(TElement node) => GetElement(node).LeftIsChild;
71
72     protected override ref TElement GetLeftReference(TElement node) => ref
        ↳ GetElement(node).Left;
73
74     protected override TElement GetLeft(TElement node) => GetElement(node).Left;
75
76     protected override bool GetRightIsChild(TElement node) => GetElement(node).RightIsChild;
77
78     protected override ref TElement GetRightReference(TElement node) => ref
        ↳ GetElement(node).Right;
79
80     protected override TElement GetRight(TElement node) => GetElement(node).Right;
81
82     protected override TElement GetSize(TElement node) => GetElement(node).Size;
83
84     protected override void PrintNodeValue(TElement node, StringBuilder sb) =>
        ↳ sb.Append(node);
85
86     protected override void SetBalance(TElement node, sbyte value) =>
        ↳ GetElement(node).Balance = value;
87
88     protected override void SetLeft(TElement node, TElement left) => GetElement(node).Left =
        ↳ left;
89
90     protected override void SetLeftIsChild(TElement node, bool value) =>
        ↳ GetElement(node).LeftIsChild = value;
91
92     protected override void SetRight(TElement node, TElement right) =>
        ↳ GetElement(node).Right = right;
93
94     protected override void SetRightIsChild(TElement node, bool value) =>
        ↳ GetElement(node).RightIsChild = value;
95
96     protected override void SetSize(TElement node, TElement size) => GetElement(node).Size =
        ↳ size;
97
98     private ref TreeElement GetElement(TElement node) => ref
        ↳ _elements[UncheckedConverter<TElement, long>.Default.Convert(node)];
99 }
100 }

```

1.16 ./csharp/Platform.Collections.Methods.Tests/TestExtensions.cs

```

1  using System;
2  using System.Collections.Generic;
3  using Xunit;
4  using Platform.Collections.Methods.Trees;
5  using Platform.Converters;
6
7  namespace Platform.Collections.Methods.Tests
8  {
9      public static class TestExtensions
10     {
11         public static void TestMultipleCreationsAndDeletions<TElement>(this
            ↳ SizedBinaryTreeMethodsBase<TElement> tree, Func<TElement> allocate, Action<TElement>
            ↳ free, ref TElement root, Func<TElement> treeCount, int maximumOperationsPerCycle)
12         {
13             for (var N = 1; N < maximumOperationsPerCycle; N++)
14             {
15                 var currentCount = 0;
16                 for (var i = 0; i < N; i++)
17                 {
18                     var node = allocate();
19                     tree.Attach(ref root, node);
20                     currentCount++;
21                     Assert.Equal(currentCount, (int)UncheckedConverter<TElement,
                        ↳ int>.Default.Convert(treeCount()));
22                 }
23                 for (var i = 1; i <= N; i++)
24                 {

```

```

25         TElement node = UncheckedConverter<int, TElement>.Default.Convert(i);
26         if (tree.Contains(node, root))
27         {
28             tree.Detach(ref root, node);
29             free(node);
30             currentCount--;
31             Assert.Equal(currentCount, (int)UncheckedConverter<TElement,
                ↪ int>.Default.Convert(treeCount()));
32         }
33     }
34 }
35 }
36
37 public static void TestMultipleRandomCreationsAndDeletions<TElement>(this
    ↪ SizedBinaryTreeMethodsBase<TElement> tree, ref TElement root, Func<TElement>
    ↪ treeCount, int maximumOperationsPerCycle)
38 {
39     var random = new System.Random(0);
40     var added = new HashSet<TElement>();
41     var currentCount = 0;
42     for (var N = 1; N < maximumOperationsPerCycle; N++)
43     {
44         for (var i = 0; i < N; i++)
45         {
46             var node = UncheckedConverter<int, TElement>.Default.Convert(random.Next(1,
                ↪ N));
47             if (added.Add(node))
48             {
49                 tree.Attach(ref root, node);
50                 currentCount++;
51                 Assert.Equal(currentCount, (int)UncheckedConverter<TElement,
                    ↪ int>.Default.Convert(treeCount()));
52             }
53         }
54         for (var i = 1; i <= N; i++)
55         {
56             TElement node = UncheckedConverter<int,
                ↪ TElement>.Default.Convert(random.Next(1, N));
57             if (tree.Contains(node, root))
58             {
59                 tree.Detach(ref root, node);
60                 currentCount--;
61                 Assert.Equal(currentCount, (int)UncheckedConverter<TElement,
                    ↪ int>.Default.Convert(treeCount()));
62                 added.Remove(node);
63             }
64         }
65     }
66 }
67 }
68 }

```

1.17 ./csharp/Platform.Collections.Methods.Tests/TreesTests.cs

```

1 using Xunit;
2
3 namespace Platform.Collections.Methods.Tests
4 {
5     public static class TreesTests
6     {
7         private const int _n = 500;
8
9         [Fact]
10        public static void RecursionlessSizeBalancedTreeMultipleAttachAndDetachTest()
11        {
12            var recursionlessSizeBalancedTree = new RecursionlessSizeBalancedTree<uint>(10000);
13            recursionlessSizeBalancedTree.TestMultipleCreationsAndDeletions(recursionlessSizeBal
                ↪ ancedTree.Allocate, recursionlessSizeBalancedTree.Free, ref
                ↪ recursionlessSizeBalancedTree.Root, () => recursionlessSizeBalancedTree.Count,
                ↪ _n);
14        }
15
16        [Fact]
17        public static void SizeBalancedTreeMultipleAttachAndDetachTest()
18        {
19            var sizeBalancedTree = new SizeBalancedTree<uint>(10000);
20            sizeBalancedTree.TestMultipleCreationsAndDeletions(sizeBalancedTree.Allocate,
                ↪ sizeBalancedTree.Free, ref sizeBalancedTree.Root, () => sizeBalancedTree.Count,
                ↪ _n);

```

```

21     }
22
23     [Fact]
24     public static void SizedAndThreadedAVLBalancedTreeMultipleAttachAndDetachTest()
25     {
26         var avlTree = new SizedAndThreadedAVLBalancedTree<uint>(10000);
27         avlTree.TestMultipleCreationsAndDeletions(avlTree.Allocate, avlTree.Free, ref
            ↪ avlTree.Root, () => avlTree.Count, _n);
28     }
29
30     [Fact]
31     public static void RecursionlessSizeBalancedTreeMultipleRandomAttachAndDetachTest()
32     {
33         var recursionlessSizeBalancedTree = new RecursionlessSizeBalancedTree<uint>(10000);
34         recursionlessSizeBalancedTree.TestMultipleRandomCreationsAndDeletions(ref
            ↪ recursionlessSizeBalancedTree.Root, () => recursionlessSizeBalancedTree.Count,
            ↪ _n);
35     }
36
37     [Fact]
38     public static void SizeBalancedTreeMultipleRandomAttachAndDetachTest()
39     {
40         var sizeBalancedTree = new SizeBalancedTree<uint>(10000);
41         sizeBalancedTree.TestMultipleRandomCreationsAndDeletions(ref sizeBalancedTree.Root,
            ↪ () => sizeBalancedTree.Count, _n);
42     }
43
44     [Fact]
45     public static void SizedAndThreadedAVLBalancedTreeMultipleRandomAttachAndDetachTest()
46     {
47         var avlTree = new SizedAndThreadedAVLBalancedTree<uint>(10000);
48         avlTree.TestMultipleRandomCreationsAndDeletions(ref avlTree.Root, () =>
            ↪ avlTree.Count, _n);
49     }
50 }
51 }

```


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