

# 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 range between minimum and maximum values.</para>
11    /// <para>Представляет диапазон между минимальным и максимальным значениями.</para>
12    /// </summary>
13    /// <remarks>
14    /// <para>Based on <a href="http://stackoverflow.com/questions/5343006/is-there-a-c-sharp-type-for-representing-an-integer-range">the question at StackOverflow</a>.</para>
15    /// <para>Основано на <a href="http://stackoverflow.com/questions/5343006/is-there-a-c-sharp-type-for-representing-an-integer-range">вопросе в StackOverflow</a>.</para>
16    /// </remarks>
17    public abstract class GenericCollectionMethodsBase<TElement>
18    {
19        /// <summary>
20        /// <para>Presents the Range in readable format.</para>
21        /// <para>Представляет диапазон в удобном для чтения формате.</para>
22        /// </summary>
23        /// <returns><para>String representation of the Range.</para><para>Строковое представление диапазона.</para></returns>
24        [MethodImpl(MethodImplOptions.AggressiveInlining)]
25        protected virtual TElement GetZero() => default;
26
27        /// <summary>
28        /// <para>Presents the Range in readable format.</para>
29        /// <para>Представляет диапазон в удобном для чтения формате.</para>
30        /// </summary>
31        /// <returns><para>String representation of the Range.</para><para>Строковое представление диапазона.</para></returns>
32        [MethodImpl(MethodImplOptions.AggressiveInlining)]
33        protected virtual bool EqualToZero(TElement value) => EqualityComparer.Equals(value, 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 представление диапазона.</para></returns>
40        [MethodImpl(MethodImplOptions.AggressiveInlining)]
41        protected virtual bool AreEqual(TElement first, TElement second) => EqualityComparer.Equals(first, second);
42
43        /// <summary>
44        /// <para>Presents the Range in readable format.</para>
45        /// <para>Представляет диапазон в удобном для чтения формате.</para>
46        /// </summary>
47        /// <returns><para>String representation of the Range.</para><para>Строковое представление диапазона.</para></returns>
48        [MethodImpl(MethodImplOptions.AggressiveInlining)]
49        protected virtual bool GreaterThanZero(TElement value) => Comparer.Compare(value, Zero) > 0;
50
51        /// <summary>
52        /// <para>Presents the Range in readable format.</para>
53        /// <para>Представляет диапазон в удобном для чтения формате.</para>
54        /// </summary>
55        /// <returns><para>String representation of the Range.</para><para>Строковое представление диапазона.</para></returns>
56        [MethodImpl(MethodImplOptions.AggressiveInlining)]
57        protected virtual bool GreaterThan(TElement first, TElement second) => Comparer.Compare(first, second) > 0;
58
59        /// <summary>
60        /// <para>Presents the Range in readable format.</para>
61        /// <para>Представляет диапазон в удобном для чтения формате.</para>
62        /// </summary>
```

```

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

```

```

125     /// <para>Представляет диапазон в удобном для чтения формате.</para>
126     /// </summary>
127     /// <returns><para>String representation of the Range.</para><para>Строковое
    ↪ представление диапазона.</para></returns>
128     [MethodImpl(MethodImplOptions.AggressiveInlining)]
129     protected virtual TElement Add(TElement first, TElement second) =>
    ↪ Arithmetic<TElement>.Add(first, second);

130
131     /// <summary>
132     /// <para>Presents the Range in readable format.</para>
133     /// <para>Представляет диапазон в удобном для чтения формате.</para>
134     /// </summary>
135     /// <returns><para>String representation of the Range.</para><para>Строковое
    ↪ представление диапазона.</para></returns>
136     [MethodImpl(MethodImplOptions.AggressiveInlining)]
137     protected virtual TElement Subtract(TElement first, TElement second) =>
    ↪ Arithmetic<TElement>.Subtract(first, second);

138
139     protected readonly TElement Zero;
140     protected readonly TElement One;
141     protected readonly TElement Two;
142     protected readonly EqualityComparer<TElement> EqualityComparer;
143     protected readonly Comparer<TElement> Comparer;
144
145     /// <summary>
146     /// <para>Presents the Range in readable format.</para>
147     /// <para>Представляет диапазон в удобном для чтения формате.</para>
148     /// </summary>
149     /// <returns><para>String representation of the Range.</para><para>Строковое
    ↪ представление диапазона.</para></returns>
150     protected GenericCollectionMethodsBase()
151     {
152         EqualityComparer = EqualityComparer<TElement>.Default;
153         Comparer = Comparer<TElement>.Default;
154         Zero = GetZero(); //-V3068
155         One = Increment(Zero); //-V3068
156         Two = Increment(One); //-V3068
157     }
158 }
159 }

```

## 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         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);

```

```

20
21     [MethodImpl(MethodImplOptions.AggressiveInlining)]
22     protected abstract void SetLast(TElement element);
23
24     [MethodImpl(MethodImplOptions.AggressiveInlining)]
25     protected abstract void SetSize(TElement size);
26
27     [MethodImpl(MethodImplOptions.AggressiveInlining)]
28     protected void IncrementSize() => SetSize(Increment(GetSize()));
29
30     [MethodImpl(MethodImplOptions.AggressiveInlining)]
31     protected void DecrementSize() => SetSize(Decrement(GetSize()));
32 }
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              {
47                  SetFirst(element);
48                  SetLast(element);
49                  SetPrevious(element, Zero);
50                  SetNext(element, Zero);
51                  IncrementSize();
52              }
53              else
54              {
55                  AttachBefore(first, element);
56              }
57          }
58
59          public void AttachAsLast(TElement element)
60          {
61              var last = GetLast();
62              if (EqualToZero(last))
63              {

```

```

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> :
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 (AreEqual(baseElement, GetFirst(headElement)))
14             {

```

```

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         public void AttachAfter(TElement headElement, 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(headElement, newElement);
33             }
34             else
35             {
36                 SetPrevious(baseElementNext, newElement);
37             }
38             SetNext(baseElement, newElement);
39         }
40     }
41 }
```



```

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> :
6          ↳ SizedBinaryTreeMethodsBase<TElement>
7      {
8          protected override void AttachCore(ref TElement root, TElement node)
9          {
10              while (true)
11              {
12                  ref var left = ref GetLeftReference(root);
13                  var leftSize = GetSizeOrZero(left);
14                  ref var right = ref GetRightReference(root);
15                  var rightSize = GetSizeOrZero(right);
16                  if (FirstIsToTheLeftOfSecond(node, root)) // node.Key less than root.Key
17                  {
18                      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
46                 ↪ root and a node itself
47                 SetLeft(root, Zero);
48                 SetSize(root, One);
49                 root = node;
50                 return;
51             }
52             LeftRotate(ref left);
53             RightRotate(ref root);
54         }
55         else
56         {
57             IncrementSize(root);
58             root = ref left;
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
71         ↪ right.Key
72         {
73             if (GreaterThan(Increment(rightSize), leftSize))
74             {
75                 LeftRotate(ref root);
76             }
77             else
78             {
79                 IncrementSize(root);
80                 root = ref right;
81             }
82         }
83         else // node.Key less than right.Key
84         {
85             var rightLeftSize = GetSizeOrZero(GetLeft(right));
86             if (GreaterThan(Increment(rightLeftSize), leftSize))
87             {
88                 if (EqualToZero(rightLeftSize) && EqualToZero(leftSize))
89                 {
90                     SetLeft(node, root);
91                     SetRight(node, right);
92                     SetSize(node, Add(rightSize, Two)); // Two (2) - node the size
93                     ↪ of root and a node itself
94                     SetRight(root, Zero);
95                     SetSize(root, One);

```

```

94         root = node;
95         return;
96     }
97     RightRotate(ref right);
98     LeftRotate(ref root);
99 }
100 else
101 {
102     IncrementSize(root);
103     root = ref right;
104 }
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         else // key equals to root.Key
158         {
159             if (GreaterThanZero(leftSize) && GreaterThanZero(rightSize))
160             {
161                 TElement replacement;
162                 if (GreaterThan(leftSize, rightSize))
163                 {
164                     replacement = GetRighttest(left);
165                     DetachCore(ref left, replacement);
166                 }
167                 else
168                 {
169                     replacement = GetLefttest(right);
170                     DetachCore(ref right, replacement);
171                 }
172             }
173         }
174     }
175 }

```

```

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;
38             while (!AreEqual(currentNode, nodeToDetach))
39             {
40                 DecrementSize(currentNode);
41                 if (FirstIsToTheLeftOfSecond(nodeToDetach, currentNode))
42                 {
43                     parent = ref currentNode;
44                     currentNode = ref GetLeftReference(currentNode);
45                 }
46                 else if (FirstIsToTheRightOfSecond(nodeToDetach, currentNode))
47                 {
48                     parent = ref currentNode;
49                     currentNode = ref GetRightReference(currentNode);
50                 }
51                 else
52                 {
53                     throw new InvalidOperationException("Duplicate link found in the tree.");
54                 }
55             }
56         }
57     }
58 }

```

```

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),
        ↪      GetSize(node))));
67     }
68     else
69     {
70         SetSize(lefttestNode, Increment(GetSize(nodeToDetachLeft)));
71     }
72     replacementNode = lefttestNode;
73 }
74 else if (!EqualToZero(nodeToDetachLeft))
75 {
76     replacementNode = nodeToDetachLeft;
77 }
78 else if (!EqualToZero(node))
79 {
80     replacementNode = node;
81 }
82 if (AreEqual(root, nodeToDetach))
83 {
84     root = replacementNode;
85 }
86 else if (AreEqual(GetLeft(parent), nodeToDetach))
87 {
88     SetLeft(parent, replacementNode);
89 }
90 else if (AreEqual(GetRight(parent), nodeToDetach))
91 {
92     SetRight(parent, replacementNode);
93 }
94 ClearNode(nodeToDetach);
95 }
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
114             {
115                 var rootLeftNodeRightNode = GetRight(rootLeftNode);
116                 if (!EqualToZero(rootLeftNodeRightNode) &&
117                     (EqualToZero(rootRightNode) ||
118                     ↪      GreaterThan(GetSize(rootLeftNodeRightNode), rootRightNodeSize)))
119                 {
120                     LeftRotate(ref GetLeftReference(root));
121                     RightRotate(ref root);
122                 }
123                 else
124                 {
125                     return;
126                 }
127             }
128         }
129         LeftMaintain(ref GetLeftReference(root));
130         RightMaintain(ref GetRightReference(root));
131     }
132 }

```

```

128         LeftMaintain(ref root);
129         RightMaintain(ref root);
130     }
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             }
161             else
162             {
163                 return;
164             }
165         }
166         LeftMaintain(ref GetLeftReference(root));
167         RightMaintain(ref GetRightReference(root));
168         LeftMaintain(ref root);
169         RightMaintain(ref root);
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_
18     ⇨ enerated/AVLTreeList.cs">TreeLib.AVLTreeList</a>.
19     /// Which itself based on: <a
20     ⇨ href="https://github.com/GNOME/glib/blob/master/glib/gtree.c">GNOME/glib/gtree</a>.
21     /// </remarks>
22     public abstract class SizedAndThreadedAVLBalancedTreeMethods<TElement> :
23     ⇨ SizedBinaryTreeMethodsBase<TElement>
24     {
25         private static readonly int _maxPath = 11 * NumericType<TElement>.BytesSize + 4;
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected override TElement GetRightest(TElement current)
29         {
30             var currentRight = GetRightOrDefault(current);
31             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 [MethodImpl(MethodImplOptions.AggressiveInlining)]
105 protected abstract void SetBalance(TElement node, sbyte value);
106
107 protected override void AttachCore(ref TElement root, TElement node)
108 {
109     unchecked
110     {
111         // TODO: Check what is faster to use simple array or array from array pool
112         // TODO: Try to use stackalloc as an optimization (requires code generation,
113         ↪ because of generics)
114 #if USEARRAYPOOL
115     var path = ArrayPool.Allocate<TElement>(MaxPath);
116     var pathPosition = 0;
117     path[pathPosition++] = default;
118 #else
119     var path = new TElement[_maxPath];
120     var pathPosition = 1;
121 #endif
122     var currentNode = root;
123     while (true)
124     {
125         if (FirstIsToTheLeftOfSecond(node, currentNode))
126         {
127             if (GetLeftIsChild(currentNode))
128             {
129                 IncrementSize(currentNode);
130                 path[pathPosition++] = currentNode;
131                 currentNode = GetLeft(currentNode);
132             }
133             else
134             {
135                 // Threads
136                 SetLeft(node, GetLeft(currentNode));
137                 SetRight(node, currentNode);
138                 SetLeft(currentNode, node);
139                 SetLeftIsChild(currentNode, true);
140                 DecrementBalance(currentNode);
141                 SetSize(node, One);
142                 FixSize(currentNode); // Should be incremented already
143                 break;
144             }
145         }
146         else if (FirstIsToTheRightOfSecond(node, currentNode))
147         {
148             if (GetRightIsChild(currentNode))
149             {
150                 IncrementSize(currentNode);
151                 path[pathPosition++] = currentNode;
152                 currentNode = GetRight(currentNode);
153             }
154             else
155             {
156                 // Threads
157                 SetRight(node, GetRight(currentNode));
158                 SetLeft(node, currentNode);
159                 SetRight(currentNode, node);
160                 SetRightIsChild(currentNode, true);
161                 IncrementBalance(currentNode);
162                 SetSize(node, One);
163                 FixSize(currentNode); // Should be incremented already
164                 break;
165             }
166         }
167         else
168         {
169             throw new InvalidOperationException("Node with the same key already
170             ↪ attached to a tree.");
171         }
172     }
173     // Restore balance. This is the goodness of a non-recursive
174     // implementation, when we are done with balancing we 'break'
175     // the loop and we are done.
176     while (true)
177     {
178         var parent = path[--pathPosition];
179         var isLeftNode = !AreEqual(parent, default) && AreEqual(currentNode,
180         ↪ GetLeft(parent));

```



```

179     var currentNodeBalance = GetBalance(currentNode);
180     if (currentNodeBalance < -1 || currentNodeBalance > 1)
181     {
182         currentNode = Balance(currentNode);
183         if (AreEqual(parent, default))
184         {
185             root = currentNode;
186         }
187         else if (isLeftNode)
188         {
189             SetLeft(parent, currentNode);
190             FixSize(parent);
191         }
192         else
193         {
194             SetRight(parent, currentNode);
195             FixSize(parent);
196         }
197     }
198     currentNodeBalance = GetBalance(currentNode);
199     if (currentNodeBalance == 0 || AreEqual(parent, default))
200     {
201         break;
202     }
203     if (isLeftNode)
204     {
205         DecrementBalance(parent);
206     }
207     else
208     {
209         IncrementBalance(parent);
210     }
211     currentNode = parent;
212 }
213 #if USEARRAYPOOL
214     ArrayPool.Free(path);
215 #endif
216 }
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
346 [MethodImpl(MethodImplOptions.AggressiveInlining)]
347 protected override TElement GetNext(TElement node)
348 {
349     var current = GetRight(node);
350     if (GetRightIsChild(node))
351     {
352         return GetLefttest(current);
353     }
354     return current;
355 }
356
357 [MethodImpl(MethodImplOptions.AggressiveInlining)]
358 protected override TElement GetPrevious(TElement node)
359 {
360     var current = GetLeft(node);
361     if (GetLeftIsChild(node))
362     {
363         return GetRighttest(current);
364     }
365     return current;
366 }
367
368 protected override void DetachCore(ref TElement root, TElement node)
369 {
370     unchecked
371     {
372 #if USEARRAYPOOL
373         var path = ArrayPool.Allocate<TElement>(MaxPath);
374         var pathPosition = 0;
375         path[pathPosition++] = default;
376 #else
377         var path = new TElement[_maxPath];
378         var pathPosition = 1;
379 #endif
380         var currentNode = root;
381         while (true)
382         {
383             if (FirstIsToTheLeftOfSecond(node, currentNode))
384             {
385                 if (!GetLeftIsChild(currentNode))
386                 {
387                     throw new InvalidOperationException("Cannot find a node.");
388                 }
389                 DecrementSize(currentNode);
390                 path[pathPosition++] = currentNode;
391                 currentNode = GetLeft(currentNode);
392             }
393             else if (FirstIsToTheRightOfSecond(node, currentNode))
394             {
395                 if (!GetRightIsChild(currentNode))
396                 {
397                     throw new InvalidOperationException("Cannot find a node.");
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,
411             ↪ GetLeft(parent));
412         if (!GetLeftIsChild(currentNode))
413         {
414             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;
553             }
554             else if (isLeftNode)
555             {
556                 SetLeft(balanceParent, balanceNode);
557             }
558             else
559             {
560                 SetRight(balanceParent, balanceNode);
561             }
562         }
563         currentNodeBalance = GetBalance(balanceNode);
564         if (currentNodeBalance != 0 || AreEqual(balanceParent, default))
565         {
566             break;
567         }
568         if (isLeftNode)
569         {

```

```

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
34         [MethodImpl(MethodImplOptions.AggressiveInlining)]
35         protected abstract void SetRight(TElement node, TElement right);
36
37         [MethodImpl(MethodImplOptions.AggressiveInlining)]
38         protected abstract void SetSize(TElement node, TElement size);
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         protected abstract bool FirstIsToLeftOfSecond(TElement first, TElement second);
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         protected abstract bool FirstIsToTheRightOfSecond(TElement first, TElement second);
45
46         [MethodImpl(MethodImplOptions.AggressiveInlining)]
47         protected virtual TElement GetLeftOrDefault(TElement node) => AreEqual(node, default) ?
48             ↳ default : GetLeft(node);
49
50         [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
109     [MethodImpl(MethodImplOptions.AggressiveInlining)]
110     protected virtual TElement GetRighttest(TElement current)
111     {
112         var currentRight = GetRight(current);
113         while (!EqualToZero(currentRight))
114         {
115             current = currentRight;
116             currentRight = GetRight(current);
117         }
118         return current;
119     }
120
121     [MethodImpl(MethodImplOptions.AggressiveInlining)]
122     protected virtual TElement GetLefttest(TElement current)
123     {
124         var currentLeft = GetLeft(current);

```

```

125         while (!EqualToZero(currentLeft))
126         {
127             current = currentLeft;
128             currentLeft = GetLeft(current);
129         }
130         return current;
131     }
132
133     [MethodImpl(MethodImplOptions.AggressiveInlining)]
134     protected virtual TElement GetNext(TElement node) => GetLefttest(GetRight(node));
135
136     [MethodImpl(MethodImplOptions.AggressiveInlining)]
137     protected virtual TElement GetPrevious(TElement node) => GetRighttest(GetLeft(node));
138
139     [MethodImpl(MethodImplOptions.AggressiveInlining)]
140     public virtual bool Contains(TElement node, TElement root)
141     {
142         while (!EqualToZero(root))
143         {
144             if (FirstIsToTheLeftOfSecond(node, root)) // node.Key < root.Key
145             {
146                 root = GetLeft(root);
147             }
148             else if (FirstIsToTheRightOfSecond(node, root)) // node.Key > root.Key
149             {
150                 root = GetRight(root);
151             }
152             else // node.Key == root.Key
153             {
154                 return true;
155             }
156         }
157         return false;
158     }
159
160     [MethodImpl(MethodImplOptions.AggressiveInlining)]
161     protected virtual void ClearNode(TElement node)
162     {
163         SetLeft(node, Zero);
164         SetRight(node, Zero);
165         SetSize(node, Zero);
166     }
167
168     [MethodImpl(MethodImplOptions.AggressiveInlining)]
169     public void Attach(ref TElement root, TElement node)
170     {
171         #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
172             ValidateSizes(root);
173             Debug.WriteLine("--BeforeAttach--");
174             Debug.WriteLine(PrintNodes(root));
175             Debug.WriteLine("-----");
176             var sizeBefore = GetSize(root);
177         #endif
178         if (EqualToZero(root))
179         {
180             SetSize(node, One);
181             root = node;
182             return;
183         }
184         AttachCore(ref root, node);
185         #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
186             Debug.WriteLine("--AfterAttach--");
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($"Элемент с {node} не содержится в
        ↳ дереве.");
212     }
213 #endif
214     DetachCore(ref root, node);
215 #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
216     Debug.WriteLine("--AfterDetach--");
217     Debug.WriteLine(PrintNodes(root));
218     Debug.WriteLine("-----");
219     ValidateSizes(root);
220     var sizeAfter = GetSize(root);
221     if (!AreEqual(Arithmetic.Decrement(sizeBefore), sizeAfter))
222     {
223         throw new InvalidOperationException("Tree was broken after detach.");
224     }
225 #endif
226 }
227
228 protected abstract void DetachCore(ref TElement root, TElement node);
229
230 public void FixSizes(TElement node)
231 {
232     if (AreEqual(node, default))
233     {
234         return;
235     }
236     FixSizes(GetLeft(node));
237     FixSizes(GetRight(node));
238     FixSize(node);
239 }
240
241 public void ValidateSizes(TElement node)
242 {
243     if (AreEqual(node, default))
244     {
245         return;
246     }
247     var size = GetSize(node);
248     var leftSize = GetLeftSize(node);
249     var rightSize = GetRightSize(node);
250     var expectedSize = Arithmetic.Increment(Arithmetic.Add(leftSize, rightSize));
251     if (!AreEqual(size, expectedSize))
252     {
253         throw new InvalidOperationException($"Size of {node} is not valid. Expected
        ↳ size: {expectedSize}, actual size: {size}.");
254     }
255     ValidateSizes(GetLeft(node));
256     ValidateSizes(GetRight(node));
257 }
258
259 public void ValidateSize(TElement node)
260 {
261     var size = GetSize(node);
262     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> :
11         ↳ RecursionlessSizeBalancedTreeMethods<TElement>
12     {
13         private struct TreeElement
14         {
15             public TElement Size;
16             public TElement Left;
17             public TElement Right;
18         }
19
20         private readonly TreeElement[] _elements;
21         private TElement _allocated;
22
23         public TElement Root;
24
25         public TElement Count => GetSizeOrZero(Root);
26
27         public RecursionlessSizeBalancedTree(int capacity) => (_elements, _allocated) = (new
28             ↳ TreeElement[capacity], One);
29
30         public TElement Allocate()
31         {
32             var newNode = _allocated;
33             if (IsEmpty(newNode))
34             {
35                 _allocated = Arithmetic.Increment(_allocated);
36                 return newNode;
37             }
38             else
39             {
40                 throw new InvalidOperationException("Allocated tree element is not empty.");
41             }
42         }
43     }
44 }

```

```

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) =>
60         => EqualityComparer<TreeElement>.Default.Equals(GetElement(node), default);
61
62     protected override bool FirstIsToTheLeftOfSecond(TElement first, TElement second) =>
63         => Comparer.Compare(first, second) < 0;
64
65     protected override bool FirstIsToTheRightOfSecond(TElement first, TElement second) =>
66         => Comparer.Compare(first, second) > 0;
67
68     protected override ref TElement GetLeftReference(TElement node) => ref
69         => GetElement(node).Left;
70
71     protected override TElement GetLeft(TElement node) => GetElement(node).Left;
72
73     protected override ref TElement GetRightReference(TElement node) => ref
74         => GetElement(node).Right;
75
76     protected override TElement GetRight(TElement node) => GetElement(node).Right;
77
78     protected override TElement GetSize(TElement node) => GetElement(node).Size;
79
80     protected override void PrintNodeValue(TElement node, StringBuilder sb) =>
81         => sb.Append(node);
82
83     protected override void SetLeft(TElement node, TElement left) => GetElement(node).Left =
84         => left;
85
86     protected override void SetRight(TElement node, TElement right) =>
87         => GetElement(node).Right = right;
88
89     protected override void SetSize(TElement node, TElement size) => GetElement(node).Size =
90         => size;
91
92     private ref TreeElement GetElement(TElement node) => ref
93         => _elements[UncheckedConverter<TElement, long>.Default.Convert(node)];
94 }
95 }

```

#### 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 =
    ↳ 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 }

```

## 1.15 ./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> :
        ↳ SizedAndThreadedAVLBalancedTreeMethods<TElement>
11     {
12         private struct TreeElement
13         {
14             public TElement Size;
15             public TElement Left;
16             public TElement Right;
17             public sbyte Balance;
18             public bool LeftIsChild;
19             public bool RightIsChild;
20         }
21
22         private readonly TreeElement[] _elements;
23         private TElement _allocated;
24
25         public TElement Root;
26
27         public TElement Count => GetSizeOrZero(Root);
28
29         public SizedAndThreadedAVLBalancedTree(int capacity) => (_elements, _allocated) = (new
        ↳ TreeElement[capacity], One);
30
31         public TElement Allocate()
32         {
33             var newNode = _allocated;
34             if (IsEmpty(newNode))
35             {
36                 _allocated = Arithmetic.Increment(_allocated);
37                 return newNode;
38             }
39             else
40             {
41                 throw new InvalidOperationException("Allocated tree element is not empty.");
42             }
43         }
44
45         public void Free(TElement node)
46         {
47             while (!EqualityComparer.Equals(_allocated, One) && IsEmpty(node))
48             {
49                 var lastNode = Arithmetic.Decrement(_allocated);
50                 if (EqualityComparer.Equals(lastNode, node))
51                 {
52                     _allocated = lastNode;
53                     node = Arithmetic.Decrement(node);
54                 }
55                 else
56                 {
57                     return;
58                 }
59             }
60         }
61
62         public bool IsEmpty(TElement node) =>
        ↳ 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,
47             ↪ N));
48         if (added.Add(node))
49         {
50             tree.Attach(ref root, node);
51             currentCount++;
52             Assert.Equal(currentCount, (int)UncheckedConverter<TElement,
53                 ↪ int>.Default.Convert(tree.Count()));
54         }
55     }
56     for (var i = 1; i <= N; i++)
57     {
58         TElement node = UncheckedConverter<int,
59             ↪ TElement>.Default.Convert(random.Next(1, N));
60         if (tree.Contains(node, root))
61         {
62             tree.Detach(ref root, node);
63             currentCount--;
64             Assert.Equal(currentCount, (int)UncheckedConverter<TElement,
65                 ↪ int>.Default.Convert(tree.Count()));
66             added.Remove(node);
67         }
68     }
69 }

```

## 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(recursionlessSizeBalancedTree.Allocate,
14                ↪ recursionlessSizeBalancedTree.Free, ref
15                ↪ recursionlessSizeBalancedTree.Root, () => recursionlessSizeBalancedTree.Count,
16                ↪ _n);
17        }
18
19        [Fact]
20        public static void SizeBalancedTreeMultipleAttachAndDetachTest()
21        {
22            var sizeBalancedTree = new SizeBalancedTree<uint>(10000);
23            sizeBalancedTree.TestMultipleCreationsAndDeletions(sizeBalancedTree.Allocate,
24                ↪ sizeBalancedTree.Free, ref sizeBalancedTree.Root, () => sizeBalancedTree.Count,
25                ↪ _n);
26        }
27
28        [Fact]
29        public static void SizedAndThreadedAVLBalancedTreeMultipleAttachAndDetachTest()
30        {
31            var avlTree = new SizedAndThreadedAVLBalancedTree<uint>(10000);
32            avlTree.TestMultipleCreationsAndDeletions(avlTree.Allocate, avlTree.Free, ref
33                ↪ avlTree.Root, () => avlTree.Count, _n);
34        }
35
36        [Fact]
37        public static void RecursionlessSizeBalancedTreeMultipleRandomAttachAndDetachTest()
38        {
39            var recursionlessSizeBalancedTree = new RecursionlessSizeBalancedTree<uint>(10000);
40            recursionlessSizeBalancedTree.TestMultipleRandomCreationsAndDeletions(ref
41                ↪ recursionlessSizeBalancedTree.Root, () => recursionlessSizeBalancedTree.Count,
42                ↪ _n);
43        }
44    }
45 }

```

```

37 [Fact]
38 public static void SizeBalancedTreeMultipleRandomAttachAndDetachTest()
39 {
40     var sizeBalancedTree = new SizeBalancedTree<uint>(10000);
41     sizeBalancedTree.TestMultipleRandomCreationsAndDeletions(ref sizeBalancedTree.Root,
42         ↪ () => sizeBalancedTree.Count, _n);
43 }
44 [Fact]
45 public static void SizedAndThreadedAVLBalancedTreeMultipleRandomAttachAndDetachTest()
46 {
47     var avlTree = new SizedAndThreadedAVLBalancedTree<uint>(10000);
48     avlTree.TestMultipleRandomCreationsAndDeletions(ref avlTree.Root, () =>
49         ↪ avlTree.Count, _n);
50 }
51 }

```



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