

# 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      public abstract class GenericCollectionMethodsBase<TElement>
10     {
11         [MethodImpl(MethodImplOptions.AggressiveInlining)]
12         protected virtual TElement GetZero() => default;
13
14         [MethodImpl(MethodImplOptions.AggressiveInlining)]
15         protected virtual bool EqualToZero(TElement value) => EqualityComparer.Equals(value,
16             ↪ Zero);
17
18         [MethodImpl(MethodImplOptions.AggressiveInlining)]
19         protected virtual bool AreEqual(TElement first, TElement second) =>
20             ↪ EqualityComparer.Equals(first, second);
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected virtual bool GreaterThanZero(TElement value) => Comparer.Compare(value, Zero)
24             ↪ > 0;
25
26         [MethodImpl(MethodImplOptions.AggressiveInlining)]
27         protected virtual bool GreaterThan(TElement first, TElement second) =>
28             ↪ Comparer.Compare(first, second) > 0;
29
30         [MethodImpl(MethodImplOptions.AggressiveInlining)]
31         protected virtual bool GreaterOrEqualThanZero(TElement value) => Comparer.Compare(value,
32             ↪ Zero) >= 0;
33
34         [MethodImpl(MethodImplOptions.AggressiveInlining)]
35         protected virtual bool GreaterOrEqualThan(TElement first, TElement second) =>
36             ↪ Comparer.Compare(first, second) >= 0;
37
38         [MethodImpl(MethodImplOptions.AggressiveInlining)]
39         protected virtual bool LessOrEqualThanZero(TElement value) => Comparer.Compare(value,
40             ↪ Zero) <= 0;
41
42         [MethodImpl(MethodImplOptions.AggressiveInlining)]
43         protected virtual bool LessOrEqualThan(TElement first, TElement second) =>
44             ↪ Comparer.Compare(first, second) <= 0;
45
46         [MethodImpl(MethodImplOptions.AggressiveInlining)]
47         protected virtual bool LessThanZero(TElement value) => Comparer.Compare(value, Zero) < 0;
48
49         [MethodImpl(MethodImplOptions.AggressiveInlining)]
50         protected virtual bool LessThan(TElement first, TElement second) =>
51             ↪ Comparer.Compare(first, second) < 0;
52
53         [MethodImpl(MethodImplOptions.AggressiveInlining)]
54         protected virtual TElement Increment(TElement value) =>
55             ↪ Arithmetic<TElement>.Increment(value);
56
57         [MethodImpl(MethodImplOptions.AggressiveInlining)]
58         protected virtual TElement Decrement(TElement value) =>
59             ↪ Arithmetic<TElement>.Decrement(value);
60
61         [MethodImpl(MethodImplOptions.AggressiveInlining)]
62         protected virtual TElement Add(TElement first, TElement second) =>
63             ↪ Arithmetic<TElement>.Add(first, second);
64
65         [MethodImpl(MethodImplOptions.AggressiveInlining)]
66         protected virtual TElement Subtract(TElement first, TElement second) =>
67             ↪ Arithmetic<TElement>.Subtract(first, second);
68
69         protected readonly TElement Zero;
70         protected readonly TElement One;
71         protected readonly TElement Two;
72         protected readonly EqualityComparer<TElement> EqualityComparer;
73         protected readonly Comparer<TElement> Comparer;
74
75         protected GenericCollectionMethodsBase()
76         {
77             EqualityComparer = EqualityComparer<TElement>.Default;
78         }
79     }
80 }
```

```

65         Comparer = Comparer<TElement>.Default;
66         Zero = GetZero(); //-V3068
67         One = Increment(Zero); //-V3068
68         Two = Increment(One); //-V3068
69     }
70 }
71 }

```

## 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> :
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 (AreEqual(baseElement, GetFirst()))
14             {
15                 SetFirst(newElement);
16             }
17             SetNext(baseElementPrevious, newElement);
18             SetPrevious(baseElement, newElement);
19             IncrementSize();
20         }
21
22         public void AttachAfter(TElement baseElement, TElement newElement)
23         {
24             var baseElementNext = GetNext(baseElement);
25             SetPrevious(newElement, baseElement);
26             SetNext(newElement, baseElementNext);
27             if (AreEqual(baseElement, GetLast()))
28             {
29                 SetLast(newElement);
30             }
31             SetPrevious(baseElementNext, newElement);
32             SetNext(baseElement, newElement);
33             IncrementSize();
34         }
35
36         public void AttachAsFirst(TElement element)
37         {
38             var first = GetFirst();
39             if (EqualToZero(first))
40             {
41                 SetFirst(element);
42                 SetLast(element);
43                 SetPrevious(element, element);
44                 SetNext(element, element);
45                 IncrementSize();
46             }
47             else
48             {
49                 AttachBefore(first, element);
50             }
51         }
52
53         public void AttachAsLast(TElement element)
54         {
55             var last = GetLast();
56             if (EqualToZero(last))
57             {
58                 AttachAsFirst(element);
59             }
60             else
61             {
62                 AttachAfter(last, element);
63             }
64         }
65
66         public void Detach(TElement element)
67         {
68             var elementPrevious = GetPrevious(element);
69             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     }
34 }

```

### 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

```

```

17         {
18             SetNext(baseElementPrevious, newElement);
19         }
20         SetPrevious(baseElement, newElement);
21         IncrementSize();
22     }
23
24     public void AttachAfter(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(newElement);
32         }
33         else
34         {
35             SetPrevious(baseElementNext, newElement);
36         }
37         SetNext(baseElement, newElement);
38         IncrementSize();
39     }
40
41     public void AttachAsFirst(TElement element)
42     {
43         var first = GetFirst();
44         if (EqualToZero(first))
45         {
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> :
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             {
15                 SetFirst(headElement, newElement);
16             }
17             SetNext(baseElementPrevious, newElement);
18             SetPrevious(baseElement, newElement);
19             IncrementSize(headElement);
20         }
21
22         public void AttachAfter(TElement headElement, TElement baseElement, TElement newElement)
23         {
24             var baseElementNext = GetNext(baseElement);
25             SetPrevious(newElement, baseElement);
26             SetNext(newElement, baseElementNext);
27             if (AreEqual(baseElement, GetLast(headElement)))
28             {
29                 SetLast(headElement, newElement);
30             }
31             SetPrevious(baseElementNext, newElement);
32             SetNext(baseElement, newElement);
33             IncrementSize(headElement);
34         }
35
36         public void AttachAsFirst(TElement headElement, TElement element)
37         {
38             var first = GetFirst(headElement);
39             if (EqualToZero(first))
40             {
41                 SetFirst(headElement, element);
42                 SetLast(headElement, element);
43                 SetPrevious(element, element);
44                 SetNext(element, element);
45                 IncrementSize(headElement);
46             }
47         }
48     }
49 }

```

```

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)));

```

```

29     [MethodImpl(MethodImplOptions.AggressiveInlining)]
30     protected void DecrementSize(TElement headElement) => SetSize(headElement,
31         ↪ Decrement(GetSize(headElement)));
32 }
33 }

```

## 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              IncrementSize(headElement);
40          }
41
42          public void AttachAsFirst(TElement headElement, TElement element)
43          {
44              var first = GetFirst(headElement);
45              if (EqualToZero(first))
46              {
47                  SetFirst(headElement, element);
48                  SetLast(headElement, element);
49                  SetPrevious(element, Zero);
50                  SetNext(element, Zero);
51                  IncrementSize(headElement);
52              }
53              else
54              {
55                  AttachBefore(headElement, first, element);
56              }
57          }
58
59          public void AttachAsLast(TElement headElement, TElement element)
60          {
61              var last = GetLast(headElement);
62              if (EqualToZero(last))
63              {
64                  AttachAsFirst(headElement, element);
65              }
66              else
67              {
68                  AttachAfter(headElement, last, element);
69              }
70          }
71      }
72  }

```

```

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))
19                     {
20                         IncrementSize(root);
21                         SetSize(node, One);
22                         left = node;
23                         return;
24                     }
25                     if (FirstIsToTheLeftOfSecond(node, left)) // node.Key less than left.Key
26                     {
27                         if (GreaterThan(Increment(leftSize), rightSize))
28                         {
29                             RightRotate(ref root);
30                         }
31                         else
32                         {
33                             IncrementSize(root);
34                             root = ref left;
35                         }
36                     }
37                     else // node.Key greater than left.Key
38                     {
39                         var leftRightSize = GetSizeOrZero(GetRight(left));
40                         if (GreaterThan(Increment(leftRightSize), rightSize))
41                         {
42                             if (EqualToZero(leftRightSize) && EqualToZero(rightSize))
43                             {
44                                 SetLeft(node, left);
45                                 SetRight(node, root);
46                                 SetSize(node, Add(leftSize, Two)); // Two (2) - node the size of
47                                 ↪ root and a node itself
48                                 SetLeft(root, Zero);
49                                 SetSize(root, One);
50                             }
51                         }
52                     }
53                 }
54             }
55         }
56     }
57 }

```



```

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
                    ↪ of root and a node itself
92                 SetRight(root, Zero);
93                 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)),
                ↪ decrementedLeftSize))
122             {

```

```

123         LeftRotate(ref root);
124     }
125     else if (GreaterThan(GetSizeOrZero(GetLeftOrDefault(right)),
126         ↪ decrementedLeftSize))
127     {
128         RightRotate(ref right);
129         LeftRotate(ref root);
130     }
131     else
132     {
133         DecrementSize(root);
134         root = ref left;
135     }
136 }
137 else if (FirstIsToTheRightOfSecond(node, root)) // node.Key greater than root.Key
138 {
139     var decrementedRightSize = Decrement(rightSize);
140     if (GreaterThan(GetSizeOrZero(GetLeftOrDefault(left)), decrementedRightSize))
141     {
142         RightRotate(ref root);
143     }
144     else if (GreaterThan(GetSizeOrZero(GetRightOrDefault(left)),
145         ↪ decrementedRightSize))
146     {
147         LeftRotate(ref left);
148         RightRotate(ref root);
149     }
150     else
151     {
152         DecrementSize(root);
153         root = ref right;
154     }
155 }
156 else // key equals to root.Key
157 {
158     if (GreaterThanZero(leftSize) && GreaterThanZero(rightSize))
159     {
160         TElement replacement;
161         if (GreaterThan(leftSize, rightSize))
162         {
163             replacement = GetRighttest(left);
164             DetachCore(ref left, replacement);
165         }
166         else
167         {
168             replacement = GetLefttest(right);
169             DetachCore(ref right, replacement);
170         }
171         SetLeft(replacement, left);
172         SetRight(replacement, right);
173         SetSize(replacement, Add(leftSize, rightSize));
174         root = replacement;
175     }
176     else if (GreaterThanZero(leftSize))
177     {
178         root = left;
179     }
180     else if (GreaterThanZero(rightSize))
181     {
182         root = right;
183     }
184     else
185     {
186         root = Zero;
187     }
188     ClearNode(node);
189     return;
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         var nodeToDetachLeft = GetLeft(nodeToDetach);
57         var node = GetRight(nodeToDetach);
58         if (!EqualToZero(nodeToDetachLeft) && !EqualToZero(node))
59         {
60             var lefttestNode = GetLefttest(node);
61             DetachCore(ref GetRightReference(nodeToDetach), lefttestNode);
62             SetLeft(lefttestNode, nodeToDetachLeft);
63             node = GetRight(nodeToDetach);
64             if (!EqualToZero(node))
65             {
66                 SetRight(lefttestNode, node);
67                 SetSize(lefttestNode, Increment(Add(GetSize(nodeToDetachLeft),
68                     ↳ GetSize(node))));
69             }
70             else
71             {
72                 SetSize(lefttestNode, Increment(GetSize(nodeToDetachLeft)));
73             }
74             replacementNode = lefttestNode;
75         }
76         else if (!EqualToZero(nodeToDetachLeft))
77         {
78             replacementNode = nodeToDetachLeft;
79         }
80         else if (!EqualToZero(node))
81         {
82             replacementNode = node;
83         }
84         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             LeftMaintain(ref GetLeftReference(root));
129             RightMaintain(ref GetRightReference(root));
130             LeftMaintain(ref root);
131             RightMaintain(ref root);
132         }
133     }
134 }
135
136 private void RightMaintain(ref TElement root)
137 {
138     if (!EqualToZero(root))
139     {
140         var rootRightNode = GetRight(root);
141         if (!EqualToZero(rootRightNode))
142         {
143             var rootLeftNode = GetLeft(root);
144             var rootLeftNodeSize = GetSize(rootLeftNode);
145             var rootRightNodeRightNode = GetRight(rootRightNode);
146             if (!EqualToZero(rootRightNodeRightNode) &&
147                 (EqualToZero(rootLeftNode) ||
148                  ⇨ GreaterThan(GetSize(rootRightNodeRightNode), rootLeftNodeSize)))
149             {
150                 LeftRotate(ref root);
151             }
152             else
153             {
154                 var rootRightNodeLeftNode = GetLeft(rootRightNode);
155                 if (!EqualToZero(rootRightNodeLeftNode) &&
156                     (EqualToZero(rootLeftNode) ||
157                      ⇨ GreaterThan(GetSize(rootRightNodeLeftNode), rootLeftNodeSize)))
158                 {
159                     RightRotate(ref GetRightReference(root));
160                     LeftRotate(ref root);
161                 }
162             }
163         }
164     }
165 }

```

```

157         }
158         else
159         {
160             return;
161         }
162     }
163     LeftMaintain(ref GetLeftReference(root));
164     RightMaintain(ref GetRightReference(root));
165     LeftMaintain(ref root);
166     RightMaintain(ref root);
167 }
168 }
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
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 GetRighttest(TElement current)
29         {
30             var currentRight = GetRightOrDefault(current);
31             while (!EqualToZero(currentRight))
32             {
33                 current = currentRight;
34                 currentRight = GetRightOrDefault(current);
35             }
36             return current;
37         }
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected override TElement GetLefttest(TElement current)
41         {
42             var currentLeft = GetLeftOrDefault(current);
43             while (!EqualToZero(currentLeft))
44             {
45                 current = currentLeft;
46                 currentLeft = GetLeftOrDefault(current);
47             }
48             return current;
49         }
50
51         public override bool Contains(TElement node, TElement root)
52         {
53             while (!EqualToZero(root))
54             {
55                 if (FirstIsToTheLeftOfSecond(node, root)) // node.Key < root.Key
56                 {
57                     root = GetLeftOrDefault(root);
58                 }
59                 else if (FirstIsToTheRightOfSecond(node, root)) // node.Key > root.Key
60                 {
61                     root = GetRightOrDefault(root);
62                 }
63             }
64         }
65     }
66 }

```

```

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,
80     ↪ (sbyte)(GetBalance(node) + 1));
81
82 [MethodImpl(MethodImplOptions.AggressiveInlining)]
83 protected void DecrementBalance(TElement node) => SetBalance(node,
84     ↪ (sbyte)(GetBalance(node) - 1));
85
86 [MethodImpl(MethodImplOptions.AggressiveInlining)]
87 protected override TElement GetLeftOrDefault(TElement node) => GetLeftIsChild(node) ?
88     ↪ GetLeft(node) : default;
89
90 [MethodImpl(MethodImplOptions.AggressiveInlining)]
91 protected override TElement GetRightOrDefault(TElement node) => GetRightIsChild(node) ?
92     ↪ GetRight(node) : default;
93
94 [MethodImpl(MethodImplOptions.AggressiveInlining)]
95 protected abstract bool GetLeftIsChild(TElement node);
96
97 [MethodImpl(MethodImplOptions.AggressiveInlining)]
98 protected abstract void SetLeftIsChild(TElement node, bool value);
99
100 [MethodImpl(MethodImplOptions.AggressiveInlining)]
101 protected abstract bool GetRightIsChild(TElement node);
102
103 [MethodImpl(MethodImplOptions.AggressiveInlining)]
104 protected abstract void SetRightIsChild(TElement node, bool value);
105
106 [MethodImpl(MethodImplOptions.AggressiveInlining)]
107 protected abstract sbyte GetBalance(TElement node);
108
109 [MethodImpl(MethodImplOptions.AggressiveInlining)]
110 protected abstract void SetBalance(TElement node, sbyte value);
111
112 protected override void AttachCore(ref TElement root, TElement node)
113 {
114     unchecked
115     {
116         // TODO: Check what is faster to use simple array or array from array pool
117         // TODO: Try to use stackalloc as an optimization (requires code generation,
118         ↪ because of generics)
119
120 #if USEARRAYPOOL
121         var path = ArrayPool.Allocate<TElement>(MaxPath);
122         var pathPosition = 0;
123         path[pathPosition++] = default;
124 #else
125         var path = new TElement[_maxPath];
126         var pathPosition = 1;
127 #endif
128
129         var currentNode = root;
130         while (true)
131         {
132             if (FirstIsToTheLeftOfSecond(node, currentNode))
133             {
134                 if (GetLeftIsChild(currentNode))
135                 {
136                     IncrementSize(currentNode);
137                     path[pathPosition++] = currentNode;
138                     currentNode = GetLeft(currentNode);
139                 }
140                 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 // 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);

```

```

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
415                 {
416                     if (AreEqual(parent, default))
417                     {
418                         root = Zero;
419                     }
420                     else if (isLeftNode)
421                     {
422                         SetLeftIsChild(parent, false);
423                         SetLeft(parent, GetLeft(currentNode));
424                         IncrementBalance(parent);
425                     }
426                     else
427                     {
428                         SetRightIsChild(parent, false);
429                         SetRight(parent, GetRight(currentNode));
430                         DecrementBalance(parent);
431                     }
432                 }
433                 else // node has a right child
434                 {
435                     var successor = GetNext(currentNode);
436                     SetLeft(successor, GetLeft(currentNode));
437                     var right = GetRight(currentNode);
438                     if (AreEqual(parent, default))
439                     {
440                         root = right;
441                     }
442                     else if (isLeftNode)
443                     {
444                         SetLeft(parent, right);
445                         IncrementBalance(parent);
446                     }
447                 }
448             }
449         }
450     }

```

```

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             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
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)]
51         protected virtual TElement GetRightOrDefault(TElement node) => AreEqual(node, default) ?
52             ↳ default : GetRight(node);
53
54         [MethodImpl(MethodImplOptions.AggressiveInlining)]
55         protected void IncrementSize(TElement node) => SetSize(node, Increment(GetSize(node)));
56
57         [MethodImpl(MethodImplOptions.AggressiveInlining)]
58         protected void DecrementSize(TElement node) => SetSize(node, Decrement(GetSize(node)));
59
60         [MethodImpl(MethodImplOptions.AggressiveInlining)]
61         protected TElement GetLeftSize(TElement node) => GetSizeOrZero(GetLeftOrDefault(node));
62
63         [MethodImpl(MethodImplOptions.AggressiveInlining)]
64         protected TElement GetRightSize(TElement node) => GetSizeOrZero(GetRightOrDefault(node));
65
66         [MethodImpl(MethodImplOptions.AggressiveInlining)]
67         protected TElement GetSizeOrZero(TElement node) => EqualToZero(node) ? Zero :
68             ↳ GetSize(node);
69
70         [MethodImpl(MethodImplOptions.AggressiveInlining)]
71         protected void FixSize(TElement node) => SetSize(node, Increment(Add(GetLeftSize(node),
72             ↳ GetRightSize(node))));
73
74         [MethodImpl(MethodImplOptions.AggressiveInlining)]
75         protected void LeftRotate(ref TElement root) => root = LeftRotate(root);
76
77         [MethodImpl(MethodImplOptions.AggressiveInlining)]
78         protected TElement LeftRotate(TElement root)
79         {
80             var right = GetRight(root);
81             #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
82                 if (EqualToZero(right))
83             {

```

```

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
212                     ↳ дереве.");
213             }
214         #endif
215         DetachCore(ref root, node);
216         #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
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     }

```

```

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         public void Free(TElement node)
45         {
46             while (!EqualityComparer.Equals(_allocated, One) && IsEmpty(node))
47             {
48                 var lastNode = Arithmetic.Decrement(_allocated);
49                 if (EqualityComparer.Equals(lastNode, node))
50                 {
51                     _allocated = lastNode;
52                     node = Arithmetic.Decrement(node);
53                 }
54                 else
55                 {
56                     return;
57                 }
58             }
59         }
60
61         public bool IsEmpty(TElement node) =>
62             ↳ EqualityComparer<TreeElement>.Default.Equals(GetElement(node), default);
63
64         protected override bool FirstIsToTheLeftOfSecond(TElement first, TElement second) =>
65             ↳ Comparer.Compare(first, second) < 0;
66
67         protected override bool FirstIsToTheRightOfSecond(TElement first, TElement second) =>
68             ↳ Comparer.Compare(first, second) > 0;
69
70         protected override ref TElement GetLeftReference(TElement node) => ref
71             ↳ GetElement(node).Left;
72
73         protected override TElement GetLeft(TElement node) => GetElement(node).Left;
74
75     }
76 }

```

```

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 =
    ↳ 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) =>
63     ↳ EqualityComparer<TreeElement>.Default.Equals(GetElement(node), default);
64
65 protected override bool FirstIsToTheLeftOfSecond(TElement first, TElement second) =>
66     ↳ Comparer.Compare(first, second) < 0;
67
68 protected override bool FirstIsToTheRightOfSecond(TElement first, TElement second) =>
69     ↳ Comparer.Compare(first, second) > 0;
70
71 protected override sbyte GetBalance(TElement node) => GetElement(node).Balance;
72
73 protected override bool GetLeftIsChild(TElement node) => GetElement(node).LeftIsChild;
74
75 protected override ref TElement GetLeftReference(TElement node) => ref
76     ↳ GetElement(node).Left;
77
78 protected override TElement GetLeft(TElement node) => GetElement(node).Left;
79
80 protected override bool GetRightIsChild(TElement node) => GetElement(node).RightIsChild;
81
82 protected override ref TElement GetRightReference(TElement node) => ref
83     ↳ GetElement(node).Right;
84
85 protected override TElement GetRight(TElement node) => GetElement(node).Right;
86
87 protected override TElement GetSize(TElement node) => GetElement(node).Size;
88
89 protected override void PrintNodeValue(TElement node, StringBuilder sb) =>
90     ↳ sb.Append(node);
91
92 protected override void SetBalance(TElement node, sbyte value) =>
93     ↳ GetElement(node).Balance = value;
94
95 protected override void SetLeft(TElement node, TElement left) => GetElement(node).Left =
96     ↳ left;
97
98 protected override void SetLeftIsChild(TElement node, bool value) =>
99     ↳ GetElement(node).LeftIsChild = value;
100
101 protected override void SetRight(TElement node, TElement right) =>
102     ↳ GetElement(node).Right = right;
103
104 protected override void SetRightIsChild(TElement node, bool value) =>
105     ↳ GetElement(node).RightIsChild = value;
106
107 protected override void SetSize(TElement node, TElement size) => GetElement(node).Size =
108     ↳ size;
109
110 private ref TreeElement GetElement(TElement node) => ref
111     ↳ _elements[UncheckedConverter<TElement, long>.Default.Convert(node)];
112 }

```

## 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
12             ↪ SizedBinaryTreeMethodsBase<TElement> tree, Func<TElement> allocate, Action<TElement>
13             ↪ free, ref TElement root, Func<TElement> treeCount, int maximumOperationsPerCycle)
14         {
15             for (var N = 1; N < maximumOperationsPerCycle; N++)
16             {
17                 var currentCount = 0;
18                 for (var i = 0; i < N; i++)
19                 {
20                     var node = allocate();
21                     tree.Attach(ref root, node);
22                     currentCount++;
23                     Assert.Equal(currentCount, (int)UncheckedConverter<TElement,
24                         ↪ int>.Default.Convert(treeCount()));
25                 }
26                 for (var i = 1; i <= N; i++)
27                 {
28                     TElement node = UncheckedConverter<int, TElement>.Default.Convert(i);
29                     if (tree.Contains(node, root))
30                     {
31                         tree.Detach(ref root, node);
32                         free(node);
33                         currentCount--;
34                         Assert.Equal(currentCount, (int)UncheckedConverter<TElement,
35                             ↪ int>.Default.Convert(treeCount()));
36                     }
37                 }
38             }
39         }
40
41         public static void TestMultipleRandomCreationsAndDeletions<TElement>(this
42             ↪ SizedBinaryTreeMethodsBase<TElement> tree, ref TElement root, Func<TElement>
43             ↪ treeCount, int maximumOperationsPerCycle)
44         {
45             var random = new System.Random(0);
46             var added = new HashSet<TElement>();
47             var currentCount = 0;
48             for (var N = 1; N < maximumOperationsPerCycle; N++)
49             {
50                 for (var i = 0; i < N; i++)
51                 {
52                     var node = UncheckedConverter<int, TElement>.Default.Convert(random.Next(1,
53                         ↪ N));
54                     if (added.Add(node))
55                     {
56                         tree.Attach(ref root, node);
57                         currentCount++;
58                         Assert.Equal(currentCount, (int)UncheckedConverter<TElement,
59                             ↪ int>.Default.Convert(treeCount()));
60                     }
61                 }
62                 for (var i = 1; i <= N; i++)
63                 {
64                     TElement node = UncheckedConverter<int,
65                         ↪ TElement>.Default.Convert(random.Next(1, N));
66                     if (tree.Contains(node, root))
67                     {
68                         tree.Detach(ref root, node);
69                         currentCount--;
70                         Assert.Equal(currentCount, (int)UncheckedConverter<TElement,
71                             ↪ int>.Default.Convert(treeCount()));
72                         added.Remove(node);
73                     }
74                 }
75             }
76         }
77     }
78 }

```

```
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
14             ↪ ancedTree.Allocate, 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         [Fact]
46         public static void SizeBalancedTreeMultipleRandomAttachAndDetachTest()
47         {
48             var sizeBalancedTree = new SizeBalancedTree<uint>(10000);
49             sizeBalancedTree.TestMultipleRandomCreationsAndDeletions(ref sizeBalancedTree.Root,
50             ↪ () => sizeBalancedTree.Count, _n);
51         }
52
53         [Fact]
54         public static void SizedAndThreadedAVLBalancedTreeMultipleRandomAttachAndDetachTest()
55         {
56             var avlTree = new SizedAndThreadedAVLBalancedTree<uint>(10000);
57             avlTree.TestMultipleRandomCreationsAndDeletions(ref avlTree.Root, () =>
58             ↪ avlTree.Count, _n);
59         }
60     }
61 }
```

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