

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
12         /// <summary>
13         /// <para>Represents a range between minimum and maximum values.</para>
14         /// <para>Представляет диапазон между минимальным и максимальным значениями.</para>
15         /// </summary>
16         /// <remarks>
17         /// <para>Based on <a href="http://stackoverflow.com/questions/5343006/is-there-a-c-_">
18         ↪ sharp-type-for-representing-an-integer-range">the question at
19         ↪ StackOverflow</a>.</para>
20         /// <para>Основано на <a href="http://stackoverflow.com/questions/5343006/is-there-a-_">
21         ↪ -c-sharp-type-for-representing-an-integer-range">вопросе в
22         ↪ StackOverflow</a>.</para>
23         /// </remarks>
24
25         [MethodImpl(MethodImplOptions.AggressiveInlining)]
26         protected virtual TElement GetZero() => default;
27
28         [MethodImpl(MethodImplOptions.AggressiveInlining)]
29         protected virtual bool EqualToZero(TElement value) => EqualityComparer.Equals(value,
30         ↪ Zero);
31
32         [MethodImpl(MethodImplOptions.AggressiveInlining)]
33         protected virtual bool AreEqual(TElement first, TElement second) =>
34         ↪ EqualityComparer.Equals(first, second);
35
36         [MethodImpl(MethodImplOptions.AggressiveInlining)]
37         protected virtual bool GreaterThanZero(TElement value) => Comparer.Compare(value, Zero)
38         ↪ > 0;
39
40         [MethodImpl(MethodImplOptions.AggressiveInlining)]
41         protected virtual bool GreaterThan(TElement first, TElement second) =>
42         ↪ Comparer.Compare(first, second) > 0;
43
44         [MethodImpl(MethodImplOptions.AggressiveInlining)]
45         protected virtual bool GreaterOrEqualThanZero(TElement value) => Comparer.Compare(value,
46         ↪ Zero) >= 0;
47
48         [MethodImpl(MethodImplOptions.AggressiveInlining)]
49         protected virtual bool GreaterOrEqualThan(TElement first, TElement second) =>
50         ↪ Comparer.Compare(first, second) >= 0;
51
52         [MethodImpl(MethodImplOptions.AggressiveInlining)]
53         protected virtual bool LessOrEqualThanZero(TElement value) => Comparer.Compare(value,
54         ↪ Zero) <= 0;
55
56         [MethodImpl(MethodImplOptions.AggressiveInlining)]
57         protected virtual bool LessOrEqualThan(TElement first, TElement second) =>
58         ↪ Comparer.Compare(first, second) <= 0;
59
60         [MethodImpl(MethodImplOptions.AggressiveInlining)]
61         protected virtual bool LessThanZero(TElement value) => Comparer.Compare(value, Zero) < 0;
62
63         [MethodImpl(MethodImplOptions.AggressiveInlining)]
64         protected virtual bool LessThan(TElement first, TElement second) =>
65         ↪ Comparer.Compare(first, second) < 0;
66
67         [MethodImpl(MethodImplOptions.AggressiveInlining)]
68         protected virtual TElement Increment(TElement value) =>
69         ↪ Arithmetic<TElement>.Increment(value);
70
71         [MethodImpl(MethodImplOptions.AggressiveInlining)]
72         protected virtual TElement Decrement(TElement value) =>
73         ↪ Arithmetic<TElement>.Decrement(value);
74
75         [MethodImpl(MethodImplOptions.AggressiveInlining)]
76     }
```

```

61     protected virtual TElement Add(TElement first, TElement second) =>
        ↪ Arithmetic<TElement>.Add(first, second);
62
63     [MethodImpl(MethodImplOptions.AggressiveInlining)]
64     protected virtual TElement Subtract(TElement first, TElement second) =>
        ↪ Arithmetic<TElement>.Subtract(first, second);
65
66     protected readonly TElement Zero;
67     protected readonly TElement One;
68     protected readonly TElement Two;
69     protected readonly EqualityComparer<TElement> EqualityComparer;
70     protected readonly Comparer<TElement> Comparer;
71
72     protected GenericCollectionMethodsBase()
73     {
74
75         /// <summary>
76         /// <para>Represents a range between minimum and maximum values.</para>
77         /// <para>Представляет диапазон между минимальным и максимальным
78         ↪ значениями.</para>
79         /// </summary>
80         /// <remarks>
81         /// <para>Based on <a href="http://stackoverflow.com/questions/5343006/is-there-
82         ↪ a-c-sharp-type-for-representing-an-integer-range">the question at
83         ↪ StackOverflow</a>.</para>
84         /// <para>Основано на <a href="http://stackoverflow.com/questions/5343006/is-the-
85         ↪ re-a-c-sharp-type-for-representing-an-integer-range">вопросе в
86         ↪ StackOverflow</a>.</para>
87         /// </remarks>
88         EqualityComparer = EqualityComparer<TElement>.Default;
89         Comparer = Comparer<TElement>.Default;
90         Zero = GetZero(); //-V3068
91         One = Increment(Zero); //-V3068
92         Two = Increment(One); //-V3068
93     }
94 }
95

```

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             {

```

```

40         SetFirst(element);
41         SetLast(element);
42         SetPrevious(element, element);
43         SetNext(element, element);
44         IncrementSize();
45     }
46     else
47     {
48         AttachBefore(first, element);
49     }
50 }
51
52 public void AttachAsLast(TElement element)
53 {
54     var last = GetLast();
55     if (EqualToZero(last))
56     {
57         AttachAsFirst(element);
58     }
59     else
60     {
61         AttachAfter(last, element);
62     }
63 }
64
65 public void Detach(TElement element)
66 {
67     var elementPrevious = GetPrevious(element);
68     var elementNext = GetNext(element);
69     if (AreEqual(elementNext, element))
70     {
71         SetFirst(Zero);
72         SetLast(Zero);
73     }
74     else
75     {
76         SetNext(elementPrevious, elementNext);
77         SetPrevious(elementNext, elementPrevious);
78         if (AreEqual(element, GetFirst()))
79         {
80             SetFirst(elementNext);
81         }
82         if (AreEqual(element, GetLast()))
83         {
84             SetLast(elementPrevious);
85         }
86     }
87     SetPrevious(element, Zero);
88     SetNext(element, Zero);
89     DecrementSize();
90 }
91 }
92 }

```

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

```

1 using System.Runtime.CompilerServices;
2
3 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
4
5 namespace Platform.Collections.Methods.Lists
6 {
7     public abstract class AbsoluteDoublyLinkedListMethodsBase<TElement> :
8     ↪ DoublyLinkedListMethodsBase<TElement>
9     {
10         [MethodImpl(MethodImplOptions.AggressiveInlining)]
11         protected abstract TElement GetFirst();
12
13         [MethodImpl(MethodImplOptions.AggressiveInlining)]
14         protected abstract TElement GetLast();
15
16         [MethodImpl(MethodImplOptions.AggressiveInlining)]
17         protected abstract TElement GetSize();
18
19         [MethodImpl(MethodImplOptions.AggressiveInlining)]
20         protected abstract void SetFirst(TElement element);
21
22         [MethodImpl(MethodImplOptions.AggressiveInlining)]
23         protected abstract void SetLast(TElement element);
24     }
25 }

```

```

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              {
64                  AttachAsFirst(element);
65              }
66              else
67              {

```

```

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 (EqualZero(elementPrevious))
76     {
77         SetFirst(elementNext);
78     }
79     else
80     {
81         SetNext(elementPrevious, elementNext);
82     }
83     if (EqualZero(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         }
20     }
21 }

```

```

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             IncrementSize(headElement);
40         }
41
42         public void AttachAsFirst(TElement headElement, TElement element)
43         {

```

```

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))
19                      {
20                          IncrementSize(root);
21                          SetSize(node, One);
22                          left = node;
23                          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);
96                     root = node;
97                     return;
98                 }
99                 RightRotate(ref right);
100                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                 SetLeft(replacement, left);
173                 SetRight(replacement, right);
174                 SetSize(replacement, Add(leftSize, rightSize));
175                 root = replacement;
176             }
177         }
178     }
179 }

```

```

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             var nodeToDetachLeft = GetLeft(nodeToDetach);
57             var node = GetRight(nodeToDetach);
58             if (!EqualToZero(nodeToDetachLeft) && !EqualToZero(node))

```

```

58     {
59         var lefttestNode = GetLefttest(node);
60         DetachCore(ref GetRightReference(nodeToDetach), lefttestNode);
61         SetLeft(lefttestNode, nodeToDetachLeft);
62         node = GetRight(nodeToDetach);
63         if (!EqualToZero(node))
64         {
65             SetRight(lefttestNode, node);
66             SetSize(lefttestNode, Increment(Add(GetSize(nodeToDetachLeft),
67                 ↪ GetSize(node))));
68         }
69         else
70         {
71             SetSize(lefttestNode, Increment(GetSize(nodeToDetachLeft)));
72         }
73         replacementNode = lefttestNode;
74     }
75     else if (!EqualToZero(nodeToDetachLeft))
76     {
77         replacementNode = nodeToDetachLeft;
78     }
79     else if (!EqualToZero(node))
80     {
81         replacementNode = node;
82     }
83     if (AreEqual(root, nodeToDetach))
84     {
85         root = replacementNode;
86     }
87     else if (AreEqual(GetLeft(parent), nodeToDetach))
88     {
89         SetLeft(parent, replacementNode);
90     }
91     else if (AreEqual(GetRight(parent), nodeToDetach))
92     {
93         SetRight(parent, replacementNode);
94     }
95     ClearNode(nodeToDetach);
96 }
97 private void LeftMaintain(ref TElement root)
98 {
99     if (!EqualToZero(root))
100     {
101         var rootLeftNode = GetLeft(root);
102         if (!EqualToZero(rootLeftNode))
103         {
104             var rootRightNode = GetRight(root);
105             var rootRightNodeSize = GetSize(rootRightNode);
106             var rootLeftNodeLeftNode = GetLeft(rootLeftNode);
107             if (!EqualToZero(rootLeftNodeLeftNode) &&
108                 (EqualToZero(rootRightNode) ||
109                 ↪ GreaterThan(GetSize(rootLeftNodeLeftNode), rootRightNodeSize)))
110             {
111                 RightRotate(ref root);
112             }
113             else
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 }

```

```

133 private void RightMaintain(ref TElement root)
134 {
135     if (!EqualToZero(root))
136     {
137         var rootRightNode = GetRight(root);
138         if (!EqualToZero(rootRightNode))
139         {
140             var rootLeftNode = GetLeft(root);
141             var rootLeftNodeSize = GetSize(rootLeftNode);
142             var rootRightNodeRightNode = GetRight(rootRightNode);
143             if (!EqualToZero(rootRightNodeRightNode) &&
144                 (EqualToZero(rootLeftNode) ||
145                  ⇨ GreaterThan(GetSize(rootRightNodeRightNode), rootLeftNodeSize)))
146             {
147                 LeftRotate(ref root);
148             }
149             else
150             {
151                 var rootRightNodeLeftNode = GetLeft(rootRightNode);
152                 if (!EqualToZero(rootRightNodeLeftNode) &&
153                     (EqualToZero(rootLeftNode) ||
154                      ⇨ GreaterThan(GetSize(rootRightNodeLeftNode), rootLeftNodeSize)))
155                 {
156                     RightRotate(ref GetRightReference(root));
157                     LeftRotate(ref root);
158                 }
159                 else
160                 {
161                     return;
162                 }
163             }
164             LeftMaintain(ref GetLeftReference(root));
165             RightMaintain(ref GetRightReference(root));
166             LeftMaintain(ref root);
167             RightMaintain(ref root);
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 GetRightest(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 }

```

```

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,
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)

```

```

109     {
110         unchecked
111         {
112             // TODO: Check what is faster to use simple array or array from array pool
113             // TODO: Try to use stackalloc as an optimization (requires code generation,
114             // ↳ because of generics)
115         }
116     }
117 #if USEARRAYPOOL
118     var path = ArrayPool.Allocate<TElement>(MaxPath);
119     var pathPosition = 0;
120     path[pathPosition++] = default;
121 #else
122     var path = new TElement[_maxPath];
123     var pathPosition = 1;
124 #endif
125 while (true)
126 {
127     var currentNode = root;
128     while (true)
129     {
130         if (FirstIsToTheLeftOfSecond(node, currentNode))
131         {
132             if (GetLeftIsChild(currentNode))
133             {
134                 IncrementSize(currentNode);
135                 path[pathPosition++] = currentNode;
136                 currentNode = GetLeft(currentNode);
137             }
138             else
139             {
140                 // Threads
141                 SetLeft(node, GetLeft(currentNode));
142                 SetRight(node, currentNode);
143                 SetLeft(currentNode, node);
144                 SetLeftIsChild(currentNode, true);
145                 DecrementBalance(currentNode);
146                 SetSize(node, One);
147                 FixSize(currentNode); // Should be incremented already
148                 break;
149             }
150         }
151         else if (FirstIsToTheRightOfSecond(node, currentNode))
152         {
153             if (GetRightIsChild(currentNode))
154             {
155                 IncrementSize(currentNode);
156                 path[pathPosition++] = currentNode;
157                 currentNode = GetRight(currentNode);
158             }
159             else
160             {
161                 // Threads
162                 SetRight(node, GetRight(currentNode));
163                 SetLeft(node, currentNode);
164                 SetRight(currentNode, node);
165                 SetRightIsChild(currentNode, true);
166                 IncrementBalance(currentNode);
167                 SetSize(node, One);
168                 FixSize(currentNode); // Should be incremented already
169                 break;
170             }
171         }
172         else
173         {
174             throw new InvalidOperationException("Node with the same key already
175             ↳ attached to a tree.");
176         }
177     }
178 }
179 // Restore balance. This is the goodness of a non-recursive
180 // implementation, when we are done with balancing we 'break'
181 // the loop and we are done.
182 while (true)
183 {
184     var parent = path[--pathPosition];
185     var isLeftNode = !AreEqual(parent, default) && AreEqual(currentNode,
186     ↳ GetLeft(parent));
187     var currentNodeBalance = GetBalance(currentNode);
188     if (currentNodeBalance < -1 || currentNodeBalance > 1)
189     {
190         currentNode = Balance(currentNode);
191         if (AreEqual(parent, default))
192         {
193             // ...
194         }
195     }
196 }

```

```

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
415             {
416                 if (AreEqual(parent, default))
417                 {
418                     root = Zero;
419                 }
420             }
421         }
422     }
423 }

```

```

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         {
570             IncrementBalance(balanceParent);
571         }
572         else
573         {
574             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 FirstIsToTheLeftOfSecond(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 }

```

```

53 [MethodImpl(MethodImplOptions.AggressiveInlining)]
54 protected void DecrementSize(TElement node) => SetSize(node, Decrement(GetSize(node)));
55
56 [MethodImpl(MethodImplOptions.AggressiveInlining)]
57 protected TElement GetLeftSize(TElement node) => GetSizeOrZero(GetLeftOrDefault(node));
58
59 [MethodImpl(MethodImplOptions.AggressiveInlining)]
60 protected TElement GetRightSize(TElement node) => GetSizeOrZero(GetRightOrDefault(node));
61
62 [MethodImpl(MethodImplOptions.AggressiveInlining)]
63 protected TElement GetSizeOrZero(TElement node) => EqualToZero(node) ? Zero :
64     ↳ GetSize(node);
65
66 [MethodImpl(MethodImplOptions.AggressiveInlining)]
67 protected void FixSize(TElement node) => SetSize(node, Increment(Add(GetLeftSize(node),
68     ↳ GetRightSize(node))));
69
70 [MethodImpl(MethodImplOptions.AggressiveInlining)]
71 protected void LeftRotate(ref TElement root) => root = LeftRotate(root);
72
73 [MethodImpl(MethodImplOptions.AggressiveInlining)]
74 protected TElement LeftRotate(TElement root)
75 {
76     var right = GetRight(root);
77     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
78         if (EqualToZero(right))
79         {
80             throw new InvalidOperationException("Right is null.");
81         }
82     #endif
83     SetRight(root, GetLeft(right));
84     SetLeft(right, root);
85     SetSize(right, GetSize(root));
86     FixSize(root);
87     return right;
88 }
89
90 [MethodImpl(MethodImplOptions.AggressiveInlining)]
91 protected void RightRotate(ref TElement root) => root = RightRotate(root);
92
93 [MethodImpl(MethodImplOptions.AggressiveInlining)]
94 protected TElement RightRotate(TElement root)
95 {
96     var left = GetLeft(root);
97     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
98         if (EqualToZero(left))
99         {
100             throw new InvalidOperationException("Left is null.");
101         }
102     #endif
103     SetLeft(root, GetRight(left));
104     SetRight(left, root);
105     SetSize(left, GetSize(root));
106     FixSize(root);
107     return left;
108 }
109
110 [MethodImpl(MethodImplOptions.AggressiveInlining)]
111 protected virtual TElement GetRighttest(TElement current)
112 {
113     var currentRight = GetRight(current);
114     while (!EqualToZero(currentRight))
115     {
116         current = currentRight;
117         currentRight = GetRight(current);
118     }
119     return current;
120 }
121
122 [MethodImpl(MethodImplOptions.AggressiveInlining)]
123 protected virtual TElement GetLefttest(TElement current)
124 {
125     var currentLeft = GetLeft(current);
126     while (!EqualToZero(currentLeft))
127     {
128         current = currentLeft;
129         currentLeft = GetLeft(current);
130     }
131 }

```

```

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         public void Free(TElement node)
45         {
46             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
27             ↳ TreeElement[capacity], One);
28     }
29 }

```

```

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) =>
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 }

```

1.15 ./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) =>
85         ↪ sb.Append(node);
86
87     protected override void SetBalance(TElement node, sbyte value) =>
88         ↪ GetElement(node).Balance = value;
89
90     protected override void SetLeft(TElement node, TElement left) => GetElement(node).Left =
91         ↪ left;
92
93     protected override void SetLeftIsChild(TElement node, bool value) =>
94         ↪ GetElement(node).LeftIsChild = value;
95
96     protected override void SetRight(TElement node, TElement right) =>
97         ↪ GetElement(node).Right = right;
98
99     protected override void SetRightIsChild(TElement node, bool value) =>
100         ↪ GetElement(node).RightIsChild = value;
101
102     protected override void SetSize(TElement node, TElement size) => GetElement(node).Size =
103         ↪ size;
104
105     private ref TreeElement GetElement(TElement node) => ref
106         ↪ _elements[UncheckedConverter<TElement, long>.Default.Convert(node)];
107 }
108 }

```

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++)

```

```

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(treeCount()));
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(treeCount()));
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(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);

```

```
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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