

LinksPlatform's Platform.Collections.Methods Class Library

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

```
1 using System.Collections.Generic;
2 using System.Runtime.CompilerServices;
3 using Platform.Numbers;
4
5 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
6
7 namespace Platform.Collections.Methods
8 {
9     /// <summary>
10     /// <para>Represents a range between minimum and maximum values.</para>
11     /// <para>Представляет диапазон между минимальным и максимальным значениями.</para>
12     /// </summary>
13     /// <remarks>
14     /// <para>Based on <a href="http://stackoverflow.com/questions/5343006/is-there-a-c-sharp-type-for-representing-an-integer-range">the question at StackOverflow</a>.</para>
15     /// <para>Основано на <a href="http://stackoverflow.com/questions/5343006/is-there-a-c-sharp-type-for-representing-an-integer-range">вопросе в StackOverflow</a>.</para>
16     /// </remarks>
17     public abstract class GenericCollectionMethodsBase<TElement>
18     {
19
20         [MethodImpl(MethodImplOptions.AggressiveInlining)]
21         protected virtual TElement GetZero() => default;
22
23         [MethodImpl(MethodImplOptions.AggressiveInlining)]
24         protected virtual bool EqualToZero(TElement value) => EqualityComparer.Equals(value,
25             ↪ Zero);
26
27         [MethodImpl(MethodImplOptions.AggressiveInlining)]
28         protected virtual bool AreEqual(TElement first, TElement second) =>
29             ↪ EqualityComparer.Equals(first, second);
30
31         [MethodImpl(MethodImplOptions.AggressiveInlining)]
32         protected virtual bool GreaterThanZero(TElement value) => Comparer.Compare(value, Zero)
33             ↪ > 0;
34
35         [MethodImpl(MethodImplOptions.AggressiveInlining)]
36         protected virtual bool GreaterThan(TElement first, TElement second) =>
37             ↪ Comparer.Compare(first, second) > 0;
38
39         [MethodImpl(MethodImplOptions.AggressiveInlining)]
40         protected virtual bool GreaterOrEqualThanZero(TElement value) => Comparer.Compare(value,
41             ↪ Zero) >= 0;
42
43         [MethodImpl(MethodImplOptions.AggressiveInlining)]
44         protected virtual bool GreaterOrEqualThan(TElement first, TElement second) =>
45             ↪ Comparer.Compare(first, second) >= 0;
46
47         [MethodImpl(MethodImplOptions.AggressiveInlining)]
48         protected virtual bool LessOrEqualThanZero(TElement value) => Comparer.Compare(value,
49             ↪ Zero) <= 0;
50
51         [MethodImpl(MethodImplOptions.AggressiveInlining)]
52         protected virtual bool LessOrEqualThan(TElement first, TElement second) =>
53             ↪ Comparer.Compare(first, second) <= 0;
54
55         [MethodImpl(MethodImplOptions.AggressiveInlining)]
56         protected virtual TElement Increment(TElement value) =>
57             ↪ Arithmetic<TElement>.Increment(value);
58
59         [MethodImpl(MethodImplOptions.AggressiveInlining)]
60         protected virtual TElement Decrement(TElement value) =>
61             ↪ Arithmetic<TElement>.Decrement(value);
62
63         [MethodImpl(MethodImplOptions.AggressiveInlining)]
64         protected virtual TElement Add(TElement first, TElement second) =>
65             ↪ Arithmetic<TElement>.Add(first, second);
66     }
67 }
```

```

61 [MethodImpl(MethodImplOptions.AggressiveInlining)]
62 protected virtual TElement Subtract(TElement first, TElement second) =>
63     ↪ Arithmetic<TElement>.Subtract(first, second);
64
65 protected readonly TElement Zero;
66 protected readonly TElement One;
67 protected readonly TElement Two;
68 protected readonly EqualityComparer<TElement> EqualityComparer;
69 protected readonly Comparer<TElement> Comparer;
70
71 /// <summary>
72 /// <para>Presents the Range in readable format.</para>
73 /// <para>Представляет диапазон в удобном для чтения формате.</para>
74 /// </summary>
75 /// <returns><para>String representation of the Range.</para><para>Строковое
76     ↪ представление диапазона.</para></returns>
77 protected GenericCollectionMethodsBase()
78 {
79     EqualityComparer = EqualityComparer<TElement>.Default;
80     Comparer = Comparer<TElement>.Default;
81     Zero = GetZero(); //-V3068
82     One = Increment(Zero); //-V3068
83     Two = Increment(One); //-V3068
84 }
85 }

```

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 }

```

```

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

```

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

```

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

```

```

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     [MethodImpl(MethodImplOptions.AggressiveInlining)]
13     protected abstract TElement GetLast(TElement headElement);
14
15     [MethodImpl(MethodImplOptions.AggressiveInlining)]
16     protected abstract TElement GetSize(TElement headElement);
17
18     [MethodImpl(MethodImplOptions.AggressiveInlining)]
19     protected abstract void SetFirst(TElement headElement, TElement element);
20
21     [MethodImpl(MethodImplOptions.AggressiveInlining)]
22     protected abstract void SetLast(TElement headElement, TElement element);
23
24     [MethodImpl(MethodImplOptions.AggressiveInlining)]
25     protected abstract void SetSize(TElement headElement, TElement size);
26
27     [MethodImpl(MethodImplOptions.AggressiveInlining)]
28     protected void IncrementSize(TElement headElement) => SetSize(headElement,
    ↪ Increment(GetSize(headElement)));
29
30     [MethodImpl(MethodImplOptions.AggressiveInlining)]
31     protected void DecrementSize(TElement headElement) => SetSize(headElement,
    ↪ 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> :
    ↪ RelativeDoublyLinkedListMethodsBase<TElement>
6     {
7         public void AttachBefore(TElement headElement, TElement baseElement, TElement newElement)
8         {
9             var baseElementPrevious = GetPrevious(baseElement);
10             SetPrevious(newElement, baseElementPrevious);
11             SetNext(newElement, baseElement);
12             if (EqualToZero(baseElementPrevious))
13             {
14                 SetFirst(headElement, newElement);
15             }
16             else
17             {
18                 SetNext(baseElementPrevious, newElement);
19             }
20             SetPrevious(baseElement, newElement);
21             IncrementSize(headElement);
22         }
23
24         public void AttachAfter(TElement headElement, TElement baseElement, TElement newElement)
25         {
26             var baseElementNext = GetNext(baseElement);
27             SetPrevious(newElement, baseElement);
28             SetNext(newElement, baseElementNext);
29             if (EqualToZero(baseElementNext))
30             {
31                 SetLast(headElement, newElement);
32             }
33             else
34             {
35                 SetPrevious(baseElementNext, newElement);
36             }
37             SetNext(baseElement, newElement);
38             IncrementSize(headElement);
39         }
40
41         public void AttachAsFirst(TElement headElement, TElement element)
42         {
43             var first = GetFirst(headElement);
44             if (EqualToZero(first))
45             {
46                 SetFirst(headElement, element);
47                 SetLast(headElement, element);
48                 SetPrevious(element, Zero);
49                 SetNext(element, Zero);
50                 IncrementSize(headElement);
51             }
52             else

```

```

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

```

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

```

1  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
2
3  namespace Platform.Collections.Methods.Trees
4  {
5      public abstract class RecursionlessSizeBalancedTreeMethods<TElement> :
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);

```



```

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);
101         }
102         else
103         {
104             IncrementSize(root);
105             root = ref right;
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             else if (GreaterThanZero(leftSize))
178             {
179                 root = left;
180             }
181             else if (GreaterThanZero(rightSize))
182             {
183                 root = right;
184             }
185             else
186             {
187             }
188         }
189     }
190 }

```



```

67     }
68     else
69     {
70         SetSize(lefttestNode, Increment(GetSize(nodeToDetachLeft)));
71     }
72     replacementNode = lefttestNode;
73 }
74 else if (!EqualToZero(nodeToDetachLeft))
75 {
76     replacementNode = nodeToDetachLeft;
77 }
78 else if (!EqualToZero(node))
79 {
80     replacementNode = node;
81 }
82 if (AreEqual(root, nodeToDetach))
83 {
84     root = replacementNode;
85 }
86 else if (AreEqual(GetLeft(parent), nodeToDetach))
87 {
88     SetLeft(parent, replacementNode);
89 }
90 else if (AreEqual(GetRight(parent), nodeToDetach))
91 {
92     SetRight(parent, replacementNode);
93 }
94 ClearNode(nodeToDetach);
95 }
96
97 private void LeftMaintain(ref TElement root)
98 {
99     if (!EqualToZero(root))
100     {
101         var rootLeftNode = GetLeft(root);
102         if (!EqualToZero(rootLeftNode))
103         {
104             var rootRightNode = GetRight(root);
105             var rootRightNodeSize = GetSize(rootRightNode);
106             var rootLeftNodeLeftNode = GetLeft(rootLeftNode);
107             if (!EqualToZero(rootLeftNodeLeftNode) &&
108                 (EqualToZero(rootRightNode) ||
109                  ⇨ GreaterThan(GetSize(rootLeftNodeLeftNode), rootRightNodeSize)))
110             {
111                 RightRotate(ref root);
112             }
113             else
114             {
115                 var rootLeftNodeRightNode = GetRight(rootLeftNode);
116                 if (!EqualToZero(rootLeftNodeRightNode) &&
117                     (EqualToZero(rootRightNode) ||
118                      ⇨ GreaterThan(GetSize(rootLeftNodeRightNode), rootRightNodeSize)))
119                 {
120                     LeftRotate(ref GetLeftReference(root));
121                     RightRotate(ref root);
122                 }
123                 else
124                 {
125                     return;
126                 }
127             }
128             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);

```

```

143         var rootRightNodeRightNode = GetRight(rootRightNode);
144         if (!EqualToZero(rootRightNodeRightNode) &&
145             (EqualToZero(rootLeftNode) ||
146              ⇨ GreaterThan(GetSize(rootRightNodeRightNode), rootLeftNodeSize)))
147         {
148             LeftRotate(ref root);
149         }
150         else
151         {
152             var rootRightNodeLeftNode = GetLeft(rootRightNode);
153             if (!EqualToZero(rootRightNodeLeftNode) &&
154                 (EqualToZero(rootLeftNode) ||
155                  ⇨ GreaterThan(GetSize(rootRightNodeLeftNode), rootLeftNodeSize)))
156             {
157                 RightRotate(ref GetRightReference(root));
158                 LeftRotate(ref root);
159             }
160             else
161             {
162                 return;
163             }
164         }
165         LeftMaintain(ref GetLeftReference(root));
166         RightMaintain(ref GetRightReference(root));
167         LeftMaintain(ref root);
168         RightMaintain(ref root);
169     }
170 }
171 }

```

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

```

1  using System;
2  using System.Runtime.CompilerServices;
3  using System.Text;
4  #if USEARRAYPOOL
5  using Platform.Collections;
6  #endif
7  using Platform.Reflection;
8
9  #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
10
11 namespace Platform.Collections.Methods.Trees
12 {
13     /// <summary>
14     /// Combination of Size, Height (AVL), and threads.
15     /// </summary>
16     /// <remarks>
17     /// Based on: <a href="https://github.com/programatom/TreeLib/blob/master/TreeLib/TreeLib/G_
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         }
49     }
50 }

```

```

44     }
45     return current;
46 }
47
48 public override bool Contains(TElement node, TElement root)
49 {
50     while (!EqualToZero(root))
51     {
52         if (FirstIsToTheLeftOfSecond(node, root)) // node.Key < root.Key
53         {
54             root = GetLeftOrDefault(root);
55         }
56         else if (FirstIsToTheRightOfSecond(node, root)) // node.Key > root.Key
57         {
58             root = GetRightOrDefault(root);
59         }
60         else // node.Key == root.Key
61         {
62             return true;
63         }
64     }
65     return false;
66 }
67
68 protected override void PrintNode(TElement node, StringBuilder sb, int level)
69 {
70     base.PrintNode(node, sb, level);
71     sb.Append(' ');
72     sb.Append(GetLeftIsChild(node) ? 'l' : 'L');
73     sb.Append(GetRightIsChild(node) ? 'r' : 'R');
74     sb.Append(' ');
75     sb.Append(GetBalance(node));
76 }
77
78 [MethodImpl(MethodImplOptions.AggressiveInlining)]
79 protected void IncrementBalance(TElement node) => SetBalance(node,
    ↪ (sbyte)(GetBalance(node) + 1));
80
81 [MethodImpl(MethodImplOptions.AggressiveInlining)]
82 protected void DecrementBalance(TElement node) => SetBalance(node,
    ↪ (sbyte)(GetBalance(node) - 1));
83
84 [MethodImpl(MethodImplOptions.AggressiveInlining)]
85 protected override TElement GetLeftOrDefault(TElement node) => GetLeftIsChild(node) ?
    ↪ GetLeft(node) : default;
86
87 [MethodImpl(MethodImplOptions.AggressiveInlining)]
88 protected override TElement GetRightOrDefault(TElement node) => GetRightIsChild(node) ?
    ↪ GetRight(node) : default;
89
90 [MethodImpl(MethodImplOptions.AggressiveInlining)]
91 protected abstract bool GetLeftIsChild(TElement node);
92
93 [MethodImpl(MethodImplOptions.AggressiveInlining)]
94 protected abstract void SetLeftIsChild(TElement node, bool value);
95
96 [MethodImpl(MethodImplOptions.AggressiveInlining)]
97 protected abstract bool GetRightIsChild(TElement node);
98
99 [MethodImpl(MethodImplOptions.AggressiveInlining)]
100 protected abstract void SetRightIsChild(TElement node, bool value);
101
102 [MethodImpl(MethodImplOptions.AggressiveInlining)]
103 protected abstract sbyte GetBalance(TElement node);
104
105 [MethodImpl(MethodImplOptions.AggressiveInlining)]
106 protected abstract void SetBalance(TElement node, sbyte value);
107
108 protected override void AttachCore(ref TElement root, TElement node)
109 {
110     unchecked
111     {
112         // TODO: Check what is faster to use simple array or array from array pool
113         // TODO: Try to use stackalloc as an optimization (requires code generation,
114         ↪ because of generics)
115         #if USEARRAYPOOL
116         var path = ArrayPool.Allocate<TElement>(MaxPath);
117         var pathPosition = 0;
118         path[pathPosition++] = default;

```

```

118 #else
119     var path = new TElement[_maxPath];
120     var pathPosition = 1;
121 #endif
122     var currentNode = root;
123     while (true)
124     {
125         if (FirstIsToTheLeftOfSecond(node, currentNode))
126         {
127             if (GetLeftIsChild(currentNode))
128             {
129                 IncrementSize(currentNode);
130                 path[pathPosition++] = currentNode;
131                 currentNode = GetLeft(currentNode);
132             }
133             else
134             {
135                 // Threads
136                 SetLeft(node, GetLeft(currentNode));
137                 SetRight(node, currentNode);
138                 SetLeft(currentNode, node);
139                 SetLeftIsChild(currentNode, true);
140                 DecrementBalance(currentNode);
141                 SetSize(node, One);
142                 FixSize(currentNode); // Should be incremented already
143                 break;
144             }
145         }
146         else if (FirstIsToTheRightOfSecond(node, currentNode))
147         {
148             if (GetRightIsChild(currentNode))
149             {
150                 IncrementSize(currentNode);
151                 path[pathPosition++] = currentNode;
152                 currentNode = GetRight(currentNode);
153             }
154             else
155             {
156                 // Threads
157                 SetRight(node, GetRight(currentNode));
158                 SetLeft(node, currentNode);
159                 SetRight(currentNode, node);
160                 SetRightIsChild(currentNode, true);
161                 IncrementBalance(currentNode);
162                 SetSize(node, One);
163                 FixSize(currentNode); // Should be incremented already
164                 break;
165             }
166         }
167         else
168         {
169             throw new InvalidOperationException("Node with the same key already
170                 ↳ attached to a tree.");
171         }
172     }
173     // Restore balance. This is the goodness of a non-recursive
174     // implementation, when we are done with balancing we 'break'
175     // the loop and we are done.
176     while (true)
177     {
178         var parent = path[--pathPosition];
179         var isLeftNode = !AreEqual(parent, default) && AreEqual(currentNode,
180             ↳ GetLeft(parent));
181         var currentNodeBalance = GetBalance(currentNode);
182         if (currentNodeBalance < -1 || currentNodeBalance > 1)
183         {
184             currentNode = Balance(currentNode);
185             if (AreEqual(parent, default))
186             {
187                 root = currentNode;
188             }
189             else if (isLeftNode)
190             {
191                 SetLeft(parent, currentNode);
192                 FixSize(parent);
193             }
194             else
195             {
196                 SetRight(parent, currentNode);
197                 FixSize(parent);
198             }
199         }
200     }

```

```

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                 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                 }
431             }
432         }
433     }
434 }

```

```

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             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     }
67 }

```

```

63     [MethodImpl(MethodImplOptions.AggressiveInlining)]
64     protected TElement GetSizeOrZero(TElement node) => EqualToZero(node) ? Zero :
        ↳ GetSize(node);

65
66     [MethodImpl(MethodImplOptions.AggressiveInlining)]
67     protected void FixSize(TElement node) => SetSize(node, Increment(Add(GetLeftSize(node),
        ↳ GetRightSize(node))));

68
69     [MethodImpl(MethodImplOptions.AggressiveInlining)]
70     protected void LeftRotate(ref TElement root) => root = LeftRotate(root);

71
72     [MethodImpl(MethodImplOptions.AggressiveInlining)]
73     protected TElement LeftRotate(TElement root)
74     {
75         var right = GetRight(root);
76         #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
77             if (EqualToZero(right))
78             {
79                 throw new InvalidOperationException("Right is null.");
80             }
81         #endif
82         SetRight(root, GetLeft(right));
83         SetLeft(right, root);
84         SetSize(right, GetSize(root));
85         FixSize(root);
86         return right;
87     }

88
89     [MethodImpl(MethodImplOptions.AggressiveInlining)]
90     protected void RightRotate(ref TElement root) => root = RightRotate(root);

91
92     [MethodImpl(MethodImplOptions.AggressiveInlining)]
93     protected TElement RightRotate(TElement root)
94     {
95         var left = GetLeft(root);
96         #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
97             if (EqualToZero(left))
98             {
99                 throw new InvalidOperationException("Left is null.");
100             }
101         #endif
102         SetLeft(root, GetRight(left));
103         SetRight(left, root);
104         SetSize(left, GetSize(root));
105         FixSize(root);
106         return left;
107     }

108
109     [MethodImpl(MethodImplOptions.AggressiveInlining)]
110     protected virtual TElement GetRighttest(TElement current)
111     {
112         var currentRight = GetRight(current);
113         while (!EqualToZero(currentRight))
114         {
115             current = currentRight;
116             currentRight = GetRight(current);
117         }
118         return current;
119     }

120
121     [MethodImpl(MethodImplOptions.AggressiveInlining)]
122     protected virtual TElement GetLefttest(TElement current)
123     {
124         var currentLeft = GetLeft(current);
125         while (!EqualToZero(currentLeft))
126         {
127             current = currentLeft;
128             currentLeft = GetLeft(current);
129         }
130         return current;
131     }

132
133     [MethodImpl(MethodImplOptions.AggressiveInlining)]
134     protected virtual TElement GetNext(TElement node) => GetLefttest(GetRight(node));

135
136     [MethodImpl(MethodImplOptions.AggressiveInlining)]
137     protected virtual TElement GetPrevious(TElement node) => GetRighttest(GetLeft(node));

138
139     [MethodImpl(MethodImplOptions.AggressiveInlining)]

```

```

140 public virtual bool Contains(TElement node, TElement root)
141 {
142     while (!EqualToZero(root))
143     {
144         if (FirstIsToTheLeftOfSecond(node, root)) // node.Key < root.Key
145         {
146             root = GetLeft(root);
147         }
148         else if (FirstIsToTheRightOfSecond(node, root)) // node.Key > root.Key
149         {
150             root = GetRight(root);
151         }
152         else // node.Key == root.Key
153         {
154             return true;
155         }
156     }
157     return false;
158 }
159
160 [MethodImpl(MethodImplOptions.AggressiveInlining)]
161 protected virtual void ClearNode(TElement node)
162 {
163     SetLeft(node, Zero);
164     SetRight(node, Zero);
165     SetSize(node, Zero);
166 }
167
168 [MethodImpl(MethodImplOptions.AggressiveInlining)]
169 public void Attach(ref TElement root, TElement node)
170 {
171     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
172         ValidateSizes(root);
173         Debug.WriteLine("--BeforeAttach--");
174         Debug.WriteLine(PrintNodes(root));
175         Debug.WriteLine("-----");
176         var sizeBefore = GetSize(root);
177     #endif
178     if (EqualToZero(root))
179     {
180         SetSize(node, One);
181         root = node;
182         return;
183     }
184     AttachCore(ref root, node);
185     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
186         Debug.WriteLine("--AfterAttach--");
187         Debug.WriteLine(PrintNodes(root));
188         Debug.WriteLine("-----");
189         ValidateSizes(root);
190         var sizeAfter = GetSize(root);
191         if (!AreEqual(Arithmetic.Increment(sizeBefore), sizeAfter))
192         {
193             throw new InvalidOperationException("Tree was broken after attach.");
194         }
195     #endif
196 }
197
198 protected abstract void AttachCore(ref TElement root, TElement node);
199
200 [MethodImpl(MethodImplOptions.AggressiveInlining)]
201 public void Detach(ref TElement root, TElement node)
202 {
203     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
204         ValidateSizes(root);
205         Debug.WriteLine("--BeforeDetach--");
206         Debug.WriteLine(PrintNodes(root));
207         Debug.WriteLine("-----");
208         var sizeBefore = GetSize(root);
209         if (EqualToZero(root))
210         {
211             throw new InvalidOperationException($"Элемент с {node} не содержится в
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     #endif
220 }

```

```

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))
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 }

```

```

55     }
56 }
57 }
58
59 public bool IsEmpty(TElement node) =>
    ↳ EqualityComparer<TreeElement>.Default.Equals(GetElement(node), default);
60
61 protected override bool FirstIsToTheLeftOfSecond(TElement first, TElement second) =>
    ↳ Comparer.Compare(first, second) < 0;
62
63 protected override bool FirstIsToTheRightOfSecond(TElement first, TElement second) =>
    ↳ Comparer.Compare(first, second) > 0;
64
65 protected override ref TElement GetLeftReference(TElement node) => ref
    ↳ GetElement(node).Left;
66
67 protected override TElement GetLeft(TElement node) => GetElement(node).Left;
68
69 protected override ref TElement GetRightReference(TElement node) => ref
    ↳ GetElement(node).Right;
70
71 protected override TElement GetRight(TElement node) => GetElement(node).Right;
72
73 protected override TElement GetSize(TElement node) => GetElement(node).Size;
74
75 protected override void PrintNodeValue(TElement node, StringBuilder sb) =>
    ↳ sb.Append(node);
76
77 protected override void SetLeft(TElement node, TElement left) => GetElement(node).Left =
    ↳ left;
78
79 protected override void SetRight(TElement node, TElement right) =>
    ↳ GetElement(node).Right = right;
80
81 protected override void SetSize(TElement node, TElement size) => GetElement(node).Size =
    ↳ size;
82
83 private ref TreeElement GetElement(TElement node) => ref
    ↳ _elements[UncheckedConverter<TElement, long>.Default.Convert(node)];
84 }
85 }

```

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

```

1 using System;
2 using System.Collections.Generic;
3 using System.Text;
4 using Platform.Numbers;
5 using Platform.Collections.Methods.Trees;
6 using Platform.Converters;
7
8 namespace Platform.Collections.Methods.Tests
9 {
10     public class SizeBalancedTree<TElement> : SizeBalancedTreeMethods<TElement>
11     {
12         private struct TreeElement
13         {
14             public TElement Size;
15             public TElement Left;
16             public TElement Right;
17         }
18
19         private readonly TreeElement[] _elements;
20         private TElement _allocated;
21
22         public TElement Root;
23
24         public TElement Count => GetSizeOrZero(Root);
25
26         public SizeBalancedTree(int capacity) => (_elements, _allocated) = (new
            ↳ TreeElement[capacity], One);
27
28         public TElement Allocate()
29         {
30             var newNode = _allocated;
31             if (IsEmpty(newNode))
32             {
33                 _allocated = Arithmetic.Increment(_allocated);
34                 return newNode;
35             }
36             else

```

```

37         {
38             throw new InvalidOperationException("Allocated tree element is not empty.");
39         }
40     }
41
42     public void Free(TElement node)
43     {
44         while (!EqualityComparer.Equals(_allocated, One) && IsEmpty(node))
45         {
46             var lastNode = Arithmetic.Decrement(_allocated);
47             if (EqualityComparer.Equals(lastNode, node))
48             {
49                 _allocated = lastNode;
50                 node = Arithmetic.Decrement(node);
51             }
52             else
53             {
54                 return;
55             }
56         }
57     }
58
59     public bool IsEmpty(TElement node) =>
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> :
11     ↪ SizedAndThreadedAVLBalancedTreeMethods<TElement>
12     {
13         private struct TreeElement
14         {
15             public TElement Size;
16             public TElement Left;
17             public TElement Right;
18             public sbyte Balance;
19             public bool LeftIsChild;

```

```

19     public bool RightIsChild;
20 }
21
22 private readonly TreeElement[] _elements;
23 private TElement _allocated;
24
25 public TElement Root;
26
27 public TElement Count => GetSizeOrZero(Root);
28
29 public SizedAndThreadedAVLBalancedTree(int capacity) => (_elements, _allocated) = (new
    ↪ TreeElement[capacity], One);
30
31 public TElement Allocate()
32 {
33     var newNode = _allocated;
34     if (IsEmpty(newNode))
35     {
36         _allocated = Arithmetic.Increment(_allocated);
37         return newNode;
38     }
39     else
40     {
41         throw new InvalidOperationException("Allocated tree element is not empty.");
42     }
43 }
44
45 public void Free(TElement node)
46 {
47     while (!EqualityComparer.Equals(_allocated, One) && IsEmpty(node))
48     {
49         var lastNode = Arithmetic.Decrement(_allocated);
50         if (EqualityComparer.Equals(lastNode, node))
51         {
52             _allocated = lastNode;
53             node = Arithmetic.Decrement(node);
54         }
55         else
56         {
57             return;
58         }
59     }
60 }
61
62 public bool IsEmpty(TElement node) =>
    ↪ EqualityComparer<TreeElement>.Default.Equals(GetElement(node), default);
63
64 protected override bool FirstIsToTheLeftOfSecond(TElement first, TElement second) =>
    ↪ Comparer.Compare(first, second) < 0;
65
66 protected override bool FirstIsToTheRightOfSecond(TElement first, TElement second) =>
    ↪ Comparer.Compare(first, second) > 0;
67
68 protected override sbyte GetBalance(TElement node) => GetElement(node).Balance;
69
70 protected override bool GetLeftIsChild(TElement node) => GetElement(node).LeftIsChild;
71
72 protected override ref TElement GetLeftReference(TElement node) => ref
    ↪ GetElement(node).Left;
73
74 protected override TElement GetLeft(TElement node) => GetElement(node).Left;
75
76 protected override bool GetRightIsChild(TElement node) => GetElement(node).RightIsChild;
77
78 protected override ref TElement GetRightReference(TElement node) => ref
    ↪ GetElement(node).Right;
79
80 protected override TElement GetRight(TElement node) => GetElement(node).Right;
81
82 protected override TElement GetSize(TElement node) => GetElement(node).Size;
83
84 protected override void PrintNodeValue(TElement node, StringBuilder sb) =>
    ↪ sb.Append(node);
85
86 protected override void SetBalance(TElement node, sbyte value) =>
    ↪ GetElement(node).Balance = value;
87
88 protected override void SetLeft(TElement node, TElement left) => GetElement(node).Left =
    ↪ left;

```

```

89
90     protected override void SetLeftIsChild(TElement node, bool value) =>
91         ↪ GetElement(node).LeftIsChild = value;
92
93     protected override void SetRight(TElement node, TElement right) =>
94         ↪ GetElement(node).Right = right;
95
96     protected override void SetRightIsChild(TElement node, bool value) =>
97         ↪ GetElement(node).RightIsChild = value;
98
99     protected override void SetSize(TElement node, TElement size) => GetElement(node).Size =
100         ↪ size;
101
102     private ref TreeElement GetElement(TElement node) => ref
103         ↪ _elements[UncheckedConverter<TElement, long>.Default.Convert(node)];
104 }
105 }

```

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             }
63         }
64     }
65 }

```

```

52     }
53 }
54 for (var i = 1; i <= N; i++)
55 {
56     TElement node = UncheckedConverter<int,
57     ↪ TElement>.Default.Convert(random.Next(1, N));
58     if (tree.Contains(node, root))
59     {
60         tree.Detach(ref root, node);
61         currentCount--;
62         Assert.Equal(currentCount, (int)UncheckedConverter<TElement,
63         ↪ int>.Default.Convert(tree.Count()));
64         added.Remove(node);
65     }
66 }
67 }
68 }

```

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

```

1  using Xunit;
2
3  namespace Platform.Collections.Methods.Tests
4  {
5      public static class TreesTests
6      {
7          private const int _n = 500;
8
9          [Fact]
10         public static void RecursionlessSizeBalancedTreeMultipleAttachAndDetachTest()
11         {
12             var recursionlessSizeBalancedTree = new RecursionlessSizeBalancedTree<uint>(10000);
13             recursionlessSizeBalancedTree.TestMultipleCreationsAndDeletions(recursionlessSizeBal
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 }

```

49
50
51

}

}

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