

# LinksPlatform's Platform.Collections.Methods Class Library

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

```

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

```

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

```

```

124    /// <returns><para>String representation of the Range.</para><para>Строковое
    ↪ представление диапазона.</para></returns>
125    [MethodImpl(MethodImplOptions.AggressiveInlining)]
126    protected virtual TElement Add(TElement first, TElement second) =>
    ↪ Arithmetic<TElement>.Add(first, second);

127
128    /// <summary>
129    /// <para>Presents the Range in readable format.</para>
130    /// <para>Представляет диапазон в удобном для чтения формате.</para>
131    /// </summary>
132    /// <returns><para>String representation of the Range.</para><para>Строковое
    ↪ представление диапазона.</para></returns>
133    [MethodImpl(MethodImplOptions.AggressiveInlining)]
134    protected virtual TElement Subtract(TElement first, TElement second) =>
    ↪ Arithmetic<TElement>.Subtract(first, second);

135
136    /// <summary>
137    /// <para>Returns minimum value of the range.</para>
138    /// <para>Возвращает минимальное значение диапазона.</para>
139    /// </summary>
140    protected readonly TElement Zero;

141
142    /// <summary>
143    /// <para>Returns minimum value of the range.</para>
144    /// <para>Возвращает минимальное значение диапазона.</para>
145    /// </summary>
146    protected readonly TElement One;

147
148    /// <summary>
149    /// <para>Returns minimum value of the range.</para>
150    /// <para>Возвращает минимальное значение диапазона.</para>
151    /// </summary>
152    protected readonly TElement Two;

153
154    /// <summary>
155    /// <para>Returns minimum value of the range.</para>
156    /// <para>Возвращает минимальное значение диапазона.</para>
157    /// </summary>
158    protected readonly EqualityComparer<TElement> EqualityComparer;

159
160    /// <summary>
161    /// <para>Returns minimum value of the range.</para>
162    /// <para>Возвращает минимальное значение диапазона.</para>
163    /// </summary>
164    protected readonly Comparer<TElement> Comparer;

165
166    /// <summary>
167    /// <para>Presents the Range in readable format.</para>
168    /// <para>Представляет диапазон в удобном для чтения формате.</para>
169    /// </summary>
170    /// <returns><para>String representation of the Range.</para><para>Строковое
    ↪ представление диапазона.</para></returns>
171    protected GenericCollectionMethodsBase()
172    {
173        EqualityComparer = EqualityComparer<TElement>.Default;
174        Comparer = Comparer<TElement>.Default;
175        Zero = GetZero(); //-V3068
176        One = Increment(Zero); //-V3068
177        Two = Increment(One); //-V3068
178    }
179 }
180 }

```

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

```

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

```

```

15     }
16     SetNext(baseElementPrevious, newElement);
17     SetPrevious(baseElement, newElement);
18     IncrementSize();
19 }
20
21 public void AttachAfter(TElement baseElement, TElement newElement)
22 {
23     var baseElementNext = GetNext(baseElement);
24     SetPrevious(newElement, baseElement);
25     SetNext(newElement, baseElementNext);
26     if (AreEqual(baseElement, GetLast()))
27     {
28         SetLast(newElement);
29     }
30     SetPrevious(baseElementNext, newElement);
31     SetNext(baseElement, newElement);
32     IncrementSize();
33 }
34
35 public void AttachAsFirst(TElement element)
36 {
37     var first = GetFirst();
38     if (EqualToZero(first))
39     {
40         SetFirst(element);
41         SetLast(element);
42         SetPrevious(element, element);
43         SetNext(element, element);
44         IncrementSize();
45     }
46     else
47     {
48         AttachBefore(first, element);
49     }
50 }
51
52 public void AttachAsLast(TElement element)
53 {
54     var last = GetLast();
55     if (EqualToZero(last))
56     {
57         AttachAsFirst(element);
58     }
59     else
60     {
61         AttachAfter(last, element);
62     }
63 }
64
65 public void Detach(TElement element)
66 {
67     var elementPrevious = GetPrevious(element);
68     var elementNext = GetNext(element);
69     if (AreEqual(elementNext, element))
70     {
71         SetFirst(Zero);
72         SetLast(Zero);
73     }
74     else
75     {
76         SetNext(elementPrevious, elementNext);
77         SetPrevious(elementNext, elementPrevious);
78         if (AreEqual(element, GetFirst()))
79         {
80             SetFirst(elementNext);
81         }
82         if (AreEqual(element, GetLast()))
83         {
84             SetLast(elementPrevious);
85         }
86     }
87     SetPrevious(element, Zero);
88     SetNext(element, Zero);
89     DecrementSize();
90 }
91 }
92 }

```

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

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

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

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

```

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

```

```

21     [MethodImpl(MethodImplOptions.AggressiveInlining)]
22     protected abstract void SetNext(TElement element, TElement next);
23 }
24 }

```

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

```

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

```



```

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);
34                             root = ref left;
35                         }
36                     }
37                     else // node.Key greater than left.Key
38                     {
39                         var leftRightSize = GetSizeOrZero(GetRight(left));
40                         if (GreaterThan(Increment(leftRightSize), rightSize))
41                         {
42                             if (EqualToZero(leftRightSize) && EqualToZero(rightSize))
43                             {
44                                 SetLeft(node, left);
45                                 SetRight(node, root);
46                                 SetSize(node, Add(leftSize, Two)); // Two (2) - node the size of
47                                     ↳ root and a node itself
48                                 SetLeft(root, Zero);
49                                 SetSize(root, One);
50                                 root = node;
51                                 return;
52                             }
53                             LeftRotate(ref left);
54                             RightRotate(ref root);
55                         }
56                         else
57                         {
58                             IncrementSize(root);
59                             root = ref left;
60                         }
61                     }
62                 }
63                 else // node.Key greater than root.Key
64                 {
65                     if (EqualToZero(right))
66                     {
67                         IncrementSize(root);
68                         SetSize(node, One);
69                         right = node;
70                         return;
71                     }
72                     if (FirstIsToTheRightOfSecond(node, right)) // node.Key greater than
73                         ↳ right.Key
74                     {
75                         if (GreaterThan(Increment(rightSize), leftSize))
76                         {
77                             if (EqualToZero(rightSize) && EqualToZero(leftSize))
78                             {
79                                 SetRight(node, right);
80                                 SetLeft(node, root);
81                                 SetSize(node, Add(rightSize, Two)); // Two (2) - node the size of
82                                     ↳ root and a node itself
83                                 SetRight(root, Zero);
84                                 SetSize(root, One);
85                                 root = node;
86                                 return;
87                             }
88                             LeftRotate(ref right);
89                             RightRotate(ref root);
90                         }
91                         else
92                         {
93                             IncrementSize(root);
94                             root = ref right;
95                         }
96                     }
97                     else
98                     {
99                         var rightLeftSize = GetSizeOrZero(GetLeft(right));
100                         if (GreaterThan(Increment(rightLeftSize), leftSize))
101                         {
102                             if (EqualToZero(rightLeftSize) && EqualToZero(leftSize))
103                             {
104                                 SetRight(node, right);
105                                 SetLeft(node, root);
106                                 SetSize(node, Add(rightLeftSize, Two)); // Two (2) - node the size of
107                                     ↳ root and a node itself
108                                 SetRight(root, Zero);
109                                 SetSize(root, One);
110                                 root = node;
111                                 return;
112                             }
113                             LeftRotate(ref right);
114                             RightRotate(ref root);
115                         }
116                         else
117                         {
118                             IncrementSize(root);
119                             root = ref right;
120                         }
121                     }
122                 }
123             }
124         }
125     }
126 }
```

```

74         LeftRotate(ref root);
75     }
76     else
77     {
78         IncrementSize(root);
79         root = ref right;
80     }
81 }
82 else // node.Key less than right.Key
83 {
84     var rightLeftSize = GetSizeOrZero(GetLeft(right));
85     if (GreaterThan(Increment(rightLeftSize), leftSize))
86     {
87         if (EqualToZero(rightLeftSize) && EqualToZero(leftSize))
88         {
89             SetLeft(node, root);
90             SetRight(node, right);
91             SetSize(node, Add(rightSize, Two)); // Two (2) - node the size
92             ↪ of root and a node itself
93             SetRight(root, Zero);
94             SetSize(root, One);
95             root = node;
96             return;
97         }
98         RightRotate(ref right);
99         LeftRotate(ref root);
100     }
101     else
102     {
103         IncrementSize(root);
104         root = ref right;
105     }
106 }
107 }
108 }
109
110 protected override void DetachCore(ref TElement root, TElement node)
111 {
112     while (true)
113     {
114         ref var left = ref GetLeftReference(root);
115         var leftSize = GetSizeOrZero(left);
116         ref var right = ref GetRightReference(root);
117         var rightSize = GetSizeOrZero(right);
118         if (FirstIsToTheLeftOfSecond(node, root)) // node.Key less than root.Key
119         {
120             var decrementedLeftSize = Decrement(leftSize);
121             if (GreaterThan(GetSizeOrZero(GetRightOrDefault(right)),
122                 ↪ decrementedLeftSize))
123             {
124                 LeftRotate(ref root);
125             }
126             else if (GreaterThan(GetSizeOrZero(GetLeftOrDefault(right)),
127                 ↪ decrementedLeftSize))
128             {
129                 RightRotate(ref right);
130                 LeftRotate(ref root);
131             }
132             else
133             {
134                 DecrementSize(root);
135                 root = ref left;
136             }
137         }
138         else if (FirstIsToTheRightOfSecond(node, root)) // node.Key greater than root.Key
139         {
140             var decrementedRightSize = Decrement(rightSize);
141             if (GreaterThan(GetSizeOrZero(GetLeftOrDefault(left)), decrementedRightSize))
142             {
143                 RightRotate(ref root);
144             }
145             else if (GreaterThan(GetSizeOrZero(GetRightOrDefault(left)),
146                 ↪ decrementedRightSize))
147             {
148                 LeftRotate(ref left);
149                 RightRotate(ref root);
150             }
151         }
152     }
153 }

```

```

148         else
149         {
150             DecrementSize(root);
151             root = ref right;
152         }
153     }
154     else // key equals to root.Key
155     {
156         if (GreaterThanZero(leftSize) && GreaterThanZero(rightSize))
157         {
158             TElement replacement;
159             if (GreaterThan(leftSize, rightSize))
160             {
161                 replacement = GetRighttest(left);
162                 DetachCore(ref left, replacement);
163             }
164             else
165             {
166                 replacement = GetLefttest(right);
167                 DetachCore(ref right, replacement);
168             }
169             SetLeft(replacement, left);
170             SetRight(replacement, right);
171             SetSize(replacement, Add(leftSize, rightSize));
172             root = replacement;
173         }
174         else if (GreaterThanZero(leftSize))
175         {
176             root = left;
177         }
178         else if (GreaterThanZero(rightSize))
179         {
180             root = right;
181         }
182         else
183         {
184             root = Zero;
185         }
186         ClearNode(node);
187         return;
188     }
189 }
190 }
191 }
192 }

```

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

```

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

```

```

32 protected override void DetachCore(ref TElement root, TElement nodeToDetach)
33 {
34     ref var currentNode = ref root;
35     ref var parent = ref root;
36     var replacementNode = Zero;
37     while (!AreEqual(currentNode, nodeToDetach))
38     {
39         DecrementSize(currentNode);
40         if (FirstIsToTheLeftOfSecond(nodeToDetach, currentNode))
41         {
42             parent = ref currentNode;
43             currentNode = ref GetLeftReference(currentNode);
44         }
45         else if (FirstIsToTheRightOfSecond(nodeToDetach, currentNode))
46         {
47             parent = ref currentNode;
48             currentNode = ref GetRightReference(currentNode);
49         }
50         else
51         {
52             throw new InvalidOperationException("Duplicate link found in the tree.");
53         }
54     }
55     var nodeToDetachLeft = GetLeft(nodeToDetach);
56     var node = GetRight(nodeToDetach);
57     if (!EqualToZero(nodeToDetachLeft) && !EqualToZero(node))
58     {
59         var lefttestNode = GetLefttest(node);
60         DetachCore(ref GetRightReference(nodeToDetach), lefttestNode);
61         SetLeft(lefttestNode, nodeToDetachLeft);
62         node = GetRight(nodeToDetach);
63         if (!EqualToZero(node))
64         {
65             SetRight(lefttestNode, node);
66             SetSize(lefttestNode, Increment(Add(GetSize(nodeToDetachLeft),
67                 ↪ GetSize(node))));
68         }
69         else
70         {
71             SetSize(lefttestNode, Increment(GetSize(nodeToDetachLeft)));
72         }
73         replacementNode = lefttestNode;
74     }
75     else if (!EqualToZero(nodeToDetachLeft))
76     {
77         replacementNode = nodeToDetachLeft;
78     }
79     else if (!EqualToZero(node))
80     {
81         replacementNode = node;
82     }
83     if (AreEqual(root, nodeToDetach))
84     {
85         root = replacementNode;
86     }
87     else if (AreEqual(GetLeft(parent), nodeToDetach))
88     {
89         SetLeft(parent, replacementNode);
90     }
91     else if (AreEqual(GetRight(parent), nodeToDetach))
92     {
93         SetRight(parent, replacementNode);
94     }
95     ClearNode(nodeToDetach);
96 }
97 private void LeftMaintain(ref TElement root)
98 {
99     if (!EqualToZero(root))
100     {
101         var rootLeftNode = GetLeft(root);
102         if (!EqualToZero(rootLeftNode))
103         {
104             var rootRightNode = GetRight(root);
105             var rootRightNodeSize = GetSize(rootRightNode);
106             var rootLeftNodeLeftNode = GetLeft(rootLeftNode);
107             if (!EqualToZero(rootLeftNodeLeftNode) &&
108                 (EqualToZero(rootRightNode) ||
109                 ↪ GreaterThan(GetSize(rootLeftNodeLeftNode), rootRightNodeSize)))

```

```

109         {
110             RightRotate(ref root);
111         }
112         else
113         {
114             var rootLeftNodeRightNode = GetRight(rootLeftNode);
115             if (!EqualToZero(rootLeftNodeRightNode) &&
116                 (EqualToZero(rootRightNode) ||
117                  ⇨ GreaterThan(GetSize(rootLeftNodeRightNode), rootRightNodeSize)))
118             {
119                 LeftRotate(ref GetLeftReference(root));
120                 RightRotate(ref root);
121             }
122             else
123             {
124                 return;
125             }
126             LeftMaintain(ref GetLeftReference(root));
127             RightMaintain(ref GetRightReference(root));
128             LeftMaintain(ref root);
129             RightMaintain(ref root);
130         }
131     }
132 }
133
134 private void RightMaintain(ref TElement root)
135 {
136     if (!EqualToZero(root))
137     {
138         var rootRightNode = GetRight(root);
139         if (!EqualToZero(rootRightNode))
140         {
141             var rootLeftNode = GetLeft(root);
142             var rootLeftNodeSize = GetSize(rootLeftNode);
143             var rootRightNodeRightNode = GetRight(rootRightNode);
144             if (!EqualToZero(rootRightNodeRightNode) &&
145                 (EqualToZero(rootLeftNode) ||
146                  ⇨ GreaterThan(GetSize(rootRightNodeRightNode), rootLeftNodeSize)))
147             {
148                 LeftRotate(ref root);
149             }
150             else
151             {
152                 var rootRightNodeLeftNode = GetLeft(rootRightNode);
153                 if (!EqualToZero(rootRightNodeLeftNode) &&
154                     (EqualToZero(rootLeftNode) ||
155                      ⇨ GreaterThan(GetSize(rootRightNodeLeftNode), rootLeftNodeSize)))
156                 {
157                     RightRotate(ref GetRightReference(root));
158                     LeftRotate(ref root);
159                 }
160                 else
161                 {
162                     return;
163                 }
164             }
165             LeftMaintain(ref GetLeftReference(root));
166             RightMaintain(ref GetRightReference(root));
167             LeftMaintain(ref root);
168             RightMaintain(ref root);
169         }
170     }
171 }

```

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

```

1 using System;
2 using System.Runtime.CompilerServices;
3 using System.Text;
4 #if USEARRAYPOOL
5 using Platform.Collections;
6 #endif
7 using Platform.Reflection;
8
9 #pragma warning disable CS1591 // Missing XML comment for publicly visible type or member
10
11 namespace Platform.Collections.Methods.Trees

```

```

12 {
13     /// <summary>
14     /// Combination of Size, Height (AVL), and threads.
15     /// </summary>
16     /// <remarks>
17     /// Based on: <a href="https://github.com/programatom/TreeLib/blob/master/TreeLib/TreeLib/G_
    ↳ enerated/AVLTreeList.cs">TreeLib.AVLTreeList</a>.
18     /// Which itself based on: <a
    ↳ href="https://github.com/GNOME/glib/blob/master/glib/gtree.c">GNOME/glib/gtree</a>.
19     /// </remarks>
20 public abstract class SizedAndThreadedAVLBalancedTreeMethods<TElement> :
    ↳ SizedBinaryTreeMethodsBase<TElement>
21 {
22     private static readonly int _maxPath = 11 * NumericType<TElement>.BytesSize + 4;
23
24     [MethodImpl(MethodImplOptions.AggressiveInlining)]
25     protected override TElement GetRighttest(TElement current)
26     {
27         var currentRight = GetRightOrDefault(current);
28         while (!EqualToZero(currentRight))
29         {
30             current = currentRight;
31             currentRight = GetRightOrDefault(current);
32         }
33         return current;
34     }
35
36     [MethodImpl(MethodImplOptions.AggressiveInlining)]
37     protected override TElement GetLefttest(TElement current)
38     {
39         var currentLeft = GetLeftOrDefault(current);
40         while (!EqualToZero(currentLeft))
41         {
42             current = currentLeft;
43             currentLeft = GetLeftOrDefault(current);
44         }
45         return current;
46     }
47
48     public override bool Contains(TElement node, TElement root)
49     {
50         while (!EqualToZero(root))
51         {
52             if (FirstIsToTheLeftOfSecond(node, root)) // node.Key < root.Key
53             {
54                 root = GetLeftOrDefault(root);
55             }
56             else if (FirstIsToTheRightOfSecond(node, root)) // node.Key > root.Key
57             {
58                 root = GetRightOrDefault(root);
59             }
60             else // node.Key == root.Key
61             {
62                 return true;
63             }
64         }
65         return false;
66     }
67
68     protected override void PrintNode(TElement node, StringBuilder sb, int level)
69     {
70         base.PrintNode(node, sb, level);
71         sb.Append(' ');
72         sb.Append(GetLeftIsChild(node) ? 'l' : 'L');
73         sb.Append(GetRightIsChild(node) ? 'r' : 'R');
74         sb.Append(' ');
75         sb.Append(GetBalance(node));
76     }
77
78     [MethodImpl(MethodImplOptions.AggressiveInlining)]
79     protected void IncrementBalance(TElement node) => SetBalance(node,
    ↳ (sbyte)(GetBalance(node) + 1));
80
81     [MethodImpl(MethodImplOptions.AggressiveInlining)]
82     protected void DecrementBalance(TElement node) => SetBalance(node,
    ↳ (sbyte)(GetBalance(node) - 1));
83
84     [MethodImpl(MethodImplOptions.AggressiveInlining)]

```





```

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

```

```

237         if (GetBalance(right) < 0)
238         {
239             SetRight(node, RightRotateWithBalance(right));
240             FixSize(node);
241         }
242         node = LeftRotateWithBalance(node);
243     }
244     return node;
245 }
246
247
248 protected TElement LeftRotateWithBalance(TElement node)
249 {
250     unchecked
251     {
252         var right = GetRight(node);
253         if (GetLeftIsChild(right))
254         {
255             SetRight(node, GetLeft(right));
256         }
257         else
258         {
259             SetRightIsChild(node, false);
260             SetLeftIsChild(right, true);
261         }
262         SetLeft(right, node);
263         // Fix size
264         SetSize(right, GetSize(node));
265         FixSize(node);
266         // Fix balance
267         var rootBalance = GetBalance(node);
268         var rightBalance = GetBalance(right);
269         if (rightBalance <= 0)
270         {
271             if (rootBalance >= 1)
272             {
273                 SetBalance(right, (sbyte)(rightBalance - 1));
274             }
275             else
276             {
277                 SetBalance(right, (sbyte)(rootBalance + rightBalance - 2));
278             }
279             SetBalance(node, (sbyte)(rootBalance - 1));
280         }
281         else
282         {
283             if (rootBalance <= rightBalance)
284             {
285                 SetBalance(right, (sbyte)(rootBalance - 2));
286             }
287             else
288             {
289                 SetBalance(right, (sbyte)(rightBalance - 1));
290             }
291             SetBalance(node, (sbyte)(rootBalance - rightBalance - 1));
292         }
293         return right;
294     }
295 }
296
297 protected TElement RightRotateWithBalance(TElement node)
298 {
299     unchecked
300     {
301         var left = GetLeft(node);
302         if (GetRightIsChild(left))
303         {
304             SetLeft(node, GetRight(left));
305         }
306         else
307         {
308             SetLeftIsChild(node, false);
309             SetRightIsChild(left, true);
310         }
311         SetRight(left, node);
312         // Fix size
313         SetSize(left, GetSize(node));
314         FixSize(node);

```

```

315 // Fix balance
316 var rootBalance = GetBalance(node);
317 var leftBalance = GetBalance(left);
318 if (leftBalance <= 0)
319 {
320     if (leftBalance > rootBalance)
321     {
322         SetBalance(left, (sbyte)(leftBalance + 1));
323     }
324     else
325     {
326         SetBalance(left, (sbyte)(rootBalance + 2));
327     }
328     SetBalance(node, (sbyte)(rootBalance - leftBalance + 1));
329 }
330 else
331 {
332     if (rootBalance <= -1)
333     {
334         SetBalance(left, (sbyte)(leftBalance + 1));
335     }
336     else
337     {
338         SetBalance(left, (sbyte)(rootBalance + leftBalance + 2));
339     }
340     SetBalance(node, (sbyte)(rootBalance + 1));
341 }
342 return left;
343 }
344 }
345
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,
    ↪ GetLeft(parent));
411 if (!GetLeftIsChild(currentNode))
412 {
413     if (!GetRightIsChild(currentNode)) // node has no children
414     {
415         if (AreEqual(parent, default))
416         {
417             root = Zero;
418         }
419         else if (isLeftNode)
420         {
421             SetLeftIsChild(parent, false);
422             SetLeft(parent, GetLeft(currentNode));
423             IncrementBalance(parent);
424         }
425         else
426         {
427             SetRightIsChild(parent, false);
428             SetRight(parent, GetRight(currentNode));
429             DecrementBalance(parent);
430         }
431     }
432     else // node has a right child
433     {
434         var successor = GetNext(currentNode);
435         SetLeft(successor, GetLeft(currentNode));
436         var right = GetRight(currentNode);
437         if (AreEqual(parent, default))
438         {
439             root = right;
440         }
441         else if (isLeftNode)
442         {
443             SetLeft(parent, right);
444             IncrementBalance(parent);
445         }
446         else
447         {
448             SetRight(parent, right);
449             DecrementBalance(parent);
450         }
451     }
452 }
453 else // node has a left child
454 {
455     if (!GetRightIsChild(currentNode))
456     {
457         var predecessor = GetPrevious(currentNode);
458         SetRight(predecessor, GetRight(currentNode));
459         var leftValue = GetLeft(currentNode);
460         if (AreEqual(parent, default))
461         {
462             root = leftValue;
463         }
464         else if (isLeftNode)
465         {
466             SetLeft(parent, leftValue);
467             IncrementBalance(parent);
468         }
469         else
470         {

```

```

471         SetRight(parent, leftValue);
472         DecrementBalance(parent);
473     }
474 }
475 else // node has a both children (left and right)
476 {
477     var predecessor = GetLeft(currentNode);
478     var successor = GetRight(currentNode);
479     var successorParent = currentNode;
480     int previousPathPosition = ++pathPosition;
481     // find the immediately next node (and its parent)
482     while (GetLeftIsChild(successor))
483     {
484         path[++pathPosition] = successorParent = successor;
485         successor = GetLeft(successor);
486         if (!AreEqual(successorParent, currentNode))
487         {
488             DecrementSize(successorParent);
489         }
490     }
491     path[previousPathPosition] = successor;
492     balanceNode = path[pathPosition];
493     // remove 'successor' from the tree
494     if (!AreEqual(successorParent, currentNode))
495     {
496         if (!GetRightIsChild(successor))
497         {
498             SetLeftIsChild(successorParent, false);
499         }
500         else
501         {
502             SetLeft(successorParent, GetRight(successor));
503         }
504         IncrementBalance(successorParent);
505         SetRightIsChild(successor, true);
506         SetRight(successor, GetRight(currentNode));
507     }
508     else
509     {
510         DecrementBalance(currentNode);
511     }
512     // set the predecessor's successor link to point to the right place
513     while (GetRightIsChild(predecessor))
514     {
515         predecessor = GetRight(predecessor);
516     }
517     SetRight(predecessor, successor);
518     // prepare 'successor' to replace 'node'
519     var left = GetLeft(currentNode);
520     SetLeftIsChild(successor, true);
521     SetLeft(successor, left);
522     SetBalance(successor, GetBalance(currentNode));
523     FixSize(successor);
524     if (AreEqual(parent, default))
525     {
526         root = successor;
527     }
528     else if (isLeftNode)
529     {
530         SetLeft(parent, successor);
531     }
532     else
533     {
534         SetRight(parent, successor);
535     }
536 }
537 }
538 // restore balance
539 if (!AreEqual(balanceNode, default))
540 {
541     while (true)
542     {
543         var balanceParent = path[--pathPosition];
544         isLeftNode = !AreEqual(balanceParent, default) && AreEqual(balanceNode,
545             ↪ GetLeft(balanceParent));
546         var currentNodeBalance = GetBalance(balanceNode);
547         if (currentNodeBalance < -1 || currentNodeBalance > 1)

```

```

548         balanceNode = Balance(balanceNode);
549         if (AreEqual(balanceParent, default))
550         {
551             root = balanceNode;
552         }
553         else if (isLeftNode)
554         {
555             SetLeft(balanceParent, balanceNode);
556         }
557         else
558         {
559             SetRight(balanceParent, balanceNode);
560         }
561     }
562     currentNodeBalance = GetBalance(balanceNode);
563     if (currentNodeBalance != 0 || AreEqual(balanceParent, default))
564     {
565         break;
566     }
567     if (isLeftNode)
568     {
569         IncrementBalance(balanceParent);
570     }
571     else
572     {
573         DecrementBalance(balanceParent);
574     }
575     balanceNode = balanceParent;
576 }
577 }
578 ClearNode(node);
579 #if USEARRAYPOOL
580     ArrayPool.Free(path);
581 #endif
582 }
583 }
584
585 [MethodImpl(MethodImplOptions.AggressiveInlining)]
586 protected override void ClearNode(TElement node)
587 {
588     SetLeft(node, Zero);
589     SetRight(node, Zero);
590     SetSize(node, Zero);
591     SetLeftIsChild(node, false);
592     SetRightIsChild(node, false);
593     SetBalance(node, 0);
594 }
595 }
596 }

```

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

```

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

```

```

29 [MethodImpl(MethodImplOptions.AggressiveInlining)]
30 protected abstract void SetLeft(TElement node, TElement left);
31
32 [MethodImpl(MethodImplOptions.AggressiveInlining)]
33 protected abstract void SetRight(TElement node, TElement right);
34
35 [MethodImpl(MethodImplOptions.AggressiveInlining)]
36 protected abstract void SetSize(TElement node, TElement size);
37
38 [MethodImpl(MethodImplOptions.AggressiveInlining)]
39 protected abstract bool FirstIsToTheLeftOfSecond(TElement first, TElement second);
40
41 [MethodImpl(MethodImplOptions.AggressiveInlining)]
42 protected abstract bool FirstIsToTheRightOfSecond(TElement first, TElement second);
43
44 [MethodImpl(MethodImplOptions.AggressiveInlining)]
45 protected virtual TElement GetLeftOrDefault(TElement node) => AreEqual(node, default) ?
46     ↳ default : GetLeft(node);
47
48 [MethodImpl(MethodImplOptions.AggressiveInlining)]
49 protected virtual TElement GetRightOrDefault(TElement node) => AreEqual(node, default) ?
50     ↳ default : GetRight(node);
51
52 [MethodImpl(MethodImplOptions.AggressiveInlining)]
53 protected void IncrementSize(TElement node) => SetSize(node, Increment(GetSize(node)));
54
55 [MethodImpl(MethodImplOptions.AggressiveInlining)]
56 protected void DecrementSize(TElement node) => SetSize(node, Decrement(GetSize(node)));
57
58 [MethodImpl(MethodImplOptions.AggressiveInlining)]
59 protected TElement GetLeftSize(TElement node) => GetSizeOrZero(GetLeftOrDefault(node));
60
61 [MethodImpl(MethodImplOptions.AggressiveInlining)]
62 protected TElement GetRightSize(TElement node) => GetSizeOrZero(GetRightOrDefault(node));
63
64 [MethodImpl(MethodImplOptions.AggressiveInlining)]
65 protected TElement GetSizeOrZero(TElement node) => EqualToZero(node) ? Zero :
66     ↳ GetSize(node);
67
68 [MethodImpl(MethodImplOptions.AggressiveInlining)]
69 protected void FixSize(TElement node) => SetSize(node, Increment(Add(GetLeftSize(node),
70     ↳ GetRightSize(node))));
71
72 [MethodImpl(MethodImplOptions.AggressiveInlining)]
73 protected void LeftRotate(ref TElement root) => root = LeftRotate(root);
74
75 [MethodImpl(MethodImplOptions.AggressiveInlining)]
76 protected TElement LeftRotate(TElement root)
77 {
78     var right = GetRight(root);
79     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
80     if (EqualToZero(right))
81     {
82         throw new InvalidOperationException("Right is null.");
83     }
84     #endif
85     SetRight(root, GetLeft(right));
86     SetLeft(right, root);
87     SetSize(right, GetSize(root));
88     FixSize(root);
89     return right;
90 }
91
92 [MethodImpl(MethodImplOptions.AggressiveInlining)]
93 protected void RightRotate(ref TElement root) => root = RightRotate(root);
94
95 [MethodImpl(MethodImplOptions.AggressiveInlining)]
96 protected TElement RightRotate(TElement root)
97 {
98     var left = GetLeft(root);
99     #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
100     if (EqualToZero(left))
101     {
102         throw new InvalidOperationException("Left is null.");
103     }
104     #endif
105     SetLeft(root, GetRight(left));
106     SetRight(left, root);

```

```

104         SetSize(left, GetSize(root));
105         FixSize(root);
106         return left;
107     }
108
109     [MethodImpl(MethodImplOptions.AggressiveInlining)]
110     protected virtual TElement GetRighttest(TElement current)
111     {
112         var currentRight = GetRight(current);
113         while (!EqualToZero(currentRight))
114         {
115             current = currentRight;
116             currentRight = GetRight(current);
117         }
118         return current;
119     }
120
121     [MethodImpl(MethodImplOptions.AggressiveInlining)]
122     protected virtual TElement GetLefttest(TElement current)
123     {
124         var currentLeft = GetLeft(current);
125         while (!EqualToZero(currentLeft))
126         {
127             current = currentLeft;
128             currentLeft = GetLeft(current);
129         }
130         return current;
131     }
132
133     [MethodImpl(MethodImplOptions.AggressiveInlining)]
134     protected virtual TElement GetNext(TElement node) => GetLefttest(GetRight(node));
135
136     [MethodImpl(MethodImplOptions.AggressiveInlining)]
137     protected virtual TElement GetPrevious(TElement node) => GetRighttest(GetLeft(node));
138
139     [MethodImpl(MethodImplOptions.AggressiveInlining)]
140     public virtual bool Contains(TElement node, TElement root)
141     {
142         while (!EqualToZero(root))
143         {
144             if (FirstIsToTheLeftOfSecond(node, root)) // node.Key < root.Key
145             {
146                 root = GetLeft(root);
147             }
148             else if (FirstIsToTheRightOfSecond(node, root)) // node.Key > root.Key
149             {
150                 root = GetRight(root);
151             }
152             else // node.Key == root.Key
153             {
154                 return true;
155             }
156         }
157         return false;
158     }
159
160     [MethodImpl(MethodImplOptions.AggressiveInlining)]
161     protected virtual void ClearNode(TElement node)
162     {
163         SetLeft(node, Zero);
164         SetRight(node, Zero);
165         SetSize(node, Zero);
166     }
167
168     [MethodImpl(MethodImplOptions.AggressiveInlining)]
169     public void Attach(ref TElement root, TElement node)
170     {
171         #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
172         ValidateSizes(root);
173         Debug.WriteLine("--BeforeAttach--");
174         Debug.WriteLine(PrintNodes(root));
175         Debug.WriteLine("-----");
176         var sizeBefore = GetSize(root);
177         #endif
178         if (EqualToZero(root))
179         {
180             SetSize(node, One);
181             root = node;
182             return;

```



```

183     }
184     AttachCore(ref root, node);
185 #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
186     Debug.WriteLine("--AfterAttach--");
187     Debug.WriteLine(PrintNodes(root));
188     Debug.WriteLine("-----");
189     ValidateSizes(root);
190     var sizeAfter = GetSize(root);
191     if (!AreEqual(Arithmetic.Increment(sizeBefore), sizeAfter))
192     {
193         throw new InvalidOperationException("Tree was broken after attach.");
194     }
195 #endif
196 }
197
198 protected abstract void AttachCore(ref TElement root, TElement node);
199
200 [MethodImpl(MethodImplOptions.AggressiveInlining)]
201 public void Detach(ref TElement root, TElement node)
202 {
203 #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
204     ValidateSizes(root);
205     Debug.WriteLine("--BeforeDetach--");
206     Debug.WriteLine(PrintNodes(root));
207     Debug.WriteLine("-----");
208     var sizeBefore = GetSize(root);
209     if (EqualToZero(root))
210     {
211         throw new InvalidOperationException($"Элемент с {node} не содержится в
212             ↳ дереве.");
213     }
214 #endif
215 DetachCore(ref root, node);
216 #if ENABLE_TREE_AUTO_DEBUG_AND_VALIDATION
217     Debug.WriteLine("--AfterDetach--");
218     Debug.WriteLine(PrintNodes(root));
219     Debug.WriteLine("-----");
220     ValidateSizes(root);
221     var sizeAfter = GetSize(root);
222     if (!AreEqual(Arithmetic.Decrement(sizeBefore), sizeAfter))
223     {
224         throw new InvalidOperationException("Tree was broken after detach.");
225     }
226 #endif
227 }
228
229 protected abstract void DetachCore(ref TElement root, TElement node);
230
231 public void FixSizes(TElement node)
232 {
233     if (AreEqual(node, default))
234     {
235         return;
236     }
237     FixSizes(GetLeft(node));
238     FixSizes(GetRight(node));
239     FixSize(node);
240 }
241
242 public void ValidateSizes(TElement node)
243 {
244     if (AreEqual(node, default))
245     {
246         return;
247     }
248     var size = GetSize(node);
249     var leftSize = GetLeftSize(node);
250     var rightSize = GetRightSize(node);
251     var expectedSize = Arithmetic.Increment(Arithmetic.Add(leftSize, rightSize));
252     if (!AreEqual(size, expectedSize))
253     {
254         throw new InvalidOperationException($"Size of {node} is not valid. Expected
255             ↳ size: {expectedSize}, actual size: {size}.");
256     }
257     ValidateSizes(GetLeft(node));
258     ValidateSizes(GetRight(node));
259 }

```

```

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> :
        ↳ RecursionlessSizeBalancedTreeMethods<TElement>
11     {
12         private struct TreeElement
13         {
14             public TElement Size;
15             public TElement Left;
16             public TElement Right;
17         }
18

```

```

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

```

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

```

1  using System;
2  using System.Collections.Generic;
3  using System.Text;
4  using Platform.Numbers;
5  using Platform.Collections.Methods.Trees;
6  using Platform.Converters;
7
8  namespace Platform.Collections.Methods.Tests
9  {
10     public class SizeBalancedTree<TElement> : SizeBalancedTreeMethods<TElement>
11     {
12         private struct TreeElement
13         {
14             public TElement Size;
15             public TElement Left;
16             public TElement Right;
17         }
18
19         private readonly TreeElement[] _elements;
20         private TElement _allocated;
21
22         public TElement Root;
23
24         public TElement Count => GetSizeOrZero(Root);
25
26         public SizeBalancedTree(int capacity) => (_elements, _allocated) = (new
27             ↳ TreeElement[capacity], One);
28
29         public TElement Allocate()
30         {
31             var newNode = _allocated;
32             if (IsEmpty(newNode))
33             {
34                 _allocated = Arithmetic.Increment(_allocated);
35                 return newNode;
36             }
37             else
38             {
39                 throw new InvalidOperationException("Allocated tree element is not empty.");
40             }
41         }
42
43         public void Free(TElement node)
44         {
45             while (!EqualityComparer.Equals(_allocated, One) && IsEmpty(node))
46             {
47                 var lastNode = Arithmetic.Decrement(_allocated);
48                 if (EqualityComparer.Equals(lastNode, node))
49                 {
50                     _allocated = lastNode;
51                     node = Arithmetic.Decrement(node);
52                 }
53                 else
54                 {
55                     return;
56                 }
57             }
58         }
59
60         public bool IsEmpty(TElement node) =>
61             ↳ EqualityComparer<TreeElement>.Default.Equals(GetElement(node), default);
62
63         protected override bool FirstIsToTheLeftOfSecond(TElement first, TElement second) =>
64             ↳ Comparer.Compare(first, second) < 0;
65
66         protected override bool FirstIsToTheRightOfSecond(TElement first, TElement second) =>
67             ↳ Comparer.Compare(first, second) > 0;
68
69         protected override ref TElement GetLeftReference(TElement node) => ref
70             ↳ GetElement(node).Left;
71
72         protected override TElement GetLeft(TElement node) => GetElement(node).Left;
73
74         protected override ref TElement GetRightReference(TElement node) => ref
75             ↳ GetElement(node).Right;
76
77         protected override TElement GetRight(TElement node) => GetElement(node).Right;
78
79         protected override TElement GetSize(TElement node) => GetElement(node).Size;

```

```

74     protected override void PrintNodeValue(TElement node, StringBuilder sb) =>
75         ↳ sb.Append(node);
76
77     protected override void SetLeft(TElement node, TElement left) => GetElement(node).Left =
78         ↳ left;
79
80     protected override void SetRight(TElement node, TElement right) =>
81         ↳ GetElement(node).Right = right;
82
83     protected override void SetSize(TElement node, TElement size) => GetElement(node).Size =
84         ↳ size;
85
86     private ref TreeElement GetElement(TElement node) => ref
87         ↳ _elements[UncheckedConverter<TElement, long>.Default.Convert(node)];
88 }
89 }

```

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

```

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

```

```

60     }
61
62     public bool IsEmpty(TElement node) =>
63         ↳ EqualityComparer<TreeElement>.Default.Equals(GetElement(node), default);
64
65     protected override bool FirstIsToTheLeftOfSecond(TElement first, TElement second) =>
66         ↳ Comparer.Compare(first, second) < 0;
67
68     protected override bool FirstIsToTheRightOfSecond(TElement first, TElement second) =>
69         ↳ Comparer.Compare(first, second) > 0;
70
71     protected override sbyte GetBalance(TElement node) => GetElement(node).Balance;
72
73     protected override bool GetLeftIsChild(TElement node) => GetElement(node).LeftIsChild;
74
75     protected override ref TElement GetLeftReference(TElement node) => ref
76         ↳ GetElement(node).Left;
77
78     protected override TElement GetLeft(TElement node) => GetElement(node).Left;
79
80     protected override bool GetRightIsChild(TElement node) => GetElement(node).RightIsChild;
81
82     protected override ref TElement GetRightReference(TElement node) => ref
83         ↳ GetElement(node).Right;
84
85     protected override TElement GetRight(TElement node) => GetElement(node).Right;
86
87     protected override TElement GetSize(TElement node) => GetElement(node).Size;
88
89     protected override void PrintNodeValue(TElement node, StringBuilder sb) =>
90         ↳ sb.Append(node);
91
92     protected override void SetBalance(TElement node, sbyte value) =>
93         ↳ GetElement(node).Balance = value;
94
95     protected override void SetLeft(TElement node, TElement left) => GetElement(node).Left =
96         ↳ left;
97
98     protected override void SetLeftIsChild(TElement node, bool value) =>
99         ↳ GetElement(node).LeftIsChild = value;
100
101     protected override void SetRight(TElement node, TElement right) =>
102         ↳ GetElement(node).Right = right;
103
104     protected override void SetRightIsChild(TElement node, bool value) =>
105         ↳ GetElement(node).RightIsChild = value;
106
107     protected override void SetSize(TElement node, TElement size) => GetElement(node).Size =
108         ↳ size;
109
110     private ref TreeElement GetElement(TElement node) => ref
111         ↳ _elements[UncheckedConverter<TElement, long>.Default.Convert(node)];
112 }
113 }

```

## 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                 }
24             }
25         }
26     }
27 }

```

```

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

```

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

```

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

```

```

18 {
19     var sizeBalancedTree = new SizeBalancedTree<uint>(10000);
20     sizeBalancedTree.TestMultipleCreationsAndDeletions(sizeBalancedTree.Allocate,
        ↪ sizeBalancedTree.Free, ref sizeBalancedTree.Root, () => sizeBalancedTree.Count,
        ↪ _n);
21 }
22
23 [Fact]
24 public static void SizedAndThreadedAVLBalancedTreeMultipleAttachAndDetachTest()
25 {
26     var avlTree = new SizedAndThreadedAVLBalancedTree<uint>(10000);
27     avlTree.TestMultipleCreationsAndDeletions(avlTree.Allocate, avlTree.Free, ref
        ↪ avlTree.Root, () => avlTree.Count, _n);
28 }
29
30 [Fact]
31 public static void RecursionlessSizeBalancedTreeMultipleRandomAttachAndDetachTest()
32 {
33     var recursionlessSizeBalancedTree = new RecursionlessSizeBalancedTree<uint>(10000);
34     recursionlessSizeBalancedTree.TestMultipleRandomCreationsAndDeletions(ref
        ↪ recursionlessSizeBalancedTree.Root, () => recursionlessSizeBalancedTree.Count,
        ↪ _n);
35 }
36
37 [Fact]
38 public static void SizeBalancedTreeMultipleRandomAttachAndDetachTest()
39 {
40     var sizeBalancedTree = new SizeBalancedTree<uint>(10000);
41     sizeBalancedTree.TestMultipleRandomCreationsAndDeletions(ref sizeBalancedTree.Root,
        ↪ () => sizeBalancedTree.Count, _n);
42 }
43
44 [Fact]
45 public static void SizedAndThreadedAVLBalancedTreeMultipleRandomAttachAndDetachTest()
46 {
47     var avlTree = new SizedAndThreadedAVLBalancedTree<uint>(10000);
48     avlTree.TestMultipleRandomCreationsAndDeletions(ref avlTree.Root, () =>
        ↪ avlTree.Count, _n);
49 }
50 }
51 }

```



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