BinTreeVisualization

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Chapter 1

General assignment

Make a visualization of basic operations on BST and AVL trees using any programming language and UI framework. Operations to support:

- Search
- Insert
- Delete
- Find min
- Find max

Should ship with documentation that focuses on the properties of binary trees and used data structured, with documentation of the UI implementation being a secondary target.

1.1 Roadmap

Project requirements:

- [X] Initial UI setup
- [X] First block spawned
- [X] Setup text output
- [X] Setup animations
- [X] Setup arrows
- [X] Fill in algorithms
- [X] Make auto layout

Additional subobjectives:

- [X] Add more UI controls
- [X] Add statistics on operation count
- [X] Scale tree to fit automatically
- [ ] Add Red Black Trees?
- [ ] Save / load trees?
- [ ] Add tests

1.2 AVL tree in general

A nice writeup on AVL trees: `https://simpledevcode.wordpress.com/2014/09/16/avl-tree-in-c/`

It is mostly a BST tree with added rotations, so a single base class with a `bool bDoRotations` should suffice.

1.3 WPF specifics

- Arrows do not exist per-se as a WPF object. Can make a container with several lines to mimic them: `https://stackoverflow.com/a/68552890`
- For centering nodes:
  - Grid supports putting its items in location relative to center. Canvas do not respect that by default.
  - Can work around that by putting Canvas in a Grid - its reflectiveness seems to be inherited.
- Animating locations of custom arrows require a DependencyProp, which then can be fed into Point↩ Animatiom:
  - `https://learn.microsoft.com/en-us/dotnet/desktop/wpf/properties/dependency-prop`
    `0`
  - `https://learn.microsoft.com/en-us/dotnet/desktop/wpf/graphics-multimedia/how-to`
- Auto-scaling canvas should be possible with a ViewBox, but it clears out entire view on use?
  - Canvas do support transforms, so can just apply ScaleTransformation dynamically

1.4 Layouting nodes

- Layouting nodes of a binary tree in such a way so that neither space is wasted nor the nodes overlay seem to be harder than expected. Might shelve it for now.
- Found suggestion: Reignold-Tilford's algorithm - but it is for normal trees and not binary ones
- A working algorithm from 1981: `https://reingold.co/tidier-drawings.pdf` (Tidier Drawing of Trees by Edward M. Reingold and John S. Tilford (IEEE Transactions on Software Engineering, Volume 7, Number 2, March 1981))
- This paper also references an easier Wetherell and Shannon algorithm, which has some flaws (as highlighted in the paper), but it also easier to implement
  - Its cons seem to be insignificant enough for this application
  - Also highlighted here: `https://willrosenbaum.com/assets/pdf/2023s-cosc-225/tidy-drawin`
    `pdf`

1.5 Performance

- Performance in instant mode is being capped by creating and running animations in the background
  - Especially by arrows whose locations are being computed on each movement.
- Optimizing for instant mode would require disabling the animations, but it is probably not worth it for the purposes of this application.

Chapter 2

Project overview

2.1 Base BST

The binary search tree is build out of nodes - starting by root, each of the subsequent children can have two children of their own.
The base property of the binary tree which allows for O(log n) search is the way the children nodes are placed - nodes smaller than their parent are placed on the left, and nodes bigger than their parent - on the right. Thanks to this, the area of tree which needs to be searched is effectively halved with each recursive iterations (assuming the tree is balanced well enough).

2.1.1 Insertion

- Proceed like with normal search, then if a spot is found where the search would continue but the spot is empty - insert a new node into it.

2.1.2 Search

- Follow the tree with the principle of going left if the searched value is smaller than the current node, and right if the searched value is bigger.
- Check if the current is the searched node if neither of those paths can be taken.

2.1.3 Deletion

- Find an item to delete.
- Next, try to find its successor - the next element which is minimally smaller than the current one (that can be obtained by going one to right and then max to left, thanks to binary tree properties).
- Once a successor is found, swap the victim with the succesor, and then remove the victim whose been moved out of the original location.
- If the victim is not placed in a leaf position (i.e. having no children), repeat finding a successor and swapping until a leaf node is reached which can then be removed safely.

All operations have O(log n) time complexity, but can grow up to O(1) with an unbalanced tree.

The tree itself has O(n) space complexity, and algorithms have O(1) space complexity.

2.2 AVL

AVL tree is a type of a binary search tree. It operates on the same base princinple regarding to the location of nodes, but with an additional mechanic - rotations.
Whenever a subtree becomes unbalances - i.e. one of its sides is at least two nodes taller than the other one - a node with the middle value is picked out of the long branch, and then the other nodes from this branch are balanced around it.
Thanks to this, a normally successive chain (eg. 1 -> 2 -> 3) becomes a neatly balanced, smaller tree (with node {2} pointing to {1} to the left and to {3} to the right).

This helps ensure that tree doesn't become unbalanced and its operations do not degrade into O(1) complexity.

The tree itself has O(n) space complexity, and algorithms have O(1) space complexity.

Operations on AVL trees start exactly the same way as on base BSTs, but then after a node is either inserted or removed, all parents of the affected node are visitied to make sure the tree is kept in balance, and rotations are performed if they are not.

2.3 App structure

The application is written utilizing C# 13 preview language, .NET 9.0 framework, as well as WPF framework for the UI.
The tree is layouted using a modified Wetherell and Shannon algorithm.
It uses Material Design (`http://materialdesigninxaml.net/`) NuGet package for the interface theme, as well as ScottPlot library (`https://scottplot.net/`) for rendering the collected performance data into graphs.
The tree's logical data structures are partially separated from the WPF elements and use a composite model.

- `BinTree<T>` and `Node<T>` are the main data logical structures that hold the info about the binary tree and can perform operations on it.
- `TreeLayout` is a helper class that can auto-layout the tree.
- `BinTreeMan` is a WPF page which holds the main user interface and delegates operations requested by user to the binary tree.
- `BinTreeControl` is a WPF UserControl that holds Canvas where the nodes are physically placed into
- `NodeControl` is a WPF UserControl that represents a visual node - each `NodeControl` is directly managed by a `Node<T>` it is associated with, and physically placed upon `BinTreeControl`'s Canvas
- `NodeArrow` is a WPF UserControl that represents and arrow that can point from one point into another. Each `Node<T>` manages an arrow pointing towards it.
- `ProgressLabel` is a WPF Control that is used for displaying descriptions.
- `TreeStats` and `StatsWindow.xaml` are classes used for gathering and displaying the statistics respectively.

Documentation PDF is generated with Doxygen.
Detailed descriptions of each of the classes, methods, and properties used in the program are contained in the following chapters of the documentation PDF.

Chapter 3

Binary Tree Visualization

A modern C# / WPF application that lets you visualize basic operations on BST and AVL trees.

3.1 Operations supported

Supports:

- Insertion
- Deletion
- Search

All steps performed during an algorithm's execution are described in the log, and all the nodes associated with the particular sub-operation are highlighted - which enables clear and easy following of an algorithm.

Additionally, the amount of performed comparisons and traversals is recorded and can be viewed in form of a graph (utilizes ScottPlott library):

This allows one to verify the algorithms' time complexity with real-world data.

3.2 Quality of Lifes

- Use "Insert 20 items" button to insert twenty random items into the tree instantly. Count can be decreased / increased with `F2` and `F3` keys respectively.
- Press `Escape` to cancel the current animation and proceed to the final result instantly
- Press `Enter` to repeat the last operation
- Click a node to quickly select it
- Graph's data updates instantly as you perform new operations
- The tree is auto-layouted using a modified Wetherell and Shannon algorithm for visually pleasant and efficient use of space

3.3 Build

Uses .NET 9.0 and C# 13 preview with WPF UI. To build with Visual Studio 2022.
Utilizes `Material Design` NuGet package for the interface theme, as well as `ScottPlot library` for rendering the collected performance data into graphs.
The interface is connected to the logical binary tree with a composite model, where `BinTree<T>` and `Node<T>` manage their respective `BinTreeControl` and `BinTreeNode` WPF controls, respectively.

Chapter 4

Namespace Index

4.1 Package List

Here are the packages with brief descriptions (if available):

Chapter 5

Hierarchical Index

5.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

Chapter 6

Class Index

6.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

Chapter 7

Namespace Documentation

7.1 BinTreeVisualization Namespace Reference

Classes

- class App

    Interaction logic for App.xaml.
- class MainWindow

    Main window which holds the BinTreeMan page.

7.2 BinTreeVisualization.Algorithms Namespace Reference

Classes

- class BinTree

    A binary search tree, associated with a WPF backing control that nodes are being represented on. Can function as a basic BST and an AVL tree.
- class Node

    A binary tree's node.
- class **SideExtensions**

    Extensions for Side
- class TextActionColorsHelper

    Helper for colors of a TextAction
- class **TreeLayout**

    Helper class that layouts a binary tree so that no nodes overlap.

Enumerations

- enum TextAction { **Base** , **Blink** , **Violet** , **Red** }

    Colors supported by the UI.
- enum Side { **Left** , **Right** }

    Represents a side of a binary tree node.

Functions

- record struct BinTreeRow< T > (int Tier, List< Node< T > > Nodes)

  A row in the binary tree, containing the tier and the nodes on that tier.

7.2.1 Function Documentation

7.2.1.1 BinTreeRow< T >()

```
record struct BinTreeVisualization.Algorithms.BinTreeRow< T > (
            int Tier,
            List< Node< T > > Nodes )
```

A row in the binary tree, containing the tier and the nodes on that tier.

Template Parameters

T	

Parameters

Tier	Tier
Nodes	All nodes in that tier

Type Constraints

***T* : *IComparable*<*T*>**

7.3 BinTreeVisualization.Stats Namespace Reference

Classes

- class StatsWindow

  Interaction logic for StatsWindow.xaml.
- class TreeStats

  Holds statistics of operations performed on a binary tree.

Enumerations

- enum OperationType { **Insert** , **Delete** , **Search** , **Discard** }

  Represents the type of operation performed on a binary tree.

Functions

- record struct OperationStats (double Comparisons, double Traversals, int TreeSize)

  Represents the statistics of a single operation.

7.3.1 Function Documentation

7.3.1.1 OperationStats()

```
record struct BinTreeVisualization.Stats.OperationStats (
            double Comparisons,
            double Traversals,
            int TreeSize )
```

Represents the statistics of a single operation.

Parameters

Comparisons	The amount of comparisons between nodes' values
Traversals	The amount of travels from one node to another
TreeSize	The count of items in the tree at the beginning of the operation

7.4 BinTreeVisualization.UI Namespace Reference

Classes

- class BinTreeControl

  WPF UserControl that holds all binary tree's nodes.
- class BinTreeMan

  Page which holds both a BinTreeControl and other controls that allow the user to interact with it.
- class NodeArrow

  Represents an arrow that can point between nodes.
- class NodeControl

  UI element that represents a node in a binary tree.
- class PointExtensions
- class ProgressLabel

  A label that can represent progress which supports spawn/despawn animations and colors.
- class **TitleBarHelper**

  Helps to setup the title bar color of a window.

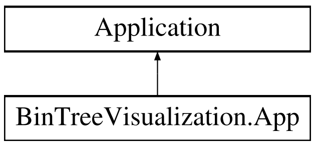
Chapter 8

Class Documentation

8.1 BinTreeVisualization.App Class Reference

Interaction logic for App.xaml.

Inheritance diagram for BinTreeVisualization.App:



8.1.1 Detailed Description

Interaction logic for App.xaml.

The documentation for this class was generated from the following file:

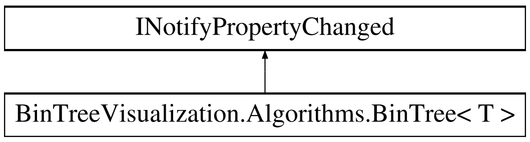
- S:/Uni/Algosy/BinTreeVisualization/App.xaml.cs

8.2 BinTreeVisualization.Algorithms.BinTree$<$ T $>$ Class Template Reference

A binary search tree, associated with a WPF backing control that nodes are being represented on.

Can function as a basic BST and an AVL tree.

Inheritance diagram for BinTreeVisualization.Algorithms.BinTree$<$ T $>$:



Public Member Functions

- Canvas GetCanvas ()

  Ref to the backing control's canvas.
- int GetHeight ()

  Get the tree's height.
- async Task< bool > VerifyTreeIsNotEmpty ()

  Verify whether the tree is not empty.
- async Task< Node< T >?> Find (T value)

  Find value in the tree.
- async Task< Node< T >?> Find (T value, Node< T > currNode)

  Recursively search the tree to find the specified value . Search starts from currNode .
- async Task< T > GetMin ()

  Get minimum value in the tree.
- async Task< T > GetMax ()

  Get maximum value in the tree.
- async Task< Node< T > > GetMin (Node< T > treeBase)

  Get minimum in the subtree starting by the specified node.
- async Task< Node< T > > GetMax (Node< T > treeBase)

  Get max in the subtree starting by the specified node.
- async void Delete (T value)

  Delete node containing the specified value from the tree.
- void VerifyTreeLayout (bool fromMiddleOfOperation=false)

  Verify that the tree's layout is correct: i.e. no nodes overlap and the scale is appropriate for all nodes to fit in the window.
- async Task SwapValues (Node< T > one, Node< T > other)

  Swap nodes' values with animation.
- async Task Delete (Node< T > victim)

  Delete specified node from the tree.
  You can find the node first with Find(T)
- void **BreakInto** ()

  Triggers debug break inside the tree.
- async Task Insert (T value)

  Insert value into the tree.
- delegate void **OnInstantModeFinishedFunc** ()

  Signature for OnInstantModeFinished
- async Task **FinishCurrOperation** ()

  Instantly finish current operation, if any is active.
- async Task< Node< T > > Insert (T value, Node< T > currNode)

  Internal insertion. Try to insert the value into the subtree starting with currNode .
- IEnumerable< Node< T > > **Traverse** ()
- List< BinTreeRow< T > > GetRows ()

  Get a list of all rows in the tree with their depths.
- List< Node< T > > GetRow (int Depth)

  Get a row of nodes at the specified depth.
- void **AssertTreeIsValid** ()

  Assert that the tree is valid.
- void **AssertNoOrphans** ()

  Assert that there are no orphaned nodes.
- void **AssertIsBinaryTree** ()

  Assert that the core property of the binary tree (lesser children on the left, bigger children on the right) is satisfied for every node in the tree.

- void **AssertCachedHeights** ()

    Assert that call cached heights are correct with the real heights.
- void **AssertIsAVLTree** ()

    Assert that it is a correct AVL tree, i.e. at no point is branch balance more than 1.

Protected Member Functions

- virtual void **OnPropertyChanged** ([CallerMemberName] string propertyName="")

Properties

- Node< T >? **Root** `[get, set]`

    Tree's root node.
- required BinTreeControl **BackingControl** `[get]`

    The UI control associated with the tree which holds all the visual nodes, arrows, and progress text.
- int **Height** `[get]`

    Tree's height.
- TreeStats **Stats** = new() `[get, private set]`

    Statistics on how many operations did each operation on the tree require.
- bool **bSkipAnimations** = false `[get, private set]`

    Whether or not to skip animations and perform operations instantly.
- SemaphoreSlim **OperationSem** = new(1, 1) `[get]`

    Semaphore to ensure only one operation is being performed at a time.
- int **CurrWaiting** = 0 `[get, set]`

    Number of tasks waiting for the operation to finish.
- int **CurrInside** = 0 `[get, set]`

    Number of tasks currently performing an operation. Should never be bigger than one!
- bool **PerformRotations** = true `[get, set]`

    Whether or not to perform AVL tree rotations.

Events

- OnInstantModeFinishedFunc **OnInstantModeFinished**

    Event that is invoked when bSkipAnimations is switched back to false.
- PropertyChangedEventHandler **PropertyChanged**

Private Member Functions

- void FinishOperationStats (OperationType type)

    Coalesce gathered statistics into an OperationStats with the specified type and append to the tree's Stats. Resets current operation's stats.
- void CreateRoot (T value)

    Create tree's root with the specified value .
- async Task< Node< T >?> Find (T value, bool bAsSupportingOp)

    Find value in the tree.
- async Task Blink (Node< T > node)

    Blink a node for 500ms and return once the blink starts to fade.
- async Task SwapNodes (Node< T > one, Node< T > other)

    Swap two nodes in the tree and relink their parents in a way so that the binary tree properties are maintained.

- async Task Delay (int ms)

  Delays the execution of the current task if in not-instant context.
  Otherwise, returns immediately.
- async Task OperationGuard ()

  Ensures only one operation is being performed at a time.
  If one is already being performed when this func is called, try to skip all of its delays and wait for it to finish.
- void **FinishOperation** ()

  Signal that an operation is finished and another one can be started.
- async Task BalanceTreeIfNeeded (Node< T > currNode)

  Check if the subtree starting with the passed node is not skewed to a side, and perform a rotation if it is.
- async Task AnimAdoption (Node< T > parent, Node< T > child)

  Perform adoption of a node by a parent with a 3-second long animation.
- async Task< Node< T > > Rotate (Node< T > currNode, bool bLeftRotation)

  Side-heavy subtree. Rotate to the specified direction.
  The subtree should be rotated left if it's right-heavy (bLeftRotation = `true`*), and right in the opposite case.*
- async Task< Node< T > > RotateRight (Node< T > currNode)

  Left-heavy subtree. Rotate middle nodes to the right.
- async Task< Node< T > > RotateLeft (Node< T > currNode)

  Right-heavy subtree. Rotate middle nodes to the right.
- void **SetText** (string text, TextAction act=TextAction.Base)
- async Task **ResetText** ()
- void **LayoutTree** ()

  Perform auto layout on the tree so that the nodes do not overlap with each other.

Private Attributes

- int **ComparisonsCount** = 0

  The count of comparisons between nodes' values which were performed during the last operation.
- int **TraversalCount** = 0

  The count of traversal between nodes (going up and down the tree) which were performed during the last operation.
- bool **bLayoutNSquare** = false

  Whether to layout the tree in a square manner.

8.2.1 Detailed Description

A binary search tree, associated with a WPF backing control that nodes are being represented on.

Can function as a basic BST and an AVL tree.

Template Parameters

T	The type of data this tree's nodes hold

Type Constraints

***T* : *IComparable*<*T*>**

8.2.2 Member Function Documentation

8.2.2.1 AnimAdoption()

```
async Task BinTreeVisualization.Algorithms.BinTree< T >.AnimAdoption (
             Node< T > parent,
             Node< T > child )  [private]
```

Perform adoption of a node by a parent with a 3-second long animation.

Parameters

parent	The new parent
child	The child to be adopted

Returns

8.2.2.2 BalanceTreeIfNeeded()

```
async Task BinTreeVisualization.Algorithms.BinTree< T >.BalanceTreeIfNeeded (
             Node< T > currNode )  [private]
```

Check if the subtree starting with the passed node is not skewed to a side, and perform a rotation if it is.

Parameters

currNode	Subtree which starts by this node

Returns

8.2.2.3 Blink()

```
async Task BinTreeVisualization.Algorithms.BinTree< T >.Blink (
             Node< T > node )  [private]
```

Blink a node for 500ms and return once the blink starts to fade.

Parameters

node	Node to blink

Returns

8.2.2.4 CreateRoot()

```
void BinTreeVisualization.Algorithms.BinTree< T >.CreateRoot (
             T value )  [private]
```

Create tree's root with the specified *value* .

Parameters

value	Value to create the root with

8.2.2.5 Delay()

```
async Task BinTreeVisualization.Algorithms.BinTree< T >.Delay (
             int ms )  [private]
```

Delays the execution of the current task if in not-instant context.

Otherwise, returns immediately.

Parameters

ms	Delay in miliseconds

Returns

8.2.2.6 Delete() [1/2]

```
async Task BinTreeVisualization.Algorithms.BinTree< T >.Delete (
             Node< T > victim )
```

Delete specified node from the tree.

You can find the node first with Find(T)

Parameters

victim	Node to delete

Returns

8.2.2.7 Delete() [2/2]

```
async void BinTreeVisualization.Algorithms.BinTree< T >.Delete (
            T value )
```

Delete node containing the specified value from the tree.

Parameters

value	The value to remove

8.2.2.8 Find() [1/3]

```
async Task< Node< T >?> BinTreeVisualization.Algorithms.BinTree< T >.Find (
            T value )
```

Find *value* in the tree.

Parameters

value	The value to find

Returns

The found node. null if node with the requested value was not found.

8.2.2.9 Find() [2/3]

```
async Task< Node< T >?> BinTreeVisualization.Algorithms.BinTree< T >.Find (
            T value,
            bool bAsSupportingOp )  [private]
```

Find *value* in the tree.

Parameters

value	The value to find
bAsSupportingOp	`true` if it's executed as part of another operation and thus should not wait for exclusivity

Returns

The found node. null if node with the requested value was not found.

8.2.2.10 Find() [3/3]

```
async Task< Node< T >?> BinTreeVisualization.Algorithms.BinTree< T >.Find (
            T value,
            Node< T > currNode )
```

Recursively search the tree to find the specified *value* . Search starts from *currNode* .

Parameters

value	The value to find.
currNode	Subtree to search for the node in currently.

Returns

The found node. null if node with the requested value was not found.

8.2.2.11 FinishOperationStats()

```
void BinTreeVisualization.Algorithms.BinTree< T >.FinishOperationStats (
            OperationType type )  [private]
```

Coalesce gathered statistics into an OperationStats with the specified *type* and append to the tree's Stats.

Resets current operation's stats.

Parameters

type	The type of operation which was performed

8.2.2.12 GetCanvas()

```
Canvas BinTreeVisualization.Algorithms.BinTree< T >.GetCanvas ( )
```

Ref to the backing control's canvas.

Returns

8.2.2.13 GetHeight()

```
int BinTreeVisualization.Algorithms.BinTree< T >.GetHeight ( )
```

Get the tree's height.

Returns

8.2.2.14 GetMax() [1/2]

```
async Task< T > BinTreeVisualization.Algorithms.BinTree< T >.GetMax ( )
```

Get maximum value in the tree.

Returns

The max value in the tree

8.2.2.15 GetMax() [2/2]

```
async Task< Node< T > > BinTreeVisualization.Algorithms.BinTree< T >.GetMax (
            Node< T > treeBase )
```

Get max in the subtree starting by the specified node.

Parameters

treeBase	Tree's base from which the search should start

Returns

The node with the maximum value in the subtree

8.2.2.16 GetMin() [1/2]

```
async Task< T > BinTreeVisualization.Algorithms.BinTree< T >.GetMin ( )
```

Get minimum value in the tree.

Returns

The min value in the tree

8.2.2.17 GetMin() [2/2]

```
async Task< Node< T > > BinTreeVisualization.Algorithms.BinTree< T >.GetMin (
            Node< T > treeBase )
```

Get minimum in the subtree starting by the specified node.

Parameters

treeBase	Tree's base from which the search should start

Returns

The node with the minimum value in the subtree

8.2.2.18 GetRow()

```
List< Node< T > > BinTreeVisualization.Algorithms.BinTree< T >.GetRow (
            int Depth )
```

Get a row of nodes at the specified depth.

Parameters

Depth	The depth

Returns

A list of all nodes at the specified depth.

8.2.2.19 GetRows()

```
List< BinTreeRow< T > > BinTreeVisualization.Algorithms.BinTree< T >.GetRows ( )
```

Get a list of all rows in the tree with their depths.

Returns

A list of all rows in the tree with their depths.

8.2.2.20 Insert() [1/2]

```
async Task BinTreeVisualization.Algorithms.BinTree< T >.Insert (
            T value )
```

Insert *value* into the tree.

Parameters

value	The value to insert.

8.2.2.21 Insert() [2/2]

```
async Task< Node< T > > BinTreeVisualization.Algorithms.BinTree< T >.Insert (
            T value,
            Node< T > currNode )
```

Internal insertion. Try to insert the *value* into the subtree starting with *currNode* .

Parameters

value	The value to insert.
currNode	Subtree which starts by this node.

Returns

Passed-in subtree with inserted *value*

8.2.2.22 OperationGuard()

```
async Task BinTreeVisualization.Algorithms.BinTree< T >.OperationGuard ( )  [private]
```

Ensures only one operation is being performed at a time.

If one is already being performed when this func is called, try to skip all of its delays and wait for it to finish.

Returns

8.2.2.23 Rotate()

```
async Task< Node< T > > BinTreeVisualization.Algorithms.BinTree< T >.Rotate (
            Node< T > currNode,
            bool bLeftRotation )  [private]
```

Side-heavy subtree. Rotate to the specified direction.

The subtree should be rotated left if it's right-heavy (*bLeftRotation* = `true`), and right in the opposite case.

Parameters

currNode	Node which the unbalanced subtree starts with
bLeftRotation	`true` if the subtree is right-heavy and should be rotated left.

`false` if the subtree is left-heavy and should be rotated right

Returns

New top child who the subtree starts with

8.2.2.24 RotateLeft()

```
async Task< Node< T > > BinTreeVisualization.Algorithms.BinTree< T >.RotateLeft (
            Node< T > currNode )  [private]
```

Right-heavy subtree. Rotate middle nodes to the right.

Parameters

currNode	Node which the unbalanced subtree starts with

Returns

New top child who the subtree starts with

8.2.2.25 RotateRight()

```
async Task< Node< T > > BinTreeVisualization.Algorithms.BinTree< T >.RotateRight (
            Node< T > currNode )  [private]
```

Left-heavy subtree. Rotate middle nodes to the right.

Parameters

currNode	Node which the unbalanced subtree starts with

Returns

New top child who the subtree starts with

8.2.2.26 SwapNodes()

```
async Task BinTreeVisualization.Algorithms.BinTree< T >.SwapNodes (
            Node< T > one,
            Node< T > other )  [private]
```

Swap two nodes in the tree and relink their parents in a way so that the binary tree properties are maintained.

Parameters

one	One node
other	The other node

8.2.2.27 SwapValues()

```
async Task BinTreeVisualization.Algorithms.BinTree< T >.SwapValues (
            Node< T > one,
            Node< T > other )
```

Swap nodes' values with animation.

Parameters

one	One node
other	The other node

Returns

8.2.2.28 VerifyTreeIsNotEmpty()

```
async Task< bool > BinTreeVisualization.Algorithms.BinTree< T >.VerifyTreeIsNotEmpty ( )
```

Verify whether the tree is not empty.

Returns

`true` if the tree is not empty, `false` otherwise

8.2.2.29 VerifyTreeLayout()

```
void BinTreeVisualization.Algorithms.BinTree< T >.VerifyTreeLayout (
            bool fromMiddleOfOperation = false )
```

Verify that the tree's layout is correct: i.e. no nodes overlap and the scale is appropriate for all nodes to fit in the window.

Parameters

fromMiddleOfOperation	`true` it is called from middle of an operation, and `false` if it's called after operations are finished

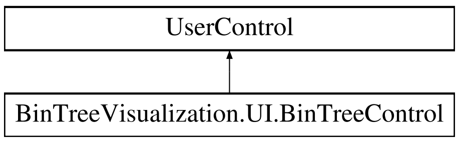
The documentation for this class was generated from the following file:

- S:/Uni/Algosy/BinTreeVisualization/Algorithms/BinTree.cs

8.3 BinTreeVisualization.UI.BinTreeControl Class Reference

WPF UserControl that holds all binary tree's nodes.

Inheritance diagram for BinTreeVisualization.UI.BinTreeControl:



Public Member Functions

- void SetScaleAnim (double newScale)

  Set the canvas scale with an animation.
- void VerifyScale< T > (BinTree< T > tree)

  Check whether a new scale is needed for all elements to fit.
- void SetText (string text, TextAction act=TextAction.Base)

  Add a new text describing the current step. The newly spawned text is animated.
- async Task ResetText (bool bWait)

  Reset all current progress texts.
- void LayoutTreeNSquare< T > (BinTree< T > tree)

  Auto layout the tree, allocating double the space for every next row. Does not account for empty branches.

Properties

- double **currVirtualWidth** `[get]`

  The amount of real space that the tree can accumulate at the current scale.

Private Member Functions

- double GetNewScale< T > (BinTree< T > tree)

  Get the new scale for the tree to fit the window.
- double GetNodesTotalWidth< T > (BinTree< T > tree)

  Get the maximum spread between the westmost and the eastmost nodes.

Private Attributes

- double **CanvasDesiredScale** = 1.0

  Current canvas desired scale after animations are finished.
- double **RescaleMultiplier** = 1.3

  Unused.
- double **MinScale** = 1

  Minimum scale of the tree. Do not make it smaller than that.

8.3.1 Detailed Description

WPF UserControl that holds all binary tree's nodes.

8.3.2 Member Function Documentation

8.3.2.1 GetNewScale< T >()

```
double BinTreeVisualization.UI.BinTreeControl.GetNewScale< T > (
            BinTree< T > tree )  [private]
```

Get the new scale for the tree to fit the window.

Template Parameters

T	

Parameters

tree	The tree

Returns

A new scale for the canvas

Type Constraints

***T* : *IComparable*<*T*>**

8.3.2.2 GetNodesTotalWidth< T >()

```
double BinTreeVisualization.UI.BinTreeControl.GetNodesTotalWidth< T > (
            BinTree< T > tree )  [private]
```

Get the maximum spread between the westmost and the eastmost nodes.

Template Parameters

T	

Parameters

tree	The tree

Returns

Spread of the tree, rounded up so that the tree stays symmetrical.

Type Constraints

***T* : *IComparable*<*T*>**

8.3.2.3 LayoutTreeNSquare< T >()

```
void BinTreeVisualization.UI.BinTreeControl.LayoutTreeNSquare< T > (
            BinTree< T > tree )
```

Auto layout the tree, allocating double the space for every next row. Does not account for empty branches.

Template Parameters

T	

Parameters

tree	The tree

Type Constraints

***T* : *IComparable*<*T*>**

8.3.2.4 ResetText()

```
async Task BinTreeVisualization.UI.BinTreeControl.ResetText (
             bool bWait )
```

Reset all current progress texts.

If any texts are currently present, they will be despawned in a 200ms long animation.

If empty, returns immediately.

8.3.2.5 SetScaleAnim()

```
void BinTreeVisualization.UI.BinTreeControl.SetScaleAnim (
             double newScale )
```

Set the canvas scale with an animation.

Parameters

newScale	The new target scale to be set to after the animation finishes.

8.3.2.6 SetText()

```
void BinTreeVisualization.UI.BinTreeControl.SetText (
             string text,
             TextAction act = TextAction::Base )
```

Add a new text describing the current step. The newly spawned text is animated.

Parameters

text	The text to add
act	Text's color

8.3.2.7 VerifyScale< T >()

```
void BinTreeVisualization.UI.BinTreeControl.VerifyScale< T > (
            BinTree< T > tree )
```

Check whether a new scale is needed for all elements to fit.

Template Parameters

T	

Parameters

tree	The tree

Type Constraints

***T* : *IComparable*<*T*>**

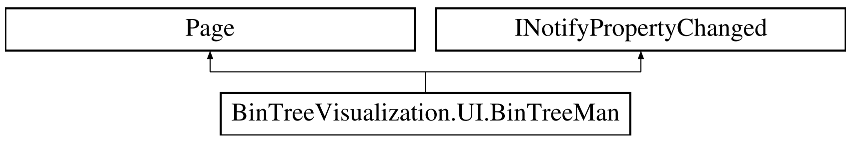
The documentation for this class was generated from the following file:

- S:/Uni/Algosy/BinTreeVisualization/UI/BinTreeControl.xaml.cs

8.4 BinTreeVisualization.UI.BinTreeMan Class Reference

Page which holds both a BinTreeControl and other controls that allow the user to interact with it.

Inheritance diagram for BinTreeVisualization.UI.BinTreeMan:



Protected Member Functions

- virtual void **OnPropertyChanged** ([CallerMemberName] string propertyName="")

Properties

- BinTree< double > **BinTree** `[get, set]`

  The associated binary tree whose data is being displayed.
- string **OperationArgument** `[get, set]`

  The argument of the operation to be performed.
- bool **PerformRotations** = true `[get, set]`

  Backing bool for whether or not to perform AVL rotations.
- int **AddItemsCount** = 20 `[get, set]`

  Backing field for the count of items to add.
- string **AddItemsCountText** `[get]`

  UI text for the "Insert X items" button.

Events

- PropertyChangedEventHandler **PropertyChanged**

Private Member Functions

- async void **Insert** (double value)
- async void OnInsert (object sender, RoutedEventArgs e)

  Click event - perform an insert operation.
- void OnGetMin (object sender, RoutedEventArgs e)

  Click event - on get min.
- void OnGetMax (object sender, RoutedEventArgs e)

  Click event - on get max.
- bool GetDoubleArg (out double arg)

  Try to get the current InputTextBox's value as a double.
- void OnFind (object sender, RoutedEventArgs e)

  Click event - on find.
- void OnDelete (object sender, RoutedEventArgs e)

  Click event - on delete.
- void SwitchAddItemsCount (bool bToDown)

  Switch the value of AddItemsCount to the next or previous value.
- async void AddRandomItems (int count)

  Click event - on add random items.
- void OnKeyDownTextbox (object sender, KeyEventArgs e)

  On key pressed inside the InputTextBox.
- void OnKeyDownBackground (object sender, KeyEventArgs e)

  On key pressed inside the entire main window.
- void OnInsertManyItems (object sender, RoutedEventArgs e)

  Click event - on insert many items.
- void OnOpenStatsWindow (object sender, RoutedEventArgs e)

  Click event - on clear.
- void **Page_SizeChanged** (object sender, SizeChangedEventArgs e)

Private Attributes

- List< int > **AddItemsCounts** = [10, 20, 50, 100, 200]

  List of possible values for AddItemsCount.
- Action< object, RoutedEventArgs > **lastOperation**

  The last operation that was performed. It will be exeucted when pressing the Enter key.

8.4.1 Detailed Description

Page which holds both a BinTreeControl and other controls that allow the user to interact with it.

8.4.2 Member Function Documentation

8.4.2.1 AddRandomItems()

```
async void BinTreeVisualization.UI.BinTreeMan.AddRandomItems (
            int count )  [private]
```

Click event - on add random items.

Parameters

count	The amount of random items to add

8.4.2.2 GetDoubleArg()

```
bool BinTreeVisualization.UI.BinTreeMan.GetDoubleArg (
            out double arg )  [private]
```

Try to get the current InputTextBox's value as a double.

Parameters

arg	Out arg: the parsed value

Returns

`true` if parse succeeded, `false` otherwise.

8.4.2.3 OnDelete()

```
void BinTreeVisualization.UI.BinTreeMan.OnDelete (
            object sender,
            RoutedEventArgs e )  [private]
```

Click event - on delete.

Parameters

sender	
e	

8.4.2.4 OnFind()

```
void BinTreeVisualization.UI.BinTreeMan.OnFind (
            object sender,
            RoutedEventArgs e )  [private]
```

Click event - on find.

Parameters

sender	
e	

8.4.2.5 OnGetMax()

```
void BinTreeVisualization.UI.BinTreeMan.OnGetMax (
             object sender,
             RoutedEventArgs e )  [private]
```

Click event - on get max.

Parameters

sender	
e	

8.4.2.6 OnGetMin()

```
void BinTreeVisualization.UI.BinTreeMan.OnGetMin (
             object sender,
             RoutedEventArgs e )  [private]
```

Click event - on get min.

Parameters

sender	
e	

8.4.2.7 OnInsert()

```
async void BinTreeVisualization.UI.BinTreeMan.OnInsert (
             object sender,
             RoutedEventArgs e )  [private]
```

Click event - perform an insert operation.

Parameters

sender	
e	

8.4.2.8 OnInsertManyItems()

```
void BinTreeVisualization.UI.BinTreeMan.OnInsertManyItems (
             object sender,
             RoutedEventArgs e )  [private]
```

Click event - on insert many items.

Parameters

sender	
e	

8.4.2.9 OnKeyDownBackground()

```
void BinTreeVisualization.UI.BinTreeMan.OnKeyDownBackground (
            object sender,
            KeyEventArgs e )  [private]
```

On key pressed inside the entire main window.

Parameters

sender	
e	

8.4.2.10 OnKeyDownTextbox()

```
void BinTreeVisualization.UI.BinTreeMan.OnKeyDownTextbox (
            object sender,
            KeyEventArgs e )  [private]
```

On key pressed inside the InputTextBox.

Parameters

sender	
e	

8.4.2.11 OnOpenStatsWindow()

```
void BinTreeVisualization.UI.BinTreeMan.OnOpenStatsWindow (
            object sender,
            RoutedEventArgs e )  [private]
```

Click event - on clear.

Parameters

sender	
e	

8.4.2.12 SwitchAddItemsCount()

```
void BinTreeVisualization.UI.BinTreeMan.SwitchAddItemsCount (
            bool bToDown )  [private]
```

Switch the value of AddItemsCount to the next or previous value.

Parameters

bToDown	Whether to switch the value down

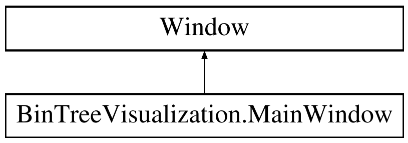
The documentation for this class was generated from the following file:

- S:/Uni/Algosy/BinTreeVisualization/UI/BinTreeMan.xaml.cs

8.5 BinTreeVisualization.MainWindow Class Reference

Main window which holds the BinTreeMan page.

Inheritance diagram for BinTreeVisualization.MainWindow:



8.5.1 Detailed Description

Main window which holds the BinTreeMan page.

The documentation for this class was generated from the following file:

- S:/Uni/Algosy/BinTreeVisualization/UI/MainWindow.xaml.cs

8.6 BinTreeVisualization.Algorithms.Node$<$ T $>$ Class Template Reference

A binary tree's node.

Public Member Functions

- void **RefreshHeight** ()

    Refresh node height. To be used after adoptions.
- Node< T > SpawnChild (T value, bool bLeft)

    Spawn a new node as child of this node. This is the only way to spawn new nodes.
- bool IsLeaf ()

    Whether the node is a leaf (i.e. has no children)
- Node< T > AdoptChild (Node< T > node)

    Adopt a child node. The child along its entire subtree will be moved to the correct side of this node.
    If selves children slots are full, the passed-in node will itself adopt one of the current children in order to create a chain.
- void OrphanChildren (bool OrphanLeftChild=true, bool OrphanRightChild=true)

    Orphan the children of this node.
- void SwapValues (Node< T > other)

    Swap value of this node with value from another one. Does NOT ensure binary tree properties are maintained!
- void **DetachFromParent** ()

    Detach this node from its parent.
- int GetDepth ()

    Get depth, i.e. how many levels deep is this node in the tree.
- int GetHeight ()

    Get height of the node, i.e. how many levels deep is the deepest child of this node.
- int CalcHeight ()

    Calculate node's height recursively.
- int GetNodeBalance ()

    Get the balance of the node - how much taller is its left children trace than the right one.
- Node< T > GetRelativeNode (int toRight)

    Get the node at a relative position to the right from the current node, as if all nodes on this level were taken.
    Returns null if the spot at this location is empty.
- IEnumerable< Node< T > > Traverse ()

    Traverse the tree in Level Order Traversal.
- IEnumerable< Node< T > > TraverseAncestors ()

    Traverse ancestors of this node in the order parent -> grandparent -> ... -> root.
- override string **ToString** ()
- void **RefreshSelfArrow** ()

    Refresh the arrow pointing to this node to account for changes in parents.
- void **Activate** ()
- void **Deactivate** ()
- void **HighlightBlue** ()
- void ActivateBlue (bool bRecursive=false)

    Change node's fill color to blue with an animation.
- void DeactivateBlue (bool bRecursive=false)

    Reset node's fill color.
- void Blink (bool bRecursive=false)

    Blink the node's UI control in blue.
- void MoveTreeToLoc (Point loc, bool bDelayAnimation=false)

    Move the associated node control to a location and make its all its children follow it.
- void MoveTreeByLoc (Point deltaLoc, bool bDelayAnimation=false)

    Move the associated node control by a delta location and make its all its children follow it.
- void MoveChildrenByLoc (Point deltaLoc, bool bDelayAnimation=false)

    Move all the children of this node (but NOT this node itself) by a delta location.
- void MoveByLoc (Point loc, bool bDelayAnimation=false)

Move the associated node control by a specified amount.

- void MoveToLoc (Point loc, bool bDelayAnimation=false)

  Move the associated node control to specified location over 0.5 seconds.
- void MoveToLocWithAnim (Point loc, bool bDelayAnimation=false)

  Move the associated node control to specified location over 0.5 seconds. Always play the animation - regardless of instant mode or others.
- void **PlayDelayedAnimation** ()

  Play cached animation now. Reset the cache state.

Static Public Member Functions

- static Node< T > CreateRoot< T > (T value, BinTree< T > tree)

  Create a root node to start a new tree.
- static bool operator< (Node< T > self, Node< T > other)

  Compare nodes value-wise.
- static bool operator> (Node< T > self, Node< T > other)

  Compare nodes value-wise.
- static bool **operator<** (T self, Node< T > other)
- static bool **operator>** (T self, Node< T > other)
- static bool operator<= (Node< T > self, Node< T > other)

  Compare nodes value-wise.
- static bool operator>= (Node< T > self, Node< T > other)

  Compare nodes value-wise.
- static bool **operator<=** (T self, Node< T > other)
- static bool **operator>=** (T self, Node< T > other)

Static Public Attributes

- const int **ToBottomOffset** = 70

  Offset by which nodes should be separated vertically.
- const int **ToSideOffset** = 100

  Offset by which children nodes should be put to side by from their parent nodes horizontally..
- const double **NodeWidth** = 120

  Node width.
- const double **NodeHeight** = 70

  Node height.

Properties

- BinTree< T > **Tree** `[get]`

  Node's tree.
- Node< T >? **Parent** `[get, set]`

  The node's parent.
- T **Value** = null `[get, private set]`

  The node's value.
- Node< T >? **Left** = null `[get, private set]`

  The left child. Use AdoptChild(Node<T>) or OrphanChildren(bool, bool) to change this reference.
- Node< T >? **Right** = null `[get, private set]`

  The right child. Use AdoptChild(Node<T>) or OrphanChildren(bool, bool) to change this reference.

- int **Height** = 1 `[get, private set]`

  Cached node height. Can be refreshed with RefreshHeight
- Node< T >? this[Side side] `[get, set]`

  Get or set a node by its side.
- required NodeControl **BackingControl** `[get]`

  Backing element placed in the UI.
- NodeArrow? **SelfArrow** = null `[get, private set]`

  UI arrow pointing to this node.
- double **CurrWidth** `[get]`

  Current width of the UI control.
- double **CurrHeight** `[get]`

  Current height of the UI control.
- Point **DesiredLoc** `[get, private set]`

  Desired location of the node. Might be either the current location, or the location the new will finish at once its animation end.
  Use MoveToLoc(Point) to move the node to a new location.
- Point **CurrLoc** `[get]`

  Current location of the node in the UI. Might be volatile because it is affected by animations.
  Use DesiredLoc for location-related operations.
- bool **HasCachedDesiredLoc** = false `[get, set]`

  Whether the node has cached loc that it should move to with PlayDelayedAnimation once available.

Private Member Functions

- Node (T value, BinTree< T > tree)

  Internal ctor. Use static method CreateRoot<T>(T, BinTree<T>) to create a new tree, or SpawnChild(T, bool) to spawn a new node.
- NodeControl CreateUIElem (T value, bool bLeft)

  Create a new UI element for a node and add it to the Canvas
- NodeArrow CreateArrowTo (Node< T > node)

  Create a UI arrow from this node pointing to another node, add it to the Canvas, and return it.

Static Private Member Functions

- static Point GetLocOf (NodeControl control)

  Get location of a specified control.

8.6.1 Detailed Description

A binary tree's node.

Template Parameters

T	The type of data this node holds

Type Constraints

T : IComparable<T>

8.6.2 Constructor & Destructor Documentation

8.6.2.1 Node()

```
BinTreeVisualization.Algorithms.Node< T >.Node (
            T value,
            BinTree< T > tree )  [private]
```

Internal ctor. Use static method CreateRoot<T>(T, BinTree<T>) to create a new tree, or SpawnChild(T, bool) to spawn a new node.

Parameters

value	Value for the new node to be spawned with
tree	The tree the node is in

8.6.3 Member Function Documentation

8.6.3.1 ActivateBlue()

```
void BinTreeVisualization.Algorithms.Node< T >.ActivateBlue (
            bool bRecursive = false )
```

Change node's fill color to blue with an animation.

Parameters

bRecursive	Whether to color the node itself, or the node and all its children as well

8.6.3.2 AdoptChild()

```
Node< T > BinTreeVisualization.Algorithms.Node< T >.AdoptChild (
            Node< T > node )
```

Adopt a child node. The child along its entire subtree will be moved to the correct side of this node.

If selves children slots are full, the passed-in *node* will itself adopt one of the current children in order to create a chain.

Parameters

node	The node to adopt

Returns

The inserted node

8.6.3.3 Blink()

```
void BinTreeVisualization.Algorithms.Node< T >.Blink (
            bool bRecursive = false )
```

Blink the node's UI control in blue.

Parameters

bRecursive	Whether to blink the node itself, or the node and all its children as well

8.6.3.4 CalcHeight()

```
int BinTreeVisualization.Algorithms.Node< T >.CalcHeight ( )
```

Calculate node's height recursively.

Returns

Height of the node

8.6.3.5 CreateArrowTo()

```
NodeArrow BinTreeVisualization.Algorithms.Node< T >.CreateArrowTo (
            Node< T > node ) [private]
```

Create a UI arrow from this node pointing to another node, add it to the Canvas, and return it.

Parameters

node	The node the arrow should point to

Returns

The created UI element.

8.6.3.6 CreateRoot< T >()

```
static Node< T > BinTreeVisualization.Algorithms.Node< T >.CreateRoot< T > (
            T value,
            BinTree< T > tree ) [static]
```

Create a root node to start a new tree.

Template Parameters

T	

Parameters

value	Value to create the root with
tree	The tree in which the root should be created

Returns

The newly created Node<T>

Type Constraints

T* : *IComparable<T>

8.6.3.7 CreateUIElem()

```
NodeControl BinTreeVisualization.Algorithms.Node< T >.CreateUIElem (
             T value,
             bool bLeft )  [private]
```

Create a new UI element for a node and add it to the Canvas

Parameters

value	Value of the new node
bLeft	Whether to prepare the child on parent's left side.

Returns

The created UI element.

8.6.3.8 DeactivateBlue()

```
void BinTreeVisualization.Algorithms.Node< T >.DeactivateBlue (
             bool bRecursive = false )
```

Reset node's fill color.

Parameters

bRecursive	Whether to blink the node itself, or the node and all its children as well

8.6.3.9 GetDepth()

```
int BinTreeVisualization.Algorithms.Node< T >.GetDepth ( )
```

Get depth, i.e. how many levels deep is this node in the tree.

Returns

Depth of the node

8.6.3.10 GetHeight()

```
int BinTreeVisualization.Algorithms.Node< T >.GetHeight ( )
```

Get height of the node, i.e. how many levels deep is the deepest child of this node.

Returns

Height of the node

8.6.3.11 GetLocOf()

```
static Point BinTreeVisualization.Algorithms.Node< T >.GetLocOf (
             NodeControl control )  [static], [private]
```

Get location of a specified control.

Parameters

control	The control to get location of

Returns

The location of the specified control

8.6.3.12 GetNodeBalance()

```
int BinTreeVisualization.Algorithms.Node< T >.GetNodeBalance ( )
```

Get the balance of the node - how much taller is its left children trace than the right one.

Returns

The node balance

8.6.3.13 GetRelativeNode()

```
Node< T > BinTreeVisualization.Algorithms.Node< T >.GetRelativeNode (
             int toRight )
```

Get the node at a relative position to the right from the current node, as if all nodes on this level were taken.

Returns null if the spot at this location is empty.

Parameters

toRight	Relative amount of node-slots to the right

Returns

The node at the requested relative position.

8.6.3.14 IsLeaf()

```
bool BinTreeVisualization.Algorithms.Node< T >.IsLeaf ( )
```

Whether the node is a leaf (i.e. has no children)

Returns

Whether the node is a leaf (i.e. has no children)

8.6.3.15 MoveByLoc()

```
void BinTreeVisualization.Algorithms.Node< T >.MoveByLoc (
            Point loc,
            bool bDelayAnimation = false )
```

Move the associated node control by a specified amount.

Parameters

loc	Final location to move the node to
bDelayAnimation	If `true`, cache the desired location and delay execution of the animation until PlayDelayedAnimation is called.

8.6.3.16 MoveChildrenByLoc()

```
void BinTreeVisualization.Algorithms.Node< T >.MoveChildrenByLoc (
            Point deltaLoc,
            bool bDelayAnimation = false )
```

Move all the children of this node (but NOT this node itself) by a delta location.

Parameters

deltaLoc	Delta location to move the tree by
bDelayAnimation	If `true`, cache the desired location and delay execution of the animation until PlayDelayedAnimation is called.

8.6.3.17 MoveToLoc()

```
void BinTreeVisualization.Algorithms.Node< T >.MoveToLoc (
            Point loc,
            bool bDelayAnimation = false )
```

Move the associated node control to specified location over 0.5 seconds.

Parameters

loc	Location to move to
bDelayAnimation	If `true`, cache the desired location and delay execution of the animation until PlayDelayedAnimation is called.

8.6.3.18 MoveToLocWithAnim()

```
void BinTreeVisualization.Algorithms.Node< T >.MoveToLocWithAnim (
            Point loc,
            bool bDelayAnimation = false )
```

Move the associated node control to specified location over 0.5 seconds. Always play the animation - regardless of instant mode or others.

Parameters

loc	Location to move to
bDelayAnimation	If `true`, cache the desired location and delay execution of the animation until PlayDelayedAnimation is called.

8.6.3.19 MoveTreeByLoc()

```
void BinTreeVisualization.Algorithms.Node< T >.MoveTreeByLoc (
            Point deltaLoc,
            bool bDelayAnimation = false )
```

Move the associated node control by a delta location and make its all its children follow it.

Parameters

deltaLoc	Delta location to move the tree by
bDelayAnimation	If `true`, cache the desired location and delay execution of the animation until PlayDelayedAnimation is called.

8.6.3.20 MoveTreeToLoc()

```
void BinTreeVisualization.Algorithms.Node< T >.MoveTreeToLoc (
            Point loc,
            bool bDelayAnimation = false )
```

Move the associated node control to a location and make its all its children follow it.

Parameters

loc	Final location to move the node to
bDelayAnimation	If `true`, cache the desired location and delay execution of the animation until PlayDelayedAnimation is called.

8.6.3.21 operator<()

```
static bool BinTreeVisualization.Algorithms.Node< T >.operator< (
            Node< T > self,
            Node< T > other )  [static]
```

Compare nodes value-wise.

Parameters

self	Left item to compare
other	Right item to compare

Returns

Whether the value of left is smaller than the value of right

8.6.3.22 operator<=()

```
static bool BinTreeVisualization.Algorithms.Node< T >.operator<= (
            Node< T > self,
            Node< T > other )  [static]
```

Compare nodes value-wise.

Parameters

self	Left item to compare
other	Right item to compare

Returns

Whether the value of left is smaller or equals to the value of right

8.6.3.23 operator>()

```
static bool BinTreeVisualization.Algorithms.Node< T >.operator> (
            Node< T > self,
            Node< T > other )  [static]
```

Compare nodes value-wise.

Parameters

self	Left item to compare
other	Right item to compare

Returns

Whether the value of left is bigger than the value of right

8.6.3.24 operator>=()

```
static bool BinTreeVisualization.Algorithms.Node< T >.operator>= (
              Node< T > self,
              Node< T > other )  [static]
```

Compare nodes value-wise.

Parameters

self	Left item to compare
other	Right item to compare

Returns

Whether the value of left is bigger or equals to the value of right

8.6.3.25 OrphanChildren()

```
void BinTreeVisualization.Algorithms.Node< T >.OrphanChildren (
              bool OrphanLeftChild = true,
              bool OrphanRightChild = true )
```

Orphan the children of this node.

Parameters

OrphanLeftChild	Whether to orphan the left child
OrphanRightChild	Whether to orphan the right child

8.6.3.26 SpawnChild()

```
Node< T > BinTreeVisualization.Algorithms.Node< T >.SpawnChild (
              T value,
              bool bLeft )
```

Spawn a new node as child of this node. This is the only way to spawn new nodes.

Parameters

value	Value for the new node to be spawned with
bLeft	Whether to spawn new node as this node's left child

Returns

The newly spawned node

8.6.3.27 SwapValues()

```
void BinTreeVisualization.Algorithms.Node< T >.SwapValues (
            Node< T > other )
```

Swap value of this node with value from another one. Does NOT ensure binary tree properties are maintained!

Parameters

other	The other node

8.6.3.28 Traverse()

```
IEnumerable< Node< T > > BinTreeVisualization.Algorithms.Node< T >.Traverse ( )
```

Traverse the tree in Level Order Traversal.

Returns

Returns IEnumerable that contains this and all children nodes

8.6.3.29 TraverseAncestors()

```
IEnumerable< Node< T > > BinTreeVisualization.Algorithms.Node< T >.TraverseAncestors ( )
```

Traverse ancestors of this node in the order parent -> grandparent -> ... -> root.

Returns

Returns IEnumerable that contains this and all parent nodes going from the bottom

8.6.4 Property Documentation

8.6.4.1 this[Side side]

```
Node<T>?  BinTreeVisualization.Algorithms.Node< T >.this[Side side]  [get], [set]
```

Get or set a node by its side.

Parameters

side	The side

Returns

Exceptions

ArgumentOutOfRangeException	

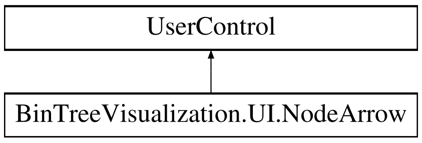
The documentation for this class was generated from the following files:

- S:/Uni/Algosy/BinTreeVisualization/Algorithms/Node.cs
- S:/Uni/Algosy/BinTreeVisualization/Algorithms/NodeUI.cs

8.7 BinTreeVisualization.UI.NodeArrow Class Reference

Represents an arrow that can point between nodes.

Inheritance diagram for BinTreeVisualization.UI.NodeArrow:



Public Member Functions

- void RotateToTarget (Point target)

    Set the arrow to instantly rotate towards specified target.
- async void **RemoveSelf** ()

    Remove this arrow from the canvas.
- void MoveSourceToLoc (Point newSource)

    Repoint the source's location to new loc in a 0.5s animation.
- void MoveTargetToLoc (Point newTarget)

    Repoint the target's location to new loc in a 0.5s animation.
- void RotateToLoc (Point newSource, Point newTarget)

    Repoint the source and target locations to new locs in a 0.5s animation.
- void **TriggerSpawnAnim** ()

    Trigger spawn fade-in animation.
- void **TriggerDespawnAnim** ()

    Trigger despawn fade-out animation.

Static Public Member Functions

- static Point GetUpperArrowSocket (Point fromUpperLeftCorner)

    Get location of a socket suitable to be pointed to by node's parent.
- static Point GetLeftArrowSocket (Point fromUpperLeftCorner)

    Get location of a socket suitable for a parent to point to the left node.
- static Point GetRightArrowSocket (Point fromUpperLeftCorner)

    Get location of socket suitable for a parent to point to the right node.
- static Point GetNodeBorder (Point fromUpperLeftCorner, double degrees)

    Get location of node's border on the specified agle, assuming degrees = 0 is pointing to vec (1, 0)
- static Point GetLowerArrowSocket (Point fromUpperLeftCorner)

    Get location of socket suitable for a parent to point right downwards.

Static Public Attributes

- static readonly DependencyProperty SourceProp

    Current source dependency prop. Sets control's Canvas position automatically on Setter.
- static readonly DependencyProperty TargetProp

    Current target dependency prop. Sets control's Canvas position automatically on Setter.

Properties

- Point **SelfLoc** `[get]`

    Current in-UI location.
- Point **Target** `[get, set]`

    The current target the arrow points to.
- Point **Source** `[get, set]`

    The current source the arrow points from.
- Point **DesiredTarget** `[get, private set]`

    The final target the arrow will point to after animations finish.
- Point **DesiredSource** `[get, private set]`

    The final source the arrow will point from after animations finish.

Private Member Functions

- Canvas GetCanvas ()

    Get the canvas this control is on.
- double GetRotToTarget (Point target)

    Get rotation in radians from current Source to the target .
    Does NOT use DesiredSource as this method is being used in live calculations.
- double GetDistanceTo (Point target)

    Get distance from current Source to the target .
    Does NOT use DesiredSource as this method is being used in live calculations.

Static Private Member Functions

- static Point GetLocOf (NodeArrow control)

  Get location of a specified control.
- static void **OnTargetChanged** (DependencyObject d, DependencyPropertyChangedEventArgs e)

  Refreshes the arrow's location on the Canvas.
- static void **OnSourceChanged** (DependencyObject d, DependencyPropertyChangedEventArgs e)

  Refreshes the arrow's location on the Canvas.
- static double GetGoodSideAngle ()

  Get a good angle counting from node's side (1, 0) for an arrow to go out of considering the amount of free space between nodes.
  Reads Node< T >.ToBottomOffset and Node< T >.NodeHeight for calculations.

Private Attributes

- bool **LastSourceSideWasRight** = false

8.7.1 Detailed Description

Represents an arrow that can point between nodes.

8.7.2 Member Function Documentation

8.7.2.1 GetCanvas()

```
Canvas BinTreeVisualization.UI.NodeArrow.GetCanvas ( )  [private]
```

Get the canvas this control is on.

Returns

8.7.2.2 GetDistanceTo()

```
double BinTreeVisualization.UI.NodeArrow.GetDistanceTo (
            Point target )  [private]
```

Get distance from current Source to the *target* .

Does NOT use DesiredSource as this method is being used in live calculations.

Parameters

target	Absolute location of point to calculate the distance to

Returns

WPF length units from to the target

8.7.2.3 GetGoodSideAngle()

```
static double BinTreeVisualization.UI.NodeArrow.GetGoodSideAngle ( )  [static], [private]
```

Get a good angle counting from node's side (1, 0) for an arrow to go out of considering the amount of free space between nodes.

Reads Node<T>.ToBottomOffset and Node<T>.NodeHeight for calculations.

Returns

A visually pleasing angle.

8.7.2.4 GetLeftArrowSocket()

```
static Point BinTreeVisualization.UI.NodeArrow.GetLeftArrowSocket (
             Point fromUpperLeftCorner )  [static]
```

Get location of a socket suitable for a parent to point to the left node.

Parameters

fromUpperLeftCorner	Upper left coord of the parent for the arrow to be sourced from

Returns

Absolute position of the point on node's border

8.7.2.5 GetLocOf()

```
static Point BinTreeVisualization.UI.NodeArrow.GetLocOf (
             NodeArrow control )  [static], [private]
```

Get location of a specified control.

Parameters

control	The control to get location of

Returns

The location of the specified control

8.7.2.6 GetLowerArrowSocket()

```
static Point BinTreeVisualization.UI.NodeArrow.GetLowerArrowSocket (
             Point fromUpperLeftCorner )  [static]
```

Get location of socket suitable for a parent to point right downwards.

Parameters

fromUpperLeftCorner	Upper left coord of the parent for the arrow to be sourced from

Returns

Absolute position of the point on node's border

8.7.2.7 GetNodeBorder()

```
static Point BinTreeVisualization.UI.NodeArrow.GetNodeBorder (
             Point fromUpperLeftCorner,
             double degrees )  [static]
```

Get location of node's border on the specified agle, assuming *degrees* = 0 is pointing to vec (1, 0)

Parameters

fromUpperLeftCorner	Upper left coord of the node
degrees	Degrees

Returns

Absolute position of the point on node's border

8.7.2.8 GetRightArrowSocket()

```
static Point BinTreeVisualization.UI.NodeArrow.GetRightArrowSocket (
             Point fromUpperLeftCorner )  [static]
```

Get location of socket suitable for a parent to point to the right node.

Parameters

fromUpperLeftCorner	Upper left coord of the parent for the arrow to be sourced from

Returns

Absolute position of the point on node's border

8.7.2.9 GetRotToTarget()

```
double BinTreeVisualization.UI.NodeArrow.GetRotToTarget (
            Point target )  [private]
```

Get rotation in radians from current Source to the *target* .

Does NOT use DesiredSource as this method is being used in live calculations.

Parameters

target	Absolute location of point to rotate to

Returns

Degrees from source to target

8.7.2.10 GetUpperArrowSocket()

```
static Point BinTreeVisualization.UI.NodeArrow.GetUpperArrowSocket (
            Point fromUpperLeftCorner )  [static]
```

Get location of a socket suitable to be pointed to by node's parent.

Parameters

fromUpperLeftCorner	Upper left coord of child node to point to

Returns

Absolute position of the point on node's border

8.7.2.11 MoveSourceToLoc()

```
void BinTreeVisualization.UI.NodeArrow.MoveSourceToLoc (
            Point newSource )
```

Repoint the source's location to new loc in a 0.5s animation.

Parameters

newSource	Upper left coord of the node's expected position

8.7.2.12 MoveTargetToLoc()

```
void BinTreeVisualization.UI.NodeArrow.MoveTargetToLoc (
            Point newTarget )
```

Repoint the target's location to new loc in a 0.5s animation.

Parameters

newTarget	Upper left coord of the node's expected position

8.7.2.13 RotateToLoc()

```
void BinTreeVisualization.UI.NodeArrow.RotateToLoc (
            Point newSource,
            Point newTarget )
```

Repoint the source and target locations to new locs in a 0.5s animation.

Parameters

newSource	The new source for the arrow to point from
newTarget	The new target for the arrow to point to

8.7.2.14 RotateToTarget()

```
void BinTreeVisualization.UI.NodeArrow.RotateToTarget (
            Point target )
```

Set the arrow to instantly rotate towards specified target.

Parameters

target	The target to rotate to

8.7.3 Member Data Documentation

8.7.3.1 SourceProp

```
readonly DependencyProperty BinTreeVisualization.UI.NodeArrow.SourceProp [static]
```

Initial value:

```
=
DependencyProperty.Register(
    "Source",
    typeof(Point),
    typeof(NodeArrow),
    new PropertyMetadata(new Point(0, 0), OnSourceChanged))
```

Current source dependency prop. Sets control's Canvas position automatically on Setter.

8.7.3.2 TargetProp

```
readonly DependencyProperty BinTreeVisualization.UI.NodeArrow.TargetProp  [static]
```

Initial value:

```
=
DependencyProperty.Register(
    "Target",
    typeof(Point),
    typeof(NodeArrow),
    new PropertyMetadata(new Point(0, 0), OnTargetChanged))
```

Current target dependency prop. Sets control's Canvas position automatically on Setter.

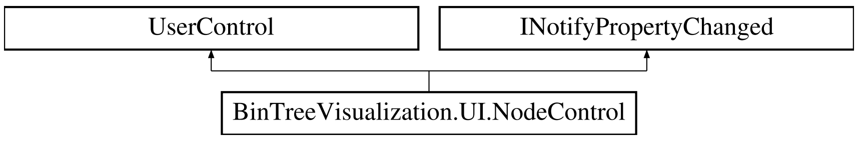
The documentation for this class was generated from the following file:

- S:/Uni/Algosy/BinTreeVisualization/UI/NodeArrow.xaml.cs

8.8 BinTreeVisualization.UI.NodeControl Class Reference

UI element that represents a node in a binary tree.

Inheritance diagram for BinTreeVisualization.UI.NodeControl:



Public Member Functions

- **NodeControl** (object value)
- void **Activate** ()

  Highlight the node in the UI.
- void **Deactivate** ()

  Remove highlight of the UI node.
- void **Blink** ()

  Briefly blink the node's borders in blue.
- void **HighlightBlue** ()

  Highlight the node in blue.
- void **DeactivateBlue** ()

  Remove the blue highlight from the node.
- void **ActivateBlue** ()

  Highlight the node in blue in the UI.
- void MoveToLoc (Point loc)

  Move the associated node control to specified location over 0.5 seconds.

Protected Member Functions

- virtual void **OnPropertyChanged** ([CallerMemberName] string propertyName="")

Properties

- Point **CurrLoc** `[get]`
- static Color **InactiveColor** `[get]`
- static Color **ActiveColor** `[get]`
- static Color **StrokeBase** `[get]`
- static Color **StrokeBlue** `[get]`
- static Color **RedColor** `[get]`
- object **Value** `[get, set]`

  Node's value.
- string **ValToStr** `[get]`

  Node's value as string. To be bound to the UI content.

Events

- PropertyChangedEventHandler **PropertyChanged**

Private Member Functions

- void Node_OnClick (object sender, MouseButtonEventArgs e)

  Click node to quickly select it in the parent UI.
  Relies on the established structure of Main Window -> MainFrame -> BinTreeMan -> InputTextBox.

8.8.1 Detailed Description

UI element that represents a node in a binary tree.

8.8.2 Member Function Documentation

8.8.2.1 MoveToLoc()

```
void BinTreeVisualization.UI.NodeControl.MoveToLoc (
            Point loc )
```

Move the associated node control to specified location over 0.5 seconds.

Parameters

loc	Location to move to

8.8.2.2 Node_OnClick()

```
void BinTreeVisualization.UI.NodeControl.Node_OnClick (
            object sender,
            MouseButtonEventArgs e )  [private]
```

Click node to quickly select it in the parent UI.

Relies on the established structure of Main Window -> MainFrame -> BinTreeMan -> InputTextBox.

Parameters

sender	
e	

The documentation for this class was generated from the following file:

- S:/Uni/Algosy/BinTreeVisualization/UI/NodeControl.xaml.cs

8.9 BinTreeVisualization.UI.PointExtensions Class Reference

Static Public Member Functions

- static double Size (this Vector p)

  Gets the size of the vector.
- static Vector Normal (this Vector p)

  Normalizes the vector.

8.9.1 Member Function Documentation

8.9.1.1 Normal()

```
static Vector BinTreeVisualization.UI.PointExtensions.Normal (
             this Vector p )  [static]
```

Normalizes the vector.

Parameters

p	The vector

Returns

A new vector, which is a normalized copy of the source

8.9.1.2 Size()

```
static double BinTreeVisualization.UI.PointExtensions.Size (
             this Vector p )  [static]
```

Gets the size of the vector.

Parameters

p	The vector

Returns

The size of the vector

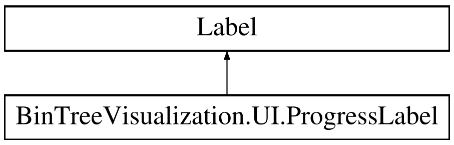
The documentation for this class was generated from the following file:

- S:/Uni/Algosy/BinTreeVisualization/UI/NodeArrow.xaml.cs

8.10 BinTreeVisualization.UI.ProgressLabel Class Reference

A label that can represent progress which supports spawn/despawn animations and colors.

Inheritance diagram for BinTreeVisualization.UI.ProgressLabel:



Public Member Functions

- void **TriggerSpawnAnim** ()

  Trigger spawn fade-in animation.
- void **TriggerDespawnAnim** ()

  Trigger despawn fade-out animation.

8.10.1 Detailed Description

A label that can represent progress which supports spawn/despawn animations and colors.

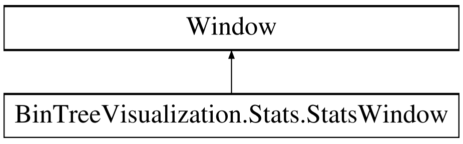
The documentation for this class was generated from the following file:

- S:/Uni/Algosy/BinTreeVisualization/UI/ProgressLabel.xaml.cs

8.11 BinTreeVisualization.Stats.StatsWindow Class Reference

Interaction logic for StatsWindow.xaml.

Inheritance diagram for BinTreeVisualization.Stats.StatsWindow:



Public Member Functions

- **StatsWindow** (TreeStats stats)

Properties

- TreeStats **StatsRef** `[get, set]`

  Ref to the tree's data.

Private Member Functions

- void **OnDataChanged** ()

  Function to call when the tree's data changes.
- void OnClosed (object sender, EventArgs e)

  Function to call on window's closing. Unsubcribes from the tree's data changed event.

8.11.1 Detailed Description

Interaction logic for StatsWindow.xaml.

8.11.2 Member Function Documentation

8.11.2.1 OnClosed()

```
void BinTreeVisualization.Stats.StatsWindow.OnClosed (
            object sender,
            EventArgs e )  [private]
```

Function to call on window's closing. Unsubcribes from the tree's data changed event.

Parameters

sender	
e	

The documentation for this class was generated from the following file:

- S:/Uni/Algosy/BinTreeVisualization/Stats/StatsWindow.xaml.cs

8.12 BinTreeVisualization.Algorithms.TextActionColorsHelper Class Reference

Helper for colors of a TextAction

Static Public Member Functions

- static System.Windows.Media.Color GetColor (this TextAction textAction)

  Convert value from a color enum to a System.Windows.Media.Color color.

8.12.1 Detailed Description

Helper for colors of a TextAction

8.12.2 Member Function Documentation

8.12.2.1 GetColor()

```
static System.Windows.Media.Color BinTreeVisualization.Algorithms.TextActionColorsHelper.Get←
Color (
             this TextAction textAction )  [static]
```

Convert value from a color enum to a System.Windows.Media.Color color.

Parameters

textAction	The text action to get the respective color of

Returns

A System.Windows.Media.Color that corresponds to the passed TextAction

Exceptions

NotImplementedException	

The documentation for this class was generated from the following file:

- S:/Uni/Algosy/BinTreeVisualization/Algorithms/BinTree.cs

8.13 BinTreeVisualization.Stats.TreeStats Class Reference

Holds statistics of operations performed on a binary tree.

Public Member Functions

- void AddStats (OperationStats stats, OperationType type)

  Add stats performed during a specified operation.
- IEnumerable< OperationStats > GetListWithAverages (OperationType type)

Calculate the list of statistics, with the average amount of operations per the count of items in the tree.

- void **ShowWindow** ()

  Show a window with plots holding the stats.
- void Refresh (StatsWindow window)

  Refresh a plots window with the newest data.
- delegate void **StatsWindowEventHandler** ()

  Event invoked when new stats are added.

Events

- StatsWindowEventHandler **OnDataChanged**

  Event invoked when new stats are added.

Private Member Functions

- List< OperationStats > GetList (OperationType type)

  Get the list of data associated with the specified operation type.
- void FillPlot (Plot plot, OperationType type)

  Fill the plot with the data of the specified operation type.
- void **FillPlot** (WpfPlot plot, OperationType type)

Private Attributes

- List< OperationStats > **InsertStats** = [ ]

  Stats for insert operations.
- List< OperationStats > **DeleteStats** = [ ]

  Stats for delete operations.
- List< OperationStats > **SearchStats** = [ ]

  Stats for search operations.

8.13.1 Detailed Description

Holds statistics of operations performed on a binary tree.

8.13.2 Member Function Documentation

8.13.2.1 AddStats()

```
void BinTreeVisualization.Stats.TreeStats.AddStats (
             OperationStats stats,
             OperationType type )
```

Add stats performed during a specified operation.

Parameters

stats	The stats to add
type	The type of the operation

8.13.2.2 FillPlot()

```
void BinTreeVisualization.Stats.TreeStats.FillPlot (
            Plot plot,
            OperationType type )  [private]
```

Fill the plot with the data of the specified operation type.

Parameters

plot	The plot
type	The operaion type

8.13.2.3 GetList()

```
List< OperationStats > BinTreeVisualization.Stats.TreeStats.GetList (
            OperationType type )  [private]
```

Get the list of data associated with the specified operation type.

Parameters

type	The operation type

Returns

List of data with the specified operation type

Exceptions

ArgumentException	

8.13.2.4 GetListWithAverages()

```
IEnumerable< OperationStats > BinTreeVisualization.Stats.TreeStats.GetListWithAverages (
            OperationType type )
```

Calculate the list of statistics, with the average amount of operations per the count of items in the tree.

Parameters

type	The operation type to get results for

Returns

An IEnumerable<T> with average comparisons and travels for each recorded tree size.

8.13.2.5 Refresh()

```
void BinTreeVisualization.Stats.TreeStats.Refresh (
             StatsWindow window )
```

Refresh a plots window with the newest data.

Parameters

window	The StatsWindow to refresh the data on

The documentation for this class was generated from the following file:

- S:/Uni/Algosy/BinTreeVisualization/Stats/TreeStats.cs

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