Binary Search Tree AP DSSC 20/21

Group Romina Doz, Davide Basso, Imola Fodor

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Chapter 1

README

Advanced programming exam 2020/2021 Group Romina Doz, Davide Basso, Imola Fodor

Chapter 2

Class Index

2.1 Class List

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

Chapter 3

Class Documentation

3.1 bst< key_type, value_type, comparison > Class Template Reference

`#include "include/node.hpp include/iterator.hpp"`

Public Member Functions

- bst ()=default
  Default iterator Constructor and Destructor.
- bst (bst &&other) noexcept=default
  Move constructor.
- bst & operator= (bst &&other) noexcept=default
  Move assignment.
- bst (const bst &other)
  Deep-copy constructor.
- bst & operator= (const bst &x)
  Deep-copy assignment.
- void clear ()
  delete tree
- void print2D () const noexcept
  pretty print
- iterator begin () noexcept
  begin of for loop with iterator
- const_iterator begin () const noexcept
  const begin of for loop with iterator
- const_iterator cbegin () const noexcept
  const begin of for loop with iterator
- iterator end () noexcept
  end of for loop with iterator
- const_iterator end () const noexcept
  const end of for loop with iterator
- const_iterator cend () const noexcept
  const end of for loop with iterator
- iterator find (const key_type &x) noexcept
  find element in tree

- const_iterator find (const key_type &x) const noexcept
  const find element in tree by key
- std::pair< iterator, bool > insert (const pair_type &x)
  insert node by pair
- std::pair< iterator, bool > insert (pair_type &&x)
  const insert node by pair
- template<class... Types>
  std::pair< iterator, bool > emplace (Types &&... args)
  emplace element
- void erase (const key_type &x)
  erase element from tree
- void balance ()
  balance tree
- std::size_t size () const noexcept
  depth of tree
- value_type & operator[ ] (const key_type &x)
- value_type & operator[ ] (key_type &&x)
- template<typename O >
  std::pair< typename bst< key_type, value_type, comparison >::iterator, bool > **_insert** (O &&x)
- template<typename T >
  node< std::pair< const key_type, value_type > > * **_find** (T &&x) const noexcept

Friends

- std::ostream & operator<< (std::ostream &os, const bst &x)
  put-to

3.1.1 Detailed Description

template<typename key_type, typename value_type, typename comparison = std::less<key_type>>
class bst< key_type, value_type, comparison >

Custom Binary Search Tree Template class. Every instance of the bst class is a hierarchical (ordered) data structure.

3.1.2 Member Function Documentation

3.1.2.1 balance()

```
template<typename key_type , typename value_type , typename comparison >
void bst< key_type, value_type, comparison >::balance
```

balance tree

Function to balance the tree.

3.1.2.2 begin() [1/2]

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
const_iterator bst< key_type, value_type, comparison >::begin ( ) const  [inline], [noexcept]
```

const begin of for loop with iterator

Return a const iterator to the left-most node (which, likely, is not the root node). The returning value is obtained using the fucntion leftiest(), which finds the leaf node placed at the very far left

3.1.2.3 begin() [2/2]

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
iterator bst< key_type, value_type, comparison >::begin ( )  [inline], [noexcept]
```

begin of for loop with iterator

Return an iterator to the left-most node (which, likely, is not the root node). The returning value is obtained using the fucntion leftiest(), which finds the leaf node placed at the very far left

3.1.2.4 cbegin()

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
const_iterator bst< key_type, value_type, comparison >::cbegin ( ) const  [inline], [noexcept]
```

const begin of for loop with iterator

Return a const iterator to the left-most node (which, likely, is not the root node). The returning value is obtained using the fucntion leftiest(), which finds the leaf node placed at the very far left

3.1.2.5 cend()

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
const_iterator bst< key_type, value_type, comparison >::cend ( ) const  [inline], [noexcept]
```

const end of for loop with iterator

Returns a const iterator to one-past the last element. Basically a const_iterator initialized to a nullptr

3.1.2.6 clear()

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
void bst< key_type, value_type, comparison >::clear ( )  [inline]
```

delete tree

Function to clear the contents of the tree by setting head to null-pointer.

3.1.2.7 emplace()

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
template<class...  Types>
std::pair<iterator,bool> bst< key_type, value_type, comparison >::emplace (
            Types &&...  args )  [inline]
```

emplace element

Inserts a new element into the container constructed in-place with the given args if there is no element with the key in the container.

3.1.2.8 end() [1/2]

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
const_iterator bst< key_type, value_type, comparison >::end ( ) const  [inline], [noexcept]
```

const end of for loop with iterator

Returns a const iterator to one-past the last element. Basically a const_iterator initialized to a nullptr

3.1.2.9 end() [2/2]

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
iterator bst< key_type, value_type, comparison >::end ( )  [inline], [noexcept]
```

end of for loop with iterator

Returns an iterator to one-past the last element. Basically an iterator initialized to a nullptr

3.1.2.10 erase()

```
template<typename key_type , typename value_type , typename comparison >
void bst< key_type, value_type, comparison >::erase (
            const key_type & x )
```

erase element from tree

Function that removes the element (if one exists) with the key equivalent to key. When element found, deleted. After erase, tree repopulated. Takes const x , l-value reference of type key.

3.1.2.11 find() [1/2]

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
const_iterator bst< key_type, value_type, comparison >::find (
            const key_type & x ) const  [inline], [noexcept]
```

const find element in tree by key

Find a given key, x passed as l-value. If the key is present, returns a const_iterator to the proper node; if not the function _find() returns a nullptr, so same result as cend().

3.1.2.12 find() [2/2]

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
iterator bst< key_type, value_type, comparison >::find (
            const key_type & x )  [inline], [noexcept]
```

find element in tree

Find a given key, x passed as l-value. If the key is present, returns an iterator to the proper node; if not the function _find() returns a nullptr, so same result as end().

3.1.2.13 insert() [1/2]

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
std::pair<iterator, bool> bst< key_type, value_type, comparison >::insert (
            const pair_type & x )  [inline]
```

insert node by pair

Function to insert node based on x , as const l-value reference pair type. The function returns a pair of an iterator (pointing to the node) and a bool. The bool is true if a new node has been allocated, false otherwise.

3.1.2.14 insert() [2/2]

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
std::pair<iterator, bool> bst< key_type, value_type, comparison >::insert (
            pair_type && x )  [inline]
```

const insert node by pair

Function to insert node based on x , as r-value reference pair type. The function returns a pair of an iterator (pointing to the node) and a bool. The bool is true if a new node has been allocated, false otherwise.

3.1.2.15 operator[]() [1/2]

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
value_type& bst< key_type, value_type, comparison >::operator[] (
            const key_type & x )  [inline]
```

subscripting l-value

Subscripting operator, takes x as l-value reference, of type key. Returns a reference to the value that is mapped to a key equivalent to x, performing an insertion if such key does not already exist. Takes advantage of the already defined insert() function.

3.1.2.16 operator[]() [2/2]

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
value_type& bst< key_type, value_type, comparison >::operator[] (
            key_type && x )  [inline]
```

subscripting r-value

Subscripting operator, takes x as r-value reference, of type key. Returns a reference to the value that is mapped to a key equivalent to x, performing an insertion if such key does not already exist. Takes advantage of the already defined insert() function.

3.1.2.17 print2D()

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
void bst< key_type, value_type, comparison >::print2D ( ) const  [inline], [noexcept]
```

pretty print

Function for a 2D design of the existing tree

3.1.2.18 size()

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
std::size_t bst< key_type, value_type, comparison >::size ( ) const  [inline], [noexcept]
```

depth of tree

Returns depth of the tree.

3.1.3 Friends And Related Function Documentation

3.1.3.1 operator<<

```
template<typename key_type , typename value_type , typename comparison = std::less<key_type>>
std::ostream& operator<< (
            std::ostream & os,
            const bst< key_type, value_type, comparison > & x )  [friend]
```

put-to

Put-to operator, takes instance of ostream, and x as l-value reference to bst type.

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

- include/bst.hpp

3.2 Iterator< pair_type, node_type > Class Template Reference

```
#include <iterator.hpp>
```

Public Types

- using **difference_type** = std::ptrdiff_t
- using **reference** = pair_type &
- using **pointer** = pair_type *
- using **iterator_category** = std::forward_iterator_tag

Public Member Functions

- node_type * next (node_type *cur) const noexcept

  next node
- Iterator ()=default

  Default iterator Constructor and Destructor.
- Iterator (node_type *other)

  Custom iterator Constructor.
- reference operator* () const noexcept
  - *overload*
- pointer operator-> () const noexcept

  -> overload
- Iterator & operator++ ()

  ++ overload
- Iterator operator++ (int)

  ++ overload

Friends

- bool operator== (const Iterator &lhs, const Iterator &rhs) noexcept

  == overload
- bool operator!= (const Iterator &lhs, const Iterator &rhs) noexcept

  != overload

3.2.1 Detailed Description

template<typename pair_type, typename node_type>
class Iterator< pair_type, node_type >

Custom Forward Iterator Template class for members of the binary search tree concept. Every instance of the Iterator class is a pointer to a Node type. Mainly used to tarverse the tree in order.

3.2.2 Constructor & Destructor Documentation

3.2.2.1 Iterator()

```
template<typename pair_type , typename node_type >
Iterator< pair_type, node_type >::Iterator (
            node_type * other )  [inline], [explicit]
```

Custom iterator Constructor.

Creates an iterator by receiving a pointer to node type as `other` .

3.2.3 Member Function Documentation

3.2.3.1 next()

```
template<typename pair_type , typename node_type >
node_type * Iterator< pair_type, node_type >::next (
            node_type * cur ) const  [noexcept]
```

next node

Function that returns pointer to the node that is successive to the current one, which is passed as a pointer `cur` .

3.2.3.2 operator∗()

```
template<typename pair_type , typename node_type >
reference Iterator< pair_type, node_type >::operator* ( ) const  [inline], [noexcept]
```

- overload

Overloading of operator ∗ to return contents of the current Iterator node instance.

3.2.3.3 operator++() [1/2]

```
template<typename pair_type , typename node_type >
Iterator& Iterator< pair_type, node_type >::operator++ ( )  [inline]
```

++ overload

Operator ++ as pre-increment

3.2.3.4 operator++() [2/2]

```
template<typename pair_type , typename node_type >
Iterator Iterator< pair_type, node_type >::operator++ (
            int  )  [inline]
```

++ overload

Operator ++ as post-increment with `int` .

3.2.3.5 operator->()

```
template<typename pair_type , typename node_type >
pointer Iterator< pair_type, node_type >::operator-> ( ) const  [inline], [noexcept]
```

-> overload

#TODO

3.2.4 Friends And Related Function Documentation

3.2.4.1 operator"!=

```
template<typename pair_type , typename node_type >
bool operator!= (
            const Iterator< pair_type, node_type > & lhs,
            const Iterator< pair_type, node_type > & rhs )  [friend]
```

!= overload

Operator != overloading. `lhs` const Iterator l-value reference used as lhs of the equation while `rhs` const Iterator l-value reference used as rhs of the equation. Returning value obtained using the == operator and taking the negation of the result.

3.2.4.2 operator==

```
template<typename pair_type , typename node_type >
bool operator== (
            const Iterator< pair_type, node_type > & lhs,
            const Iterator< pair_type, node_type > & rhs )  [friend]
```

== overload

Operator == overloading. `lhs` const Iterator l-value reference used as lhs of the equation while `rhs` const Iterator l-value reference used as rhs of the equation.

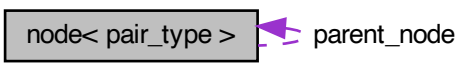
The documentation for this class was generated from the following file:

- include/iterator.hpp

3.3 node< pair_type > Class Template Reference

`#include <node.hpp>`

Collaboration diagram for node< pair_type >:



Public Member Functions

- node ()=default
  Default node Constructor and Destructor.
- node (const pair_type &d, node *parent=nullptr)
  Custom node Constructor.
- node (const pair_type &&d, node *parent=nullptr)
  Custom Node Constructor.
- node (node *parent=nullptr)
  Custom Node Constructor.
- node (node &&other) noexcept=default
  move semantics
- node & **operator=** (node &&other) noexcept=default
- node (const node &other)
  deep copy semantics
- node & operator= (const node &x)
  copy assignment
- node * get_left () noexcept
  get left child of a node
- node * get_right () noexcept
  get right child of a node
- node * get_parent () noexcept
  get parent of a node
- pair_type & get_data () noexcept
  get data contained in a node
- const pair_type & get_data () const noexcept
  get data contained in a node
- node * leftiest () noexcept
  get far left leaf node
- const node * leftiest () const noexcept
  get far left leaf node

Public Attributes

- node * parent_node
  parent node
- std::unique_ptr< node > left_child
  left child
- std::unique_ptr< node > right_child
  right child

3.3.1 Detailed Description

template<typename pair_type>
class node< pair_type >

Template class for members of the binary search tree concept. Every element of the binary search tree is a node. Each node stores a pair of a key and the associated value.

3.3.2 Constructor & Destructor Documentation

3.3.2.1 node() [1/5]

```
template<typename pair_type >
node< pair_type >::node (
            const pair_type & d,
            node< pair_type > * parent = nullptr )  [inline]
```

Custom node Constructor.

Creates a node receiving an l-value reference to the content we want to store in it,as `d` , and parent node as `parent` with default value as nullptr.

3.3.2.2 node() [2/5]

```
template<typename pair_type >
node< pair_type >::node (
            const pair_type && d,
            node< pair_type > * parent = nullptr )  [inline]
```

Custom Node Constructor.

Creates a node receiving an r-value reference to the content we want to store in it,as `d` , and parent node as `parent` with default value as nullptr.

3.3.2.3 node() [3/5]

```
template<typename pair_type >
node< pair_type >::node (
            node< pair_type > * parent = nullptr )  [inline], [explicit]
```

Custom Node Constructor.

Creates a node receiving a parent node as `parent` with default value as nullptr.

3.3.2.4 node() [4/5]

```
template<typename pair_type >
node< pair_type >::node (
            node< pair_type > && other )  [explicit], [default], [noexcept]
```

move semantics

Implementing both move constructor and move assignment using default compiler generated ones.

3.3.2.5 node() [5/5]

```
template<typename pair_type >
node< pair_type >::node (
            const node< pair_type > & other )  [inline], [explicit]
```

deep copy semantics

Managing the resources from the lowest level, to achieve a deep copy of the bst itself.

3.3.3 Member Function Documentation

3.3.3.1 get_data() [1/2]

```
template<typename pair_type >
const pair_type& node< pair_type >::get_data ( ) const  [inline], [noexcept]
```

get data contained in a node

Returns

by const reference, contents of node, as data

3.3.3.2 get_data() [2/2]

```
template<typename pair_type >
pair_type& node< pair_type >::get_data ( )  [inline], [noexcept]
```

get data contained in a node

Returns

by reference, contents of node, as data

3.3.3.3 get_left()

```
template<typename pair_type >
node* node< pair_type >::get_left ( )  [inline], [noexcept]
```

get left child of a node

Returns

pointer to left child

3.3.3.4 get_parent()

```
template<typename pair_type >
node* node< pair_type >::get_parent ( )  [inline], [noexcept]
```

get parent of a node

Returns

pointer to parent

3.3.3.5 get_right()

```
template<typename pair_type >
node* node< pair_type >::get_right ( )  [inline], [noexcept]
```

get right child of a node

Returns

pointer to right child

3.3.3.6 leftiest() [1/2]

```
template<typename pair_type >
const node* node< pair_type >::leftiest ( ) const  [inline], [noexcept]
```

get far left leaf node

Returns

const leftmost node

3.3.3.7 leftiest() [2/2]

```
template<typename pair_type >
node* node< pair_type >::leftiest ( )  [inline], [noexcept]
```

get far left leaf node

Returns

pointer to leftmost node

3.3.4 Member Data Documentation

3.3.4.1 left_child

```
template<typename pair_type >
std::unique_ptr<node> node< pair_type >::left_child
```

left child

Unique pointer to the node that is left from the current, a node with a smaller key from the current node.

3.3.4.2 parent_node

```
template<typename pair_type >
node* node< pair_type >::parent_node
```

parent node

Pointer to the node that has the current node as one of its' childs. Widely used in the insert function in order to find the correct place for a new node.

3.3.4.3 right_child

```
template<typename pair_type >
std::unique_ptr<node> node< pair_type >::right_child
```

right child

Unique pointer to the node that is right from the current, a node with a bigger key from the current node.

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

- include/node.hpp