ECE 2400 Computer Systems Programming
Fall 2017

Topic 17: Trees

School of Electrical and Computer Engineering
Cornell University

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1. Tree Concepts

2. Binary Trees

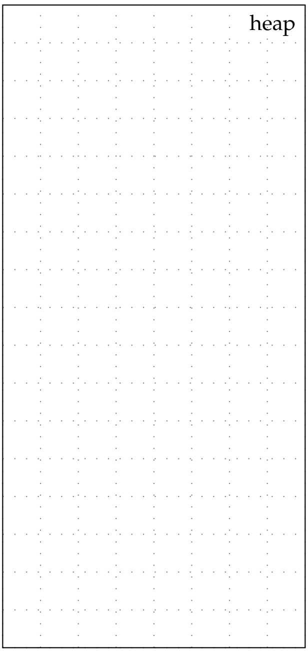
- Object-oriented binary tree which stores ints
- Could also use dynamic or static polymorphism to store any type
- Could add iterators to improve data encapsulation

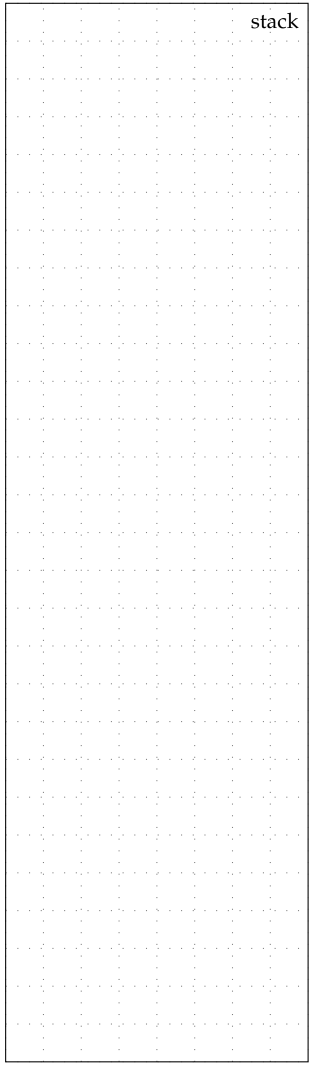
```
class BinaryTreeInt
{
  public:

  BinaryTreeInt();
  ~BinaryTreeInt();

  void insert_root( int v );
  void insert_left( Node* node_p, int v );
  void insert_right( Node* node_p, int v );

  struct Node
  {
    Node( int v );
    int   value;
    Node* left_p;
    Node* right_p;
  };

  Node* m_root_p;
};
```

- Implementation of member functions
- Let's defer implementing the destructor for now

```
BinaryTreeInt::Node::Node( int v )
 : value(v), left_p(nullptr), right_p(nullptr)
{ }

BinaryTreeInt::BinaryTreeInt()
 : m_root_p(nullptr)
{ }

void BinaryTreeInt::insert_root( int v )
{
  m_root_p = new Node(v);
}

void BinaryTreeInt::insert_left( Node* node_p, int v )
{
  node_p->left_p = new Node(v);
}

void BinaryTreeInt::insert_right( Node* node_p, int v )
{
  node_p->right_p = new Node(v);
}
```

```cpp
int main( void )
{
  BinaryTreeInt bt;
  bt.insert_root( 10 );

  typedef BinaryTreeInt::Node Node;
  Node* r = bt.m_root_p;
  bt.insert_left ( r, 11 );
  bt.insert_right( r, 12 );
  bt.insert_left ( r->left_p, 13 );

  return 0;
}
```





Recursive member function to print tree

```
void BinaryTreeInt::print_h( Node* node_p ) {
```

Recursive function to delete tree

```
void BinaryTreeInt::clear_h( Node* node_p ) {
```

3. Binary Search Trees

- Recall that set ADTs provide `add` and `contains` member functions
- Consider implementing a set ADT with a linked list vs. vector

	`add`	`contains`
list		
list (sorted)		
vector		
vector (sorted)		
binary search tree		

- A binary search tree is a binary tree with the following invariant:

For any node in the tree with value v,
all values to the left of that node are less than v and
all values to the right of that node are greater than v.

- We can use a binary search tree to achieve $O(\log_2(N))$ time complexity for both `add` and `contains`
- This time complexity bound Assumes binary tree is balanced which may or may not be a reasonable assumption

BST invariant is true

BST invariant is not true

- Let's begin by implementing a recursive member function to find which node contains a give value in the tree
- Function should return a pointer to the node with the given value
- For now assume given value is always in the tree

Recursive member function to find node with given value in tree

```
Node* BinaryTreeInt::find_h( Node* node_p, int v ) {
```

- Now assume given value is not in the tree
- Modify your algorithm to return a pointer to the node which would be the *parent* of where we could insert a new node with the new value

Member function to search for value in tree

```
bool BinaryTreeInt::contains( int v ) {
```

Member function to add value to tree

```
void BinaryTreeInt::add( int v ) {
```