COMPUTER SCIENCE 51

Spring 2010

http://cs51.seas.harvard.edu

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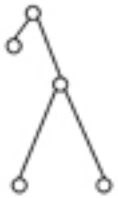
computer science 51



What's 51 about?

Programming isn't hard.

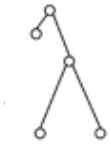
Programming **well** is **very** hard.

We want you to write code that is:

- Reliable, efficient, readable, testable, provable, maintainable… **beautiful**!

Expand your problem-solving skills:

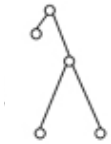
- Recognize problems & map them onto the right languages, abstractions, & algorithms.



Prime Directive

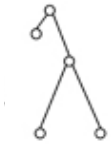
Good programmers are lazy.

- Never write the same code twice.
- Reuse libraries.
- Keep interfaces small & simple.
- Pick a language that makes writing & maintaining the code easy.



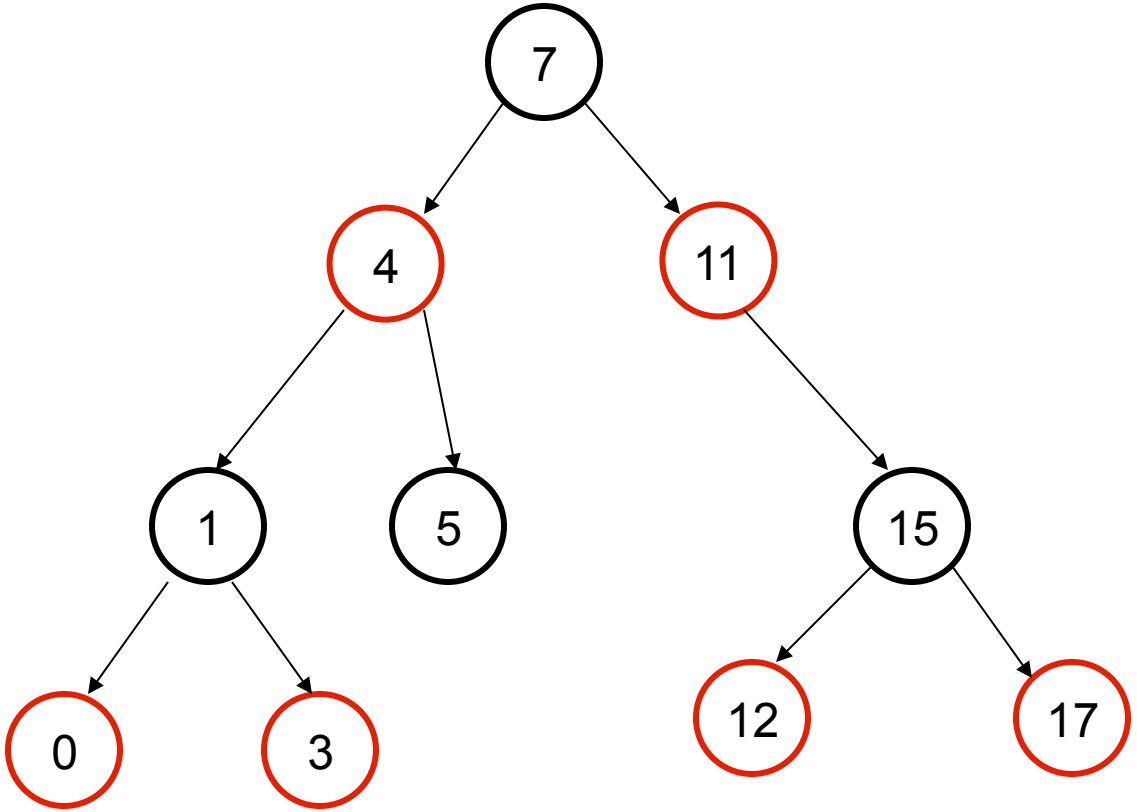
Language & Code

- Language & abstractions matter.
  - Try formulating an algorithm to multiply Roman numerals.
- Often, don't have the luxury of choosing the language.
  - We can still conceptualize & prototype using the right language abstractions.
  - If we understand relationships between linguistic abstractions, we can realize the code in any language.



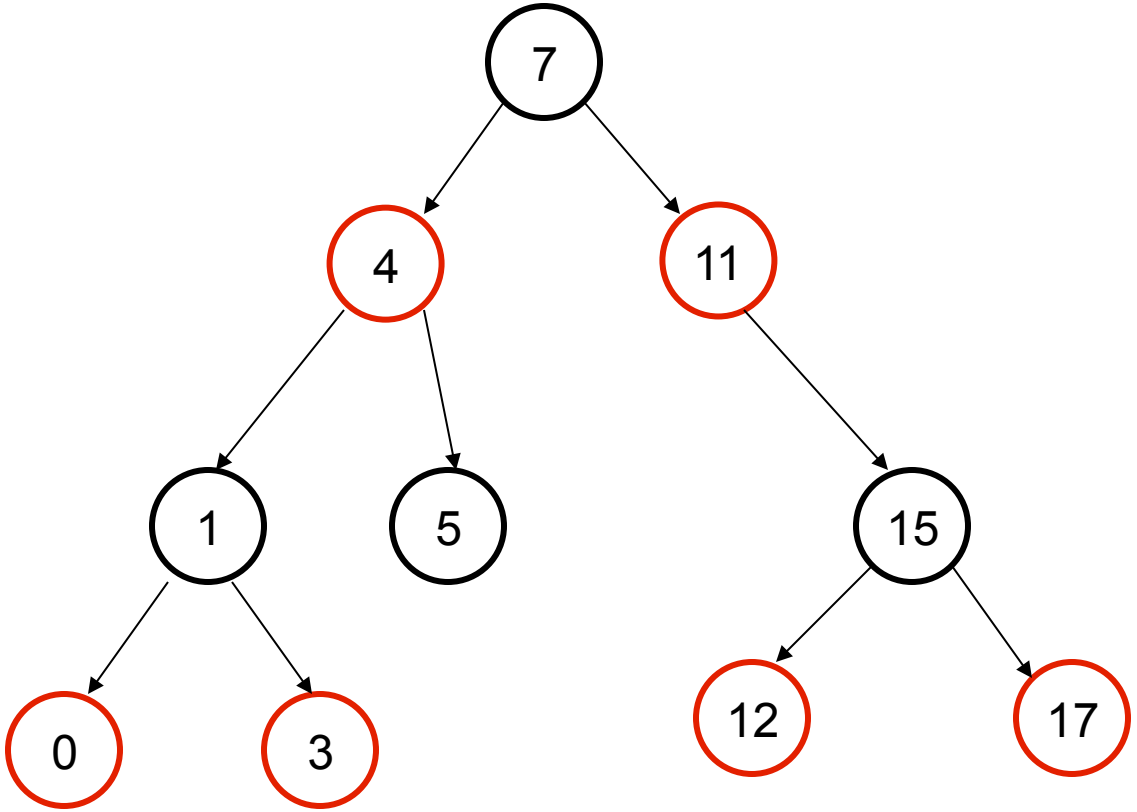
Better Example: Red-Black Trees

- A particular kind of balanced search tree [Guibas & Sedgewick 1978].

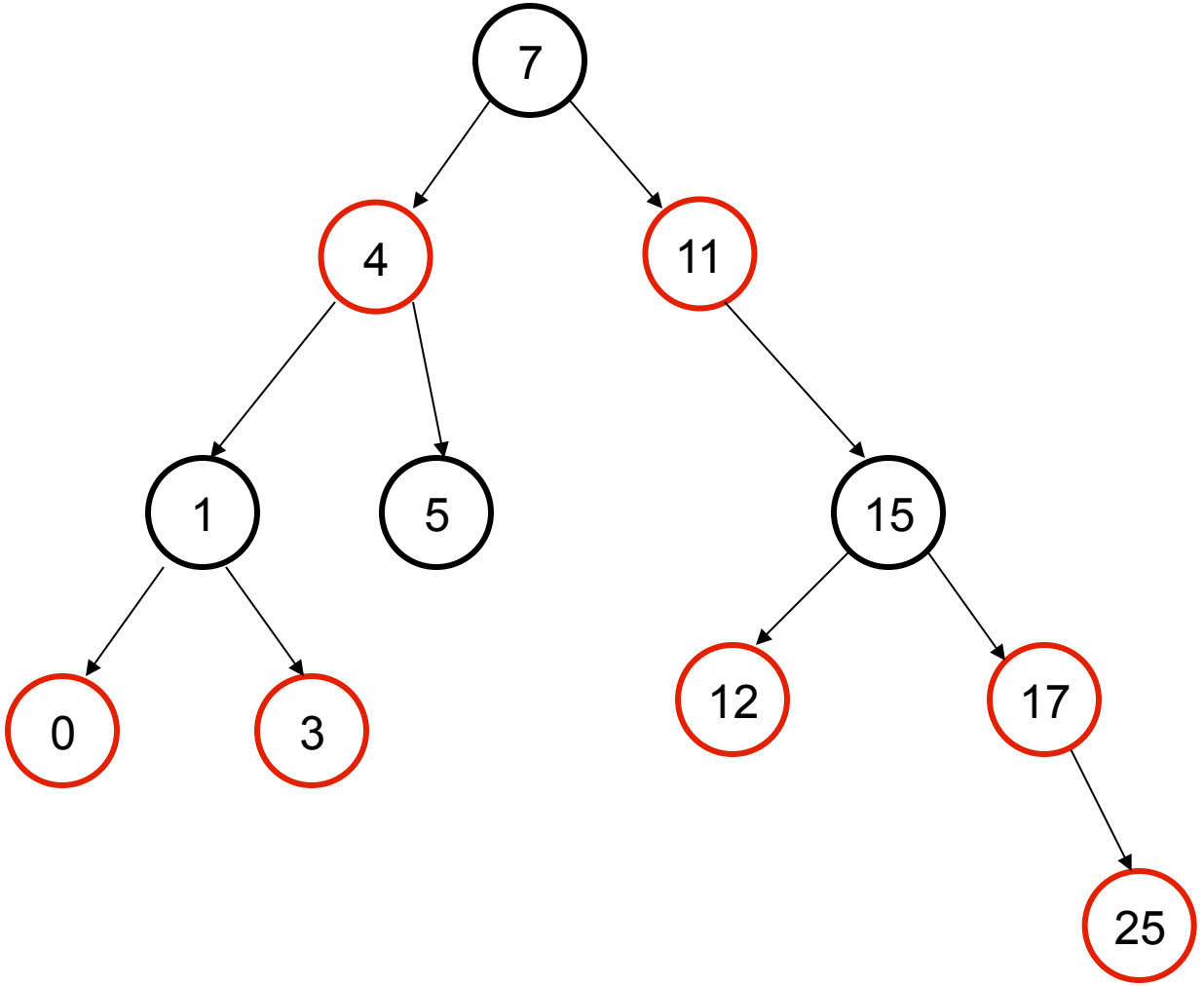


Key Invariants:

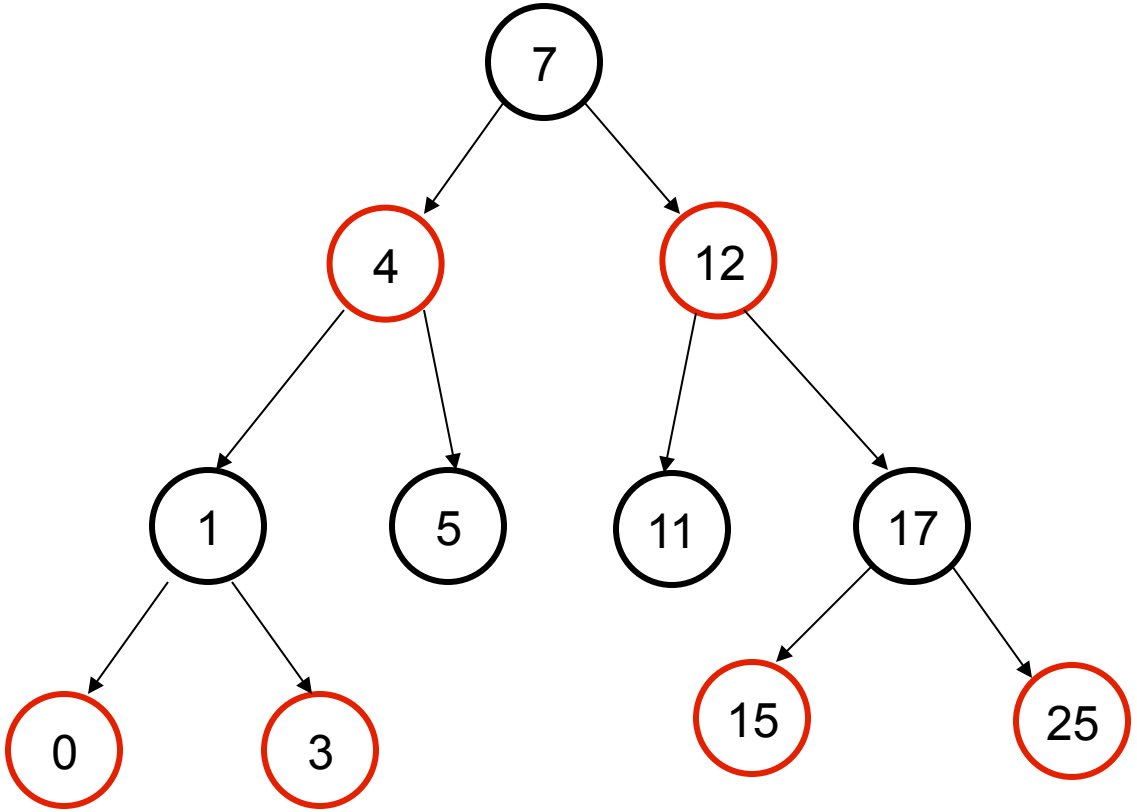
1. No red node has a red child
2. Every path from root has same number of black nodes

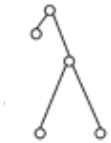


Must Rebalance



Must Rebalance

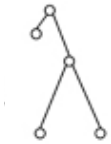




ML Code for Insert

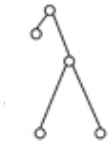
```
fun balance((Blk,T(Red,T(Red,a,x,b),y,c),z,d)
            |(Blk,T(Red,a,x,T(Red,b,y,c)),z,d)
            |(Blk,a,x,T(Red,T(Red,b,y,c),z,d))
            |(Blk,a,x,T(Red,b,y,T(Red,c,z,d)))) =
                  T(Red,T(Blk,a,x,b),y,T(Blk,c,z,d))
   | balance x = T x

fun ins x Empty = T(R,Empty,x,Empty)
  | ins x (T(color,a,y,b)) =
  if x <= y then balance(color,ins x a,y,b)
  else if x > y then balance(color,a,y,ins x b)
```



C code (part 1/4)

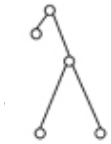
```
void rb_insert( Tree T, node x ) {
  tree_insert( T, x );
  x->colour = red;
  while ( (x != T->root) && (x->parent->colour == red) ) {
      if ( x->parent == x->parent->parent->left ) {
         y = x->parent->parent->right;
        if ( y->colour == red ) {
         x->parent->colour = black;
          y->colour = black;
          x->parent->parent->colour = red;
         x = x->parent->parent;
      } else {
       if ( x == x->parent->right ) {
          x = x->parent;
          left_rotate( T, x );
       }
       x->parent->colour = black;
       x->parent->parent->colour = red;
       right_rotate( T, x->parent->parent );
     }
    } else {
      . . . /* repeat above with red/black swapped */
```



C code (part 2/4)

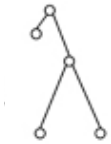
```
void left_rotate( Tree T, node x ) {
  node y;
  y = x->right;
  x->right = y->left;
  if ( y->left != NULL )
    y->left->parent = x;
  y->parent = x->parent;
  if ( x->parent == NULL )
    T->root = y;
  else if ( x == (x->parent)->left )
    x->parent->left = y;
  else
   x->parent->right = y;
   y->left = x;
   x->parent = y;
}

/* repeat above for right_rotate with “obvious” changes */
```



A Key Outcome

- Master Key Linguistic Abstractions:
  - procedural abstraction
  - control: iteration, recursion, pattern matching, laziness, exceptions, events, threads, continuations
  - encapsulation: closures, ADTs, objects, modules
  - Parameterization: higher-order procedures, modules; classes, inheritance



More Outcomes

- Exposure to software eng. techniques:
  - modular design.
  - unit tests, integration tests.
  - critical code reviews.
- Exposure to abstract models:
  - models for design & communication.
  - models & techniques for proving correctness of code.
  - models for space & time.