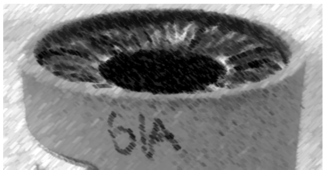

CS61A Lecture 26

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Announcements

- HW9 out tonight, due 4/3
- Ants extra credit due 4/3
  - See Piazza for submission instructions

Data Structure Applications

The data structures we cover in 61A are used everywhere in CS

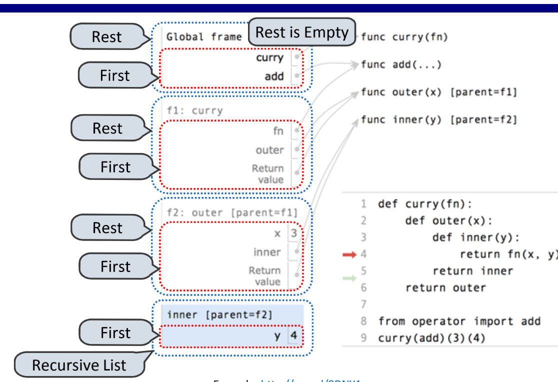
More about data structures in 61B

Example: recursive lists (also called *linked lists*)

- Operating systems
- Interpreters and compilers
- Anything that uses a queue

The Scheme programming language, which we will learn soon, uses recursive lists as its primary data structure

Example: Environments



Example: http://goo.gl/8DNY1

Trees with Internal Node Values

Trees can have values at internal nodes as well as their leaves.

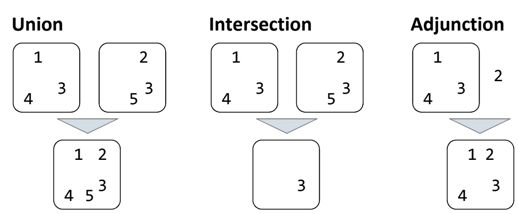
```
class Tree(object):
    def __init__(self, entry, left=None, right=None):
        self.entry = entry
        self.left = left
        self.right = right

def fib_tree(n):
    if n == 1:
        return Tree(0)
    if n == 2:
        return Tree(1)
    left = fib_tree(n - 2)
    right = fib_tree(n - 1)
    return Tree(left.entry + right.entry, left, right)
```

Implementing Sets

What we should be able to do with a set:

- Membership testing: Is a value an element of a set?
- Union: Return a set with all elements in *set1* **or** *set2*
- Intersection: Return a set with any elements in *set1* **and** *set2*
- Adjunction: Return a set with all elements in *s* and a value *v*



Sets as Unordered Sequences

Proposal 1: A set is represented by a recursive list that contains no duplicate items

This is how we implemented dictionaries

```
def empty(s):
    return s is Rlist.empty

def set_contains(s, v):
    if empty(s):
        return False
    elif s.first == v:
        return True
    return set_contains(s.rest, v)
```

Sets as Unordered Sequences

Time order of growth

```
def adjoin_set(s, v):
    if set_contains(s, v):
        return s
    return Rlist(v, s)
```

$\Theta(n)$

The size of the set

```
def intersect_set(set1, set2):
    f = lambda v: set_contains(set2, v)
    return filter_rlist(set1, f)
```

$\Theta(n^2)$

Assume sets are the same size

```
def union_set(set1, set2):
    f = lambda v: not set_contains(set2, v)
    set1_not_set2 = filter_rlist(set1, f)
    return extend_rlist(set1_not_set2, set2)
```

$\Theta(n^2)$

Sets as Ordered Sequences

Proposal 2: A set is represented by a recursive list with unique elements ordered from least to greatest

```
def set_contains2(s, v):
    if empty(s) or s.first > v:
        return False
    elif s.first == v:
        return True
    return set_contains(s.rest, v)
```

Order of growth? $\Theta(n)$

Set Intersection Using Ordered Sequences

This algorithm assumes that elements are in order.

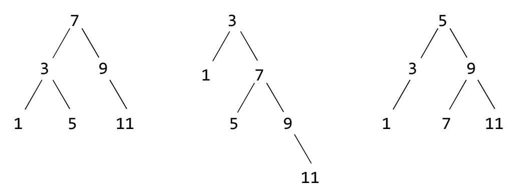
```
def intersect_set2(set1, set2):
    if empty(set1) or empty(set2):
        return Rlist.empty
    e1, e2 = set1.first, set2.first
    if e1 == e2:
        rest = intersect_set2(set1.rest, set2.rest)
        return Rlist(e1, rest)
    elif e1 < e2:
        return intersect_set2(set1.rest, set2)
    elif e2 < e1:
        return intersect_set2(set1, set2.rest)
```

Order of growth? $\Theta(n)$

Tree Sets

Proposal 3: A set is represented as a Tree. Each entry is:

- Larger than all entries in its left branch and
- Smaller than all entries in its right branch

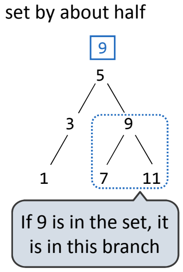


Membership in Tree Sets

Set membership tests traverse the tree

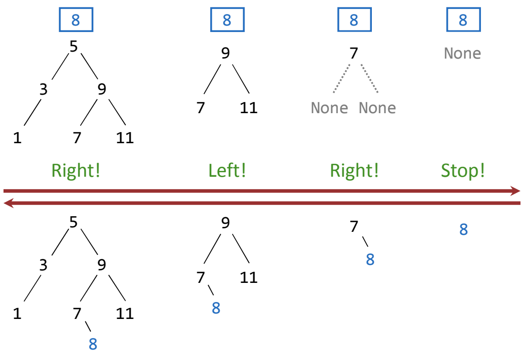
- The element is either in the left or right sub-branch
- By focusing on one branch, we reduce the set by about half

```
def set_contains3(s, v):
    if s is None:
        return False
    elif s.entry == v:
        return True
    elif s.entry < v:
        return set_contains3(s.right, v)
    elif s.entry > v:
        return set_contains3(s.left, v)
```



Order of growth?

Adjoining to a Tree Set



What Did I Leave Out?

Sets as ordered sequences:

- Adjoining an element to a set
- Union of two sets

Sets as binary trees:

- Intersection of two sets
- Union of two sets

That's homework 9!

Social Implications / Programming Practices

- Why things go wrong
- What can we do about this

Therac-25 Case Study

- Medical imaging device

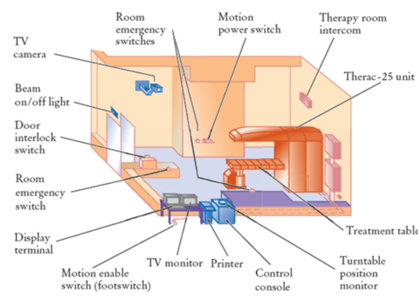


Figure 9 Typical Therac-25 Facility

Therac-25 Case Study

- What happened?
- 6 serious injuries
- 4 deaths
- Otherwise effective – saved hundreds of lives

Lesson to be learned

- Social responsibility in engineering
- First real incident of fatal software failure
- Bigger issue
  - No bad guys
  - Honestly believed there was nothing wrong

“Software Rot”

- Other engineering fields: clear sense of degradation and decay
- Can software become brittle or fractured?

A bigger picture

- **All software is part of a bigger system**
- Software degrades because:
  - Other piece of software changes
  - Hardware changes
  - Environment changes

Ex: Compatibility Issues

A bigger issue

- The makers of the Therac did not fully understand the **complexity** of their software
- Complexity of constructs in other fields more apparent

A “simple” program

- This program can delete any file you can

Complexity in the Therac-25

- Abundant user interface issues

- Cursor position and field entry
- Default values
- Too many error messages

Too many error messages

Too many error messages

(More) Complexity in the Therac-25

- No atomic test-and-set
- No hardware interlocks

How can we solve these things?

- Know your user
- Fail-Soft (or Fail-Safe)
- Audit Trail
- Correctness from the start
- Redundancy

Fail-Soft (or Fail-Safe)

```
def mutable_rlist():
    def dispatch(message, value=None):
        nonlocal contents
        if message == 'first':
            return first(contents)
        if message == 'rest':
            return rest(contents)
        if message == 'len':
            return len_rlist(contents)
        ...
        else:
            print('Unknown message')
    return dispatch
```

Correctness from the start

- Edsger Dijkstra: “On the Cruelty of Really Teaching Computing Sciences”
- CS students shouldn’t use computers
- Rigorously prove correctness of their programs

- Correctness proofs
- Compilation (pre-execution) analysis

On debugging

- Black box debugging
- Glass box debugging
- Don’t break what works

- Golden rule of debugging…

Golden rule of debugging

- “Debug by subtraction, not by addition”
  - Prof. Brian Harvey