Data structure and algorithms lab

DEBUGGING WITH GDB & TREE

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Topics of this week

- How to use debugger tool(gdb)
- Tree data structure
  - Binary Tree
  - Binary Search Tree
- Recursive processing on Tree

`gdb` for debugging (1)

- `gdb`: the Gnu DeBugger
- http://www.cs.caltech.edu/courses/cs11/material/c/mike/misc/gdb.html
- Use when program core dumps
- or when want to walk through execution of program line-by-line

`gdb` for debugging (2)

- Before using `gdb`:
  - Must compile C code with additional flag: `-g`
  - This puts all the source code into the binary executable
- Then can execute as: `gdb myprogram`
- Brings up an interpreted environment

`gdb` for debugging (3)

```
gdb> run
```

- Program runs...
- If all is well, program exits successfully, returning you to prompt
- If there is (*e.g.*) a core dump, `gdb` will tell you and abort the program

`gdb` – basic commands (1)

- Stack backtrace ("`where`")
  - Your program core dumps
  - Where was the last line in the program that was executed before the core dump?
  - That's what the `where` command tells you

gdb – basic commands (2)

```
gdb> where
#0 0x4006cb26 in free () from /lib/libc.so.6
#1 0x4006ca0d in free () from /lib/libc.so.6
#2 0x8048951 in board_updater (array=0x8049bd0,
   ncells=2) at 1dCA2.c:148
#3 0x80486be in main (argc=3, argv=0xbffff7b4) at
   1dCA2.c:44
#4 0x40035a52 in __libc_start_main () from
   /lib/libc.so.6
```

last call

last call in your code

stack backtrace

gdb – basic commands (3)

- Look for topmost location in stack backtrace that corresponds to your code
- Watch out for
  - freeing memory you didn't allocate
  - accessing arrays beyond their maximum elements
  - dereferencing pointers that don't point to part of a `malloc()`ed block

gdb – basic commands (4)

- **break, continue, next, step** commands
- **break** causes execution to stop on a given line

  gdb> break foo.c: 100 (setting a breakpoint)
- **continue** resumes execution from that point
- **next** executes the next line, then stops
- **step** executes the next statement
  - goes into functions if necessary (**next** doesn't)

gdb – basic commands (5)

- **print** and **display** commands
- **print** prints the value of any program expression

  ```
  gdb> print i
  $1 = 100
  ```
- **display** prints a particular value every time execution stops

  ```
  gdb> display i
  ```

gdb – printing arrays (1)

- `print` will print arrays as well

```
int arr[] = { 1, 2, 3 };

gdb> print arr
$1 = {1, 2, 3}
```

- N.B. the `$1` is just a name for the result

```
print $1
$2 = {1, 2, 3}
```

gdb – printing arrays (2)

- `print` has problems with dynamically-allocated arrays

```
int *arr;
arr = (int *)malloc(3 * sizeof(int));
arr[0] = 1; arr[1] = 2; arr[2] = 3;
gdb> print arr
$1 = (int *) 0x8094610
```

- Not very useful...

gdb – printing arrays (3)

- Can print this array by using @ (gdb special syntax)

```
int *arr;
arr = (int *)malloc(3 * sizeof(int));
arr[0] = 1; arr[1] = 2; arr[2] = 3;

gdb> print *arr@3
$2 = {1, 2, 3}
```

gdb – abbreviations

- Common gdb commands have abbreviations

p (same as print)

c (same as continue)

n (same as next)

s (same as step)

- More convenient to use when interactively debugging

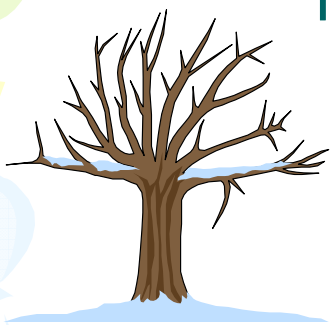
other instruction

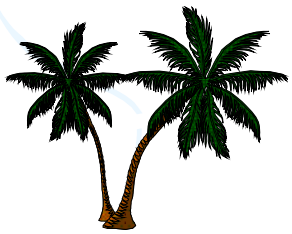
- clear : delete break point of current file.
- delete [break position]: delete breakpoint at a specific file and position
- Conditional break

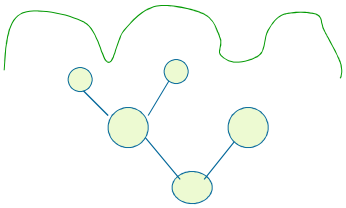
```
gdb> break foo.c: 100 if i==-1
```

- quit
- run: restart from beginning.

Tree



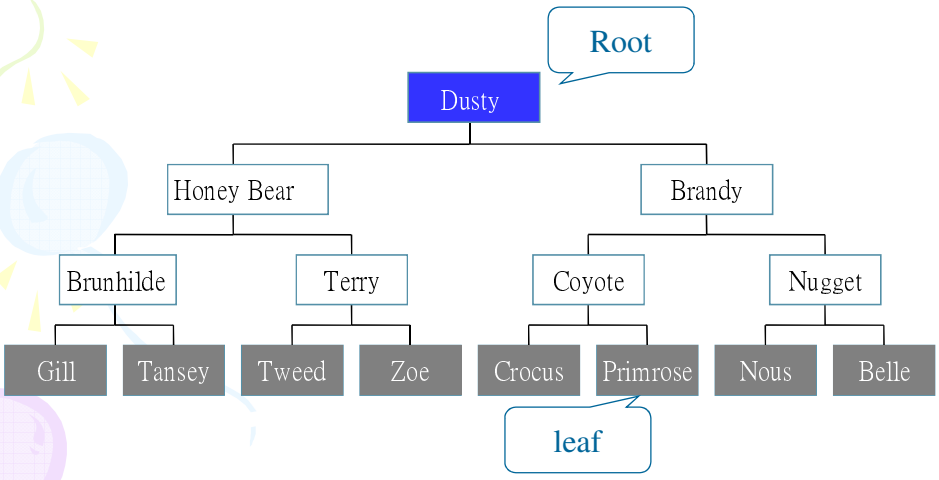




Trees, Binary Trees, and Binary Search Trees

- Linked lists are **linear structures** and it is difficult to use them to organize a **hierarchical** representation of objects.
- Although stacks and queues reflect some hierarchy, they are limited to only **one dimension**.
- To overcome this limitation, we create a new data type called a **tree** that consists of **nodes** and **arcs**. Unlike natural trees, these trees are **depicted upside down** with the **root** at the top and the **leaves** at the bottom.

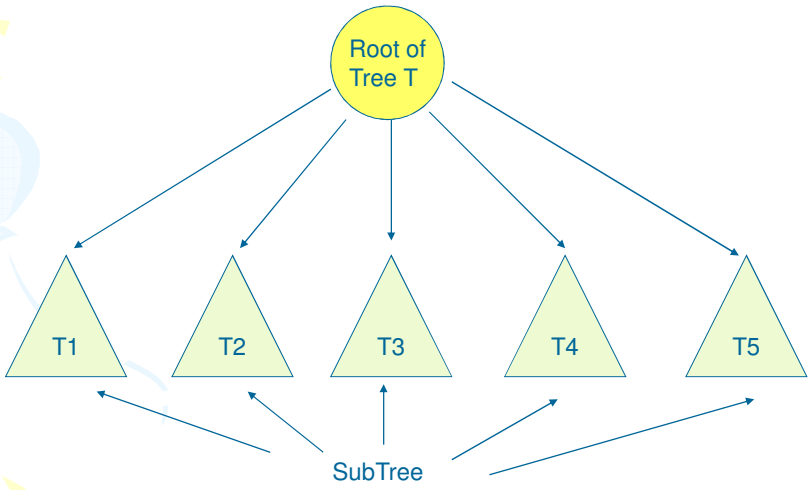
Family Tree



Definition of tree

- A tree is a finite set of one or more nodes such that:
- There is a specially designated node called the root.
- The remaining nodes are partitioned into n>=0 disjoint sets T_1, ..., T_n, where each of these sets is a tree.
- We call T_1, ..., T_n the subtrees of the root.

Recursive definition



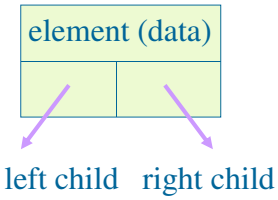
Binary Tree

- A binary tree is a tree in which no node can have more than two children.
- Each node has 0, 1, or 2 children

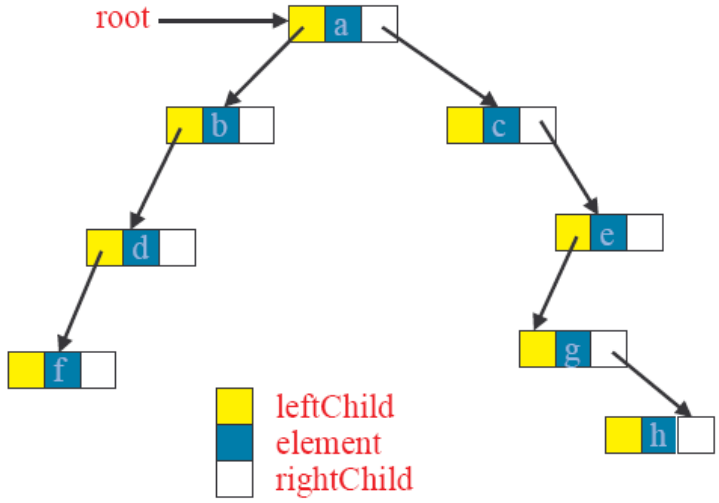
Linked Representation

- Each tree node is represented as an object whose data type is
- The space required by an n node binary tree is n * (space required by one node)

```
typedef ... elmType;
//whatever type of element
typedef struct nodeType {
   elmType element;
   struct nodeType *left, *right;
};
typedef struct nodeType *treetype;
```



A linked binary tree



Binary Tree ADT

- makenullTree(treetype *t)
- creatnewNode()
- isEmpty()

Tree initialization and verification

```
typedef  …  elmType;
typedef struct nodeType {
   elmType element;
   struct nodeType *left, *right;
} node_Type;

typedef struct nodeType *treetype;

void MakeNullTree(treetype *T){
(*T)=NULL;
}
int EmptyTree(treetype T){
  return T==NULL;
}
```

Access left and right child

```
treetype LeftChild(treetype n)
{
  if (n!=NULL) return n->left;
  else return NULL;
}
treetype RightChild(treetype n)
{
  if (n!=NULL) return n->right;
  else return NULL;
}
```

create a new node

```
node_type *create_node(elmtype NewData)
{
  node_type *N;
  N=(node_type*)malloc(sizeof(node_type));
  if (N != NULL)
  {
     N->left = NULL;
     N->right = NULL;
     N->element = NewData;
  }
  return N;
}
```

check if a node is a leaf

```
int IsLeaf(treetype n){
  if(n!=NULL)
     return(LeftChild(n)==NULL)&&(Right
     Child(n)==NULL);
   else return -1;
}
```

Recursive processing: Number of nodes

- As tree is a recursive data structure, recursive algorithms are usefuls when they are applied on tree.

```
int nb_nodes(treetype T){
if(EmptyTree(T)) return 0;
   else return 1+nb_nodes(LeftChild(T))+
      nb_nodes(RightChild(T));
}
```

Creat a tree from two sub-trees

```
treetype createfrom2(elmtype v,
  treetype l, treetype r){
  treetype N;
  N=(node_type*)malloc(sizeof(node_typ
  e));
  N->element=v;
  N->left=l;
  N->right=r;
   return N;
}
```

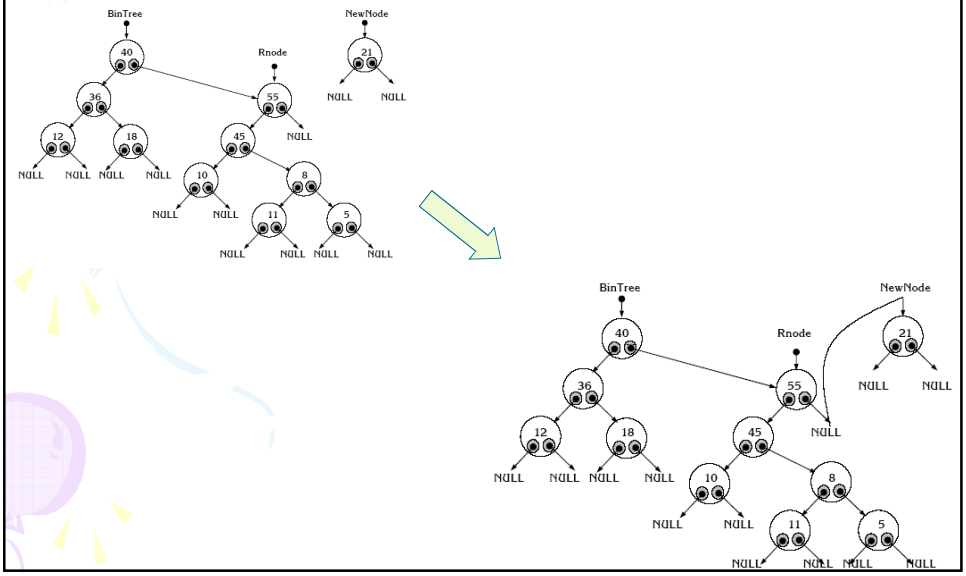
Adding a new node to the left most position

```
treetype Add_Left(treetype *Tree, elmtype NewData){
   node_type *NewNode = Create_Node(NewData);
   if (NewNode == NULL) return (NewNode);
   if (*Tree == NULL)
        *Tree = NewNode;
   else{
        node_type *Lnode = *Tree;
        while (Lnode->left != NULL)
              Lnode = Lnode->left;
        Lnode->left = NewNode;
   }
   return (NewNode);
}
```

Adding a new node to the right most position

```
treetype Add_Right(treetype *Tree, elmtype NewData){
   node_type *NewNode = Create_Node(NewData);
   if (NewNode == NULL) return (NewNode);
   if (*Tree == NULL)
        *Tree = NewNode;
   else{
        node_type *Rnode = *Tree;
        while (Rnode->right != NULL)
              Rnode = Rnode->right;
        Rnode->right = NewNode;
   }
   return (NewNode);
}
```

Illustration

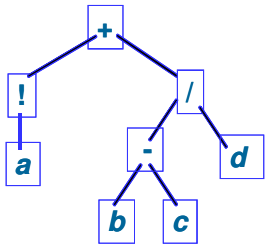


Exercise (BTVN)

- Develop the following helper functions for a tree:
  - return the height of a binary tree.
  - return the number of leafs
  - return the number of internal nodes
  - count the number of right children.

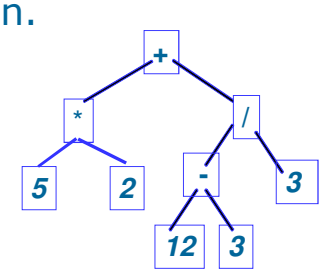
Exercise

- A binary can represent an arithmetic expression: The leaves are operands and the other nodes are operators.
- The left and right subtrees of an operator node represent subexpressions that must be evaluated before applying the operator at the root of the subtree.
- For example
  !a + (b – c)/d
- Write a program create a tree representing this expression



Exercise at Home

- Write an menu program that take a valid arithmetic expression as input and:
  - Store and represent it in a tree
  - Evaluate the expression.



Homework

- Create a text file AUOpen.txt containing the names of tennis players participating in the Australian Open tournament, one player per line. The number of player is the power of 2 and a minimum of 16 people.
- Build a tree describing the competition results until the final. Initially, the (16) opponents are leaf nodes, the winner will be stored at the parent node of a pair of players. The winner of a match is randomly selected.
- Print the results of the matches (tree content) to the screen and file treegame.txt