# CSE 2320 Notes 10: Stacks and Queues

(Last updated 1/16/20 4:09 PM)

CLRS 10.1

## 10.A. STACKS

Abstraction (Last-In, First-Out) and Operations

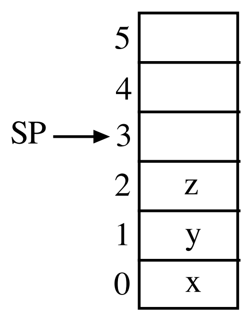
PUSH    POP    TOP    EMPTY

Policies Correspond to Code ($\Theta(1)$ for all operations)

1. Direction of growth in array

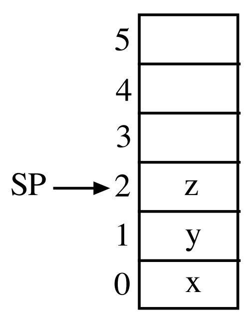
2. What does *stack pointer* indicate?

   a. Next available element:



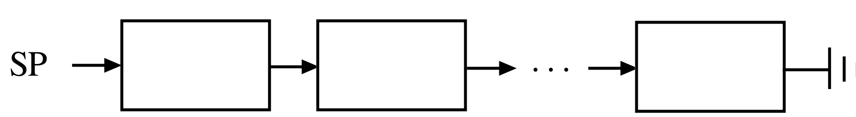

| | |
|---|---|
| EMPTY: | `return sp==0;` |
| PUSH(x): | `A[sp++]=x;` |
| POP: | `return A[--sp];` |
| TOP: | `return A[sp-1];` |

   b. Most recently pushed element:




| | |
|---|---|
| EMPTY: | `return sp==(-1);` |
| PUSH(x): | `A[++sp]=x;` |
| POP: | `return A[sp--];` |
| TOP: | `return A[sp];` |

Also easy to implement using a linked list (CLRS exercise 10.2-2):



Applications

1. Run-time environment for programming languages.
2. Compilers/parsing
3. Depth-first search on graphs (Notes 14).

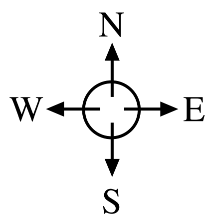
## 10.B. Rat-in-a-Maze Using a Stack (Depth-First Search)

```
. . . . . . . . . . . . . . . . .
. # . # # # # # ^ ^ ^ ^ ^ ^ ^ ^ .
. # . # . . . # . ^ . . . . . . .
. # # # . # # # . ^ ^ ^ . ^ ^ ^ .
. . . . . # . . . ^ . ^ . ^ . ^ .
.   .     # # # . ^ . ^ ^ ^ . ^ .
.   .   . . . # . . . . . . . . .
.       . # # # . ^ ^ ^ ^ ^ ^ ^ .
. . . . . # . . . ^ . . . . . ^ .
. ^ . # # # . ^ ^ ^ . ^ . ^ ^ ^ .
. ^ . # . ^ . ^ . . . ^ . ^ . . .
. # # # . ^ ^ ^ ^ ^ . ^ ^ ^ .   .
. # . . . . . . . . . . . . .   .
. # # # # # # # # # .           .
. . . . .   .   . # . . . . .   .
.           .   . # # # # # # # .
. . . . . . . . . . . . . . . . .
```

Array initially contains 0/1 for each position.
0=open (" "), 1=wall (".").

Stack contains positions on current path.

Array entries change to reflect search status:
2=discovered ("^"), 3=solution ("#").




```
http://ranger.uta.edu/~weems/NOTES2320/VERMIN/ratDFSrec.c
. . .
int DFS(int row,int col)
{
if (maze[row][col]!=0)
  return 0; // report failure
if (row==stopRow && col==stopCol)
{
  maze[row][col]=3;
  return 1; // report success
}
maze[row][col]=2;  // Mark slot as discovered
if (!DFS(row-1,col))        // Try North
  if (!DFS(row,col+1))      // Try East
    if (!DFS(row+1,col))    // Try South
      if (!DFS(row,col-1))  // Try West
        return 0;
maze[row][col]=3;  // On final path
return 1;  // Propagate success through recursion
}

int main()
{
readInput();
printf("Initial maze:\n");
printMaze();
if (DFS(startRow,startCol))
  printf("Success:\n");
else
  printf("Failure:\n");
printMaze();
}
```

http://ranger.uta.edu/~weems/NOTES2320/VERMIN/ratDFSstack.c

```
. . .
typedef enum {init,north,east,south,west} direction;
typedef struct {
  int row,col;
  direction current;
} stackEntry;
. . .

int DFS(int row,int col)
{
stackEntry work;
int returnValue;
work.row=row;
work.col=col;
work.current=init;
pushStack(work);
while (!emptyStack())
{
  work=popStack();
  if (work.current==init)  // Just arrived here?
  {
    if (maze[work.row][work.col]!=0)  // Not an open slot?
    {
      returnValue=0;
      continue;
    }
    if (work.row==stopRow && work.col==stopCol)  // At destination?
    {
      maze[work.row][work.col]=3;
      returnValue=1;
      continue;
    }
    maze[work.row][work.col]=2;  // Mark slot as discovered
  }
  else if (returnValue==1)  // Backtracking from successful search?
  {
    maze[work.row][work.col]=3;
    continue;
  }
  else if (work.current==west)  // No other directions to try
  {
    returnValue=0;
    continue;
  }
  // Try next direction.  Push current position and new position
  work.current++;
  pushStack(work);
  switch (work.current) {
    case north: work.row--; break;
    case east:  work.col++; break;
    case south: work.row++; break;
    case west:  work.col--; break;
  }
  work.current=init;
  pushStack(work);
}
return returnValue;
}
```

## 10.C. EVALUATING POSTFIX EXPRESSIONS USING A STACK

Infix: ( 1 + 2 ) * ( 3 + 1 ) / ( 1 + 1 + 1 )

Postfix: 1 2 + 3 1 + * 1 1 + 1 + /

Prefix: / * + 1 2 + 3 1 + + 1 1 1

Evaluating Postfix – Store operands on stack until popped for operator

```
while (unprocessed input tokens)
{
  get token;
  if (token is an operand)
    stack.push(token);
  else // token is an operator
  {
    operand2=stack.pop();
    operand1=stack.pop();
    stack.push(result of (operand1 token operand2));
  }
}
result=stack.pop();
if (!stack.empty())
  <error>
```

| | Stack | | |
|---|---|---|---|
| 1: | 1 | | |
| 2: | 1 | 2 | |
| +: | 3 | | |
| 3: | 3 | 3 | |
| 1: | 3 | 3 | 1 |
| +: | 3 | 4 | |
| *: | 12 | | |
| 1: | 12 | 1 | |
| 1: | 12 | 1 | 1 |
| +: | 12 | 2 | |
| 1: | 12 | 2 | 1 |
| +: | 12 | 3 | |
| /: | 4 | | |

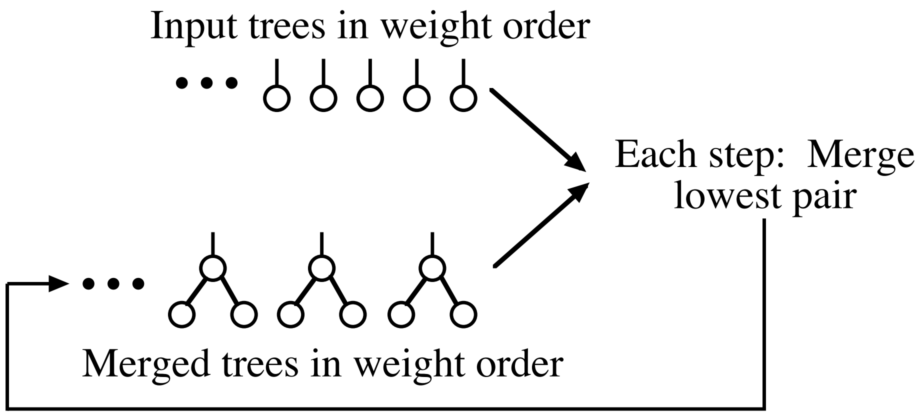
## 10.D. QUEUES

Abstraction (First-In, First-Out) and Operations

ENQUEUE (at *tail*) DEQUEUE (from *head*) EMPTY

Applications

1. Huffman coding using two queues
( `http://ranger.uta.edu/~weems/NOTES2320/huffman2Q.c` )




2. Data communications

3. Message-based concurrent programming

4. Event-interrupt handlers

5. Breadth-first search

    a. Graphs (Notes 14)

    b. Rat in a maze ( `http://ranger.uta.edu/~weems/NOTES2320/VERMIN/ratBFSqueue.c` )

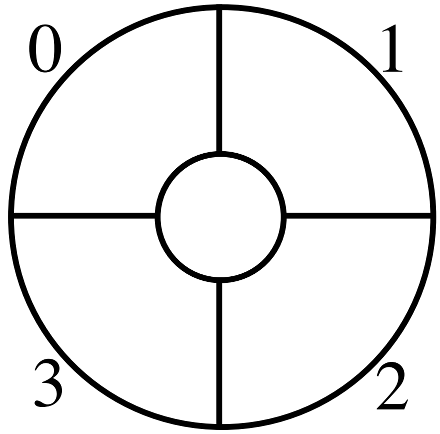
```
. . . . . . . . . . . . . . . . .
. # . # # # # # ^ ^ ^ ^ ^ ^ ^ ^ .
. # . # . . . # . ^ . . . . . . .
. # # # . # # # . ^ ^ ^ . ^ ^ ^ .
. . . . . # . . . ^ . ^ . ^ . ^ .
. ^ . ^ ^ # # # . ^ . ^ ^ ^ . ^ .
. ^ . ^ . . . # . . . . . . . . .
. ^ ^ ^ . # # # . ^ ^ ^ ^ ^ ^ ^ .
. . . . . # . . . ^ . . . . . ^ .
. ^ . # # # . ^ ^ ^ .   . ^ ^ ^ .
. ^ . # . ^ . ^ . . .   . ^ . . .
. # # # . ^ ^ ^ ^ ^ . ^ ^ ^ .   .
. # . . . . . . . . . . . . .   .
. # # # # # # # # # .           .
. . . . . ^ . ^ . # . . . . .   .
. ^ ^ ^ ^ ^ . ^ . # # # # # # # .
. . . . . . . . . . . . . . . . .
```

Demo of both versions of search:

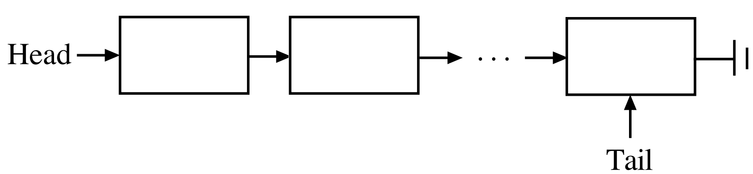
`http://ranger.uta.edu/~weems/NOTES2320/VERMIN/rat.drag.html`

Implementation using `A[0]...A[n-1]` (aside starting with Spring 2020)

| | Non-Reusable | Circular |
|---|---|---|
| Initialize | `tail=head=0;` | `tail=head=0;` |
| EMPTY | `return tail==head;` | `return tail==head;` |
| ENQUEUE(x) | `A[tail++]=x;`<br>`if (tail==n)`<br>`  < error >` | `A[tail++]=x;`<br>`if (tail==n)`<br>`  tail=0;`<br>`if (tail==head)`<br>`  < confused >` |
| DEQUEUE | `if (tail==head)`<br>`  < empty >`<br>`return A[head++];` | `if (tail==head)`<br>`  < empty >`<br>`temp=A[head++];`<br>`if (head==n)`<br>`  head=0;`<br>`return temp;` |




Implementation using a linked list (CLRS exercise 10.2-3):




Aside: Suppose a *queue* has pointers to outgoing messages. How would you maintain:

1. The average length of an outgoing message?

2. The maximum length of an outgoing message?

What if messages are in a *stack* instead?

Solution for queue is to use *two* stacks (CLRS exercise 10.1-6):

Initialize:

```
Initialize inStack
Initialize outStack
```

Enqueue(message, length):

```
if inStack.empty or length > inMaximum
    inMaximum=length
inStack.push(message, length)
```

Dequeue:

```
if outStack.empty
    if inStack.empty
        <ERROR>
    (message, length)=inStack.pop
    outStack.push(message, length)
    while !inStack.empty
        (message, length)=inStack.pop
        outStack.push(message, max(outStack.top.length, length))

(message, length)=outStack.pop
return message
```

MaxLength:

```
if inStack.empty and outStack.empty
    <ERROR>
if outStack.empty
    return inMaximum
if inStack.empty
    return outStack.top.length
return max(inMaximum, outStack.top.length)
```

Amortized vs. actual cost of operations