Data Structures – Week #3

Stacks

Outline

- Stacks
- Operations on Stacks
- Array Implementation of Stacks
- Linked List Implementation of Stacks
- Stack Applications

Stacks (Yığınlar)

- A *stack* is a list of data with the restriction that *data can be retrieved from or inserted to the "top" of the list*.
- By "top" we mean a *pointer pointing to the element that is last added to the list*.
- A stack is a *last-in-first-out (LIFO)* structure.

Operations on Stacks

- Two basic operations related to stacks:
  - *Push* (Put data to the top of the stack)
  - *Pop* (Retrieve data from the top of the stack)

Array Implementation of Stacks

- Stacks can be implemented by arrays.
- During the execution, *stack can grow or shrink within this array*.
- One end of the array is the bottom and the insertions and deletions are made from the other end.
- We also need another field that, at each point, keeps track of the current position of the **top** of the *stack*.

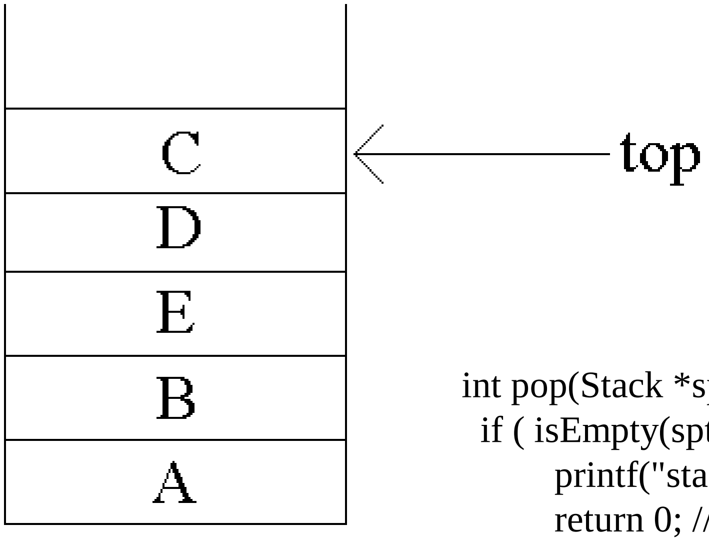
Sample C Implementation

```
#define stackSize ...;
struct dataType {
    ...
}
typedef struct dataType myType;
struct stackType {
    int top;
    myType items[stackSize];
}
typedef struct stackType stackType;
stackType stack;
```

Sample C Implementation… isEmpty()

```
//Initialize Stack (i.e., set value of top to -1)
stack.top=-1;
int isEmpty(stackType *sptr) //call by
   reference
{
   if (sptr->top == -1)
         return 1; //meaning true
   else return 0; //meaning false
}
```

Pop Operation

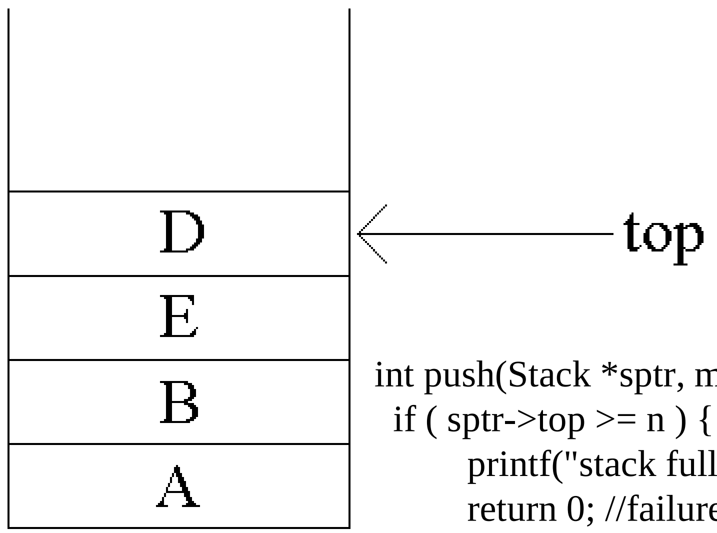



```
int pop(Stack *sptr, myType *node) {
  if ( isEmpty(sptr) ) {
        printf("stack empty");
        return 0; //failure
   }
   *node = sptr->items[sptr->top];
   sptr->top--; //or *node = sptr->items[sptr->top--];
   return 1; //success
}
```

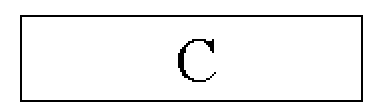
Sample C Implementation… pop()

```
int pop(stackType *sptr, myType *node) {
  if ( isEmpty(sptr) ) {
        printf("stack empty");
        return 0; //failure
   }
   *node = sptr->items[sptr->top--];
   return 1; //success
}
```

Push Operation




```
int push(Stack *sptr, myType *node, int n){
  if ( sptr->top >= n ) {
        printf("stack full");
        return 0; //failure
   }
   ++(sptr->top); //or sptr->content[++(sptr->top)]=node;
   sptr->content[ (sptr->top)]=node;
   return 1; //success
}
```



Sample C Implementation… push()

```
int push(Stack *sptr, myType *node, int n){
  if ( sptr->top >= n ) {
        printf("stack full");
        return 0; //failure
   }
   sptr->items[++(sptr->top)]=*node;
   return 1; //success
}
```

Linked List Implementation of Stacks

```
//Declaration of a stack node

struct StackNode {
   int data;
   struct StackNode *next;
}
typedef struct StackNode StackNode;
typedef StackNode * StackNodePtr;
…
```

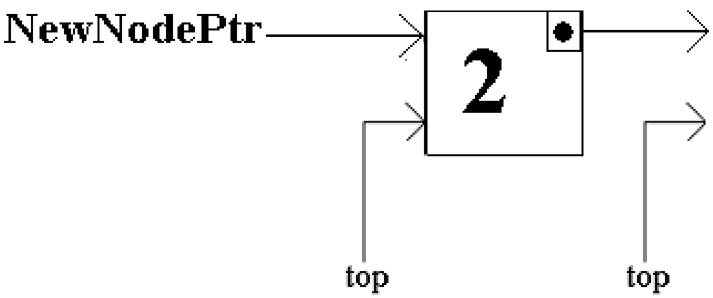
Linked List Implementation of Stacks

```
StackNodePtr NodePtr, top;
…
…
NodePtr = malloc(sizeof(StackNode));
top = NodePtr;
NodePtr->data=2;            // or top->data=2
NodePtr->next=NULL;         // or top->next=NULL;
Push(&top,&NodePtr); //Nodeptr is an output
   variable!!!
…
Pop( );
…
```

Push and Pop Functions

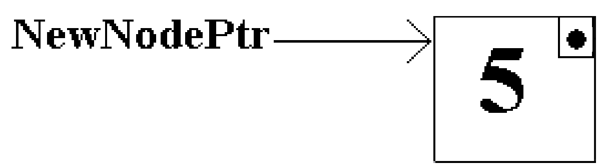
```
Void Push (StackNodePtr *TopPtr, StackNodePtr *NewNodePtr)
    {
        *NewNodePtr = malloc(sizeof(StackNode));
// NewNodePtr to pass to invoking function!!!
        (*NewNodePtr)->data=5;
        (*NewNodePtr)->next = *TopPtr;
        *TopPtr = *NewNodePtr;
}

Void Pop(StackNodePtr *TopPtr) {
        StackNodePtr TempPtr;
        TempPtr= *TopPtr;
        *TopPtr = *TopPtr->next;
        free(TempPtr); // or you may return TempPtr!!!
}
```

Linked List Implementation of Stacks




```
NodePtr = malloc(sizeof(StackNode));
top = NodePtr;
NodePtr->data=2;  // or top->data=2
NodePtr->next=NULL;// or top->next=NULL;
Push(&top,&NodePtr);
```

```
Void Push (StackNodePtr *TopPtr,
           StackNodePtr *NewNodePtr) {
        *NewNodePtr = malloc(sizeof(StackNode));
        (*NewNodePtr)->data=5;
        (*NewNodePtr)->next =NULL;
        (*NewNodePtr)->next = *TopPtr;
        *TopPtr = *NewNodePtr;
}
```



Stack Applications

- Three uses of stacks
  - Symbol matching in compiler design
  - Return address storage in function invocations
  - Evaluation of arithmetic expressions and cross-conversion into infix, prefix and postfix versions

Symbol Matching in Compiler Design

Algorithm:

1. Create an empty stack.

2. Read tokens until EOF. Ignore all tokens other than symbols.

3. If token is an **opening symbol**,

push it onto the stack.

4. If token is a **closing symbol** *and* stack empty,

report an error.

5. Else

pop the stack.

If symbol popped and opening symbol do not match

<u>report an error</u>

6. If EOF *and* stack not empty,

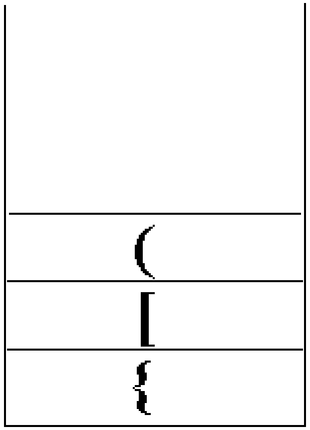
report an error

7. Else, the symbols are balanced.

Symbol Matching

Example:

```
int pop(Stack *sptr, myType *node) {
  if ( isEmpty(sptr) ) {
      printf("stack empty");
          return 0; //failure
   }
   *node = sptr->items[sptr->top--];
   return 1; //success
}
```



Use of Stacks in Function Invocation

- During a function invocation (function call)
  - Each argument value is copied to a local variable called “a dummy variable.” Any possible attempt to change the argument changes the dummy variable, not its counterpart in the caller.
  - Memory space is allocated for local and dummy variables of the called function.
  - Control is transferred to the called. Before this, return address of the caller must also be saved. This is the point where a **system stack** is used.

Use of Stacks in Function Invocation

Returning to the caller, three actions are taken:

1. Return address is retrieved.
2. Data area from the called is cleaned up.
3. Finally, control returns to the caller. Any returned value is also stored in known registers.

A Function Call Example

```
…  main(…) {
n11   …
n12   …
n13   call f2(…);
r1    …
n14   …
}
```

```
…   f2(…) {
n24     …
n25     …
n26     call f3(…);
r2      …
n27     …
}
```

```
…   f3(…) {
n37     …
n38     …
n39     call f4(…);
r3      …
}
```

```
…  f4(…) {
n41   …
n42   …
n43   …
}
```

Program Counter

n34

Stack Pointer

s0Empty

System Stack

s3	r_3
s2	r_2
s1	r_1
s0	r_0

Infix, Postfix and Prefix Formats of Arithmetic Expressions

The name of the format of arithmetic expression states the location of the operator.

Infix: operator is between the operands (L op R)

Postfix: operator is after the operands (L R op)

Prefix: operator is before the operands (op L R)

Examples to Infix, Postfix and Prefix Formats

Infix	Postfix	Prefix
A+B	AB+	+AB
A/(B+C)	ABC+/	/A+BC
A/B+C	AB/C+	+/ABC
A-B*C+D/(E+F)	ABC*-DEF+/+	+-A*BC/D+EF
A*((B+C)/(D-E)+F)-G/(H-I)	ABC+DE-/F+*GHI-/-	-*A+/+BC-DEF/G-HI

Rules to watch during Cross-conversions

<u>Associative Rules</u>

1) + and - associate left to right
2) * and / associate left to right
3) Exponentiation operator (^ or **) associates from right to left.

<u>Priorities and Precedence Rules</u>

1) + and - have the same priority
2) * and / have the same priority
3) (* and /) precede (+ and -)

Algorithm for Infix→Postfix Conversion

1. Initialize an operator stack
2. While not EOArithmeticExpression Do
   i. Get next token
   ii. case <u>token</u> of
      a. ‘(’: Push; //assume the lowest precedence for ‘(’
      b. ‘)’: Pop and place token in the incomplete postfix expression until a left parenthesis is encountered;
         If no left parenthesis return with failure
      a. an operator:
         a. If empty stack or token has a higher precedence than the top stack element, push token and go to 2.i
         b. Else pop and place in the incomplete postfix expression and go to c
      b. an operand: place token in the incomplete postfix expression
1. If EOArithmeticExpression
   i. Pop and place token in the incomplete postfix expression until stack is empty

Evaluation of Arithmetic Expressions

1. Initialize an operand stack
2. While not EOArithmeticExpression Do
    i. Get next token;
    ii. Case token of
        a. an operand: push;
        b. an operator:
            a. if the last token was an operator, return with failure;
            b. pop twice;
            c. evaluate expression;
            d. push result;

Evaluation of Arithmetic Expressions

Example: 9 8 8 6 - / 2*1+- = ?

Token	Stack Content	Operation
9	9	None
8	9 8	None
8	9 8 8	None
6	9 8 8 6	None
-	9 8 2	8-6=2
/	9 4	8/2=4
2	9 4 2	none
*	9 8	4*2=8
1	9 8 1	None
+	9 9	8+1=9
-	0	9-9