Stacks, Queues, Deques

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Stacks

Stack

- object: a container that holds some elements
- action: [constant-time] push (to the top), pop (from the top)

- last-in-first-out (LIFO): 擠電梯， 洗盤子
- very restricted data structure, but important for computers
—will discuss some cases later

A Simple Application: Parentheses Balancing

- in C, the following characters show up in pairs: (), [], {}, ""

```
good: {xxx(xxxxxx)xxxxx"xxxx"x}
bad:  {xxx(xxxxxx}xxxxx"xxxx"x}
```

$\neq$

- the LISP programming language

```
(append (pow (* (+ 3 5) 2) 4) 3)
```

how can we check parentheses balancing?

Stack Solution to Parentheses Balancing

inner-most parentheses pair $\Longrightarrow$ top-most plate

'(': 堆盤子上去 ; ')': 拿盤子下來

Parentheses Balancing Algorithm

```
for each c in the input do
  if c is a left character
    push c to the stack
  else if c is a right character
    pop d from the stack and check if match
  end if
end for
```

many more sophisticated use in compiler design

System Stack

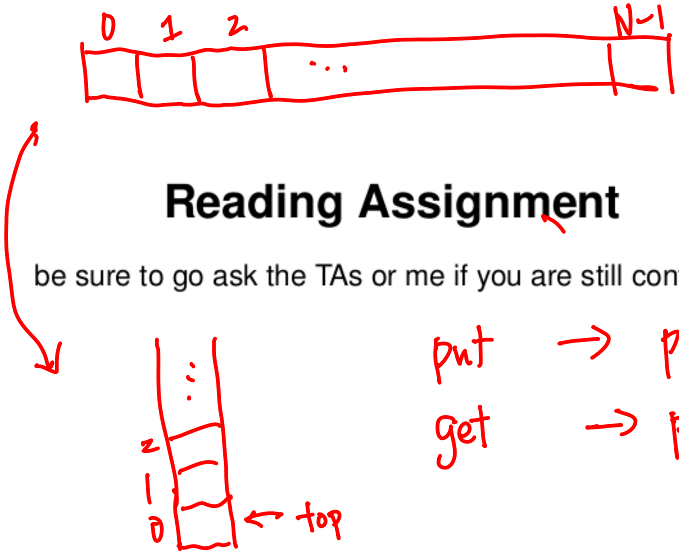
- recall: function call $\Leftrightarrow$ 拿新的草稿紙來算
- old (original) scrap paper: temporarily not used, 可以壓在下面

System Stack: 一疊草稿紙, each paper (stack frame) contains

- return address: where to return to the previous scrap paper
- local variables (including parameters): to be used for calculating within this function
- previous frame pointer: to be used when escaping from this function

some related issues: stack overflow? security attack?

Stacks Implemented on Array (5.1.4)



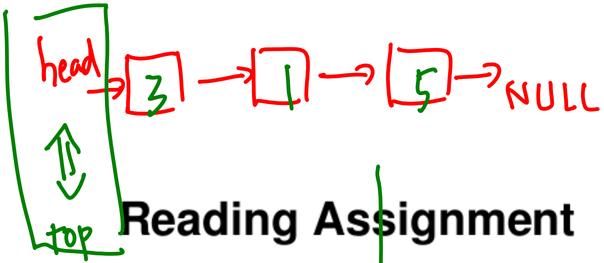
Reading Assignment

be sure to go ask the TAs or me if you are still confused

put $\rightarrow$ push

get $\rightarrow$ pop

Stacks Implemented on Linked List (5.1.5)



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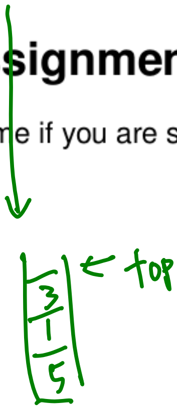

Stack for Expression Evaluation (Supplementary)

infix

$$a/b - c + d * e - a * c$$

- precedence: $\{*, /\}$ first; $\{+, -\}$ later
- steps
  - $f = a/b$
  - $g = f - c$
  - $h = d * e$
  - $i = g + h$
  - $j = a * c$
  - $\ell = i - j$

a b /
f c -
d e *
⋮

Postfix Notation

same operand order, but put "operator" after needed operands
—can "operate" immediately when seeing operator
—no need to look beyond for precedence

Postfix from Infix (Usual) Notation

- infix:

$$3 \;/\; 4 \;-\; 5 \;+\; 6 \;*\; 7 \;-\; 8 \;*\; 9$$

- parenthesize:

$$((((3 \;/\; 4) - 5) + (6 \;*\; 7)) - (8 \;*\; 9))$$

- for every triple in parentheses, switch orders

$$3\;4\;/\;5\;-\quad 6\;7\;*\;+\quad 8\;9\;*\;-$$

- remove parentheses

difficult to parenthesize efficiently

Evaluate Postfix Expressions

$$34/5-67*+89*-$$

- how to evaluate? left-to-right, “operate” when see operator
- 3, 4, / ⇒ 0.75
- 0.75, 5, - ⇒ -4.25
- -4.25, 6, 7, * ⇒ -4.25, 42 (note: -4.25 stored for latter use)
- -4.25, 42, + ⇒ 37.75
- 37.75, 8, 9, * ⇒ 37.75, 72 (note: 37.75 stored for latter use)
- 37.75, 72, - ⇒ ...

stored where?
stack so closest operands will be considered first!

Stack Solution to Postfix Evaluation

Postfix Evaluation

```
for each token in the input do
    if token is a number
        push token to the stack
    else if token is an operator
        sequentially pop operands $a_{t-1}, \cdots, a_0$ from the stack
        push token$(a_0, a_1, a_{t-1})$ to the stack
    end if
end for
return the top of stack
```

matches closely with the definition of postfix notation