CSCI 334:
Principles of Programming Languages

Lecture 11: Control Structures II

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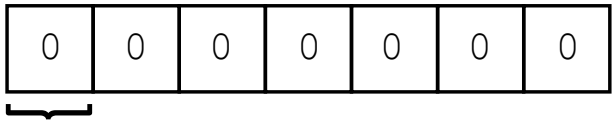
Williams

Computer Architecture
(a really really fast introduction)

Memory

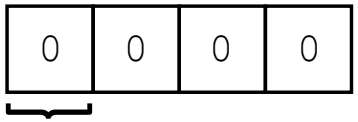
main memory (typically GB worth)



... slow

1 byte

registers (typically 32 to 512 *bytes*)



fast

1 byte

Instructions

`add x y`	add x to y, store in x
`sub x y`	subtract y from x, store in x
`jmp x`	jump to location x
`and x y`	logical and, store in x
`or x y`	logical or, store in x
`not x`	logical not, store in x
`mov x y`	copy memory from y into x
…	…

Sample x86 Assembly Program

```
L1:
.asciz "/bin/sh"
push ebp
mov ebp, esp
sub esp, 8
mov ebx, OFFSET FLAT:L1
mov DWORD PTR [ebp-8], ebx
mov DWORD PTR [ebp-4], 0
mov eax, 11
lea ecx, DWORD PTR [ebp-8]
mov edx, 0
int 0x80
leave
ret
```

BASIC

(Beginner's All-purpose Symbolic Instruction Code)

- Invented in 1964 at Dartmouth College
- Implemented by undergrads!
- An "unstructured" programming language
- Inspired by FORTRAN (and similar in spirit)
- Intentionally simplified in order to appeal to beginners.
- As powerful as any other language (Turing complete).
- Wildly popular

Activity

- Write a Java/Python/pseudocode program that…
- Asks user for their name.
- Greets them with "Hello <name>"
- Asks them how many stars (`'*'`) to print.
- Prints *n* stars
- Asks the user if they want more stars
- If yes, asks them for *m* more prints *n+m*, and asks again.
- Otherwise, quits.

Activity

```
10  INPUT "What is your name: "; U$
20  PRINT "Hello "; U$
30  INPUT "How many stars do you want: "; N
40  S$ = ""
50  FOR I = 1 TO N
60  S$ = S$ + "*"
70  NEXT I
80  PRINT S$
90  INPUT "Do you want more stars? "; A$
100 IF LEN(A$) = 0 THEN GOTO 90
110 A$ = LEFT$(A$, 1)
120 IF A$ <> "Y" AND A$ <> "y" THEN GOTO 160
130 INPUT "How many more stars? "; M
140 N = N + M
150 GOTO 40
160 PRINT "Goodbye "; U$
170 QUIT
```

Structured Programming

- Coined by Edsger Dijkstra
- "GOTO Statement Considered Harmful"
- Argued that GOTO made programming much harder to understand.
- "the quality of programmers is a decreasing function of the density of GOTO statements in the programs they produce."

(aside)

http://www.malevole.com/mv/misc/killerquiz/

Dijkstra's argument

```
10  A = 1
20  B = 2
30  C = 3
40  D = 4
50  QUIT
```

You have to debug this program.
How much information do you need to keep in your head?

Basically just a pointer.

Dijkstra's argument

```
10  A = 1
20  B = 2
30  C = 3
40  D = 4
50  FOR I = 1 TO D
60  E = D
70  NEXT I
80  QUIT
```

Add a loop.

A little harder.

Need to remember a loop counter.
(The rest you can determine by induction.)

Dijkstra's argument

```
10  A = 1
20  B = 2
30  C = 3
40  D = 4
50  FOR I = 1 TO D
60  E = D
70  NEXT I
80  IF N < 10 THEN
90    D = 10
100 ELSE
110   D = 20
140 END IF
150 QUIT
```

Add a conditional.

Don't need to remember anything new.

Dijkstra's argument

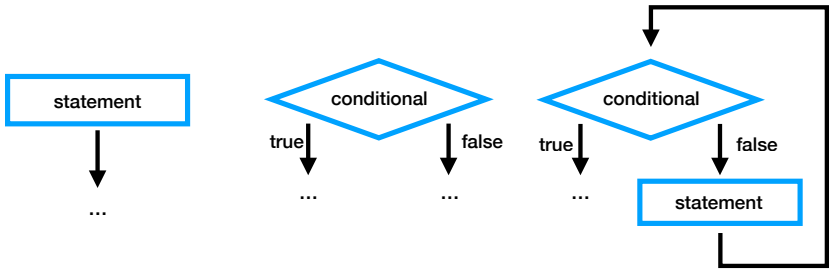
```
10  A = 1
20  B = 2
30  C = 3
40  D = 4
50  FOR I = 1 TO D
60  E = D
70  NEXT I
80  IF N < 10 THEN
90    D = 10
100   GOTO 50
100 ELSE
110   D = 20
140 END IF
150 QUIT
```

Add a GOTO.

Need to remember
all program values that might be updated.

Block Structured Programming

Only 3 building blocks for programs.

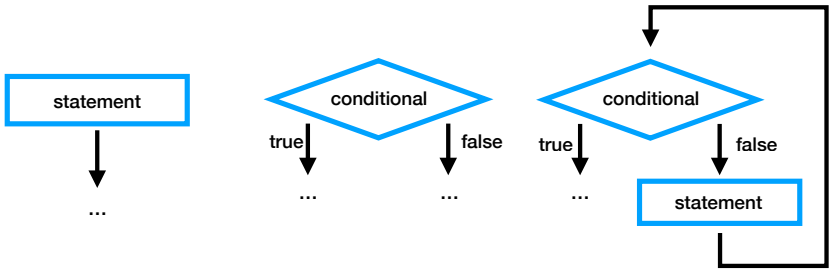


sequence conditional loop

No GOTOs.

Block Structured Programming

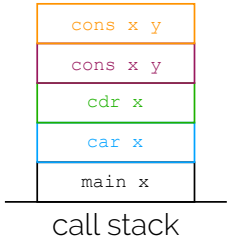
Only 3 building blocks for programs.



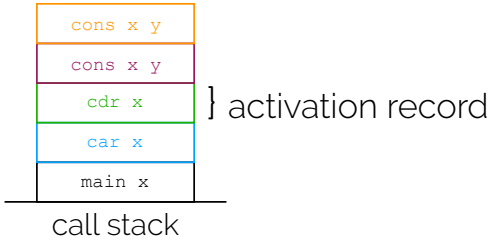
sequence conditional loop

Structured Program Theorem: Blocks are Turing-complete

Structured programs can be evaluated using a call stack

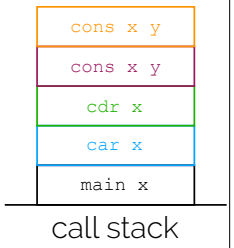


Stacks are made out of *activation records*



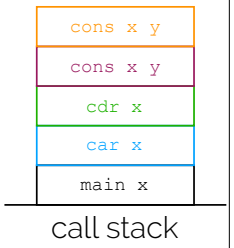
Stacks are used to track…

1. which function is being executed *now*,
2. the parameters to that function,
3. the local variables used in that function,
4. temporary results needed along the way,
5. where to return when done,
6. where to put the result when done,
7. where to find non-local variables (optional)



Those parts are named…

1. which function:	top of the stack
2. parameters:	actual parameters
3. local variables:	local variables
4. temporary results:	temporary storage
5. where to return:	control link
6. where to ret. result:	return result address
7. non-local variables:	access link



Translation for C hackers…

activation record = stack frame

top of the stack = top of the stack

actual parameters = function parameters

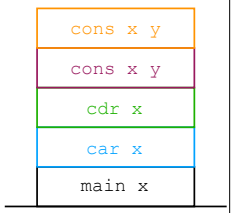
local variables = local variables

temporary storage = local variables

control link = frame pointer

return result address = EAX

access link = does not exist in C!



call stack

What can a function return?

What can a function return?

Stack frame layout

control link
return
return-result
parameters
local vars
intermediates
access link

Activity

```
fun f x y = g x + g y

fun g x = x + 1

f 1 1
```