Computer Programming

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Session: Recursive Functions – Part A

Quick Recap of Relevant Topics

- Use of simple functions in programs
- Contract-centric view of programming with functions
- Flow of control in function call and return
- Activation records and call stack
- Parameter passing by value and reference

So far, the caller and callee were different functions!

Overview of This Lecture

- Recursive functions
  - How they work
  - Activation records and call stack

Recall: Encoding Example

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- We want to store quiz 1 and quiz 2 marks of CS101 students in an encoded form
- Encoding strategy: encode(m, n) = 2^m x 3^n
- Assume all marks are integers in {1, 2, … 10}

Recall: C++ Program Structure

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```
#include <iostream>
using
int m                                    s);
int power                                exponent);
int main() { …
  for ( … ) {  …
   cipher = myEncode(q1Ma                  larks);
  …}
…
}
```

Function call from within a different function

Function call from within a different function

```
// PRECONDITION:  …
int myEncode(int q1Marks,
                    int q2Marks)
{ …
 twoRaisedQ1 = power(2, q1Marks);
 threeRaisedQ2 = power(3, q2Marks);
 … }
// POSTCONDITION:  …
```

```
// PRECONDITION:  …
int power(int base, int exponent)
{ … }
// POSTCONDITION:  …
```

Calling a Function from Itself

Can we have a function call itself?

Can we have two functions mutually call each other?

Why not? What could possibly go wrong?

Recall: Encoding Example

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- We want to store quiz 1 and quiz 2 marks of CS101 students in an encoded form
- Encoding strategy: encode(m, n) = 2^m x 3^n
- Assume all marks are integers in {1, 2, … 10}

Observe: encode(m, n) = encode(m, n-1) x 3, if m, n > 1

= encode(m-1, 1) x 2, if m > 1, n=1

= 2 x 3 = 6, if m=1, n=1

An Alternate Encoding Program

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```
#incl
using
int ne
int main() { …
 for ( … ) {  …
  cipher = newEnc(q1Marks, q2M
 …}
 …
 retur
}
```

Function call from within a different function

Function call from within the same function

```
// PRECONDITION:  …
int newEnc(int q1Marks,
                  int q2Marks)
 switch(q2Marks) {
   case 1:
     if (q1Marks == 1) {return 6;}
     else {return
           2*newEnc(q1Marks – 1, 1);
     }
      break;
   default: … }
}
// POSTCONDITION:  …
```

Recall: Activation Records in Call Stack

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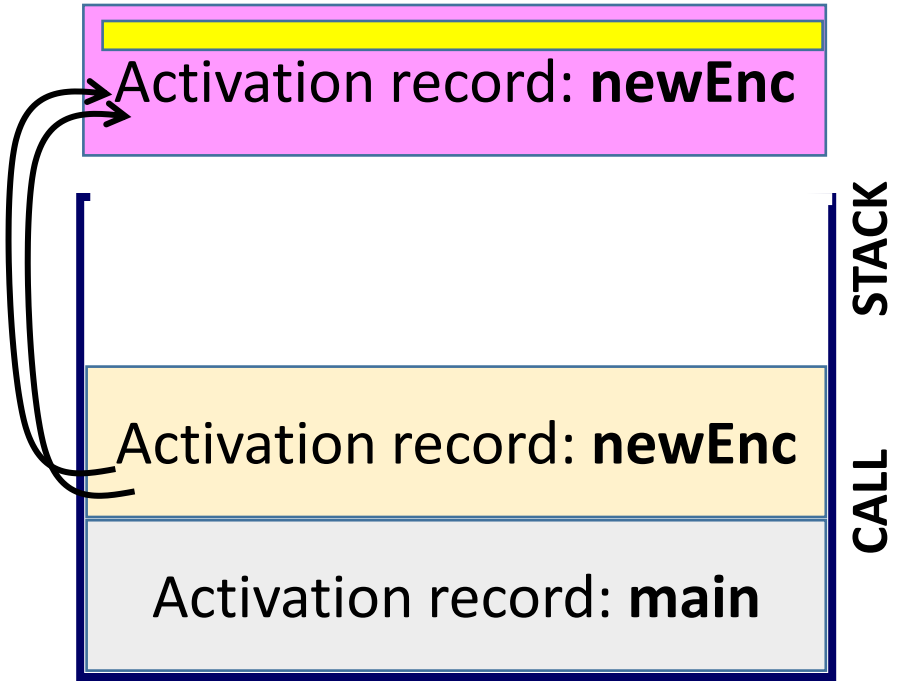
When a caller (newEnc) calls a callee (newEnc)

- a **fresh** activation record for callee created
- Values of function parameters from caller copied to space allocated for formal parameters of callee
- PC of caller saved
- Other book-keeping information updated
- Activation record for callee pushed on call stack

```
int newEnc(int q1Marks, int q2Marks)
{ ….
   return 2*newEnc(q1Marks – 1, 1);
 …}
```



Activation Records in Call Stack

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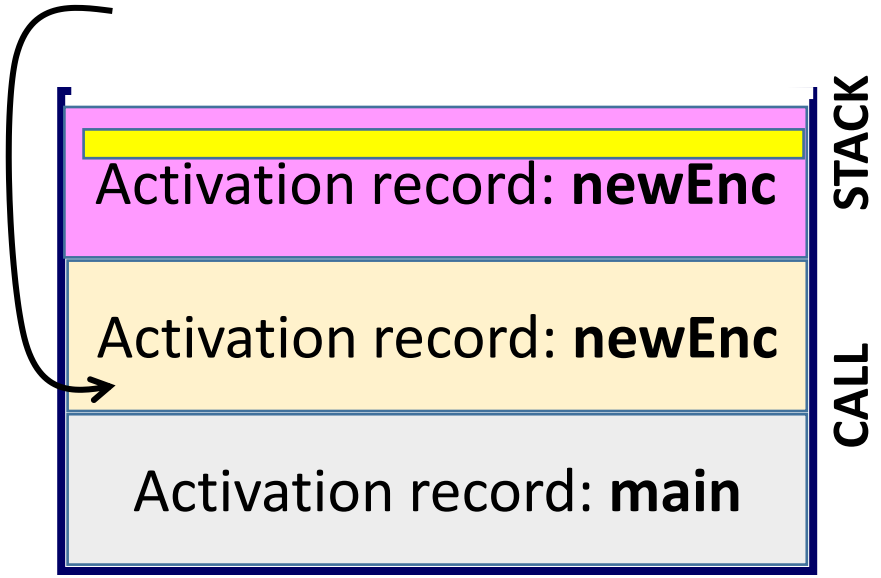
When a callee (newEnc) returns

- Callee's activation record popped from call stack
- Return value from popped activation record copied to activation record of caller (now on top of stack)
- Value of PC saved in popped activation record loaded in PC of CPU
- Free activation record of callee
- Resume execution of instruction at location given by updated PC

```
int newEnc(int q1Marks, int q2Marks)
{ ….
   return 2*newEnc(q1Marks – 1, 1);
 …}
```



Calling a Function From Itself

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- There doesn't seem to be any problem !!!
- Same mechanism of function calls and returns we studied earlier works perfectly !!!

Recursive Function: One that can call itself
Elegant and natural way to solve several problems

Mutually recursive functions
func1 calls func2, which calls func3,
which calls func1

A Recursive Solution: All Is Well So Far!

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```
#include <iostream>
using namespace std;
int newEnc(int q1Marks,int q2Marks);
int main() { …
 for ( … ) {  …
  cipher = newEnc(q1Marks, q2Marks);
 …}
…
return 0;
}
```

```
// PRECONDITION:  …
int newEnc(int q1Marks,
                  int q2Marks)
{ switch(q2Marks) {
   case 1:
     if (q1Marks == 1) {return 6;}
     else {return
            2*newEnc(q1Marks – 1, 1);
      }
      break;
   default: … }
}
// POSTCONDITION:  …
```

Summary

- Recursion as a programming construct
- Activation records and call stack in recursive calls