CS 1704

Introduction to Data Structures and Software Engineering

Recursion

- A process in which the result of each repetition is dependent upon the result of the next repetition

It Works Like Iteration

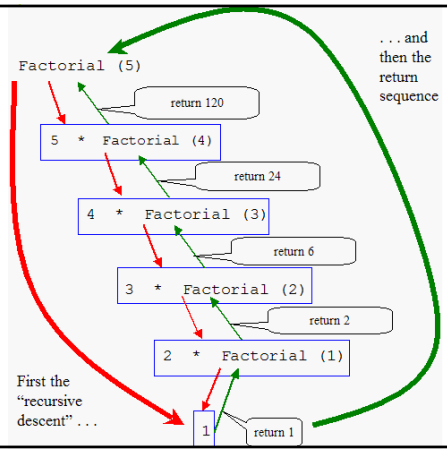
- Consider the following function, which computes
- N! = 1 * 2 * ... * N

```
int Factorial(int n) {
  int Product = 1,
      Scan    = 2;

  while ( Scan <=  n ) {
    Product  =  Product  *  Scan ;
    Scan = Scan + 1 ;
  }
  return (Product) ;
}
```

Recursive Version

```
int Factorial(int n ) {
  if ( n > 1 )
    return( n * Factorial (n-1) );
  else
    return(1);
}
```



Recursion

- Every recursive algorithm can be implemented non-recursively.
  - recursion <==> iteration
- Eventually, the routine must not call itself, allowing the code to "back out".
- Recursive routines that call themselves continuously are termed:
  - infinite recursion <==> infinite loop
- Problem with recursive factorial implementation? Negative numbers!
- Recursion is inefficient at runtime.

Array Summation

```
// X[]      array of integers to be summed
// Start    start summing at this index . . .
// Stop     . . . and stop summing at this index
//
int SumArray(const int X[], int Start, int Stop) {

                              // error check
   if (Start > Stop || Start < 0 || Stop < 0)
      return 0;
   else if (Start == Stop)   // base case
      return X[Stop];
   else                       // recursion
      return (X[Start] + SumArray(X, Start + 1, Stop));
}
```

The call:

```
const int Size = 5;
int X[Size] = {37, 14, 22, 42, 19};
SumArray(X,0,Size- 1);// note Stop is last valid
index
```

```
                                                  // return values:
SumArray(X, 0, 4)                                 // == 134
   return(X[0]+SumArray(X,1,4))                   // == 37 + 97
      return(X[1]+SumArray(X,2,4))                // == 14 + 83
         return(X[2]+SumArray(X,3,4) )            // == 22 + 61
            return(X[3]+SumArray(X,4,4))          // == 42 + 19
               return X[4]                        // == 19
```

Coding Recursion

- Solve the trivial "base" case(s).
- Restate general case in 'simpler' or 'smaller' terms of itself.
  - Divide and Conquer
- List Example
  - Determine the size of a single linked list.
    - Base Case : Empty List, size = 0
    - General Case : 1 + Size(Rest of List)

Linked List Recursion

```
int LinkList::SizeList ()
{
    return(listSize(Head));
}
//private function: listSize
int LinkList::listSize (LinkNode* list)
{
  if (list == NULL)
      return( 0 );
  else
       return( 1 + listSize(list->getNext()) );
}
```

Trace of SizeList

Trace listSize(list)

- listSize(list=(6, 28, 120, 496))
  = (1 + listSize(list=(28, 120, 496)))
  = (1 + (1 + listSize(list=(120, 496))))
  = (1 + (1 + (1 + listSize(list=(496)))))
  = (1 + (1 + (1 + (1 + listSize(list=(•)))))))
  = (1 + (1 + (1 + (1 +0))))
  = (1 + (1 + (1 + 1)))
  = (1 + (1 + 2))
  = (1 + 3) = 4

Types of Recursion

- Tail recursive
  - functions are characterized by the recursive call being the last statement in the function, (can easily be replaced by a loop).
- Head Recursive
  - Recursive call is the first statement (maybe after a base case check)
- Middle Decomposition

```
void intComma ( long  num ) {

   if (num < 0) {// display sign for negatives
      cout << '-';
      num = -num;
   }

   if (num < 1000)
      cout << setw(3) << num;
   else {
      intComma(num / 1000); //Head recursive
      cout << ',';          // display digits
      num = num % 1000;     // separately
      cout << (num / 100); // for zeroes
      num = num % 100;
      cout << (num / 10) << (num % 10);
   }
}
```

Middle Decomposition

```
int rMax(const int ray[], int start, int end ) {

  const int Unknown = -1;
  int mid, h1max, h2max;

  if (end < start) return Unknown;

  mid = (start + end) / 2;
  h1max = rMax(ray, start, mid-1);//left half

  if (h1max == Unknown) h1max = start;
      h2max = rMax(ray, mid+1, end);  //right half
  if (h2max == Unknown) h2max = end;

  if ( (ray[mid] >= ray[h1max]) &&
         (ray[mid] >= ray[h2max]) )
   return mid;
 else
    return( (ray[h1max]>ray[h2max]) ? h1max : h2max);
}
```

rMax Trace

- Give trace of the following array:

ray =

[0]	[1]	[2]	[3]	[4]
56	23	66	44	78

- Give start, end, and return for each call, including the base cases in the order they RETURNED