Crash Course Session 1—Recursion, Iteration, Lists

CS 1102S—Data Structures and Algorithms

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14 January, 2010

Languages vs Implementation

Programming language

Programming languages are the languages in which a programmer writes the instructions that the computer will ultimately execute. *Encyclopedia Britannica*

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Set of tools that help achieving this execution.

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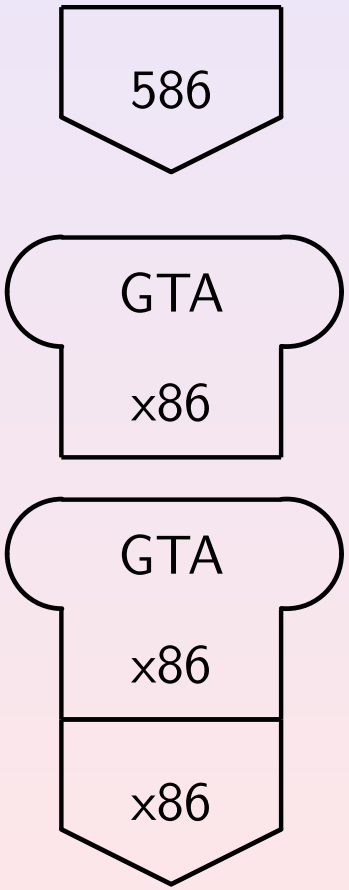
Programming system

Set of tools that help achieving this execution.

Same language, different tools

For the same language, different tools are available for different purposes.

T-Diagrams



x86 Processor

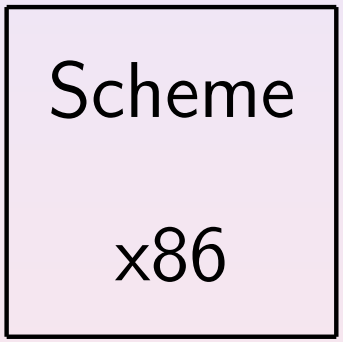
Program “GTA” (x86 code)

“GTA” running on x86

Interpreter

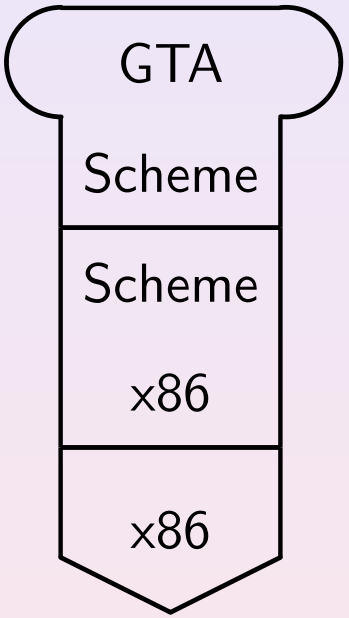
- Interpreter is program that executes another program
- The interpreter's *source language* is the language in which the interpreter is written
- The interpreter's *target language* is the language in which the programs are written which the interpreter can execute

Interpreters



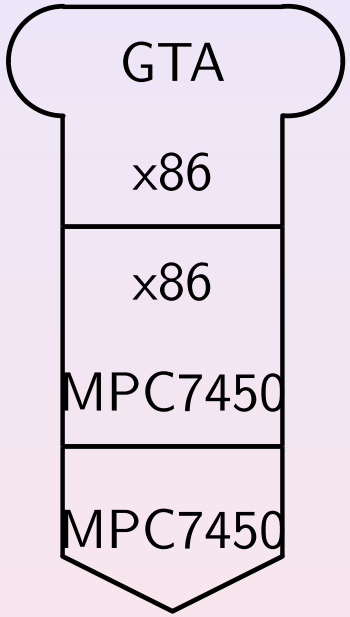
Interpreter for Scheme (x86 machine code)

Interpreting a Program



Scheme program “GTA”
running on x86 using interpretation

Hardware Emulation

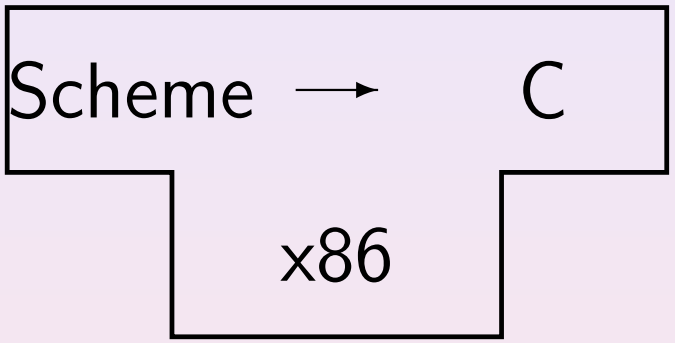


"GTA" x86 executable running on a PowerPC using hardware emulation

Translators

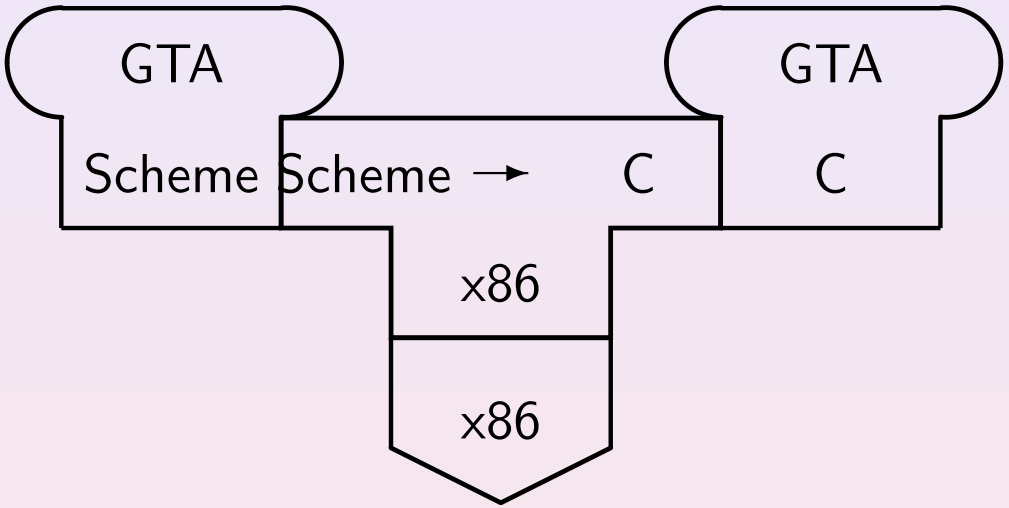
- Translator translates from one language—the *from-language*—to another language—the *to-language*
- Compiler translates from “high-level” language to “low-level” language
- De-compiler translates from “low-level” language to “high-level” language

T-Diagram of Translator



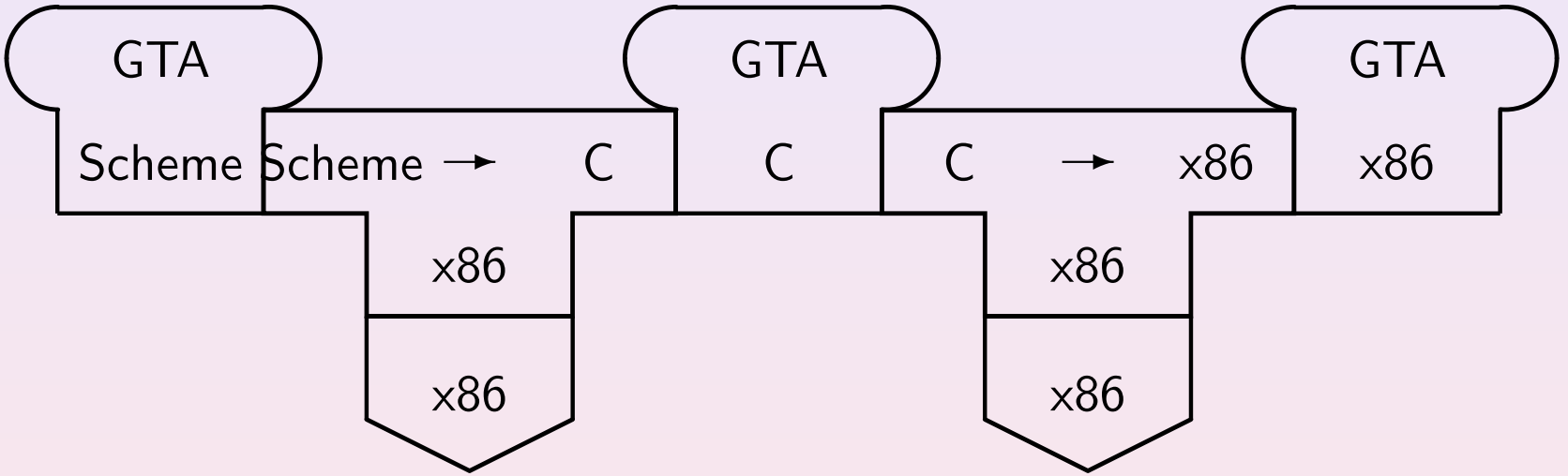
Scheme-to-C compiler written in x86 machine code

Compilation



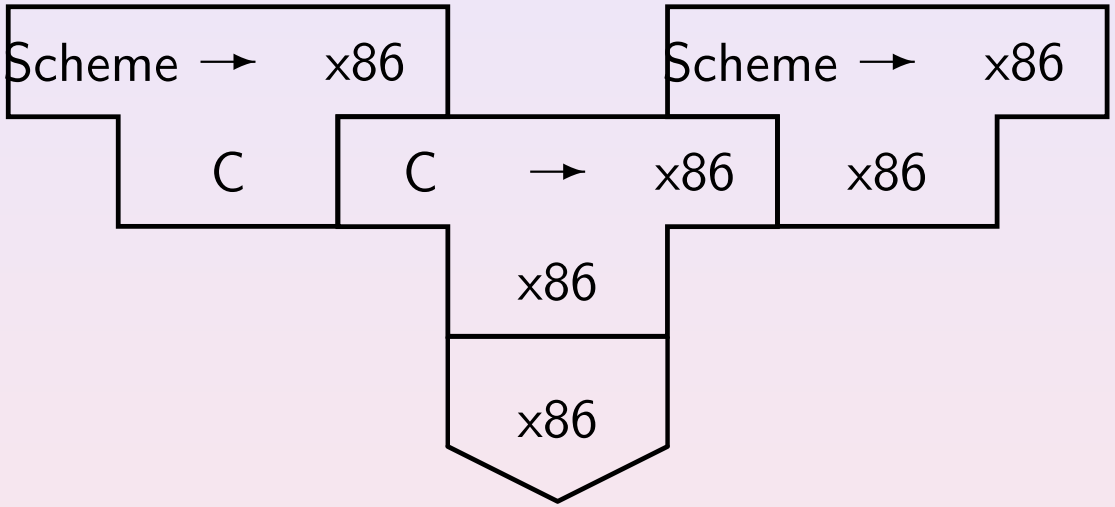
Compiling “GTA” from Scheme to C

Two-stage Compilation



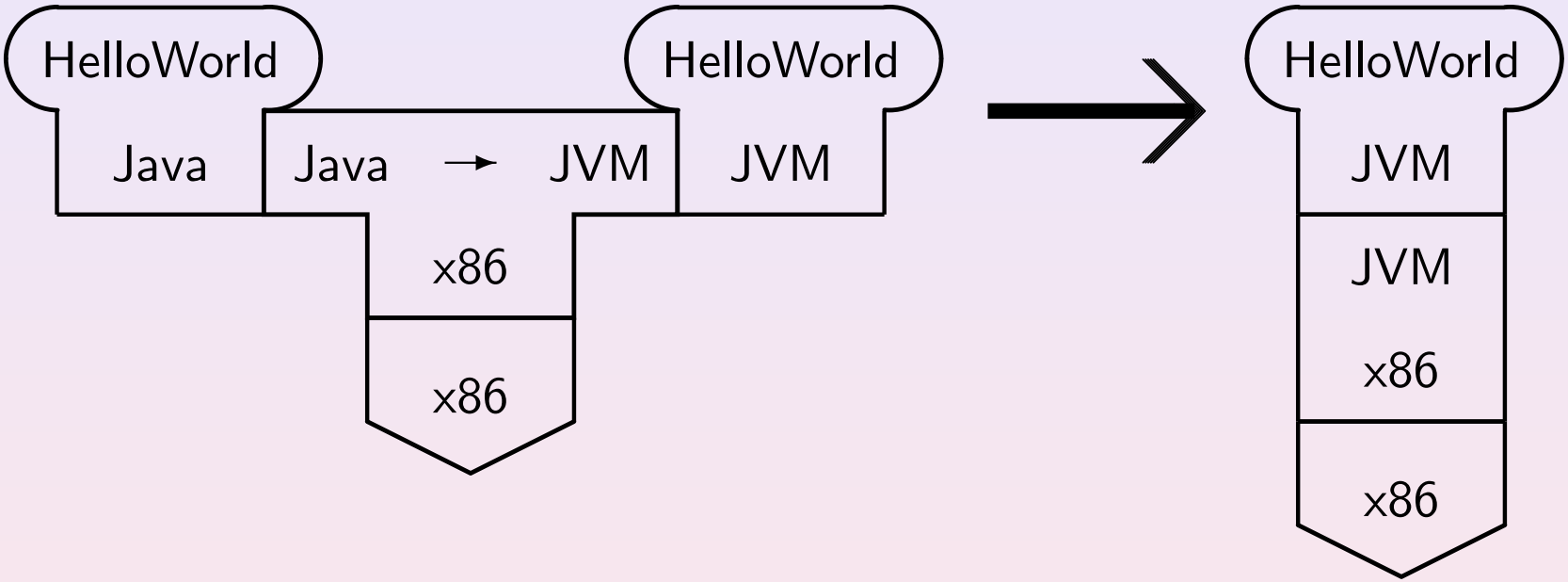
Compiling “GTA” from Scheme to C to x86 machine code

Compiling a Compiler



Compiling a Scheme-to-x86 compiler from C to x86 machine code

Typical Execution of Java Programs



Compiling “HelloWorld” from Java to JVM code, and running the JVM code on a JVM running on an x86

Factorial Function

```
(define (factorial i)
  (if (<= i 0)
    1
    (* i (factorial (- i 1)))))
```

Factorial In Java

```
public static int factorial(int i) {
        if (i <= 1) {
                return 1;
        } else {
            return i * factorial(i - 1);
        }
}
```

Iteration vs Recursion in Scheme

Iteration

A (recursive) Scheme function is *iterative*, if the recursive call is always the last thing to do in its body.

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Is Factorial Iterative?

Iteration vs Recursion in Scheme

Iteration

A (recursive) Scheme function is *iterative*, if the recursive call is always the last thing to do in its body.

Is Factorial Iterative?

No!

```
i * factorial(i - 1);
```

Iterative Factorial Function In Scheme

```
(define (iterfactorial i acc)
  (if (<= i 1)
    acc
    (iterfactorial (- i 1) (* acc i))))

(define (iterativefactorial i)
  (iterfactorial i 1))
```

Iterative Factorial Function In Java?

```
private static int iterFactorialTry(int i,int acc){
  if (i <= 1) {
    return acc;
  } else {
    return iterFactorialTry(i-1,acc*i);
  }
}
public static int iterativeFactorialTry(int i) {
        return iterFactorialTry(i,1);
}
```

The Sad Truth about Java

Java has no iterative recursion!

Every function call requires space on a Java runtime stack.

The Sad Truth about Java

Java has no iterative recursion!

Every function call requires space on a Java runtime stack.

Recursion is always recursive!

A recursive function in Java will never use constant space.

Loops to the rescue!

Loop constucts

Java contains loop constructs such as `while` and `for`.

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Loop constucts

Java contains loop constructs such as `while` and `for`.

Iteration in Java

Iteration can only be achieved using loops in Java.

Iterative Factorial Function In Java

```
public static int iterativeFactorial(int i) {
  int acc = 1;
  while (i > 1) {
    acc = acc * i;
    i = i - 1;
  }
  return acc;
}
```

Lists in Scheme and Java

Lists in Scheme

Built-in, using cons, car, cdr, '() , null?.

Lists in Java

There is a List interface in Java, see
http://java.sun.com/j2se/1.5.0/docs/api/java/util/List.html

Start with List of Integers

Here, we study a restricted form of lists first: IntList .

Lists in Scheme

```
(cons 1 2)                ;; a pair
'()                       ;; an empty list
(cons 7 '())              ;; a list with one integer
(cons 4 (cons 9 '()))     ;; a list with two integers
```

Builtin Operations on Lists in Scheme

```
'()                  ;; an empty list
(cons 1 2)           ;; a pair
(car alist)          ;; first component (head)
(cdr alist)          ;; second component (tail)
(null? alist)        ;; whether list is empty
```

Operations on Lists of Integers in Java

```
public static IntList nil = new IntList()
public static IntList cons(int i, IntList list)
public static int car(IntList list)
public static IntList cdr(IntList list)
public static boolean isNil(IntList list)
public static void print(IntList list)
```

IntList

These functions are available in the library (class) `IntList`.

Some Cheating (for convenience)

```
public static IntList intList(int [] elements)
```

Length in Scheme

```
(define (length xs)
  (if (null? xs)
    0
    (+ 1 (length (cdr xs)))))
```

Length in Java

```
public static int length(IntList aList) {
  if (IntList.isNil(aList)) {
    return 0;
  } else {
    return 1 + length(IntList.cdr(aList));
  }
}
```

Iterative Length in Scheme

```
(define (iterlength alist acc)
  (if (null? alist)
    acc
    (iterlength (cdr alist) (+ acc 1))))

(define (iterativelength alist)
  (iterlength alist 0))
```

Iterative Length in Java?

```
public static int iterLengthTry(IntList aList,
                                 int acc) {
  if (IntList.isNil(aList)) {
    return acc;
  } else {
    return iterLengthTry(IntList.cdr(aList),acc+1);
  }
}
public static int iterativeLengthTry(IntList aLst){
  return iterLengthTry(aLst,0);
}
```

Iterative Length in Java!

```
public static int iterativeLength(IntList aList) {
  int acc = 0;
  while (! IntList.isNil(aList)) {
    aList = IntList.cdr(aList);
    acc++;
  }
  return acc;
}
```

Append in Scheme

```
(define (append alist anotherlist)
  (if (null? alist)
      anotherlist
      (cons (car alist)
            (append (cdr alist) anotherlist))))
```

Append in Java

```
public static IntList append(IntList aList, IntList
  if (IntList.isNil(aList)) {
    return anotherList;
  } else {
    return
      IntList.cons(IntList.car(aList),
                   append(IntList.cdr(aList),
                          anotherList));
  }
}
```

Naive Reverse in Scheme

```
(define (naivereverse alist)
  (if (null? alist)
      '()
      (append (naivereverse (cdr alist))
                            (cons (car alist) '()))))
```

Naive Reverse in Java

```
public static IntList naiveReverse(IntList aList) {
  if (IntList.isNil(aList)) {
     return IntList.nil;
  } else {
    return append(naiveReverse(IntList.cdr(aList)),
                  IntList.cons(IntList.car(aList),
                               IntList.nil));
  }
}
```

Square All in Scheme

```
(define (squareall alist)
  (if (null? alist)
      '()
      (cons (* (car alist) (car alist))
            (squareall (cdr alist)))))
```

Square All in Java

```
public static IntList squareAll(IntList aList) {
  if (IntList.isNil(aList)) {
    return IntList.nil;
  } else {
    return
      IntList.cons(IntList.car(aList)
                   * IntList.car(aList),
                   squareAll(IntList.cdr(aList)));
  }
}
```

Sum in Scheme

```
(define (sum alist)
  (if (null? alist)
    0
    (+ (car alist) (sum (cdr alist)))))
```

Sum in Java

```
public static int sum(IntList aList) {
  if (IntList.isNil(aList)) {
    return 0;
  } else {
    return IntList.car(aList)
           + sum(IntList.cdr(aList));
  }
}
```

Next Session

- More built-in types
- Loops
- Arrays