Imperative Programming
The Case of FORTRAN

ICOM 4036

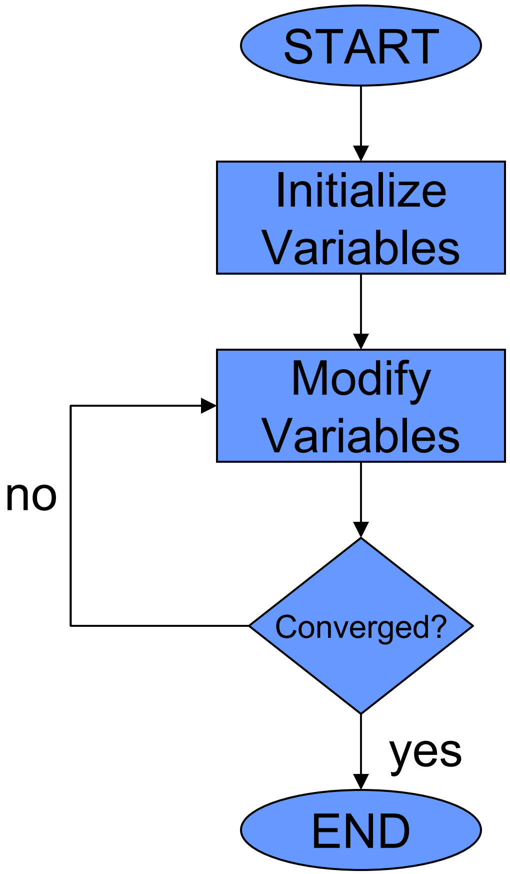
Lecture 4

The Imperative Paradigm

- Computer Model consists of bunch of variables
- A program is a sequence of state modifications or assignment statements that converge to an answer
- PL provides multiple tools for structuring and organizing these steps
  - E.g. Loops, procedures

This is what you have been doing since INGE 3016!

A Generic Imperative Program



Imperative Fibonacci Numbers (C)

```
int fibonacci(int f0, int f1, int n) {
    // Returns the nth element of the Fibonacci sequence
    int fn = f0;
    for (int i=0; i<n; i++) {
        fn = f0 + f1;
        f0 = f1;
        f1 = fn;
    }
    return fn;
}
```

Examples of (Important) Imperative Languages

- FORTRAN (J. Backus IBM late 50's)
- Pascal (N. Wirth 70's)
- C (Kernigham & Ritchie AT&T late 70's)
- C++ (Stroustrup AT&T 80's)
- Java (Sun Microsystems late 90's)
- C# (Microsoft 00's)

FORTRAN Highlights

- For High Level Programming Language ever implemented
- First compiler developed by IBM for the IBM 704 computer
- Project Leader: John Backus
- Technology-driven design
  - Batch processing, punched cards, small memory, simple I/O, GUI’s not invented yet

Some Online References

- Professional Programmer’s Guide to FORTRAN
- Getting Started with G77

Links available on course web site

Structure of a FORTRAN program

```
PROGRAM <name>

    <program_body>

END

SUBROUTINE <name> (args)

    <subroutine_body>

END

FUNCTION <name> (args)

    <function_body>

END
…
```

Lexical/Syntactic Structure

- One statement per line
- First 6 columns reserved
- Identifiers no longer than 6 symbols
- Flow control uses numeric labels
- Unstructured programs possible

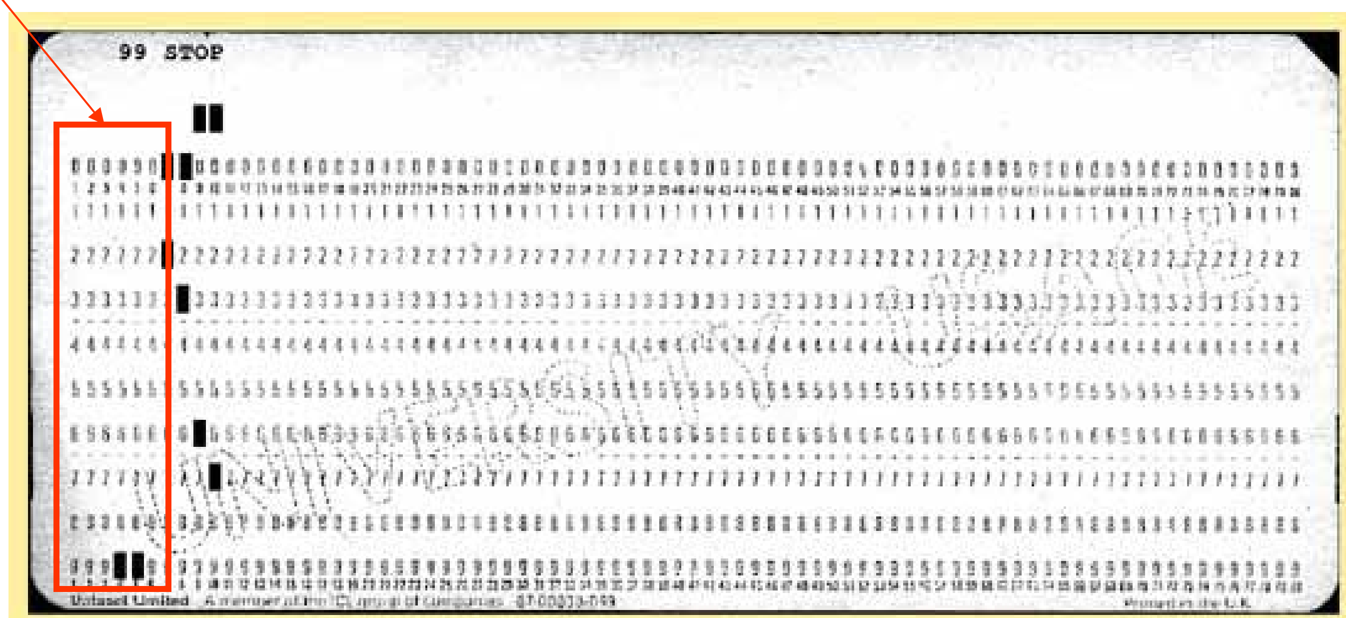
Hello World in Fortran

```
      PROGRAM TINY
            WRITE(UNIT=*, FMT=*) 'Hello, world'
      END
```

One Statement Per line

First 6 columns Reserved

Designed with the Punched Card in Mind



FORTRAN By Example 2

```
      PROGRAM LOAN
        WRITE(UNIT=*, FMT=*)'Enter amount, % rate, years'
        READ(UNIT=*, FMT=*) AMOUNT, PCRATE, NYEARS
        RATE = PCRATE / 100.0
        REPAY = RATE * AMOUNT / (1.0 - (1.0+RATE)**(-NYEARS))
        WRITE(UNIT=*, FMT=*)'Annual repayments are ', REPAY
      END
```

Implicitly Defined Variables
Type determined by initial letter
I-M ~ INTEGER
A-H, O-Z FLOAT

FORTRAN By Example 2

```
PROGRAM LOAN
  WRITE(UNIT=*, FMT=*)'Enter amount, % rate, years'
  READ(UNIT=*, FMT=*) AMOUNT, PCRATE, NYEARS
  RATE = PCRATE / 100.0
  REPAY = RATE * AMOUNT / (1.0 - (1.0+RATE)**(-NYEARS))
  WRITE(UNIT=*, FMT=*)'Annual repayments are ', REPAY
END
```

FORTRAN's Version
of
Standard Output Device

FORTRAN By Example 2

```
      PROGRAM LOAN
        WRITE(UNIT=*, FMT=*)'Enter amount, % rate, years'
        READ(UNIT=*, FMT=*) AMOUNT, PCRATE, NYEARS
        RATE = PCRATE / 100.0
        REPAY = RATE * AMOUNT / (1.0 - (1.0+RATE)**(-NYEARS))
        WRITE(UNIT=*, FMT=*)'Annual repayments are ', REPAY
      END
```

FORTRAN's Version
of
Default Format

FORTRAN By Example 3

```
      PROGRAM REDUCE
      WRITE(UNIT=*, FMT=*)'Enter amount, % rate, years'
      READ(UNIT=*, FMT=*) AMOUNT, PCRATE, NYEARS
      RATE = PCRATE / 100.0
      REPAY = RATE * AMOUNT / (1.0 - (1.0+RATE)**(-NYEARS))
      WRITE(UNIT=*, FMT=*)'Annual repayments are ', REPAY
      WRITE(UNIT=*, FMT=*)'End of Year Balance'
      DO 15,IYEAR = 1,NYEARS,1
          AMOUNT = AMOUNT + (AMOUNT * RATE) - REPAY
          WRITE(UNIT=*, FMT=*)IYEAR, AMOUNT
   15 CONTINUE
      END
```

A loop consists of two separate statements
-> Easy to construct **unstructured** programs

FORTRAN Do Loops

```
      PROGRAM REDUCE
      WRITE(UNIT=*, FMT=*)'Enter amount, % rate, years'
      READ(UNIT=*, FMT=*) AMOUNT, PCRATE, NYEARS
      RATE = PCRATE / 100.0
      REPAY = RATE * AMOUNT / (1.0 - (1.0+RATE)**(-NYEARS))
      WRITE(UNIT=*, FMT=*)'Annual repayments are ', REPAY
      WRITE(UNIT=*, FMT=*)'End of Year Balance'
      DO 15,IYEAR = 1,NYEARS,1
          AMOUNT = AMOUNT + (AMOUNT * RATE) - REPAY
          WRITE(UNIT=*, FMT=*)IYEAR, AMOUNT
   15 CONTINUE
      END
```

```
Enter amount, % rate, years
2000, 9.5, 5
Annual repayments are 520.8728
End of Year Balance
       1 1669.127
       2 1306.822
       3 910.0968
       4 475.6832
       5 2.9800416E-04
```

A loop consists of two separate statements
-> Easy to construct unstructured programs

FORTRAN Do Loops

```
      PROGRAM REDUCE
      WRITE(UNIT=*, FMT=*)'Enter amount, % rate, years'
      READ(UNIT=*, FMT=*) AMOUNT, PCRATE, NYEARS
      RATE = PCRATE / 100.0
      REPAY = RATE * AMOUNT / (1.0 - (1.0+RATE)**(-NYEARS))
      WRITE(UNIT=*, FMT=*)'Annual repayments are ', REPAY
      WRITE(UNIT=*, FMT=*)'End of Year Balance'
      DO 15,IYEAR = 1,NYEARS,1
          AMOUNT = AMOUNT + (AMOUNT * RATE) - REPAY
          WRITE(UNIT=*, FMT=*)IYEAR, AMOUNT
   15 CONTINUE
      END
```

```
Enter amount, % rate, years
2000, 9.5, 5
Annual repayments are 520.8728
End of Year Balance
       1 1669.127
       2 1306.822
       3 910.0968
       4 475.6832
       5 2.9800416E-04
```

- optional increment (can be negative)
- final value of index variable
- index variable and initial value
- end label

FORTRAN Functions I

```
      PROGRAM TRIANG
        WRITE(UNIT=*,FMT=*)'Enter lengths of three sides:'
        READ(UNIT=*,FMT=*) SIDEA, SIDEB, SIDEC
        WRITE(UNIT=*,FMT=*)'Area is ', AREA3(SIDEA,SIDEB,SIDEC)
      END

      FUNCTION AREA3(A, B, C)
*     Computes the area of a triangle from lengths of sides
        S = (A + B + C)/2.0
        AREA3 = SQRT(S * (S-A) * (S-B) * (S-C))
      END
```

- No recursion
- Parameters passed by reference only
- Arrays allowed as parameters
- No nested procedure definitions – Only two scopes
- Procedural arguments allowed
- No procedural return values

Think: why do you think FORTRAN designers made each of these choices?

FORTRAN IF-THEN-ELSE

```
      REAL FUNCTION AREA3(A, B, C)
*       Computes the area of a triangle from lengths of its sides.
*       If arguments are invalid issues error message and returns
*       zero.
        REAL A, B, C
        S = (A + B + C)/2.0
        FACTOR = S * (S-A) * (S-B) * (S-C)
        IF(FACTOR .LE. 0.0) THEN
          STOP 'Impossible triangle'
        ELSE
          AREA3 = SQRT(FACTOR)
        END IF
      END
```

NO RECURSION ALLOWED IN FORTRAN77 !!!

FORTRAN ARRAYS

```
      SUBROUTINE MEANSD(X, NPTS, AVG, SD)
        INTEGER NPTS
        REAL X(NPTS), AVG, SD
        SUM = 0.0
        SUMSQ = 0.0
        DO 15, I = 1,NPTS
          SUM = SUM + X(I)
          SUMSQ = SUMSQ + X(I)**2
15      CONTINUE
        AVG = SUM / NPTS
        SD = SQRT(SUMSQ - NPTS * AVG)/(NPTS-1)
      END
```

Subroutines are analogous to void functions in C

Parameters are passed by <u>reference</u>

```
 subroutine checksum(buffer,length,sum32)

C      Calculate a 32-bit 1's complement checksum of the input buffer, adding
C      it to the value of sum32.  This algorithm assumes that the buffer
C      length is a multiple of 4 bytes.

C      a double precision value (which has at least 48 bits of precision)
C      is used to accumulate the checksum because standard Fortran does not
C      support an unsigned integer datatype.

C      buffer  - integer buffer to be summed
C      length  - number of bytes in the buffer (must be multiple of 4)
C      sum32   - double precision checksum value (The calculated checksum
C               is added to the input value of sum32 to produce the
C               output value of sum32)

       integer buffer(*),length,i,hibits
       double precision sum32,word32
       parameter (word32=4.294967296D+09)
C               (word32 is equal to 2**32)

C      LENGTH must be less than 2**15, otherwise precision may be lost
C      in the sum
       if (length .gt. 32768)then
          print *, 'Error: size of block to sum is too large'
          return
       end if

       do i=1,length/4
          if (buffer(i) .ge. 0)then
             sum32=sum32+buffer(i)
          else
C              sign bit is set, so add the equivalent unsigned value
             sum32=sum32+(word32+buffer(i))
          end if
       end do

C      fold any overflow bits beyond 32 back into the word
10      hibits=sum32/word32
       if (hibits .gt. 0)then
          sum32=sum32-(hibits*word32)+hibits
          go to 10
       end if

       end
```

- WhiteBoard Exercises