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Transforming Assembly to WSL, a high-level language

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Introduction

- Old software can be very problematic for maintenance
  - Obsolete (or no) documentation
  - Source code not available
  - Old technologies
  - Incompatible hardware, etc.
- Out aim is to make old, low level, assembly code easier to understand, and hopefully restructure it.

Software Aging

- Software does not degrade with time on its own, the environment changes
- Two main types of aging (Parnas)
  - Lack of Movement
  - Ignorant surgery

Software Evolution

- Software Evolution is the dynamic behavior of programming systems as they are maintained and enhanced over their life times.

- The life cycle of software
- Reengineering has 3 phases:
  - Reverse engineering
  - Functional restructuring
  - Forward engineering
- Software Evolution is (largely) repeated reengineering.

WSL – Wide Spectrum Language

- Developed by Martin Ward (since 1989)
- Strong mathematical core
- Formal transformations
- Wide spectrum: from abstract specifications to low level program code
- MetaWSL – operations on WSL code
- Successfully used in migrating legacy assembly code to maintainable C/COBOL code
- Implemented as *Fermat program transformation system*

Our transformation process

- Two steps:
  - Asm2wsl – translate the assembly code to WSL
  - Trans.wsl – Automated transformations
- Possible manual transformations
- Main goal is to get a high level version of the original program.

ASM2WSL

- Translates a subset of x86 assembly to WSL
  - Mostly presumes 80286 for simplicity
- Implemented in Java
- Basically a line by line translator
- Focus is on translating all aspects, not optimization (at this stage)
- We work with a “virtual” processor

The “Processor”

- All processor registers are local variables
    - Low and High parts of registers implemented with additional operations
- Flags are variables too
- Overflow variable, needed for 8/16 bits
- Labels – Action system names
- Stack – a list
- Some special macros are recognized and translated directly
- Procedures – nested Action systems (problems)

Asm2wsl usage

```
Assembler to WSL converter. v 0.78, 2010, by Donny
usage:
        asm2wsl {-option[ +-]} filename
options: (def value in parenthesis)
        -oc : original code in comments (-)
        -c : translate comments (+)
        -dump : add memory dump commands to end (+)
```

Command translation

mov ax, dx	ax := dx
xchg ax, dx	< ax := dx , dx := ax >

add dx, ax

```
overflow := 65536;
dx := dx + ax ;
IF dx >= overflow THEN
        dx := dx MOD overflow ;
        flag_o :=1; flag_c := 1;
ELSE
        flag_o :=0; flag_c := 0;
FI ;
```

Command translation (contd.)

mov ah, n

```
t_e_m_p := n ;
ax := ( ax MOD 256) + t_e_m_p * 256;
```

add al, 12

```
overflow := 256;
t_e_m_p := ( ax MOD 255) + 12;
IF t_e_m_p >= overflow THEN
        t_e_m_p := t_e_m_p MOD overflow ;
        flag_o :=1; flag_c := 1;
ELSE
        flag_o :=0; flag_c := 0; FI ;
ax := ( ax DIV 256) *256 + t_e_m_p ;
```

Special macro translation

Possible solution for handling input and output:

print_str x print_num x	PRINT(x);
read_str x read_num x	x := @Read Line(Standard Input Port);

Transformation

- Collapse Action Systems
- Transform DO … OD loops
- Constant propagation
- Remove Redundant

Examples of translated programs

- GCD – greatest common divisor
- Array Sum – simple addition
- Factorial – artificial example, made to test the many features of the translator (arrays, stack, etc)

GCD - assembly

```
model small
.code
        mov         ax,12
        mov         bx,8
compare:
        cmp         ax,bx
        je   theend
        ja   greater
        sub  bx,ax
        jmp  compare
greater:
        sub  ax,bx
        jmp  compare
theend:
        nop
end
```

GCD - translated

```
VAR < flag_z := 0, flag_c := 0 >:
ACTIONS A_S_start:
A_S_start ==
  Ax := 12;
  Bx := 8;
  CALL compare
END
compare ==
  IF ax = bx THEN flag_z := 1 ELSE flag_z := 0 FI;
  IF ax < bx THEN flag_c := 1 ELSE flag_c := 0 FI;
  IF flag_z = 1 THEN CALL theend FI;
  IF flag_z = 0 AND flag_c = 0 THEN CALL greater FI;
  IF bx = ax THEN flag_z := 1 ELSE flag_z := 0 FI;
  IF bx < ax THEN flag_c := 1 ELSE flag_c := 0 FI;
  bx := bx - ax;
  CALL compare;
  CALL greater
END
greater ==
  IF ax = bx THEN flag_z := 1 ELSE flag_z := 0 FI;
  IF ax < bx THEN flag_c := 1 ELSE flag_c := 0 FI;
  ax := ax - bx;
  CALL compare;
  CALL theend
END
theend == CALL Z
END
ENDACTIONS
ENDVAR
```

GCD - remove flags

```
ACTIONS A_S_start:
 A_S_start == ax := 12; bx := 8; CALL compare END
 compare ==
  IF ax = bx
   THEN IF ax < bx THEN CALL theend ELSE
        CALL theend FI
   ELSE IF ax >= bx THEN CALL greater FI FI;
  bx := bx - ax;
  CALL compare;
  CALL greater END
 greater ==
  ax := ax - bx; CALL compare; CALL theend END
 theend == CALL Z END ENDACTIONS
```

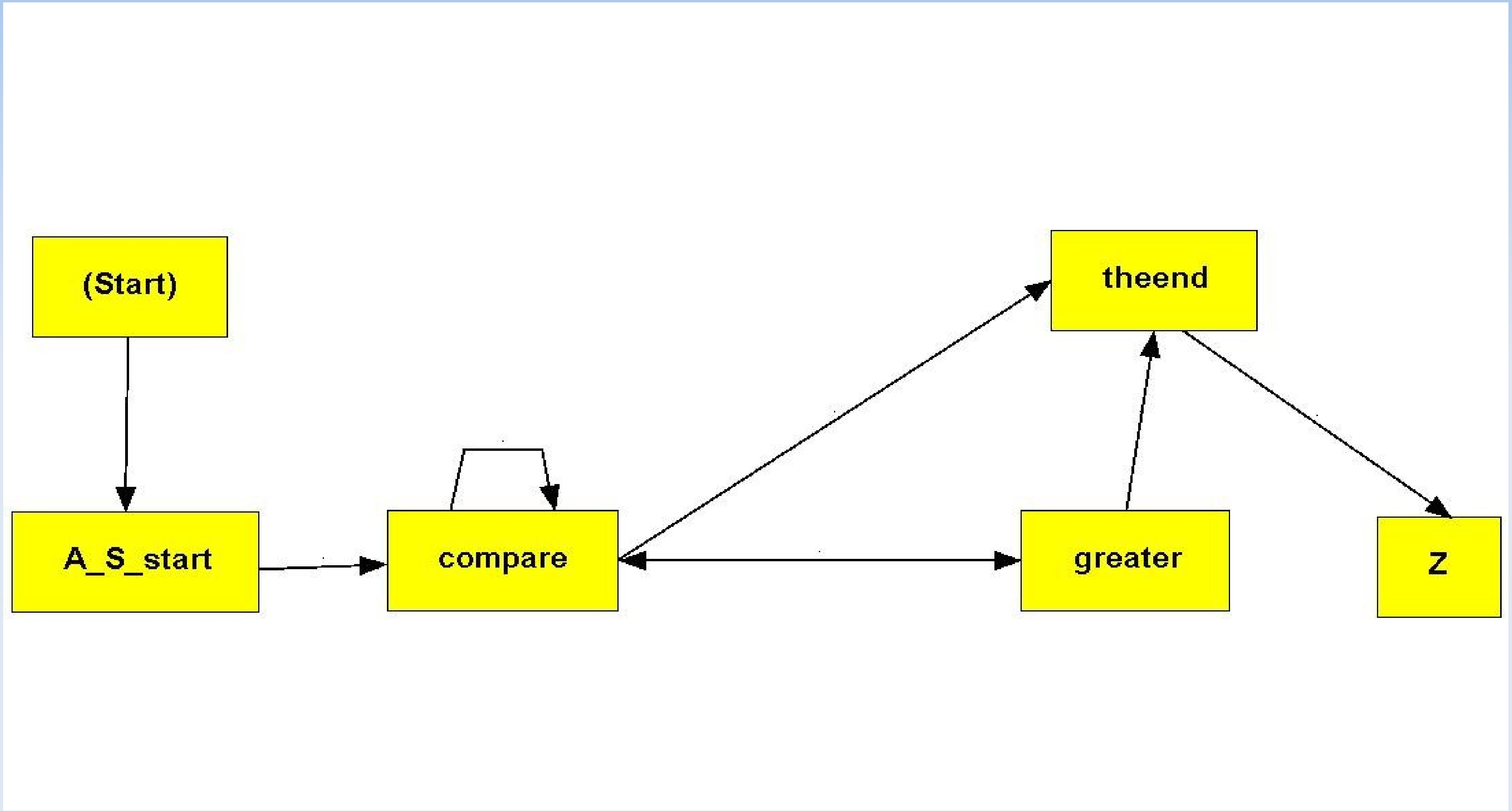
GCD – collapse action system

```
ax := 12;
bx := 8;
DO IF ax = bx
    THEN IF ax < bx THEN EXIT(1) ELSE EXIT(1) FI
    ELSE IF ax >= bx THEN ax := ax - bx ELSE
        bx := bx - ax FI
  FI OD
```

GCD – Floop to While

```
ax := 12;
bx := 8;
WHILE ax <> bx DO
  IF ax >= bx THEN ax := ax - bx ELSE bx := bx - ax FI
OD
```

GCD - diagram



- Generated with FME (Fermat Maintenance Environment)

Array Sum - assembly

```
.data
array     db  1,2,3,4,5,6,7,0
n  dw  7

.code
        mov dx, @data
        mov ds, dx
        mov bx, 0
        mov ax, 0
        mov dx, 0
mainloop:
        mov al, array[bx] ; read array member
        cmp bx,n          ; is it the n-th?
        je progend        ; if yes, go to end
        add dx, ax        ; the sum is in dx
        inc bx
        jmp mainloop
progend:
        nop
        end
```

Array Sum – Semantic slice

```
fl_flag1 := 0;
WHILE fl_flag1 = 0 DO
  IF bx = 7
    THEN fl_flag1 := 1
  ELSIF array[bx + 1] + dx >= 65536
    THEN dx := (array[bx + 1] + dx) MOD 65536;
         < bx := bx + 1, fl_flag1 := 0 >
    ELSE dx := array[bx + 1] + dx;
         < bx := bx + 1, fl_flag1 := 0 > FI OD
```

Transformation results

	GCD			Array Sum			Factorial		
Metric	Before	After	%	Before	After	%	Before	After	%
McCabe	10	11	+10	6	7	+16	12	15	+25
Statements	52	41	-22	55	42	-24	99	77	-23
CFDF	82	48	-42	80	44	-45	128	82	-36
Nodes	302	218	-28	300	213	-29	504	395	-22
Structure	450	291	-36	483	337	-31	787	548	-31

Conclusion

- Interesting first results
  - Automated transformations show more than 30% improvement of code (weighted *Structure* metric)
- A lot of space for improvements
  - More options in the assembler translation system
  - More automatic transformations
  - Overall more examples

Thank you for your attention.

Questions?