Understanding old assembly code using formal transformations

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Presentation organisation

1. Introduction
   - Software Evolution
   - WSL – Wide Spectrum Language
2. Our transformation process
   - Asm2wsl
   - Transf.wsl
3. Examples
   - Programs
4. Summary
   - Results and open questions

Presentation organisation

Introduction – Software Ageing

- Old software can be very problematic for maintenance:
  - Obsolete (or no) documentation
  - Source code not available
  - Old technologies
  - Incompatible hardware, etc.
- 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.
- Software Evolution is (largely) repeated reengineering.

- Out aim is to make old, low level, assembly code easier to understand, and hopefully restructure it.

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

Presentation organisation

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 application

- 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

Program parameters of Asm2wsl

```
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

Assembly	WSL
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 (cont.)

Assembly	WSL
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;

Translation of special macro names

Assembly	WSL
print_str x print_num x	PRINT(x);
read_str x read_num x	x := @Read_Line(Standard_Input_Port);

Automatic transformations – transf.wsl

- A small script to call the existing transformations
- Main transformations:
  - Collapse Action Systems
  - Transform DO . . . OD loops
  - Constant propagation
  - Remove Redundant
  - Flag removal

Presentation organisation

Examples

GCD – greatest common divisor

SumN – A simple program with a call to a procedure that sums the top of the stack

Assembly version of the GCD program

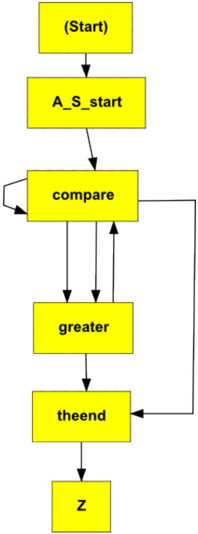
```
model small
.code
            mov ax,12
            mov bx,8
compare:
            cmp ax,bx
            je theend
            ja greater
            sub bx,ax
            jmp compare
greater:
            sub ax,bx
            jmp compare
theend:
            nop
end
```

GCD – translated to an *Action system*

```
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
```

GCD program – diagram

```
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 – *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
```

Assembly version of the SumN procedure

```
sumn proc
;if n is on top of the stack
;sum the next n top elements of the stack
        pop cx
        mov bx, 0
        mov ax, 0
        mov dx, 0
theloop:
        pop ax              ; get next from stack
        cmp bx,cx            ; is it the final one?
        je endp              ; skip to end if ti is
        add dx, ax           ; array sum is in dx
        inc bx
        jmp theloop
endp:
        push dx              ;result
    ret
sumn endp
```

SumN – translated to an *Action system*

```
ACTIONS A_S_start:
A_S_start ==
stack := < num1 > ++ stack;
stack := < num2 > ++ stack;
stack := < num3 > ++ stack;
stack := < n > ++ stack;
CALL sumn;
rez := HEAD(stack);
stack := TAIL(stack);
PRINT(rez);
CALL end1
 END
end1 ==
SKIP;
CALL Z; SKIP END
sumn ==
ACTIONS dummysys: dummysys
    ==
cx := HEAD(stack);
stack := TAIL(stack);
bx := 0;
ax := 0;
dx := 0;
CALL theloop
 END
theloop ==
ax := HEAD(stack);
stack := TAIL(stack);
IF bx = cx THEN
 flag_z := 1
 ELSE
 flag_z := 0
 FI;
...............
 bx := bx + 1;
CALL theloop;
CALL endp
 END
endp ==
stack := < dx > ++ stack;
 CALL Z;
 SKIP END
 ENDACTIONS
 END
ENDACTIONS;
```

Sumn – transformed program

```
VAR < ax := 0, bx := 0, cx := 0, dx := 0, stack := < > >:
VAR < rez := 0 >:
stack := <12> ++ stack;
stack := <8> ++ stack;
stack := <22> ++ stack;
stack := <3> ++ stack;

cx := HEAD(stack);
stack := TAIL(stack);
ax := HEAD(stack);
stack := TAIL(stack);
WHILE bx <> cx DO
  dx := ax + dx;
  IF dx >= 65536 THEN dx := dx MOD 65536 FI;
  bx := bx + 1;
  ax := HEAD(stack);
  stack := TAIL(stack) OD;
stack := <dx> ++ stack ENDVAR ENDVAR
```

num1, num2, num3, n were constants in the original program and are replaced adequately

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Summary

- Translating assembly programs to WSL gives us options to:
  - Generate call diagrams for easier understanding of original code;
  - Automatically transform the code to much simpler versions;
  - Optionally to manualy tweak the results with more transformations
- Automated transformations show more than 30% improvement of code in weighted Structure metric. Improvements are noted in other metrics as well.
- A lot of space for improvements
  - More options in the assembler translation system
  - More automatic transformations
  - Expanding existing transformations for specific examples

Thank you for your attention

Questions?