

On verifying AhirV2 generated VHDL using software testbenches

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The AhirV2 tool chain can be used to convert parts of a C program to VHDL (essentially, some of the functions in a program are mapped to VHDL). To verify the resulting VHDL, one would like to simulate it in a VHDL simulator (such as Modelsim from Mentor Graphics). The most natural way to do this is to use the original program itself as a testbench for this purpose.

- Stubs are created for the set of functions which are mapped to VHDL by the AhirV2 flow.
- The software testbench is compiled and linked with these stubs.
- Whenever a stub function is called, it tries to connect with a server created by the VHDL simulation process.
- The VHDL simulation process listens for calls from the stubs and exchanges data between the stubs and the actual VHDL being simulated.

1 An example

Consider the following program (lets say it is in file “prog.c”):

```
#include <stdlib.h>
#include <stdint.h>
#include <stdio.h>
#include <iolib.h>

uint32_t sum;

void set_sum(uint32_t x)
{
    sum = x;
```

```

}

uint32_t get_sum()
{
    return(sum);
}

void accumulate()
{
    while(1)
    {
        int nxt = read_uint32("in_data");
#ifdef SW
        printf("read %u\n", nxt);
#endif
        sum = (sum + nxt);
        write_uint32("out_data",sum);
#ifdef SW
        printf("wrote %u\n", sum);
#endif
    }
}

```

This program describes a *system* which listens for data on a pipe “in_data”, and sends data out on a pipe “out_data”. The incoming data is accumulated into the variable *sum*, and there are two methods to set and get the value of *sum*.

Now to test this program, we can write a test-bench such as this one (lets call this file “testbench.c”).

```

#include <pthread.h>
#include <signal.h>
#include <stdio.h>
#include <stdlib.h>

#ifdef SW
// for the read_*/write_* methods
#include <iolib.h>
#include "prog.h"
#else
// includes for the read_*/write_* methods
// as well as stubs for functions moved
// to hardware.
#include "vhdlCStubs.h"
#endif

```

```

void Exit(int sig)
{
    fprintf(stderr, "## Break! ##\n");
    exit(0);
}

void *accumulate_(void* fargs)
{
    accumulate();
}

void *write_pipe_(void* a)
{
    write_uint32_n("in_data", (uint32_t*)a, 10);
}

void *read_pipe_(void* a)
{
    read_uint32_n("out_data", (uint32_t*)a, 10);
}

int main(int argc, char* argv[])
{
    signal(SIGINT, Exit);
    signal(SIGTERM, Exit);

    uint32_t data_in[10], data_out[10];
    int i;

    // initial value of sum.
    set_sum(1);

    for(i = 0; i < 10; i++)
    {
        data_in[i] = i;
    }

    pthread_t acc_t, wpipe_t, rpipe_t;

#ifdef SW
    pthread_create(&acc_t, NULL, &accumulate_, NULL);
#endif
    pthread_create(&wpipe_t, NULL, &write_pipe_, (void*)data_in);
    pthread_create(&rpipe_t, NULL, &read_pipe_, (void*)data_out);

    pthread_join(wpipe_t, NULL);

```

```

pthread_join(rpipe_t, NULL);

fprintf(stdout, "from out_data, we read ");
for(i=0; i < 10; i++)
    fprintf(stdout, " %u ", data_out[i]);
fprintf(stdout, "\n");
fprintf(stdout, "final sum is %u\n", get_sum());

#ifdef SW
    pthread_cancel(acc_t);
#endif
}

```

The test-bench sets an initial value for sum, and starts three threads: one to write data to pipe in_data, one to read data from pipe out_data, and one to run the accumulate function. After the last data is read back from out_data, the test-bench gets the value of sum and prints it out.

Obviously, we would prefer to use the same test-bench to verify that the VHDL system generated from “prog.c” functions correctly. The difference is that instead of using methods in iolib, the test-bench now uses methods in SocketLib. Further, the VHDL is executed in a VHDL simulator; the simulator communicates with the testbench using sockets. The *ifdef*’s in the test-bench and the system program indicate the difference between the pure software version of the system-test-bench combination and the hardware-software version.

The following Makefile builds a software-only testbench executable, and also converts the system described in prog.c to VHDL. The same testbench can be used to test the VHDL also.

```

# build software version of testbench
# (to check the "desired behaviour")
IOLIB_INCLUDE=../../iolib/include
IOLIB_LIB=../../iolib/lib
SOCKETLIB_INCLUDE=../../CtestBench/include
SOCKETLIB_LIB=../../CtestBench/lib
VHDL_LIB=../../vhdl
VHDL_VHPI_LIB=../../CtestBench/vhdl
all: SW HW

# compile with SW defined.
# note the use of IOLIB in building the testbench.
SW: prog.c prog.h testbench.c
    gcc -c -DSW -I$(IOLIB_INCLUDE) prog.c
    gcc -c -DSW -I$(IOLIB_INCLUDE) testbench.c
    gcc -o testbench_sw prog.o testbench.o -L$(IOLIB_LIB) -lio -lpthread

```

```

# five steps from C to vhd1 simulator.
HW: c2llvmbc llvmbc2aa aa2vc vc2vhd1 vhdlsim

# C to llvm byte-code.. use clang.
c2llvmbc: prog.c prog.h testbench.c
        clang -std=gnu89 -I$(IOLIB_INCLUDE) -emit-llvm -c prog.c
        #llvm-dis prog.o
        opt -O3 prog.o > prog.opt.o
        llvm-dis prog.opt.o

# llvm byte-code to Aa..
llvmbc2aa: prog.opt.o
        llvm2aa prog.opt.o | vcFormat > prog.opt.o.aa

# Aa to vC
aa2vc: prog.opt.o.aa
        Aa2VC -O -C prog.opt.o.aa | vcFormat > prog.opt.o.aa.vc

# vC to VHDL
vc2vhd1: prog.opt.o.aa.vc
        vc2vhd1 -C -e ahir_system -w -s ghdl\
                -T accumulate -t set_sum -t get_sum\
                -f prog.opt.o.aa.vc
        vhd1Format < ahir_system.unformatted_vhdl > ahir_system.vhdl
        vhd1Format < ahir_system_test_bench.unformatted_vhdl\
                > ahir_system_test_bench.vhdl

# build testbench and ghdl executable
# note the use of SOCKETLIB in building the testbench.
vhdlsim: ahir_system.vhdl ahir_system_test_bench.vhdl\
        testbench.c vhd1CStubs.h vhd1CStubs.c
        gcc -c vhd1CStubs.c -I./ -I$(SOCKETLIB_INCLUDE)
        gcc -c testbench.c -I./ -I$(SOCKETLIB_INCLUDE)
        gcc -o testbench_hw testbench.o vhd1CStubs.o\
                -L$(SOCKETLIB_LIB) -lSocketLib -lpthread
        ghdl --clean
        ghdl --remove
        ghdl -i --work=ahir $(VHDL_LIB)/ahir.vhdl
        ghdl -i --work=ieee_proposed $(VHDL_LIB)/ieee_proposed.vhdl
        ghdl -i --work=work $(VHDL_VHPI_LIB)/Utility_Package.vhdl
        ghdl -i --work=work $(VHDL_VHPI_LIB)/Vhpi_Package.vhdl
        ghdl -i --work=work ahir_system.vhdl
        ghdl -i --work=work ahir_system_test_bench.vhdl
        ghdl -m --work=work -Wc,-g -Wl,-L$(SOCKETLIB_LIB)\
                -Wl,-lVhpi ahir_system_test_bench

```

```
clean:
    rm -f *.o* *.cf *.vhd1 vhd1CStubs.*\
        *.vcd in_data* out_data* testbench_sw\
        testbench_hw ahir_system_test_bench\
        vhpi.log
```

PHONY: all clean

To test the software, run testbench_sw. To verify the hardware (using the VHDL simulator GHDL), start testbench_sw in one shell, and then start ahir_system_test_bench in a different shell.