Building a Cross Debugger for ARM Linux

開發學生: 林盈志、高毓廷、黃資閔

高效能計算實驗室

國立中正大學 資訊工程學系

What can You Learn?

- During embedded-system development
  - Why do we need cross debugger
  - What is the role of cross debugger
- How to build a cross debugger
- How to do source-level cross debug with ARM emulator

Equipment Requirement

- PC with
  - Linux OS installed Ubuntu 16.04
  - Native gcc compiler installed
  - Internet access

Software Requirement

- GNU debugger source code (version 8.1 or newer)
  - ftp://www.gnu.org/gnu/gdb/gdb-8.1.tar.gz

Outline

- Introduction to GDB
- Build a cross debugger
- Testing and Practice: command-line mode

Outline

- Introduction to GDB
- Build a cross debugger
- Testing and Practice: command-line mode

GNU Debugger (GDB)

- Allows you to see what is going on `inside' another program while it executes
  - Start your program, specifying anything that might affect its behavior
  - Make your program stop on specified conditions
  - Examine what has happened, when your program has stopped
  - Change things in your program, so you can experiment with correcting the effects of one bug and go on to learn about another

GDB: The GNU Project Debugger

GDB: The GNU Project Debugger

[bugs] [GDB Maintainers] [contributing] [current git] [documentation] [download] [home] [irc] [links] [mailing lists] [news] [schedule] [song] [wiki]

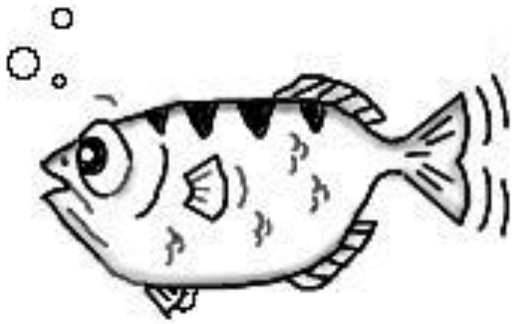
GDB: The GNU Project Debugger

What is GDB?

GDB, the GNU Project debugger, allows you to see what is going on `inside' another program while it executes -- or what another program was d

GDB can do four main kinds of things (plus other things in support of these) to help you catch bugs in the act:

- Start your program, specifying anything that might affect its behavior.
- Make your program stop on specified conditions.
- Examine what has happened, when your program has stopped.
- Change things in your program, so you can experiment with correcting the effects of one bug

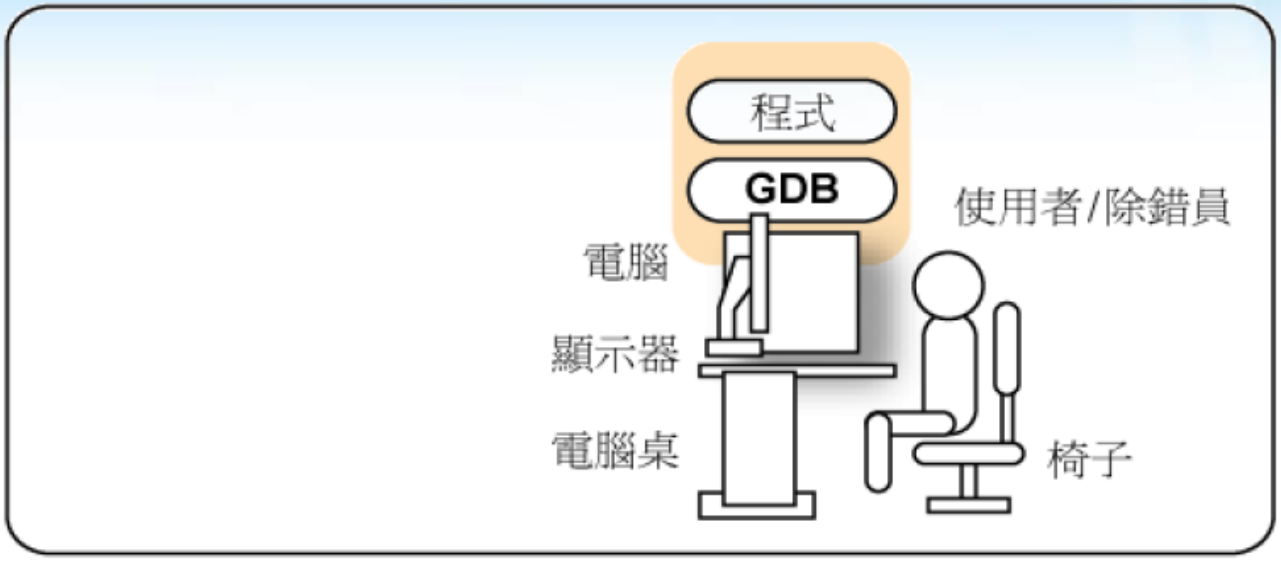


Those programs might be executing on the same machine as GDB (native), on another machine (re
variants, as well as on Mac OS X.

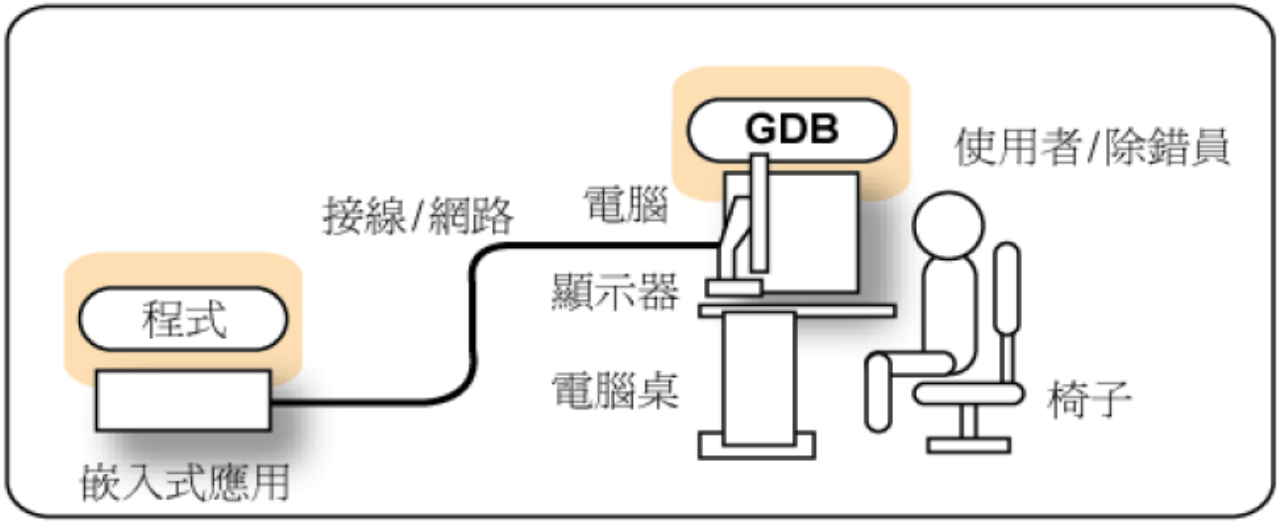
What Languages does GDB Support?

GDB supports the following languages (in alphabetical order):

近端/本機型除錯

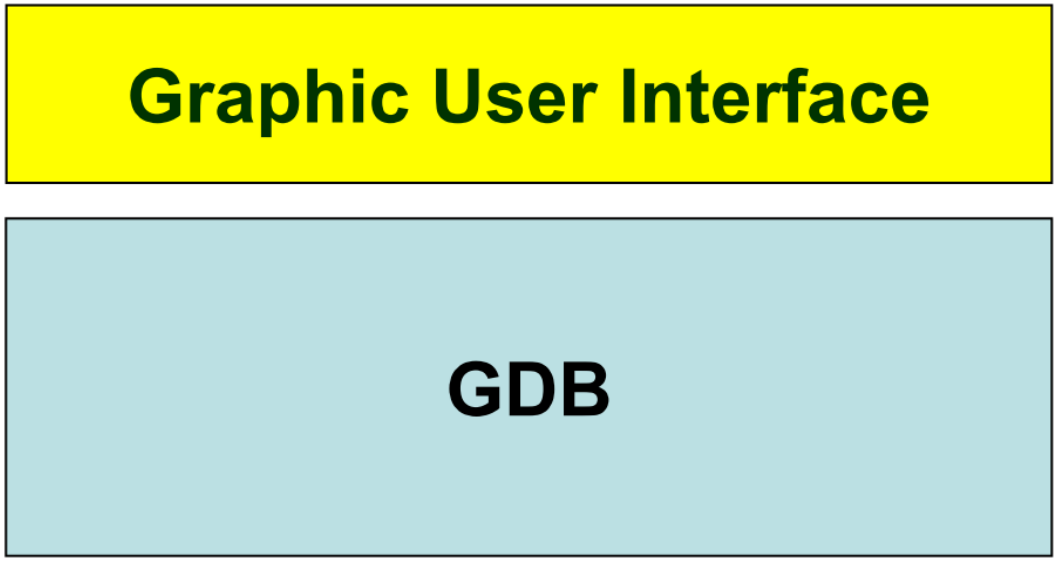


遠端/遙控型除錯

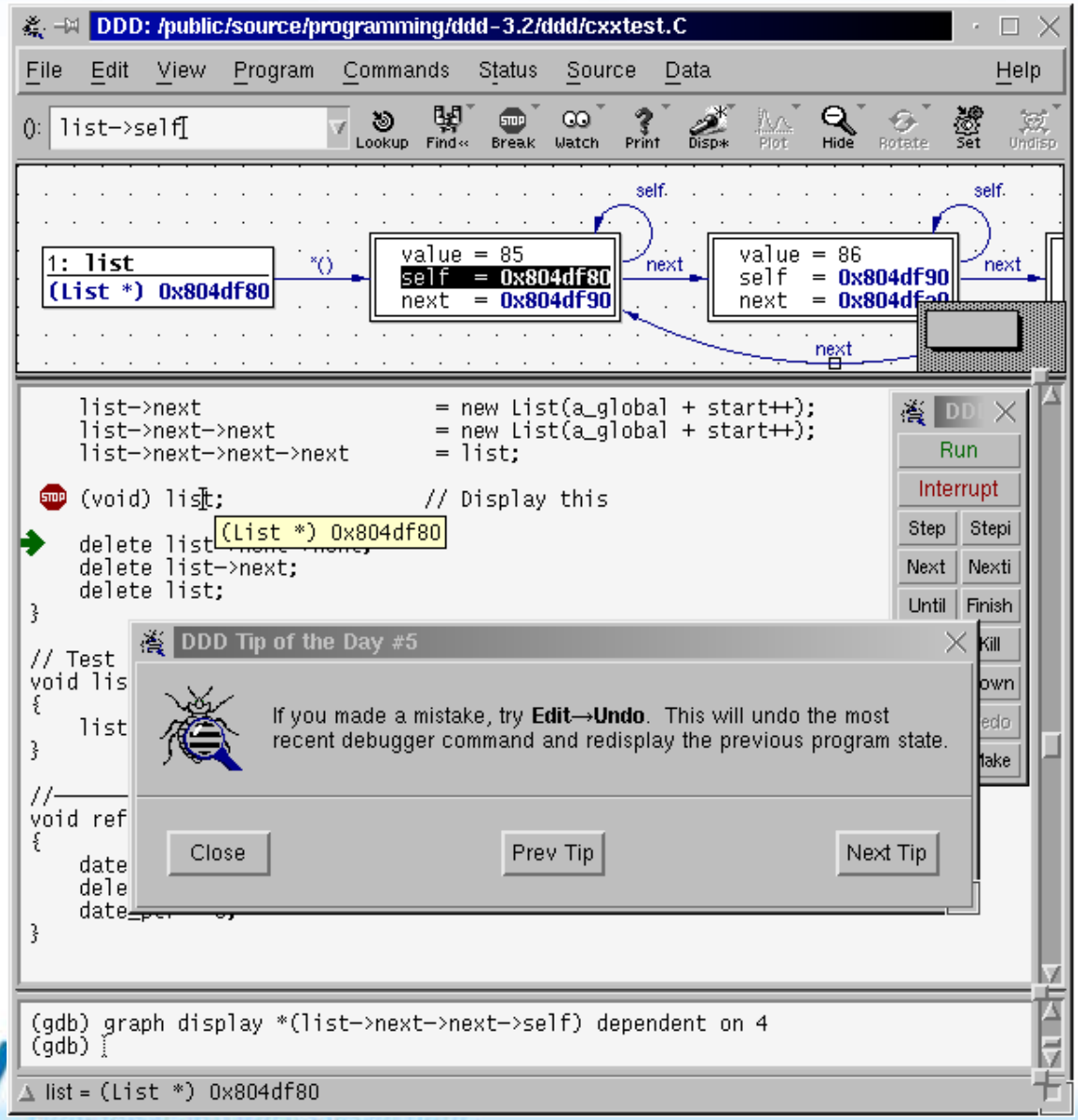


Graphic User Interface to GDB

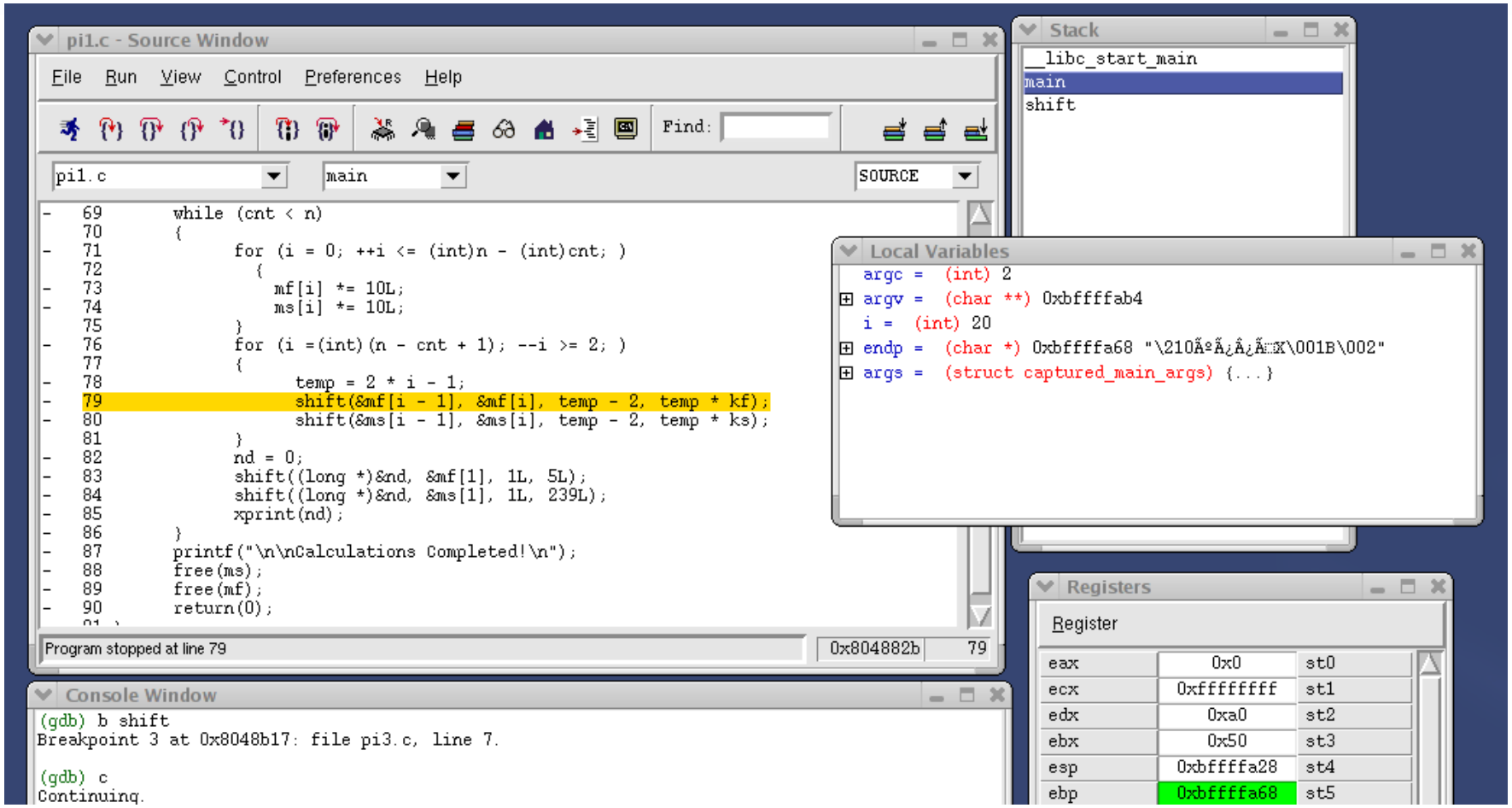
- It makes GDB easier to use
  - DDD
  - Insight
  - Eclipse CDT
  - gdbgui
  - …



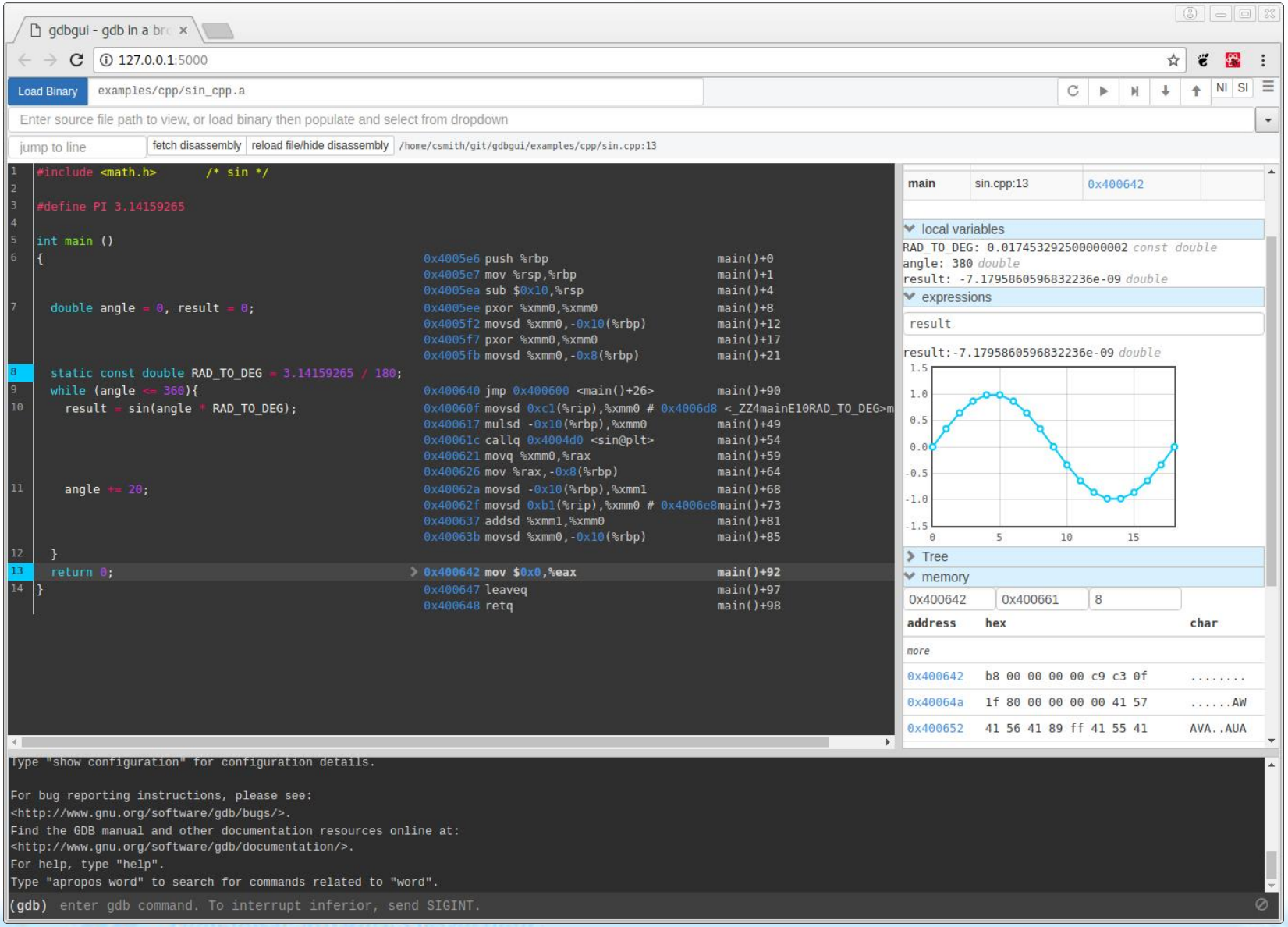
DDD (Data Display Debugger)



Insight


pi1.c - Source Window
File Run View Control Preferences Help
Find:
pi1.c
main
SOURCE
69 while (cnt < n)
70 {
71 for (i = 0; ++i <= (int)n - (int)cnt;)
72 {
73 mf[i] *= 10L;
74 ms[i] *= 10L;
75 }
76 for (i =(int)(n - cnt + 1); --i >= 2;)
77 {
78 temp = 2 * i - 1;
79 shift(&mf[i - 1], &mf[i], temp - 2, temp * kf);
80 shift(&ms[i - 1], &ms[i], temp - 2, temp * ks);
81 }
82 nd = 0;
83 shift((long *)&nd, &mf[1], 1L, 5L);
84 shift((long *)&nd, &ms[1], 1L, 239L);
85 xprint(nd);
86 }
87 printf("\n\nCalculations Completed!\n");
88 free(ms);
89 free(mf);
90 return(0);
Program stopped at line 79
0x804882b
79
Stack
__libc_start_main
main
shift
Local Variables
argc = (int) 2
argv = (char **) 0xbffffab4
i = (int) 20
endp = (char *) 0xbffffa68 "\210Ãº¿Â¿Ã¤X\001B\002"
args = (struct captured_main_args) {...}
Registers
Register
eax 0x0 st0
ecx 0xffffffff st1
edx 0xa0 st2
ebx 0x50 st3
esp 0xbffffa28 st4
ebp 0xbffffa68 st5
Console Window
(gdb) b shift
Breakpoint 3 at 0x8048b17: file pi3.c, line 7.
(gdb) c
Continuing.

gdbgui (browser-based)



Outline

- Introduction to GDB
- Build a cross debugger
- Testing and Practice: command-line mode

Prepare to Build Cross Debugger

- **Cross compiler, binutils are ready**
- **Download gdb source package**
  - ftp://www.gnu.org/gnu/gdb/gdb-8.1.tar.gz
- **Uncompress source package**

```
$ tar -zxvf gdb-8.1.tar.gz
```

GDB Source Package (1)-1

- gdb-8.1/configure (and supporting files)
  - script for configuring GDB and all its supporting libraries
- gdb-8.1/gdb
  - the source specific to GDB itself
- gdb-8.1/bfd
  - source for the Binary File Descriptor library
- gdb-8.1/include
  - GNU include files

GDB Source Package (1)-2

- gdb-8.1/libiberty
  - Source for the “liberty” free software library
  - It is a collection of subroutines used by various GNU programs.
  - Current members include:
    - getopt -- get options from command line
    - obstack -- stacks of arbitrarily-sized objects
    - strerror -- error message strings corresponding to errno
    - strtol -- string-to-long conversion
    - strtoul -- string-to-unsigned-long conversion

GDB Source Package (2)

- gdb-8.1/opcodes
  - source for the library of opcode tables and disassemblers
- gdb-8.1/readline
  - source for the GNU command-line interface
- gdb-8.1/sim
  - Source for various simulators
    - ARM
    - MIPS
    - PowerPC
    - …

Build Cross Debugger (1)

- Build cross binutils (--prefix=/MY_DIR)
- Add /MY_DIR/bin to PATH
- Build cross compiler (--prefix=/MY_DIR)

前一個實驗

```
$ cd myWORK
$ mkdir build_gdb
```

- Configure GDB

```
$ ../gdb-8.1/configure --prefix=/MY_DIR \
    --target=arm-linux-gnueabihf \
   --enable-tui=yes
```

- make
- make install

/home/pschen/WORK/crossgcc2

Build Cross Debugger (2)

- --enable-tui
  - enable full-screen terminal user interface (TUI)
- --enable-gdbtk
  - enable gdbtk graphical user interface (GUI)
- --enable-profiling
  - enable profiling of GDB
- --enable-sim
  - Link gdb with simulator
- Check GDB document for others

Outline

- Introduction to GDB
- Build a cross debugger
- Testing and Practice: command-line mode

test.c

```
#include <math.h>
#include <stdio.h>

int main(void)
{
    int a;
    double b;

    a = 10;
    b = 20 + cos((double) a);
    printf("%f\n", b);

    return 0;
}
```

Practice on Source-Level Debug (Command-line Mode)

- Use cross compiler to compile test.c
  - ”-g” option: add debug information which makes possible source-level debug

```
$ /home/pschen/WORK/crossgcc2/bin/arm-linux-gnueabihf-gcc -static -g test.c -o test.exe
```

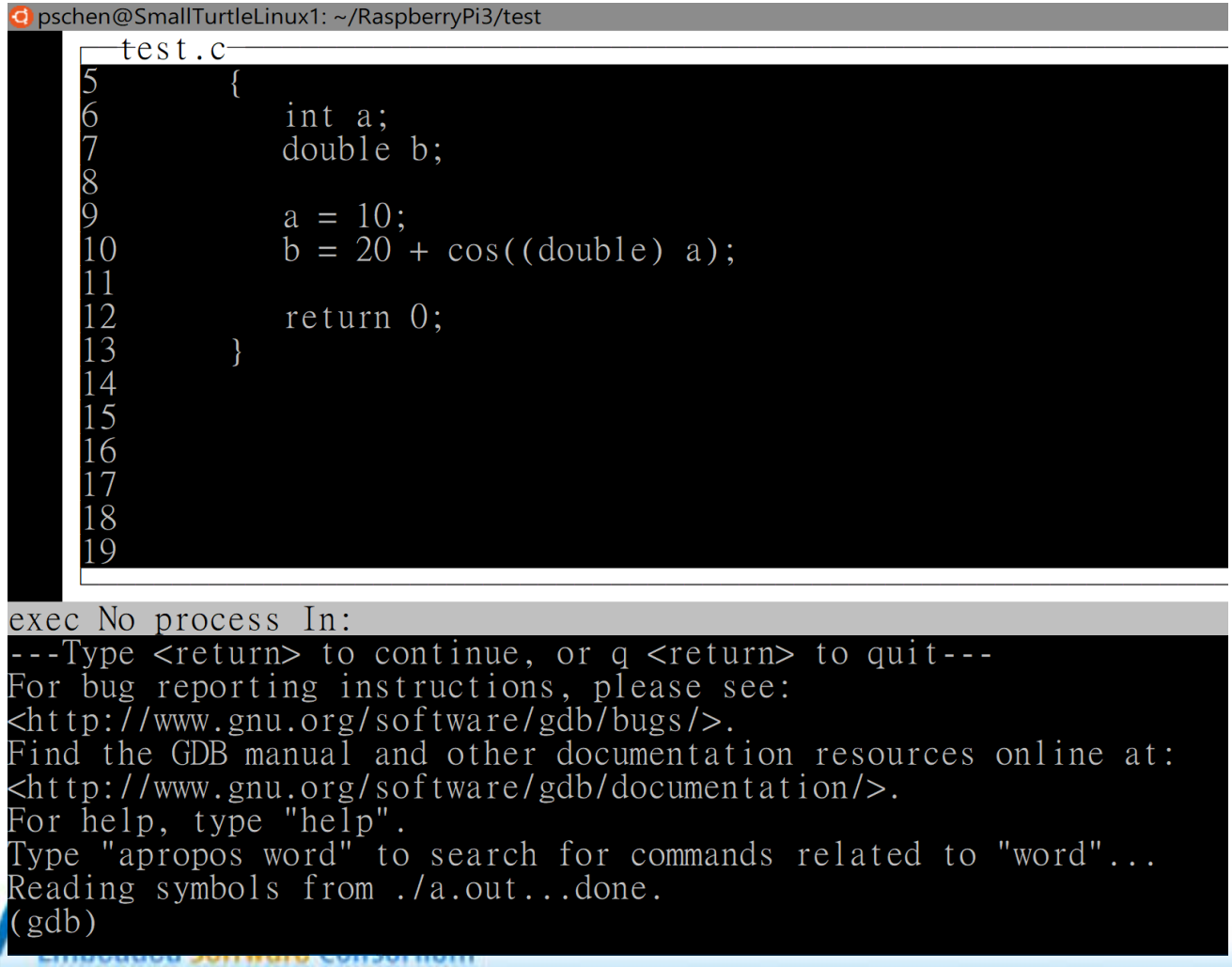
GDB Command-Line Mode (1)

$ arm-linux-gnueabihf-gdb

```
pschen@SmallTurtleLinux1: ~/WORK/crossgcc2/bin
pschen@SmallTurtleLinux1:~/WORK/crossgcc2/bin$ ./arm-linux-gnueabihf-gdb
GNU gdb (GDB) 8.1
Copyright (C) 2018 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law.  Type "show copying"
and "show warranty" for details.
This GDB was configured as "--host=x86_64-pc-linux-gnu --target=arm-linux-gnueabihf".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word".
(gdb)
```

GDB Command-Line Mode (2)

$ arm-linux-gnueabihf-gdb -tui



GDB Command-Line Mode (3)

- (gdb) file test.exe

Reading symbols from /root/test.exe...done.

- (gdb) break 10 ← Insert a breakpoint at line 10

Breakpoint 1 at 0x836e: file test.c, line 10.

- (gdb) r ← run
- (gdb) n ← next
- (gdb) s ← step (step in)
- (gdb) info register ← List all register contents

GDB Command-Line Mode (4)

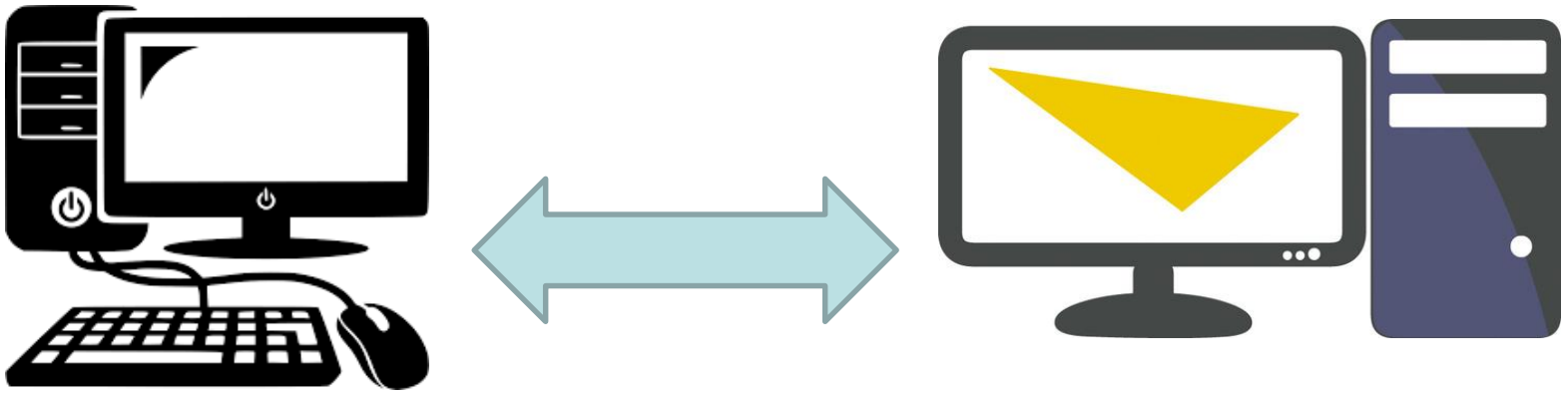
- (gdb) quit => exit GDB
- (gdb) x/10 0x0
  - dump memory content from 0x0
  - repeat count = 10

```
0x0:   0xe59ff838    0xea00089b    0xe59ff838    0xe59ff838
0x10:  0xe59ff838    0xe59ff838    0xe59ff838    0xe59ff838
0x20:  0x00000000    0x00000000
```

Try It !

- Command
  - n 單步執行
  - s 單步執行 (step in)
  - info register 觀看暫存器的值
  - help 說明
  - quit 結束

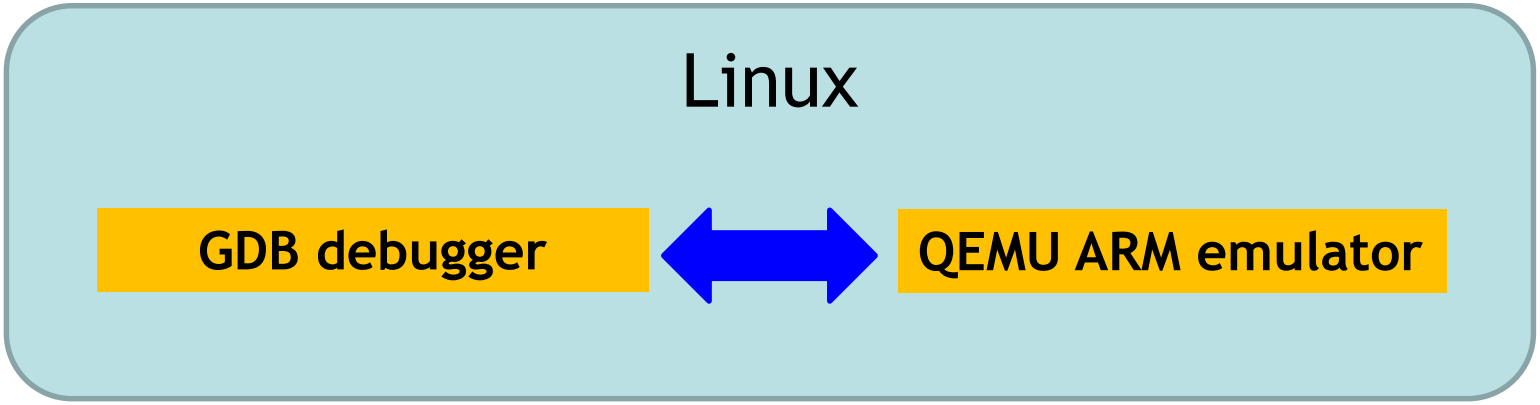
Remote Debugging Using QEMU



GDB debugger

Target program

Remote Debugging Using QEMU



安裝QEMU

- 安裝QEMU user mode emulator

```
$ apt-get install qemu-user
```

- 安裝成功，在/usr/bin目錄下有執行檔 qemu-arm

- 檢視相關使用參數

```
$ qemu-arm -help
```

qemu-arm (1)

pschen@LAPTOP-H2KVDJV3: ~

```
pschen@LAPTOP-H2KVDJV3:~$ qemu-arm -help
usage: qemu-arm [options] program [arguments...]
Linux CPU emulator (compiled for arm emulation)

Options and associated environment variables:

Argument             Env-variable      Description
-h                                     print this help
-help
-g port              QEMU_GDB          wait gdb connection to 'port'
-L path              QEMU_LD_PREFIX    set the elf interpreter prefix to 'path'
-s size              QEMU_STACK_SIZE   set the stack size to 'size' bytes
-cpu model           QEMU_CPU          select CPU (-cpu help for list)
-E var=value         QEMU_SET_ENV      sets targets environment variable (see below)
-U var               QEMU_UNSET_ENV    unsets targets environment variable (see below)
-0 argv0             QEMU_ARGV0        forces target process argv[0] to be 'argv0'
-r uname             QEMU_UNAME        set qemu uname release string to 'uname'
-B address           QEMU_GUEST_BASE   set guest_base address to 'address'
-R size              QEMU_RESERVED_VA  reserve 'size' bytes for guest virtual address space
-d item[,...]        QEMU_LOG          enable logging of specified items (use '-d help' for a list of items)
-dfilter range[,...] QEMU_DFILTER      filter logging based on address range
-D logfile           QEMU_LOG_FILENAME write logs to 'logfile' (default stderr)
-p pagesize          QEMU_PAGESIZE     set the host page size to 'pagesize'
-singlestep          QEMU_SINGLESTEP   run in singlestep mode
-strace              QEMU_STRACE       log system calls
-seed                QEMU_RAND_SEED    Seed for pseudo-random number generator
-trace               QEMU_TRACE        [[enable=]<pattern>][,events=<file>][,file=<file>]
```

qemu-arm (2)

- -g port: 啟動qemu內部類似gdbserver的程式，等待遠端GDB的連線

- -L path: 設定cross toolchain執行檔的路徑 (set the elf interpreter prefix to 'path')

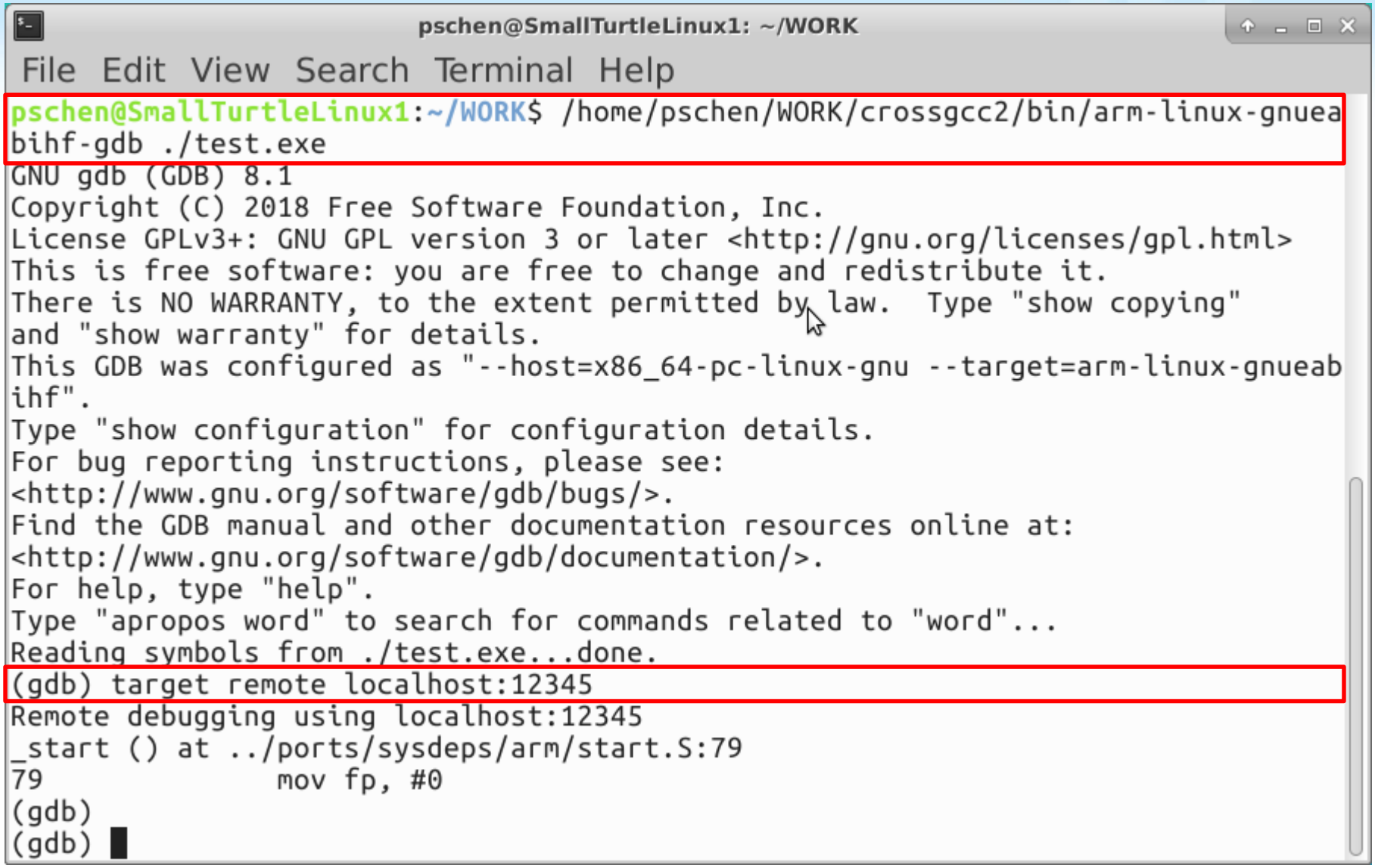
切換到test.exe所在的目錄，執行:

```
$ qemu-arm  -g  12345 ./test.exe
```

qemu-arm (3)

- 開啟另一個終端機視窗

```
$ arm-linux-gnueabihf-gdb ./test.exe
```

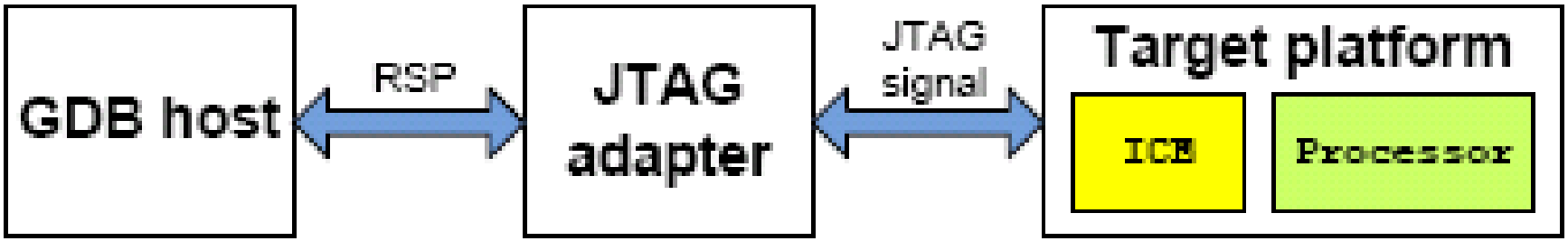

pschen@SmallTurtleLinux1: ~/WORK
File Edit View Search Terminal Help
pschen@SmallTurtleLinux1:~/WORK$ /home/pschen/WORK/crossgcc2/bin/arm-linux-gnueabihf-gdb ./test.exe
GNU gdb (GDB) 8.1
Copyright (C) 2018 Free Software Foundation, Inc.
License GPLv3+: GNU GPL version 3 or later <http://gnu.org/licenses/gpl.html>
This is free software: you are free to change and redistribute it.
There is NO WARRANTY, to the extent permitted by law. Type "show copying"
and "show warranty" for details.
This GDB was configured as "--host=x86_64-pc-linux-gnu --target=arm-linux-gnueabihf".
Type "show configuration" for configuration details.
For bug reporting instructions, please see:
<http://www.gnu.org/software/gdb/bugs/>.
Find the GDB manual and other documentation resources online at:
<http://www.gnu.org/software/gdb/documentation/>.
For help, type "help".
Type "apropos word" to search for commands related to "word"...
Reading symbols from ./test.exe...done.
(gdb) target remote localhost:12345
Remote debugging using localhost:12345
_start () at ../ports/sysdeps/arm/start.S:79
79 mov fp, #0
(gdb)
(gdb)

qemu-arm (4)

- 設定remote debugging

```
(gdb) target remote localhost:12345
(gdb) break main          //設定中斷點
(gdb) c                   // 繼續執行程式
```

GDB for ICE/Simulator



Remote Serial Protocol

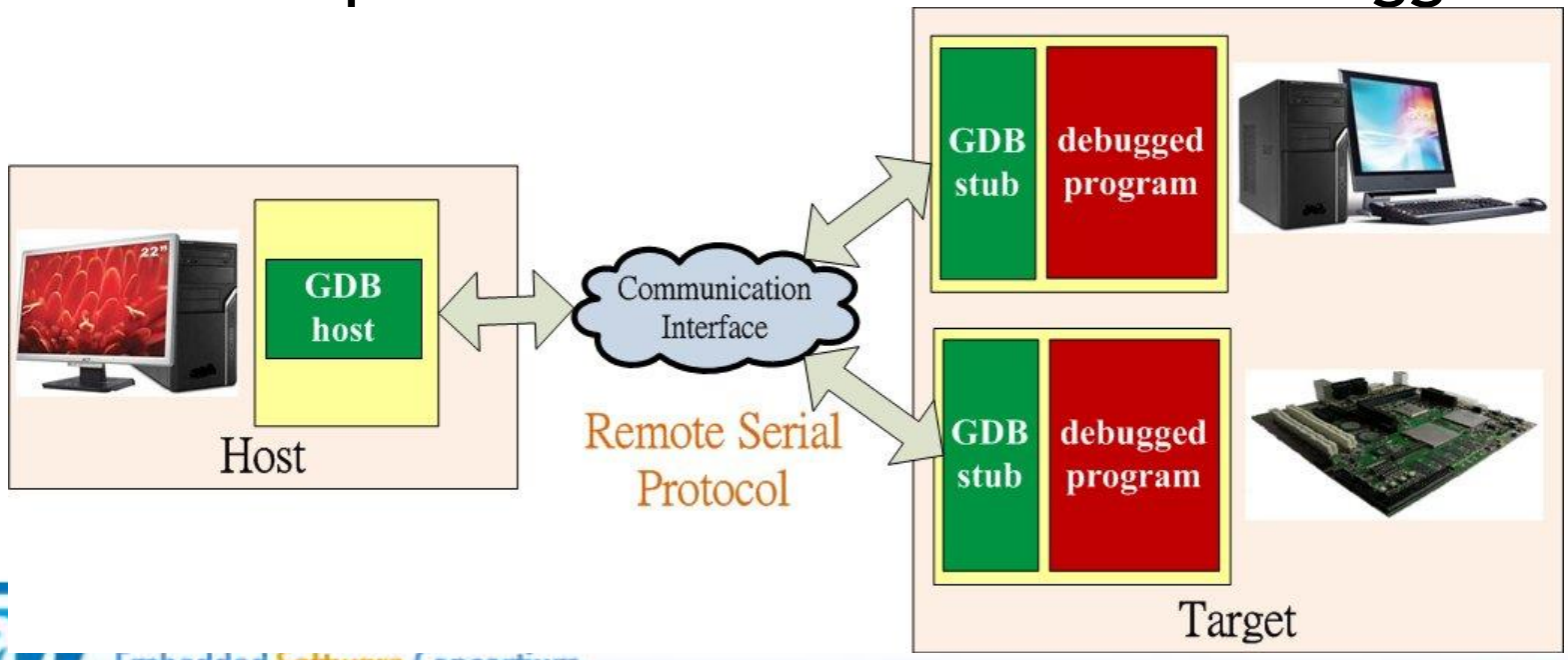
- All GDB commands and responses are sent by using the remote serial protocol
- ASCII message-based protocol
  - **Packet format: $packet-data#checksum**
  - **Example :**

Set register conent

GDB:	$P10=0040149c#b3
Target:	+ $OK#9a

What is GDB stub

- An agent of the GDB host
  - Monitor and control the debugged program
  - Communicate with GDB host
  - Be compiled and linked with the debugged



Implementation of the GDB stub

```
int main(void)
{
  set_debug_traps();
  breakpoint();
  int a, b;
  a = 10;
  b = 20 + a;
  return 0;
}
```

debugged_program.c

- Set_debug_trap()
  - Set **exceptionHandler** for each traps
- Breakpoint()
  - Directly halt the execution of the program
  - Wait the commands from GDB host

Reference

- GNU GDB
  - http://sources.redhat.com/gdb
- Insight
  - http://sources.redhat.com/insight
- DDD
  - http://www.gnu.org/software/ddd/

Questions

- What is “GDB server”?
- What is “GDB stub”?

請在實驗報告裡回覆相關問題

Backup