Eidgenössische Technische Hochschule Zürich
Swiss Federal Institute of Technology Zurich

System Construction Course 2017,

Assignment 6

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1 Debugging a Kernel

Lessons to Learn

- Learn how to debug a kernel using virtual environments.
- Understand call chains and stack traces.

Preparation

1. Install a recent version of the Bochs emulator, .e.g from https://sourceforge.net/projects/bochs/files/bochs/2.6.8/. Ubuntu linux users install it using `apt-get install bochs bochs-x`.
2. Open a console in directory assignments/assignment6

This lab is about debugging a kernel using the A2-built in tracing features and a hardware emulating tool (Bochs).

Find the Bugs!

For this lab we have prepared an implementation of the A2 kernel together with build scripts to set it up and run it in a virtual machine. The system reports a successful boot with the following output

```
A2 Test System
Successfully booted
```

You will *not* see this report in the first place because we have injected bugs into the kernel that prevent it from booting successfully. Find and correct the bugs!

Guidelines:

1. Use the script in file MakeA2.cmds in order to to compile and link the boot-file and to inject the files into a bootable HDD image by calling `oberon execute MakeA2.txt` or, equivalently, by executing `SystemTools.DoFile MakeA2.txt` within the Oberon shell.

   The linker log file `linker.log` can contain valuable information about the arrangement. Have a look at it!

2. Use the hardware emulator Bochs (2.6.8) for starting and debugging the kernel.

   (a) Windows users start the system by clicking a2.bxrc. If you right-click this file, using the context menu you can start the debugging mode of Bochs. Use the command “help” to find out about facilities of the debugger.

   (b) Linux users start the system by executing `bochs -f linuxBochsSettings.txt`. The Linux version starts in debugging mode. In order to start the emulation, enter `c` (for **c**ontinue).

3. The log of A2 will be written to the serial port. Bochs redirects it to the file `a2.log`. Hint: Use the log file for tracing the kind of errors that provide a trap stack trace-back report. Stack trace-backs are described in the next section of this document.

- Further hints: when in debugging mode, you can interrupt a running system with Ctrl-C (typed at the debugging console of Bochs). Make use of time-breakpoints in Bochs, when you cannot locate the exact location of a problem. Use the linker-log to find out where you are with respect to the source code.

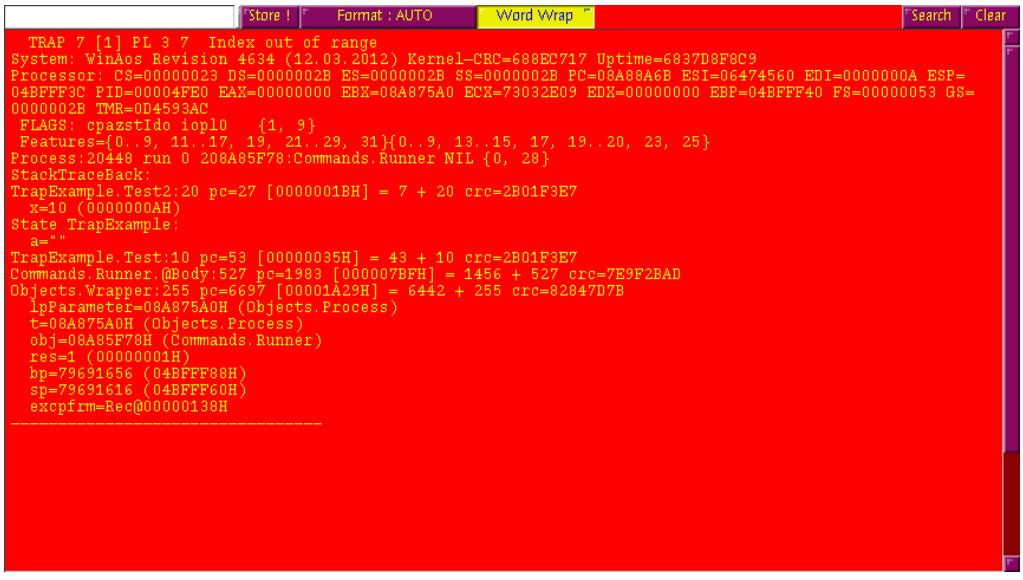
Understanding a Trap Traceback

When you (later on) run code in $\mathcal{A}_2$, it can happen that you see a red window popping up. Such a red window indicates that something went wrong. Usually it happens as a result of an unhandled runtime exception that needs intervention, such an array index out of bounds, nil pointer access, programmed halt, assert failed etc. During startup of a kernel the information is displayed on the text console and / or written to other debug channels such as a serial port.

The following module, for example, will produce a trap when `TrapExample.Test` is executed.

```
MODULE TrapExample;

VAR a: ARRAY 2 OF CHAR;

      PROCEDURE Test2(x: LONGINT);
      BEGIN
            a[x] := "A"; (* if x exceeds the length of a,
                  this will lead to a trap *)
      END Test2;

      PROCEDURE Test*;
      BEGIN
            Test2(10);
      END Test;

END TrapExample.
```

In $\mathcal{A}_2$ the result is a red window popping up that looks like this:



The trap output can be used to diagnose the history of a trap. Inspection of the trap is also

referred to as *Post Mortem Debugging*. A trap starts with information on the trap number and reason (here: index out of range). Then there is more general information on the system release followed by the state of the registers and flags. After that we see the process ID and the active object that is associated with the process (here: `Commands.Runner`).

```
1 TRAP 7 [1] PL 3 7 Index out of range
2 System: WinAos Revision 4634 (12.03.2012) Kernel_CRC=688EC717
      Uptime=C17E0CB3B7
3 Processor: CS=00000023 DS=0000002B ES=0000002B SS=0000002B PC=08C810CB ...
4  FLAGS: cpazstIdo iopl0 {1, 9}
5  Features={0..9, 11..17, 19, 21..29, 31}{0..9, 13..15, 17, 19..20, 23, 25}
6 Process:20956 run 0 208C7D2F8:Commands.Runner NIL {0, 28}
```

After this prolog starts the stack trace. The runtime builds this information by traversing the stack frames from top to bottom. Read from bottom to top (lines 8,7,6,2), it shows how procedures were called. In our example it starts with `Objects.Wrapper`. `Objects.Wrapper` executed the body of object `Commands.Runner` that called `TrapExample.Test` which itself called `TrapExample.Test2`. This is where the trap occured. More specifically, at offset 20 relative to the start of `TrapExample.Test2`. The offset can be utilized to determine the exact location of a trap both in binary code but also, using the compiler, in source code. At line 4 we see state information about the module involved in the trap. In a kernel output, the `pc=number [hex number]` shows the location of the program counter as absolute value and therefore allows also to examine where the trap happened by comparison with the linker script.

Between procedure and module names we see other names followed by an equal sign. They denote the variables and parameters of the respective procedures. For example, in procedure `TrapExample.Test2`, variable `x` had a value of 10, ultimately causing the index out of bound trap.

```
1  StackTraceBack:
2  TrapExample.Test2:20 pc=27 [0000001BH] = 7 + 20 crc=2B01F3E7
3    x=10 (0000000AH)
4  State TrapExample:
5    a=""
6  TrapExample.Test:10 pc=53 [00000035H] = 43 + 10 crc=2B01F3E7
7  Commands.Runner.@Body:527 pc=1983 [000007BFH] = 1456 + 527 crc=7E9F2BAD
8  Objects.Wrapper:255 pc=6697 [00001A29H] = 6442 + 255 crc=82847D7B
9    lpParameter=08C7E920H (Objects.Process)
10   t=08C7E920H (Objects.Process)
11   obj=08C7D2F8H (Commands.Runner)
12   res=1 (00000001H)
13   bp=76087176 (0488FF88H)
14   sp=76087136 (0488FF60H)
15   excpfrm=Rec@00000138H
16 ------------------------------------
```

Documents

- System Construction Lecture 6 slides from the course-homepage
  http://lec.inf.ethz.ch/syscon
- $\mathcal{A}_2$ Programming Quickstart Guide. File A2QuickStartGuide.pdf in folder documents/oberon