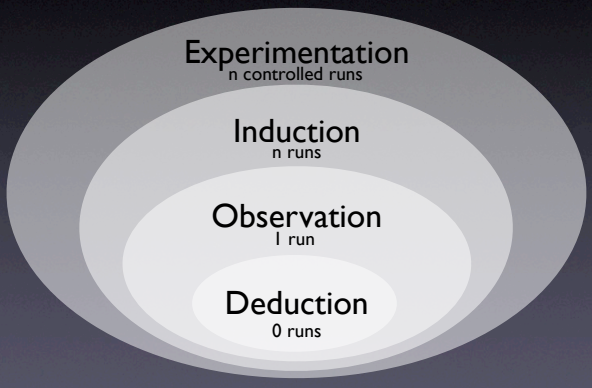
Observing Facts

Andreas Zeller

1

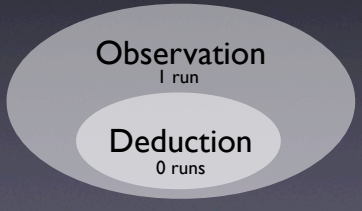
Reasoning about Runs



2

2

Reasoning about Runs



3

3

Principles of Observation

- Don't interfere.
- Know what and when to observe.
- Proceed systematically.

Logging execution

- General idea: Insert *output statements* at specific places in the program
- Also known as *printf debugging*

Demonstrate technique, using sample program

Printf Problems

- Clobbered code
- Clobbered output
- Slow down
- Possible loss of data (due to buffering)

Better Logging

- Use standard formats
- Make logging optional
- Allow for variable granularity
- Be persistent

Logging Functions

- Have specific functions for logging (e.g. dprintf() to print to a specific logging channel)
- Have specific *macros* that can be turned on or off–for focusing as well as for production code

Again, demonstrate the use of LOG() interactively

Logging Frameworks

- Past: home-grown logging facilities
- Future: *standard libraries* for logging
- Example: The LOGFORJ framework

LOGFORJ

```
// Initialize a logger.
final ULogger logger =
    LoggerFactory.getLogger(TestLogging.class);

// Try a few logging methods
public static void main(String args[]) {
    logger.debug("Start of main()");
    logger.info ("A log message with level set to INFO");
    logger.warn ("A log message with level set to WARN");
    logger.error("A log message with level set to ERROR");
    logger.fatal("A log message with level set to FATAL");

    new TestLogging().init();
}
```

10

The core idea of LOGFORJ is to assign each class in an application an individual or common *logger.* A logger is a component which takes a request for logging and logs it. Each logger has a level, from DEBUG over INFO, WARN, and ERROR to FATAL (very important messages).

10

Customizing Logs

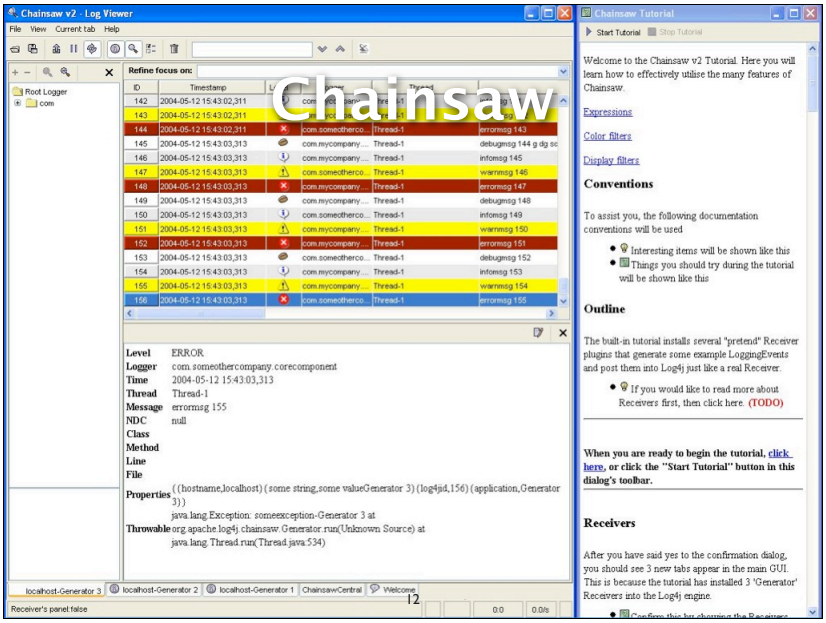
```
# Set root logger level to DEBUG and its only appender to A1.
log4j.rootLogger=DEBUG, A1

# A1 is set to be a ConsoleAppender.
log4j.appender.A1=org.apache.log4j.ConsoleAppender

# A1 uses PatternLayout.
log4j.appender.A1.layout=org.apache.log4j.PatternLayout
log4j.appender.A1.layout.ConversionPattern=\
%d [%t] %-5p %c %x - %m%n
```

```
2005-02-06 20:47:31,508 [main] DEBUG  TestLogging - Start of
main()
2005-02-06 20:47:31,529 [main] INFO   TestLogging - A log
message with level set to INFO
```

11

The core idea of LOGFORJ is to assign each class in an application an individual or common *logger.* A logger is a component which takes a request for logging and logs it. Each logger has a level, from DEBUG over INFO, WARN, and ERROR to FATAL (very important messages).

11



12

12

Logging with Aspects

- Basic idea: Separate concerns into individual syntactic entities *(aspects)*
- Aspect code *(advice)* is *woven* into the program code at specific places *(join points)*
- The same aspect code can be woven into multiple places *(pointcuts)*

A Logging Aspect

```
public aspect LogBuy {
    pointcut buyMethod():
        call(public void Article.buy());
    before(): buyMethod() {
      System.out.println("Entering Article.buy()")
    }
    after(): buyMethod() {
      System.out.println("Leaving Article.buy()")
    }
}
```

```
$ ajc logBuy.aj Article.java
$ java Article
```


Using Pointcuts

```
public aspect LogArticle {
  pointcut allMethods():
    call(public * Article.*(..));
  before(): allMethods() {
    System.out.println("Entering " + thisJoinPoint)
  }
  after(): allMethods() {
    System.out.println("Leaving " + thisJoinPoint)
  }
}
```

Aspect Arguments

```
public aspect LogMoves {
    pointcut setP(Line a_line, Point p):
        call(void a_line.setP*(p));

    after(Line a_line, Point p): setP(a_line, p) {
        System.out.println(a_line +
                           " moved to " + p + ".");
    }
}
```


Observation Tools

- Getting started fast – without altering the program code at hand
- Flexible observation of arbitrary events
- Transient sessions – no code is written

Debuggers

- Execute the program and make it stop under specific conditions
- Observe the state of the stopped program
- Change the state of the program

A Debugging Session

```
static void shell_sort(int a[], int size)
{
    int i, j;
    int h = 1;
    do {
        h = h * 3 + 1;
    } while (h <= size);
    do {
        h /= 3;
        for (i = h; i < size; i++)
        {
            int v = a[i];
            for (j = i; j >= h && a[j - h] > v; j -= h)
                a[j] = a[j - h];
            if (i != j)
                a[j] = v;
        }
    } while (h != 1);
}
```


Show this interactively with GDB or DDD

More Features

- Control environment
- Post mortem debugging
- Logging data
- Fix and continue

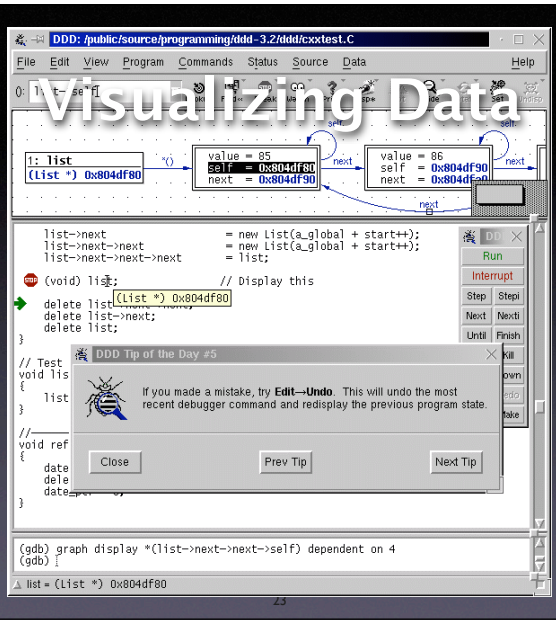
More on Breakpoints

- Data breakpoints (watchpoints)
- Conditional breakpoints

Demonstrate watchpoints and conditionals interactively

Debugger Caveats

- A debugger is a tool, not a toy!



Visualizing Data

Again, demonstrate DDD interactively

Concepts

★ Logging functions ("printf debugging") are easy to use, but clobber code and output

★ To encapsulate and reuse debugging code, use dedicated logging functions or aspects

Concepts (2)

- ★ Logging functions can be turned on or off (and may even remain in the source code)
- ★ Aspects elegantly keep all logging code in one place
- ★ Debuggers allow flexible + quick observation of arbitrary events

Concepts (3)

- ★ To observe the final state of a crashing program, use a debugger
- ★ Advanced debuggers allow to query events in a declarative fashion…
- ★ …as well as visualizing events and data