Monitoring: Runtime Behavior & Software Development Process

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Monitoring runtime behavior
Monitoring runtime behavior

- **Goals**
  - Recording information about program behavior
  - Notification about specific important events

- **Information:** performance, security, exceptions

- **Target domain:** long-running programs
  - Application servers (JBoss, Tomcat, WebSphere, ...)
  - Network servers and daemons (Apache, Sendmail)

- **Alternative name:** tracing
Basic approaches

- Manual implementation of logging commands
- Using tools for automated runtime monitoring
Tools

- Unix-like platforms
  - Syslog, strace, ltrace, DTrace
- Java ecosystem
  - Log4j 2, Java Logging API, JVisualVM, JVM TI
- Windows/.NET
  - Log4net, NLog, Process Explorer

- Events: custom messages, system calls, library calls
- Output: text log files (off-line inspection), GUI
Log4j

- Popular logging framework for Java platform
  - [http://logging.apache.org/log4j/2.x/](http://logging.apache.org/log4j/2.x/)

- Features
  - Hierarchy of loggers based on class names
  - Filtering messages based on logging levels
  - Dynamically updateable configuration (XML)
  - Multiple output destinations (console, file)
  - Formatting log messages (printf-style, HTML)
Log4j API: example

```java
import org.apache.logging.log4j.LogManager;
import org.apache.logging.log4j.Logger;

// get a Logger object with a particular name
Logger logger = LogManager.getLogger("cz.cuni.mff");

logger.warn("Running out of disk space");
... 
logger.error("File {} not found", f.getName());
...
logger.info("Something normal happened");
```
Using Log4j

• Levels
  ▪ TRACE < DEBUG < INFO < WARN < ERROR < FATAL

• Logger objects
  ▪ Identified by logical names (e.g., Java class names)
  ▪ They make a hierarchy based on the name prefixes
    • Logger named “cz.cuni” is a parent for the Logger “cz.cuni.mff”
    • Inheriting configuration (levels, appenders, formatting pattern)
    • Root Logger always exists at the top of any custom hierarchy

• Configuration: XML, programmatic
  ▪ Default file name `log4j2.xml` (must be on classpath)
<?xml version="1.0" encoding="UTF-8"?>
<Configuration>
  <Appenders>
    <Console name="konzole" target="SYSTEM_OUT">
      <PatternLayout pattern="%d{HH:mm:ss} %-5level %c{36} - %m%n"/>
    </Console>
    <File name="logfile" fileName="test.log">
      <PatternLayout pattern="%d{HH:mm:ss} %-5level %c{36} - %m%n"/>
    </File>
  </Appenders>
  <Loggers>
    <Logger name="cz.cuni.mff" level="info">
      <AppenderRef ref="konzole"/>
    </Logger>
    <Root level="error">
      <AppenderRef ref="logfile"/>
    </Root>
  </Loggers>
</Configuration>
**Appenders**

- Responsible for writing log messages to actual target destinations

- **Supported targets**
  - Console (stdout, stderr)
  - File (buffered, appending)
  - Database (via JDBC)
  - SMTP (sending emails)
  - Network socket (TCP, UDP)
  - Unix/Linux syslog service
Purpose: formatting messages

Available layouts

- Pattern
  - %m // message text
  - %n // line separator
  - %-5level // level, justified to the right, width five chars
  - %d{HH:mm:ss} // current datetime with pattern
  - %c{20} // logger name with the maximal length
  - %C %M %L // class name, method name, line number
  - %t // thread name

- HTML, XML, Syslog
public Object doSomething(int arg1) {
    logger.entry(arg1);
    try {
        ...
        Object res = ...
    }
    catch (Exception ex) {
        logger.catching(ex)
    }
    logger.exit(res);
}
Log4j: other features

- Filtering messages
  - markers, regular expression, time

- Automatic reconfiguration
  - if you update the XML configuration file at runtime
Logging platforms for .NET (C#, VB)

- Log4net
- NLog
  - [http://nlog-project.org/](http://nlog-project.org/)
  - [https://github.com/NLog/NLog/wiki](https://github.com/NLog/NLog/wiki)

- Features
  - Configuration: file (XML), programmatic (API)
  - Multiple targets (file, database, console, email)
  - Layouts (plain text, CSV, XML, JSON)
Task 1

- Download Log4j/Log4net from the web
  - [http://logging.apache.org/log4j/2.x/](http://logging.apache.org/log4j/2.x/)
    - Only important JAR files: core, api

- Write simple program in Java or C#
  - You can also take some existing program (anywhere)

- Try important features of the particular logging framework
  - Use several Loggers
  - Different log levels
  - Configuration (XML)
  - Tracing control flow

- Check the output (console, log files)
Syslog

- Standard logging framework for Unix-like systems

- Service
  - Collecting messages from different sources (applications)
  - Writing received messages to various output destinations
    - log files (/var/log), another computer over network
  - Configuration: /etc/syslog.conf, /etc/rsyslog.conf
  - Log rotation: /var/log/messages, /var/log/messages.1, ...

- Protocol
  - Format of data exchanged between applications and the service
  - Message: content (plaintext, < 1024 bytes), priority
  - Supported priorities (low to high)
    - debug, info, notice, warning, error, critical, alert, emergency
  - Definition: RFC 3164, 3195
Configuration: example

- Sendmail
- Apache
- MySQL

Syslogd

- /var/log/mail.log
- /var/log/mysql.log
- /var/log/httpd/httpd.log
#include <syslog.h>

openlog("myprog", LOG_CONS | LOG_PID, LOG_USER);

syslog(LOG_NOTICE, "Program runs for %d hours", 2);
syslog(LOG_ERROR, "File %s does not exist", fname);

closelog();
strace

- Tool for monitoring interactions with the operating system kernel
  - System calls performed by the given program
  - Signals received by the given program from OS
- Available for Unix-like platforms

- **Usage:** `strace <program>`
  - Attaching to a running process: `strace -p <pid>`

- **Output:** list of system calls and signals
  
  ```
  open(“/etc/passwd”, O_RDONLY) = 3
  open(“/etc/passwords”, O_RDONLY) = -1 ENOENT (No such file)
  ```
Task 2

- Try using
  - `strace` (syscalls)
  - `ltrace` (libraries)

- Check output
JConsole & JVisualVM

- Available in Oracle JDK

- Key features
  - Provides useful information
    - CPU usage, memory consumption, threads
  - Nice graphical interface
  - Connection to remote JVM

- How to run it: `jconsole` / `jvisualvm`

- Live demo
Monitoring tools for C#/.NET

- .NET Memory Profiler

- dotMemory
  - https://www.jetbrains.com/dotmemory/
Windows Sysinternals

- Process Explorer
  - Displays information about running processes

- Process Monitor
  - [https://docs.microsoft.com/cs-cz/sysinternals/downloads/procmon](https://docs.microsoft.com/cs-cz/sysinternals/downloads/procmon)
  - Displays some live (real-time) process activity
Other monitoring tools

- Instrumentation (binary, source code)
- Notification about specific events
  - accesses to object fields and variables
  - locking (acquisition, release, attempts)
  - procedure calls (e.g., user-defined list)
- Pin: dynamic binary instrumentation tool
- JVM Tool Interface (TI)
  - [https://docs.oracle.com/javase/8/docs/platform/jvmti/jvmti.html](https://docs.oracle.com/javase/8/docs/platform/jvmti/jvmti.html)
- Valgrind: heavyweight dynamic binary translation
- DiSL ([https://disl.ow2.org/bin/view/Main/](https://disl.ow2.org/bin/view/Main/))
Log analysis tools

- Elasticsearch + Logstash
  - https://www.elastic.co/

- LOGalyze
  - http://www.logalyze.com/

- Splunk
  - https://www.splunk.com/

- Azure Monitor (Application Insights)
Monitoring development process
Issue tracking systems

• Typically part of a project management system
  ■ https://github.com/, https://bitbucket.org/

• Popular systems
  ■ Bugzilla, Trac, JIRA, YouTrack

• Components
  ■ Some database of known issues
  ■ User interface (WWW, desktop)
Bug characteristics

- Time of reporting
- Product (module)
- Version of the product
- **Severity of the bug**
  - blocker, critical, major, normal, minor, enhancement
- Platform (OS, HW, SW)
- Textual comments
- **Current status**
  - new, unconfirmed, assigned, fixed, wontfix, resolved
- Assigned to
  - Who should fix the bug
Lifecycle of a bug

Figure taken from http://www.bugzilla.org/docs
Common actions

- Developer
  - Entering new bug reports
  - Search for assigned bugs
  - Changing status of a bug

- Manager
  - Inspecting overall statistics
  - Look for unresolved bugs
  - Assign priorities to features
Bugzilla

- Web-based tool
  - [http://www.bugzilla.org](http://www.bugzilla.org)

- SW requirements
  - Database (MySQL, PostgreSQL)
  - Perl 5 with specific modules
  - Web server (e.g., Apache httpd)

- Features
  - Advanced queries
    - Boolean operators (and, or, not)
  - Saved search
  - Cloning of bugs

- Test installation
Trac

• Project management system
  - http://trac.edgewall.org/

• Features
  - Tracking issues (bugs, feature requests)
  - Good integration with version control
    • Supported tools: Subversion, Mercurial, Git
    • Links from bug reports to source code files
  - Source code browser (version control)
  - Wiki pages (e.g., for documentation)
Test coverage

- Criteria: statement, branch, path
- Mutation testing
  - Detects missing tests
- Fault injection

- Practice: achieving 100% coverage is hard
Test coverage – tools

- Mutation testing and fault injection
  - Jester ([http://jester.sourceforge.net](http://jester.sourceforge.net))
  - PIT ([http://pitest.org/](http://pitest.org/))
  - Major ([http://mutation-testing.org/](http://mutation-testing.org/))
  - NinjaTurtles ([http://www.mutation-testing.net/](http://www.mutation-testing.net/))

- Coverage analysis
  - dotCover ([https://www.jetbrains.com/dotcover/](https://www.jetbrains.com/dotcover/))
  - Support in Visual Studio (Test Explorer)
Continuous integration

- Frequent merge, building, and test execution

- Travis CI ([https://travis-ci.org/](https://travis-ci.org/))
Other links

- Syslog

- DTrace
  - [http://dtrace.org/blogs/about/](http://dtrace.org/blogs/about/)

- JConsole

- Swiss Java Knife
  - [https://github.com/aragozin/jvm-tools](https://github.com/aragozin/jvm-tools)

- YouTrack
  - [https://www.jetbrains.com/youtrack](https://www.jetbrains.com/youtrack)

- JIRA
  - [https://www.atlassian.com/software/jira](https://www.atlassian.com/software/jira)
Homework

• Assignment
  - [http://d3s.mff.cuni.cz/~parizek/teaching/sdt/](http://d3s.mff.cuni.cz/~parizek/teaching/sdt/)

• Deadline