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, VisualVM, 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)
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
Modern logging frameworks

- Simple Logging Facade for Java (SLF4J)
  - General unified API for logging frameworks
  - Supported backends: Log4j, logback, ...
  - [http://www.slf4j.org/](http://www.slf4j.org/)

- Logback
  - Replacement for Log4j
  - Implements SLF4J API
  - [http://logback.qos.ch/](http://logback.qos.ch/)
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**
  - `/var/log/mail.log`

- **Apache**
  - `/var/log/httpd/httpd.log`

- **MySQL**
  - `/var/log/mysql.log`

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**Syslogd**
Syslog API: example

```
#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
VisualVM

- Download: [https://visualvm.github.io/](https://visualvm.github.io/)

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

- How to run it: `visualvm`

- Live demo
Monitoring tools for C#/.NET

- **.NET Memory Profiler**

- **dotMemory**
  - [https://www.jetbrains.com/dotmemory/](https://www.jetbrains.com/dotmemory/)
Windows Sysinternals

• Process Explorer
  - Displays information about running processes

• Process Monitor
  - 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
  - https://docs.oracle.com/en/java/javase/17/docs/specs/jvmti.html
- .NET Profiling API
- Valgrind: heavyweight dynamic binary translation
- DiSL (https://disl.ow2.org/bin/view/Main/)
Log analysis tools

• Elasticsearch + Logstash + Kibana (ELK stack)
  ▢ https://www.elastic.co/

• Azure Monitor (Application Insights)

• Prometheus: https://prometheus.io/

• Sentry: https://sentry.io/
Monitoring development process
Issue tracking systems

• Typically part of a project management system
  ▪ [https://github.com/](https://github.com/), [https://bitbucket.org/](https://bitbucket.org/)

• Popular systems
  ▪ Bugzilla, Trac, JIRA, YouTrack

• Issue = reported bug, feature request, other task

• Components
  ▪ Some database of known issues
  ▪ User interface (WWW, desktop)
Issue characteristics

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

New bug from a user with canconfirm or a product without UNCONFIRMED state.

UNCONFIRMED

Bug confirmed or receives enough votes.

NEW

Developer takes possession.

ASSIGNED

Development is finished with bug.

RESOLVED

QA not satisfied with solution.

REOPEN

Bug is reopened.

VERIFIED

Bug is closed.

CLOSED

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

- **Developer**
  - Entering new issues (bug reports)
  - Search for assigned tickets (issues)
  - Changing status of a specific ticket

- **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
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/))
  - JaCoCo ([https://www.eclemma.org/jacoco/](https://www.eclemma.org/jacoco/))
  - Support in Visual Studio (Test Explorer)
Continuous integration

- Frequent merge, building, and test execution

- Jenkins ([https://jenkins.io/](https://jenkins.io/))
- Travis CI ([https://travis-ci.org/](https://travis-ci.org/))

- GitLab CI/CD ([https://docs.gitlab.com/ee/ci/](https://docs.gitlab.com/ee/ci/))
- GitHub Actions ([https://github.com/features/actions](https://github.com/features/actions))
Other links

- Syslog

- DTrace
  - http://dtrace.org/blogs/about/

- Swiss Java Knife
  - https://github.com/aragozin/jvm-tools

- YouTrack
  - https://www.jetbrains.com/youtrack/

- JIRA
  - https://www.atlassian.com/software/jira
Homework

• Assignment
  ▪ http://d3s.mff.cuni.cz/files/teaching/nswi154/ukoly/

• Deadline
  ▪ 11.12.2022