Monitoring: Runtime Behavior & Software Development Process

Pavel Parízek
parizek@d3s.mff.cuni.cz
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
Layout

• 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

Apache

MySQL

Syslogd

/var/log/mail.log

/var/log/mysql.log

/var/log/httpd/httpd.log
Syslog API: example

```c
#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();
```
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

```c
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/

- 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/
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](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/](https://disl.ow2.org/bin/view/Main/))
Log analysis tools

- Elasticsearch + Logstash + Kibana (ELK stack)
  - [https://www.elastic.co/](https://www.elastic.co/)

- Azure Monitor (Application Insights)

- Prometheus: [https://prometheus.io/](https://prometheus.io/)

- Sentry: [https://sentry.io/](https://sentry.io/)
Monitoring development process
Issue tracking systems

- Typically part of a project management system
  - [https://github.com/](https://github.com/)
  - [https://www.gitlab.com/](https://www.gitlab.com/)
  - [https://bitbucket.org/](https://bitbucket.org/)

- Popular systems
  - [Bugzilla](https://www.bugzilla.org), 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)

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/](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)
  - Jumble (http://jumble.sourceforge.net/)
  - PIT (http://pitest.org/)
  - Major (http://mutation-testing.org/)
  - Nester (http://nester.sourceforge.net/)
  - NinjaTurtles (http://www.mutation-testing.net/)

- Coverage analysis
  - Cobertura (http://cobertura.sourceforge.net/)
  - Clover (http://www.atlassian.com/software/clover/)
  - dotCover (https://www.jetbrains.com/dotcover/)
  - JaCoCo (https://www.eclemma.org/jacoco/)
  - Support in Visual Studio (Test Explorer)
Continuous integration

- Frequent merge, building, and test execution
  - [https://martinfowler.com/articles/continuousIntegration.html](https://martinfowler.com/articles/continuousIntegration.html)
  - [https://www.atlassian.com/continuous-delivery/continuous-integration](https://www.atlassian.com/continuous-delivery/continuous-integration)

- 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

- Deadline
  - 12.5.2024