Dynamic Analysis

Software Reengineering
(COM3523 / COM6523)

The University of Sheffield

Lab follow-up

GitLab Login Difficulties

Tech support are currently investigating the log-in problems.

- Log-in appears to work for some students but not for others.

Ensure that you are using the correct GitLab server: stugitlab.dcs.shef.ac.uk

- Requires your university of sheffield login ID (e.g. ac1nw) and password.
- Requires VPN if used remotely.

Repository Mining Task

parent directory of zxing

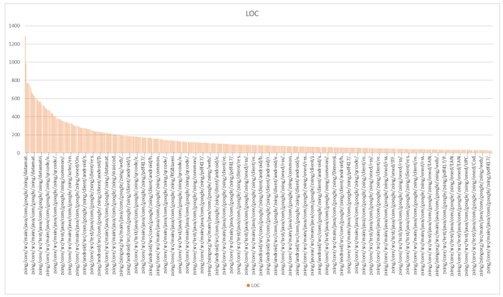
```
ac1nw@TENB88584C2F899 MINGW64 /u/Teaching/Reengineering/2022/practicals
$ reengineering-toolkit/reengineering-toolkit/src/main/scripts/repMining.sh zxing
```

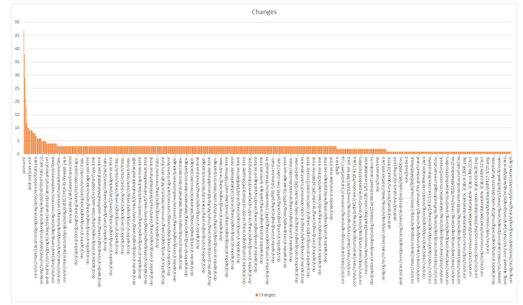
If it takes too long, pressing ctrl-C after a few minutes will produce a curtailed CSV file.

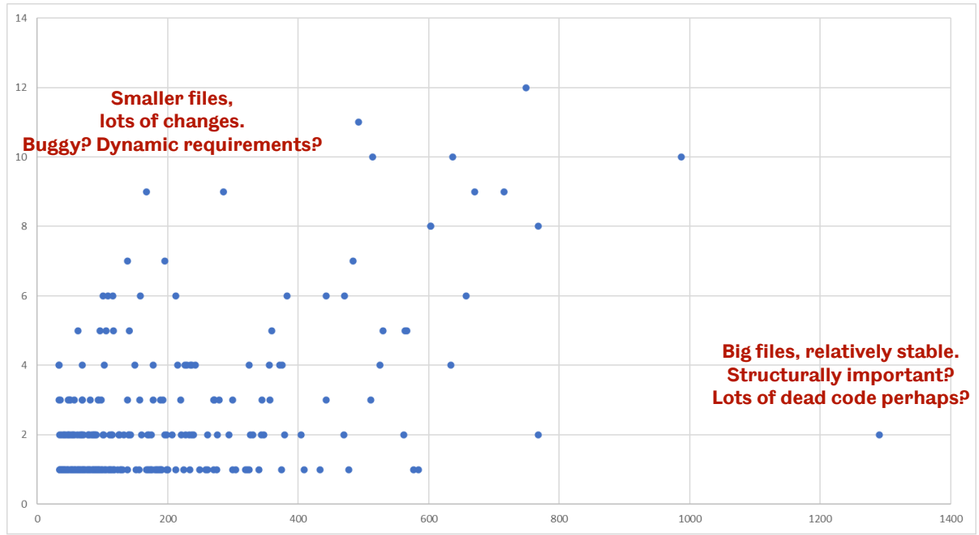
directory containing git repo

```
ac1nw@TENB88584C2F899 MINGW64 /u/Teaching/Reengineering/2022/practicals
$ reengineering-toolkit/reengineering-toolkit/src/main/scripts/listFileSizesForType.sh zxing '*.java' > zxingFileSizes.csv
```

pipe output to different csv file







Dynamic Analysis

The Problem with Static Analysis

Too much information.

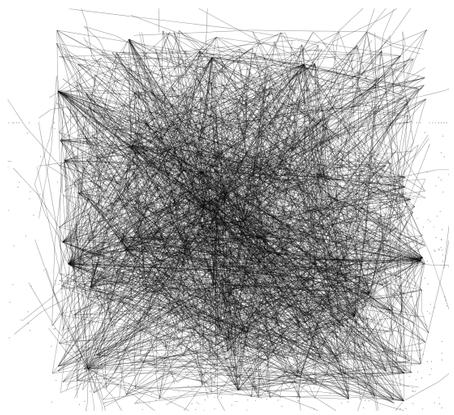
- ZXing contains >510 classes.
- What if we are only interested in a particular use-case?

Inherently **conservative**.

- Can produce lots of relations that are spurious or infeasible.
- E.g. - Produce method calls that are not possible for any actual program execution.

Many things are impossible to determine from source code analysis alone.

- Performance-related questions.
- Issues wrt. particular usage scenarios.



Call graph for Apache Commons Math.

Dynamic Analysis

Extracting information from **program executions**.

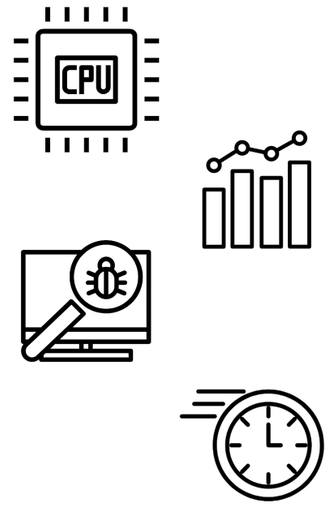
- Function calls, input-events, network-signals, ...
- Call stack depth, object states, output values, parameter inputs, memory usage, clock-time, etc.

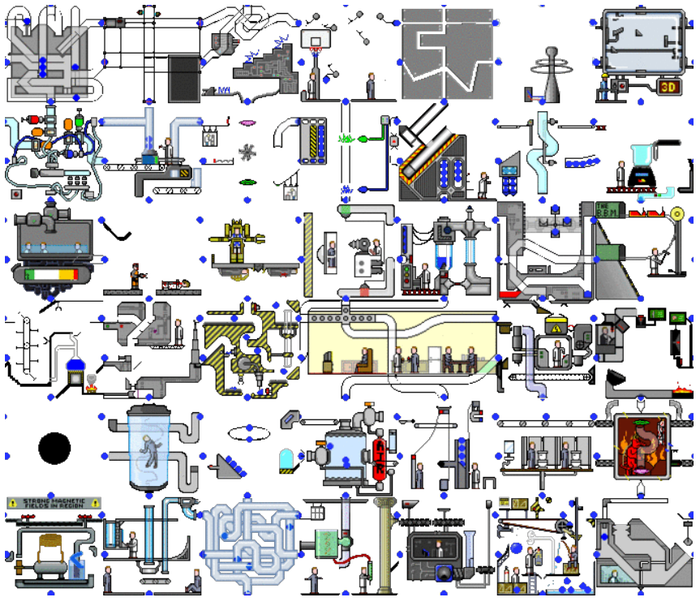
Provide information about "software behaviour".

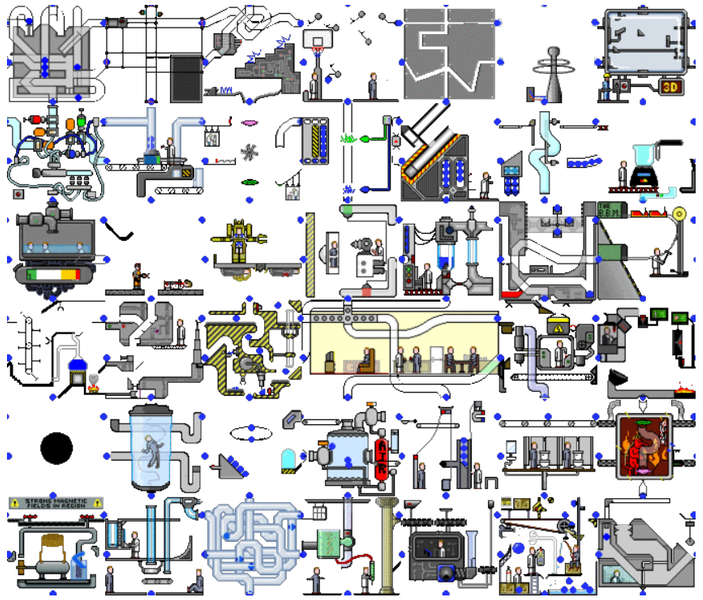
- Which elements are executed, when, for how long, ...

Common dynamic analyses:

- Testing
- Profiling
- Logging
- Debugging







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Execution Traces

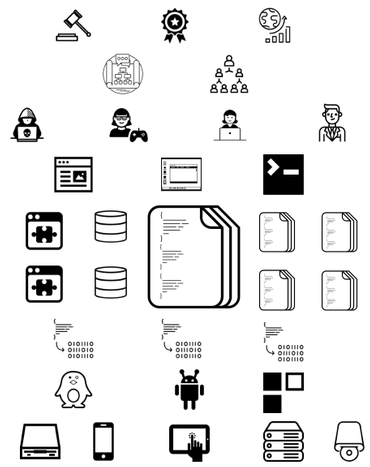
Making a “record” of an execution.

A trace is a collection of time-stamped data-points.

- Precise contents depend on the level at which the trace is collected.
- Can be at any level in the system - from hardware to business process.
- Commonly comprise an event (e.g. a method call), coupled with some data (e.g. system state information, performance data)

Can apply to distributed systems, or monolithic ones.

- Reasoning about order of trace-elements becomes harder in distributed / concurrent systems.



Loggers

Tools to automate the collection of runtime data.

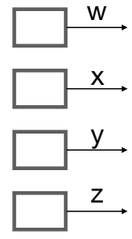
- Need a better alternative than System.out.println(...)!

Can specify:

- **Where** information is funnelled - console, file, database, ...
  - *Logging instructions tend to be inserted into code by developers.*
- **When** logging occurs - for info, debugging, errors,...
- **How** information is presented / formatted.

Lots of logging frameworks

- java.util.logging, slf4j, log4j, ...



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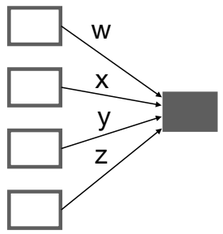


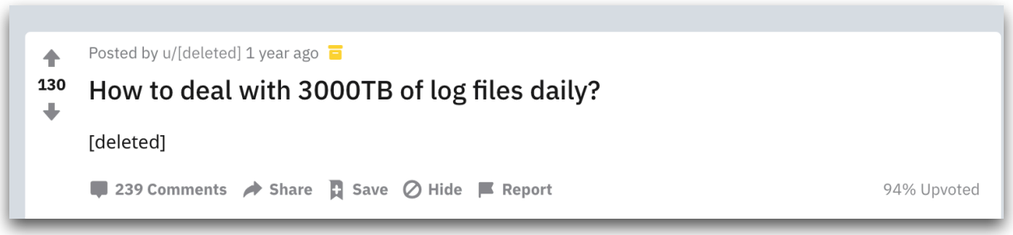
Precision is important

The size of a trace file is impossible to predict in general.

See “Halting Problem”.

Large traces are harder to analyse and manage.

Important to be selective about where, when and what to log.



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Automatically instrumenting code	🙂	🤩	🤨	🤨

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Using dTrace or bTrace to record OS-level events	🙂	🤨	🙂	🤨
Automatically instrumenting code	🙂	🤩	🤨	🤨
Recording inputs and outputs - truly "black-box"	🤩	🤨	🤩	🤩

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Examples:

- Time-sensitive programs - dynamic analysis can slow the program down.
- Programs that rely on disk access - trace storage can interfere with this.
- Programs that rely on compiler optimisations - trace instrumentation can alter the optimisations,
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Relationship to Static Analysis

Static analysis:

Conservative - considers every possible (and many impossible) executions.

Imprecise (e.g. lots of redundant calls in a call graph).

Sound. Every possible call is in the call graph.

Dynamic analysis:

Partial - only considers a single execution.

Precise - it it occurs in the trace it **must** be possible.

Unsound - observations may not generalise to **every** execution.

Ernst, Michael D. "Static and dynamic analysis: Synergy and duality." *WODA 2003: ICSE Workshop on Dynamic Analysis*. 2003.

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Automatically Instrumenting Java Code

Aspect-Oriented Programming

A way to modularise software in terms of **"cross-cutting concerns"**.

Motivated by the high amount of duplicate code in systems.

Capture code that deals with a particular 'aspect' (known as an **"advice"**).

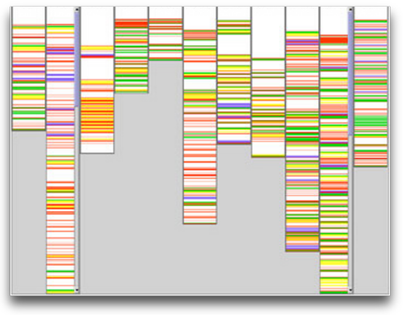
Fragment of code to be used throughout a program.

E.g. File-handling, data-base management, logging...

Advice is **"woven"** into software execution via **"join points"**.

E.g. method entry or exit points, field accesses, etc.

A specification that links advice to a join-point is known as a **"point cut"**.



Cross-cutting concerns from a 19k component. (from Bruntink, van Duersen and Tourwé)

Using Transformer Agents

There are many dedicated Aspect-Oriented Programming Libraries that could be used.

- AspectJ is one of the main ones for Java.
- Too heavyweight.

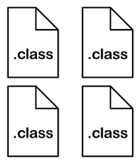
Java includes the ability to write “Transformers” that modify classes during execution.

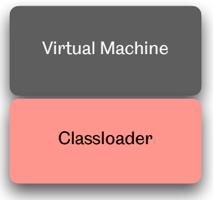
- Provide the infrastructure to implement basic aspect-oriented concepts, including automated logging.

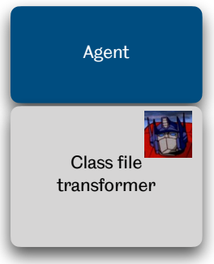
Deployed as “agents”.

- “Attached” to a Java program when it is run, have the ability to alter a class when it is loaded.

How it works







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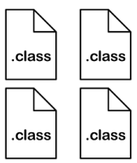

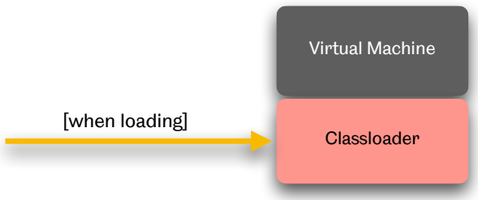

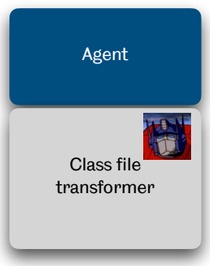

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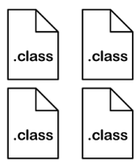

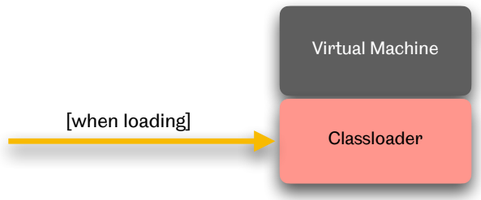

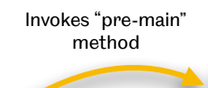

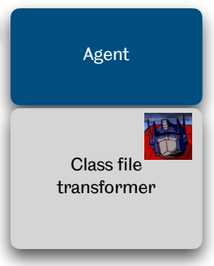

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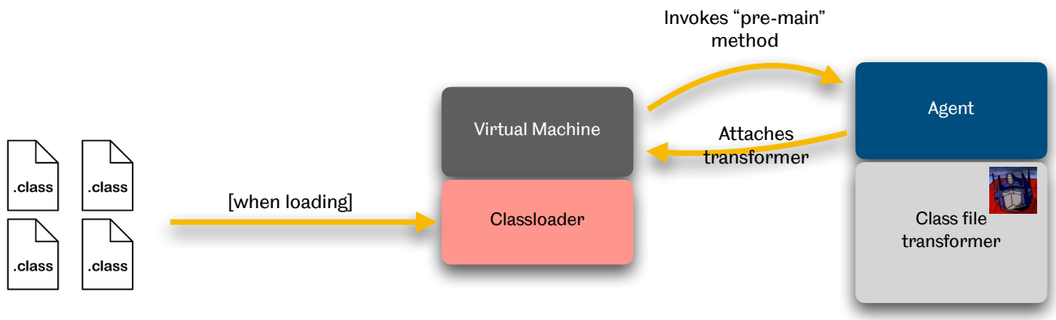

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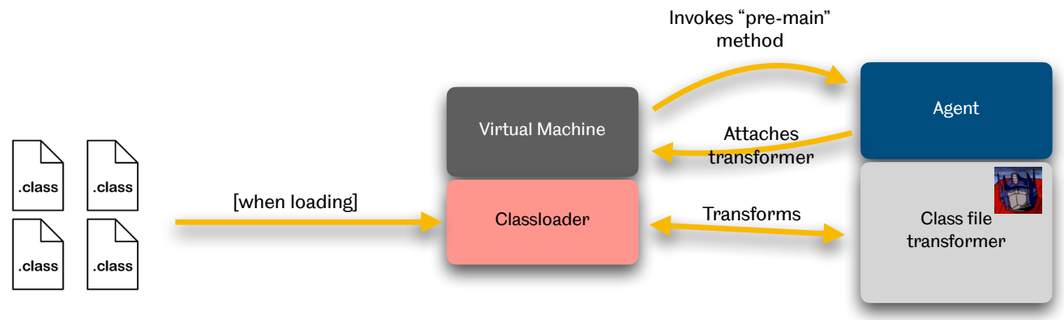

Demo

Key Takeaways

Dynamic analysis is the process of recording runtime data.

Commonly operates on “execution traces”.

- Recordings of software executions, captured as sequences of events.

Can be much more precise than static analysis, but can also be less sound.

- Relies on the analyst “covering” all of the relevant software behaviour.

Traces can be very large.