Configuration Management

Markus Raab

Institute of Information Systems Engineering, TU Wien

16.3.2018

Organization

Next lectures:

16.3.2018: **topic homework and talk (GitHub account!)**

23.3.2018: teams found together

13.4.2018: homework submitted, topics of team exercise

20.4.2018: no lecture

18.5.2018: guest lecture

25.5.2018: team exercise submitted

22.6.2018: last corrections of team exercise

Popular Topics

- 4 validation
- 4 user interface
- 3 tools (benefits?)
- 3 testability
- 3 complexity reduction (when conf. needed?)
- 3 architectural decisions
- 2 Puppet
- 2 modularity
- 2 environment variables
- 2 documentation

- 2 configuration specification
- 2 command-line args
- 2 code generation
- 1 variability
- 1 self-description
- 1 round-tripping
- 1 introspection
- 1 early
- 1 dependences
- 1 context-awareness
- 1 auto-detection
- 1 administrators
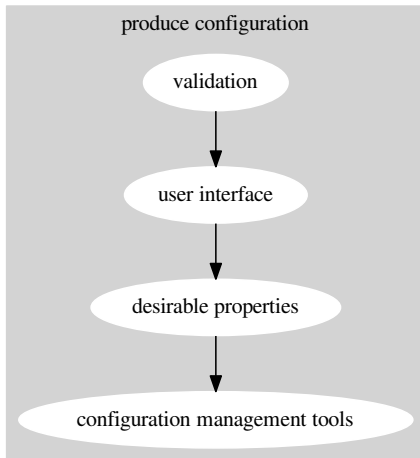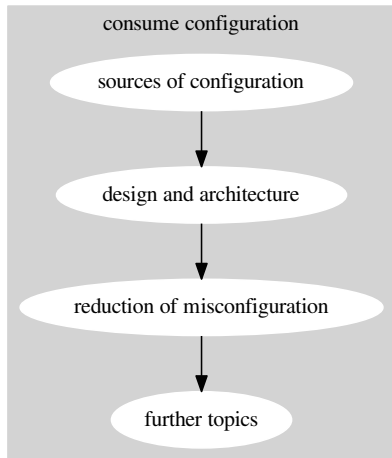
Complexity

Trend Firefox

Complexity
○●○○○○○○○○○○○○

Configuration Specification
○○○○○○○○○○○○○○○○○○○○

Architectural Decisions

Trend

Trend Chromium

Complexity
00●00000000000

Configuration Specification
0000000000000000000

Architectural Decisions
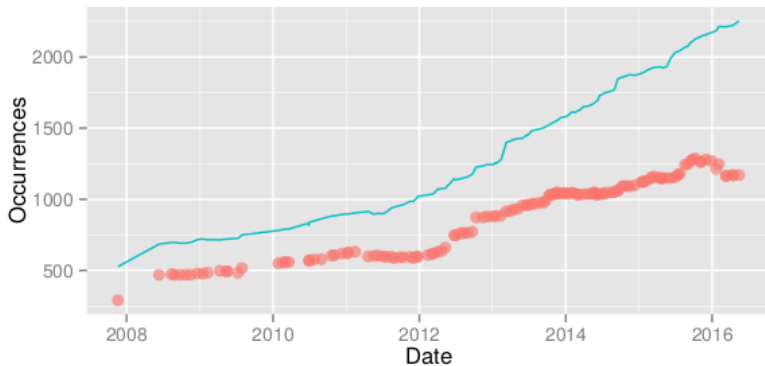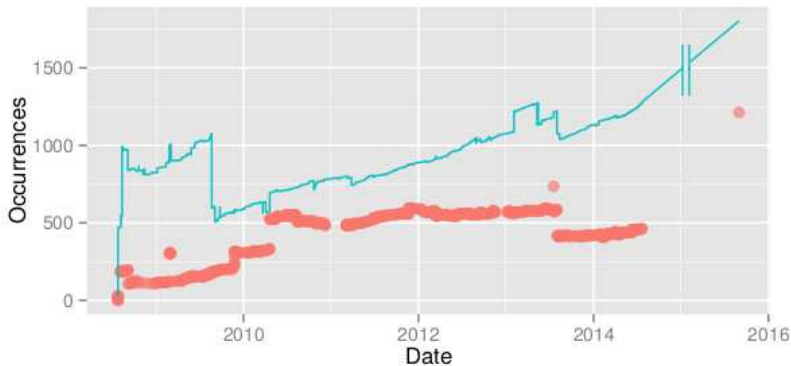
Trend

Trend Configuration Files
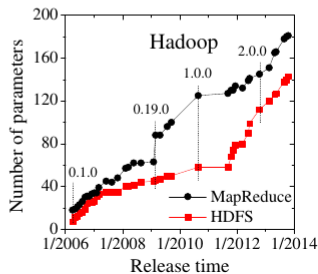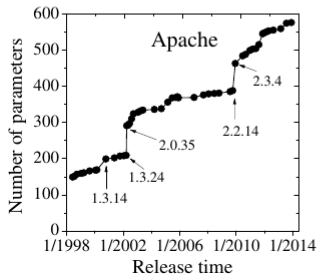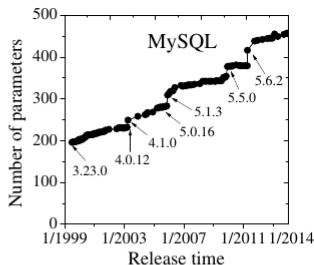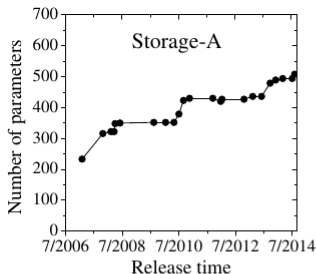
Xu et al. [8]

Types of Complexity

- complexity in access:
    - many different formats
    - non-uniformity
    - transformations
- configuration settings
    - number of settings s
    - number of values n
    - dependences between settings

Calculation of Complexity

Using enumerative combinatorics:

- number of configurations: n^s
- for N groups of different n and s (i.e., $n_1 \ldots n_N$ with $s_1 \ldots s_N$ occurrences):

$$\prod_{i=1}^{N} n_i^{s_i}$$

- more difficult to calculate (or unbounded) for dependences, module instantiations, arrays, ...

Calculation of Complexity

Examples:

- 600 boolean settings in Apache httpd (let us assume $n = 2$):

Calculation of Complexity

Examples:

- 600 boolean settings in Apache httpd (let us assume $n = 2$):
  $2^{600} \approx 10^{180}$

- 19 integer settings:

Complexity
⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤

Configuration Specification
○○○○○○○○○○○○○○○○○○

Architectural Decisions

Calculation

Calculation of Complexity

Examples:

- 600 boolean settings in Apache httpd (let us assume $n = 2$): $2^{600} \approx 10^{180}$
- 19 integer settings: $2^{32^{19}} = 2^{32 \cdot 19} = 2^{609} \approx 10^{183}$
- 2000 boolean settings in Firefox [4]:

Calculation of Complexity

Examples:

- 600 boolean settings in Apache httpd (let us assume $n = 2$): $2^{600} \approx 10^{180}$

- 19 integer settings: $2^{32^{19}} = 2^{32 \cdot 19} = 2^{609} \approx 10^{183}$

- 2000 boolean settings in Firefox [4]: $2^{2000} \approx 10^{602}$

Complexity
○○○○○○○●○○○○○○○

Configuration Specification
○○○○○○○○○○○○○○○○○○

Architectural Decisions

Calculation

Calculation of Complexity (cont.)

Examples:

- for 20 boolean and 20 enums with 5 possibilities:

---

[1]https://downloads.mysql.com/docs/refman-5.7-en.pdf

Complexity
○○○○○○○●○○○○○○○

Configuration Specification
○○○○○○○○○○○○○○○○○○

Architectural Decisions

Calculation

Calculation of Complexity (cont.)

Examples:

- for 20 boolean and 20 enums with 5 possibilities:

$$2^{20} * 5^{20} = 10^{20}$$

- MySQL has 461 settings, of which 216 are non-simple types [8] (let us assume $n = \{3, 20\}$):

---

[1] https://downloads.mysql.com/docs/refman-5.7-en.pdf

Complexity
⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤

Configuration Specification
⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤⬤

Architectural Decisions

Calculation

Calculation of Complexity (cont.)

Examples:

- for 20 boolean and 20 enums with 5 possibilities:

$$2^{20} * 5^{20} = 10^{20}$$

- MySQL has 461 settings, of which 216 are non-simple types [8]
  (let us assume $n = \{3, 20\}$): $3^{245} * 20^{216} \approx 10^{397}$
  (settings are explained in 5560 pages[1])

- an array with $1 - 20$ boolean settings:

---

[1]https://downloads.mysql.com/docs/refman-5.7-en.pdf

Calculation of Complexity (cont.)

Examples:

- for 20 boolean and 20 enums with 5 possibilities:

$$2^{20} * 5^{20} = 10^{20}$$

- MySQL has 461 settings, of which 216 are non-simple types [8] (let us assume $n = \{3, 20\}$): $3^{245} * 20^{216} \approx 10^{397}$ (settings are explained in 5560 pages[1])

- an array with $1 - 20$ boolean settings: 2^{20}

---

[1] https://downloads.mysql.com/docs/refman-5.7-en.pdf

Task

Calculate complexity for some tool you know.

Task

Possible Homework: Write tool to calculate complexity with a given configuration specification.

Decision Tree

- configuration settings may depend on each other
- form a decision tree [1, 7]
- the decision tree is an instantiation of chosen configuration settings
- calculation only needs to consider instantiations which make a difference:
  essential configuration complexity [5]

Harmful Defaults [8]

- Problem: Two major data losses on a dozen machines.
- Cause: Stayed with the default values of the data-path settings (e.g., dfs.name.dir, dfs.data.dir) which point to locations in /tmp. Thus, after the machines reboot, data losses occur. "One of the common problems from users." (from Cloudera)
- up to 53 % of misconfigurations is due to staying at defaults
- 17 % to 48 % of configuration issues are about difficulties in finding settings

Unnecessary Settings [8]

- Configuration Parameter:
  dfs.namenode.tolerate.heartbeat.multiplier
- Developers' Discussion: Since we are not sure what is a good choice, how about making it configurable? We should add a configuration option for it. Even if it's unlikely to change, if someone does want to change it they'll thank us that they don't have to change the code/recompile to do so.
- Real-World Usage:
  - No usage found by searching the entire mailing lists and Google.
  - No usage reported in a survey of 15 Hadoop users in UCSD.

Unnecessary Settings [8]

- 6 % to 17 % of settings set by majority
- up to 54 % are seldom set
- up to 47 % of numeric settings have no more than five distinct values

Usage
Reduction

Q: "Why do you think configuration should be reduced?"

- to simplify code maintenance (50 %),
- to prevent errors and misconfiguration (43 %),
- to provide better user experience (40 %),
- *"I do not think it should be reduced"* (30 %),
- because they prefer auto-detection (29 %)
  (with a possibility to override configuration settings: 32 %),
- *"because use-cases which are rarely used should not be supported"* (13 %),
- *"never find time for this task"* (9 %), and
- *"because only standard use-cases should be supported"* (1 %)

Complexity
○○○○○○○○○○○○○○○●

Configuration Specification
○○○○○○○○○○○○○○○○○○

Architectural Decisions

Usage

Question

How to specify reduction strategies of configuration settings?

Complexity
○○○○○○○○○○○○○●

Configuration Specification
○○○○○○○○○○○○○○○○○

Architectural Decisions

Usage

Question

How to specify reduction strategies of configuration settings?

Answer

Configuration Specification

Configuration Specification

Rationale

- without specification you and others do not even know which settings are available
- needed for any further techniques we will discuss

Rationale

- without specification you and others do not even know which settings are available
- needed for any further techniques we will discuss
- essential for *no-futz computing* Holland et al. [3]
- the foundation for any advanced tooling like configuration management tools

Rationale

- without specification you and others do not even know which settings are available

- needed for any further techniques we will discuss

- essential for *no-futz computing* Holland et al. [3]

- the foundation for any advanced tooling like configuration management tools

- needed as communication of producers and consumers of configuration

Task

Brainstorming: What can be part of a configuration specification?

Task

Advantages/Disadvantages?

Task

Alternatives?

Q: "Configuration specification (e.g. XSD/JSON schemas) allows you to describe possible values and their meaning. Why do/would you specify configuration?"

- 58 % for "looking up what the value does",
- 51 % it helps users to avoid common errors ("so that users avoid common errors"),
- 46 % to simplify maintenance,
- 40 % for rigorous validation,
- 39 % for documentation generation (for example, man pages, user guide),
- 30 % for external tools accessing configuration,
- 28 % for generating user interfaces,
- 25 % for code generation, and
- 24 % for specification of links between configuration settings.

Limitations of Schemata designed for Data

- like XSD/JSON schemas
- they are already very helpful but:

Limitations of Schemata designed for Data

- like XSD/JSON schemas
- they are already very helpful but:
- not key-value based
- not easy to introspect
- designed to validate data without semantics:
  file path vs. presence of file
- not always possible to extend with plugins
- tied to specific formats (e.g. XML/JSON)

Limitations of Zero-Configuration

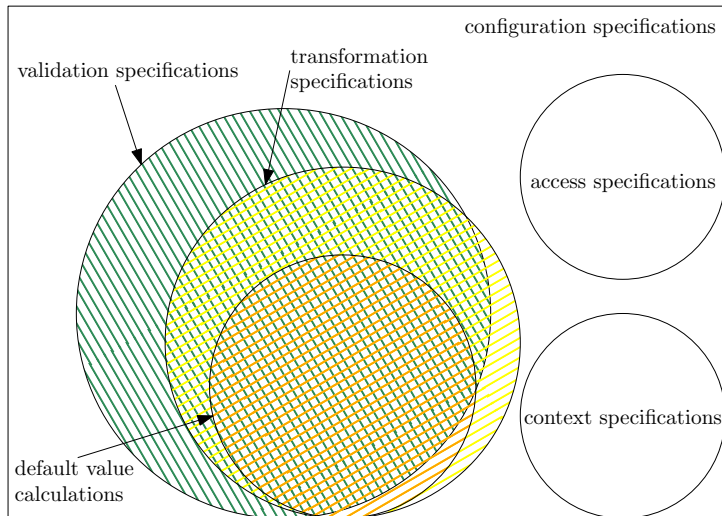- e.g. gpsd[1]

---

[1] www.aosabook.org/en/gpsd.html

Why?

Limitations of Zero-Configuration

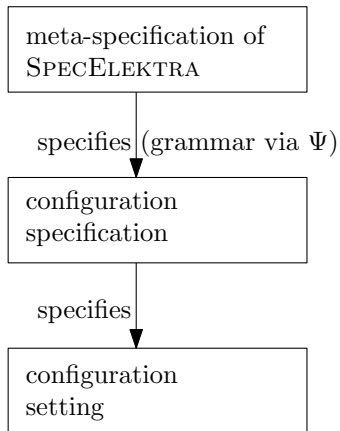- e.g. gpsd[1]
- broken hardware or protocols
- auto-detection may go wrong
- the configuration actually lives elsewhere
  (e.g., in the GPS devices)

---
[1]www.aosabook.org/en/gpsd.html

Types of Specifications

Metalevels

Task

What do we mean with a configuration specification?

Task

Which requirements do we have for a configuration specification?

Requirements

- formal/informal?
- complete?

Requirements

- formal/informal?
- complete?
- should be extensible
- should be external to application
- open for introspection (for tooling)
- should talk to users
- should allow generation of artefacts

Grammar

$\langle$ configuration specifications $\rangle$ ::= { $\langle$ configuration specification $\rangle$ }

$\langle$ configuration specification $\rangle$ ::= '[' $\langle$ key $\rangle$ ']' $\langle$ properties $\rangle$

$\langle$ properties $\rangle$ ::= { $\langle$ property $\rangle$ }

$\langle$ property $\rangle$ ::= $\langle$ property name $\rangle$ ':=' [$\langle$ property value $\rangle$]

Complexity
○○○○○○○○○○○○○○
Configuration Specification
○○○○○○○○○○○●○○○○○○○
Architectural Decisions

How?

Example

```
1 [slapd/threads/listener]
2 default := 1
3 type := int
```

Visibility

- idea: show only relevant settings for specific user group
- or disallow editing: accessibility

Visibility

- idea: show only relevant settings for specific user group
- or disallow editing: accessibility
- requires user-feedback loops [8]
- most-used settings should be best visible (or even enforce them to be changed: against harmful defaults)
- think of your users (administrators), only expose what users need
- write an rationale why someone needs it

Example

```
1 [slapd/threads/listener]
2 visibility := developer
3
4 [slapd/access/#]
5 visibility := user
```

Task

Brainstorming: Now, how do we implement such a specification?

Implementations

For example:

- generate examples/documentation
- auto-completion/syntax highlighting/IDE support
- tooling (GUI, Web UI)
- validate configuration files
- visudo-like
- plugins in configuration framework

- idea: make default value better
- is the generalization of sharing configuration values
- can be combined with visibility

- idea: make default value better
- is the generalization of sharing configuration values
- can be combined with visibility
- can be derived from other configuration settings
- can be derived from context [6]
- can be derived from hardware/system (problem with dependences)

- idea: make default value better
- is the generalization of sharing configuration values
- can be combined with visibility
- can be derived from other configuration settings
- can be derived from context [6]
- can be derived from hardware/system (problem with dependences)
- XServer vs. gpsd

Examples

Sharing:

```
1 [slapd/threads/listener]
2 fallback/#0 := slapd/threads
```

Percentages
(e.g., configured image should be additionally cropped):

Examples

Sharing:

```
1 [slapd/threads/listener]
2 fallback/#0:=slapd/threads
```

Percentages
(e.g., configured image should be additionally cropped):

```
1 [image/width]
2 type:=int
3
4 [crop]
5 type:=int
6 check/range:=0-100
```

Examples

Context:

```
1 [slapd/threads/listener]
2 context:=/slapd/threads/%cpu%/listener
```

Calculation with Context
(e.g., switch off GPS if battery low):

Examples

Context:

```
1 [slapd/threads/listener]
2 context:=/slapd/threads/%cpu%/listener
```

Calculation with Context
(e.g., switch off GPS if battery low):

```
1 [gps/status]
2 assign:=(battery > 'low') ? ('on') : ('off')
```

Architectural Decisions

Software Architecture

- architecture is high-level description of the overall system
- use ready-made patterns and templates for architecture

Software Architecture

- architecture is high-level description of the overall system
- use ready-made patterns and templates for architecture
- e.g., http://arc42.org/
- architectural decisions [2] essential (e.g., Chapter 9 in arc42)

Architectural Decisions

- describe decisions that lead to the architecture
- open decisions are high-level configuration
- useful to have patterns [2] and templates, too
- template: problem, constraints, assumptions, considered alternatives, decision, rationale, implications, related, notes

Why are configuration settings added?

Why are configuration settings added?

The typical reasons are:

1. a requirement,
2. an architectural decision,
3. a technical need, and
4. an ad hoc decision.

in Configuration Specification

```
1 [slapd/threads/listener]
2 description := adjust to use more threads
3 rationale := needed for many-core systems
4 requirement := 1234
5 visibility := developer
```

Conclusion

- alarming trend in number and complexity of configuration settings
- sharing, visibility and default value calculation often helps
- needs abstraction: configuration specification
- but also more courageous decisions and periodical reevaluation
- different ways to reduce configuration space

[1] Krzysztof Czarnecki, Paul Grünbacher, Rick Rabiser, Klaus Schmid, and Andrzej Wąsowski. Cool features and tough decisions: A comparison of variability modeling approaches. In *Proceedings of the Sixth International Workshop on Variability Modeling of Software-Intensive Systems*, VaMoS '12, pages 173–182, New York, NY, USA, 2012. ACM. ISBN 978-1-4503-1058-1. doi: $10.1145/2110147.2110167$. URL http://dx.doi.org/10.1145/2110147.2110167.

[2] Neil B Harrison, Paris Avgeriou, and Uwe Zdun. Using patterns to capture architectural decisions. *Software, IEEE*, 24(4):38–45, 2007. ISSN 0740-7459. doi: $10.1109/MS.2007.124$.

[3] David A. Holland, William Josephson, Kostas Magoutis, Margo I. Seltzer, Christopher A. Stein, and Ada Lim. Research issues in no-futz computing. In *Hot Topics in Operating Systems, 2001. Proceedings of the Eighth Workshop on*, pages 106–110. IEEE, May 2001. doi: 10.1109/HOTOS.2001.990069.

[4] Dongpu Jin, Xiao Qu, Myra B. Cohen, and Brian Robinson. Configurations everywhere: Implications for testing and debugging in practice. In *Companion Proceedings of the 36th International Conference on Software Engineering*, ICSE Companion 2014, pages 215–224, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2768-8. doi: 10.1145/2591062.2591191. URL http://dx.doi.org/10.1145/2591062.2591191.

[5] J. Meinicke, C. P. Wong, C. Kästner, T. Thüm, and G. Saake. On essential configuration complexity: Measuring interactions in highly-configurable systems. In *2016 31st IEEE/ACM International Conference on Automated Software Engineering (ASE)*, pages 483–494, Sept 2016.

[6] Markus Raab and Gergö Barany. Introducing context awareness in unmodified, context-unaware software. In *Proceedings of the 12th International Conference on Evaluation of Novel Approaches to Software Engineering - Volume 1: ENASE,*, pages 218–225. INSTICC, ScitePress, 2017. ISBN 978-989-758-250-9. doi: 10.5220/0006326602180225.

[7] Mark-Oliver Reiser. *Core Concepts of the Compositional Variability Management Framework (CVM): A Practitioner's Guide*. TU, Professoren der Fak. IV, 2009.

[8] Tianyin Xu, Long Jin, Xuepeng Fan, Yuanyuan Zhou, Shankar Pasupathy, and Rukma Talwadker. Hey, you have given me too many knobs! Understanding and dealing with over-designed configuration in system software. In *Proceedings of the 2015 10th Joint Meeting on Foundations of Software Engineering*, ESEC/FSE 2015, pages 307–319, New York, NY, USA, 2015. ACM. ISBN 978-1-4503-3675-8. doi: 10.1145/2786805.2786852. URL http://dx.doi.org/10.1145/2786805.2786852.