Configuration Management

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Lecture is every week Wednesday 09:00 - 11:00.

06.03.2019:	topic, teams
13.03.2019:	TISS registration, initial PR
20.03.2019:	other registrations, guest lecture
27.03.2019:	PR for first issue done, second started, HS: kleiner Schiffbau
03.04.2019:	first issue done, PR for second
10.04.2019:	mid-term submission of exercises
08.05.2019:	(HS?)
15.05.2019:	
22.05.2019:	
29.05.2019:	
05.06.2019:	final submission of exercises
12.06.2019:	
19.06.2019:	last corrections of exercises
26.06.2019:	exam

Popular Topics

14	tools
9	testability
9	code-generation
7	context-awareness
6	specification
6	misconfiguration
6	complexity reduction
5	validation
5	points in time
5	error messages
5	auto-detection
4	user interface
4	introspection
4	design
4	cascading
4	architecture of access
3	configuration sources
3	config-less systems
2	secure conf
2	architectural decisions
1	push vs. pull
1	infrastructure as code
1	full vs. partial
1	convention over conf
1	CI/CD
0	documentation

Tasks for today

(until 27.03.2019 23:59)

Task

Description of homework as pull request in private repo. (Inside a folder for you, use GitHub name.)

Task

Description of teamwork (which application, which CM tool) as pull request in private repo. (Inside a folder for your team.)

Task

Fix at least one issue and write some text in at least one other issue.

Slides

- slide numbering: 02a is after 02
- old slides in same repo: always check date

Some misconfigurations

- studycode is Studienkennzahl
- same name twice in TALKS.xml
- ...

Task

How did these misconfigurations happened?

Tasks for next week

(until 03.04.2019 23:59)

Task

Fix misconfigurations in private repo.

Task

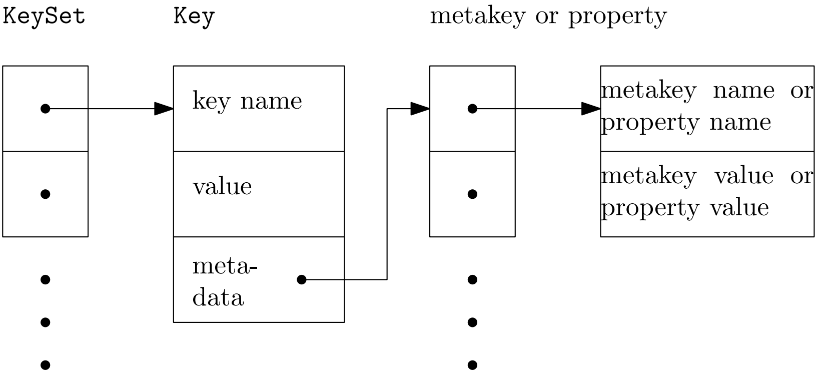
Fix feedback about homework/teamwork. Calculate complexity of your teamwork.

Task

First issue done, PR for second issue and write some text in at least one other issue (if 5 issues are not yet assigned to you).

KeySet (Recapitulation)

The common data structure between plugins:


KeySet
Key
metakey or property
key name
value
meta-data
metakey name or property name
metakey value or property value

Recapitulation

Q: "Which configuration systems/libraries/APIs have you already used or would like to use in one of your FLOSS project(s)?"

- command-line arguments (92 %, $n = 222$)
- environment variables (79 %, $n = 218$)
- configuration files (74 %, $n = 218$))

Semantics of Command-line Arguments (cont.)

- passed by main for a new process via `(int argc, char ** argv)`
- visible from other processes (e.g., via `ps aux`)
- could be passed along to subprocesses but hardly done
- need to be parsed by process
- portability: differences in parsing
- cannot be changed from outside (requires restart, no IPC)

Environment Variables

1. Environment Variables
   - Requirements
   - Conclusion
2. Complexity
   - Trend
   - Calculation
   - Usage
3. Configuration Specification
   - Why?
   - How?
   - Examples
   - Calculate Default Values
4. Architectural Decisions

Semantics

- are also per-process (`/proc/self/environ`)
- are not visible from other processes
- are automatically inherited by subprocesses
- need to be parsed by process (`[extern] char **environ`) but API is provided (`getenv`)
- cannot be changed from outside (requires restart or an additional IPC mechanism)

getenv

- is widely standardized, including SVr4, POSIX.1-2001, 4.3BSD, C89, C99 [1],
- is supported by many programming languages, and
- enforces `key=value` convention.

Usage

1. bypassing other configuration accesses (*Q:* 45 %)
2. locating configuration files
3. debugging and testing (*Q:* 55 %, *S:* 1,152, i. e. 43 %)
4. sharing configuration settings across applications (*Q:* 53 %, *S:* 716, i. e. 47 %)
5. for configuration settings unlikely to be changed by a user (*Q:* 20 %)
6. *"even when it is used inside a loop"* (*Q:* 2 %)

Portability

- no separators for values defined
- case sensitivity problems
- often many environment variables for the same purpose: TMP, TEMP, or TMPDIR
- sometimes one environment variable for different purposes: PATH

Task

What is wrong with the code in the book?

How can we deal with the many sources?

Requirement

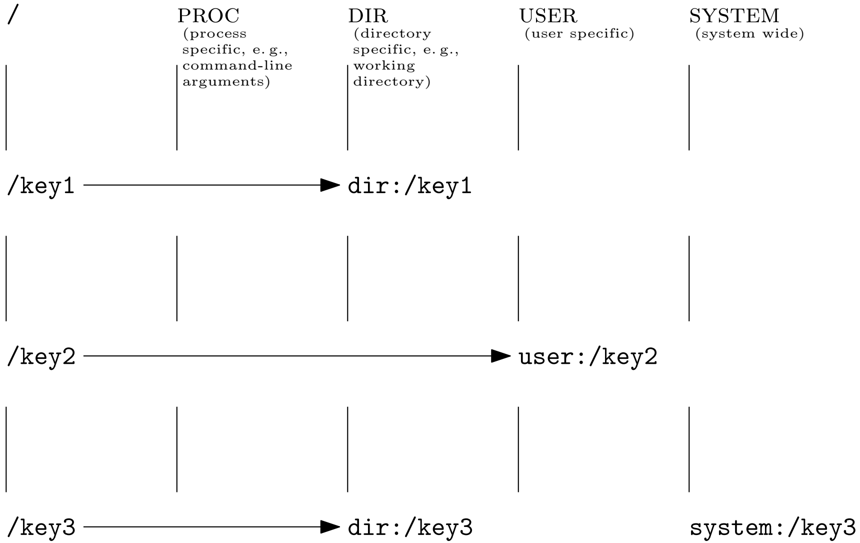
A configuration library must support all three popular ways for configuration access: configuration files, command-line options, and environment variables.

Example: Elektra

- includes library libopts
- which provides the function
  `int elektraGetOpts (KeySet, argc, argv, environ, Key)`
- which puts `Keys` in the `proc` namespace
- `https://www.libelektra.org/tutorials/command-line-options`

What is a namespace?

Cascading


/
PROC
(process specific, e. g., command-line arguments)
DIR
(directory specific, e. g., working directory)
USER
(user specific)
SYSTEM
(system wide)
/key1
dir:/key1
/key2
user:/key2
/key3
dir:/key3
system:/key3

Task

Discuss the differences of mounting and cascading with your neighbor.

User View

- command-line for trying out configuration settings
- environment variables for configuration settings within a shell
- configuration files for persistent configuration settings

Conclusion

- three different configuration sources widely used
- all three used for different reasons but often for the same configuration settings
- many different configuration file formats
- abstractions: key-value, mounting, and cascading

Complexity

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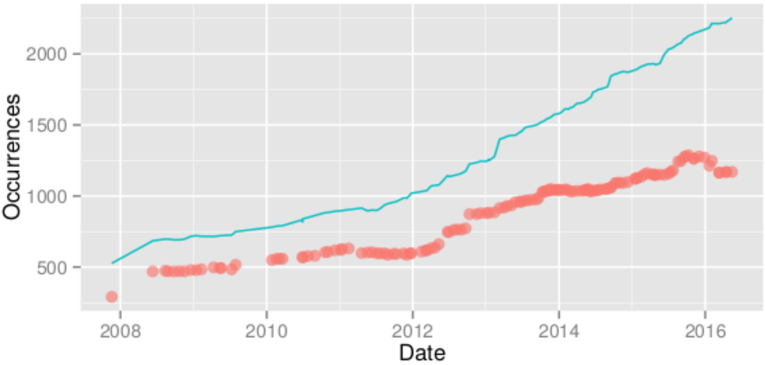
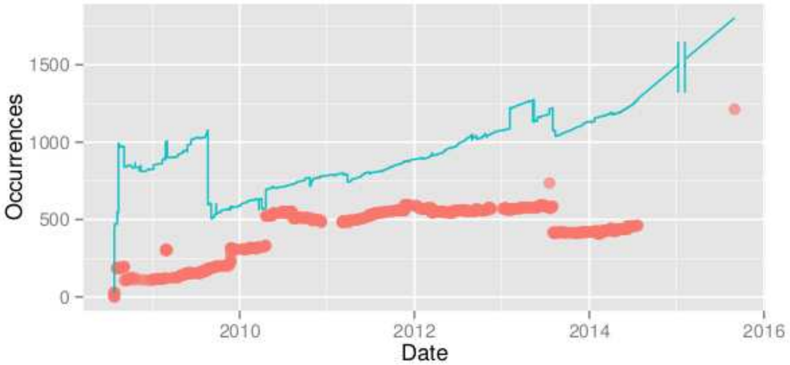
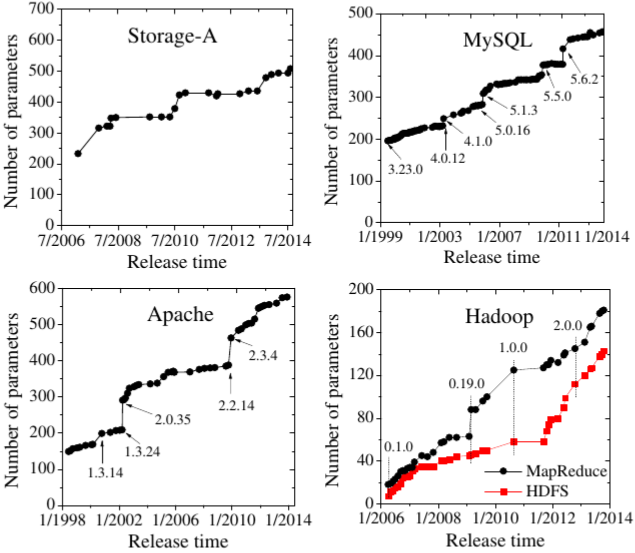
Trend Firefox



Trend Chromium



Trend Configuration Files



Xu et al. [9]

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., $n_1 \dots n_N$ with $s_1 \dots s_N$ 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 $n = 2$): $2^{600} \approx 10^{180}$
- 19 integer settings: $2^{32^{19}} = 2^{32 \cdot 19} = 2^{609} \approx 10^{183}$
- 2000 boolean settings in Firefox [5]: $2^{2000} \approx 10^{602}$

Task

Break.

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 [9] (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 of your teamwork and add to PR.

See scripts/complexity.rb

Decision Tree

- configuration settings may depend on each other
- form a decision tree [2, 8]
- the decision tree is an instantiation of chosen configuration settings
- calculation only needs to consider instantiations which make a difference:
  essential configuration complexity [6]

Harmful Defaults [9]

- 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 [9]

- 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 [9]

- 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

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 %)

Question

How to specify reduction strategies of configuration settings?

Answer

Configuration Specification

Configuration Specification

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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. [4]
- 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

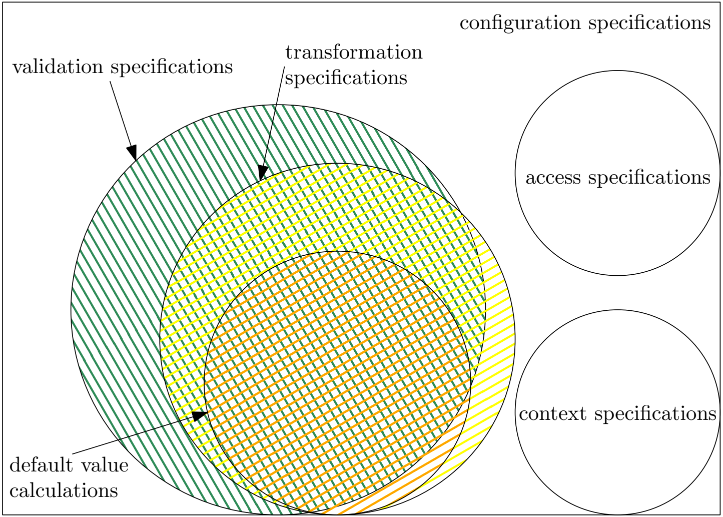
- like XSD/JSON schemas
- they are already very helpful but:
    - not key-value based
    - not easy to introspect
    - designed to validate data without semantics: file path vs. presence of file
    - not always possible to extend with plugins
    - tied to specific formats (e.g. XML/JSON)

Limitations of Zero-Configuration

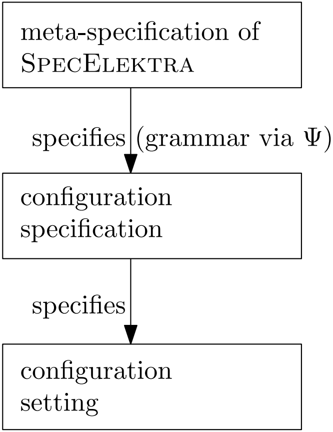
- e.g. gpsd[1]
- broken hardware or protocols
- auto-detection may go wrong
- the configuration actually lives elsewhere (e.g., in the GPS devices)

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

Types of Specifications


configuration specifications
validation specifications
transformation specifications
access specifications
context specifications
default value calculations

Metalevels



meta-specification of SpecElektra

specifies (grammar via Ψ)

configuration specification

specifies

configuration setting

Task

What do we mean with a configuration specification?

Task

Which requirements do we have for a configuration specification?

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

⟨*configuration specifications*⟩ ::= { ⟨*configuration specification*⟩ }

⟨*configuration specification*⟩ ::= '[' ⟨*key*⟩ ']' ⟨*properties*⟩

⟨*properties*⟩ ::= { ⟨*property*⟩ }

⟨*property*⟩ ::= ⟨*property name*⟩ ':=' [⟨*property value*⟩]

Example

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

Options

Environment and command-line options can be considered with:

```
[recursive]
  type:=boolean
  opt:=r
  opt/long:=recursive
  env:=RECURSIVE
  default:=0
```

Visibility

- idea: show only relevant settings for specific user group
- or disallow editing: accessibility
- requires user-feedback loops [9]
- 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

```
[slapd/threads/listener]
visibility:=developer

[slapd/access/#]
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

Calculate Default Values

- 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 [7]
- can be derived from hardware/system (problem with dependences)
- XServer vs. gpsd

Examples

Sharing:

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

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

```
[image/width]
type:=int

[crop]
type:=int
check/range:=0-100
```

Examples

Context:

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

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

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

Architectural Decisions

1. Environment Variables
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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 [3] 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 [3] and templates, too
- template: problem, constraints, assumptions, considered alternatives, decision, rationale, implications, related, notes

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

```
[slapd/threads/listener]
description:=adjust to use more threads
rationale:=needed for many-core systems
requirement:=1234
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] *getenv(3) Linux User's Manual*, March 2017.

[2] 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`.

[3] 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.

[4] 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.

[5] 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`.

[6] 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.

[7] 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: $10.5220/0006326602180225$.

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

[9] 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`.