

Configuration Management

Markus Raab

Institute of Information Systems Engineering, TU Wien

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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

03.04.2019: first issue done, PR for second

10.04.2019: mid-term submission of exercises

08.05.2019: different location: Complang Library

15.05.2019:

22.05.2019: all 5 issues done

29.05.2019:

05.06.2019: final submission of exercises

12.06.2019:

19.06.2019: last corrections of exercises

26.06.2019: exam

Tasks for today

(until 29.05.2019 23:59)

Task

Continue teamwork and homework. Make a clear description for what your team partner should do.

Tasks for next week

(until 05.06.2019 23:59)

Task

Submit teamwork and homework.

Popular Topics

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

Learning Outcomes

Students will be able to

- remember basics of context-awareness.
- remember basic characteristics of key databases.
- remember the history of configuration management.

Introspection (Recapitulation)

Task

What is internal and external specification? What is introspection?

- *internal*: within applications' source code
- *introspection*: unified get/set access to (meta*)-key/values
- access via applications, CLI, GUI, web-UI, ...
- access via any programming language (similar to file systems)
- GUI, web-UI can semantically interpret metadata
- assemble modular parts (validation, logging, ...)
- needed as communication between producers and consumers
- essential for *no-futz computing* Holland et al. [19]

Example Documentation (Recapitulation)

```
1 [slapd/threads/listener]
2   check/range := 1,2,4,8,16
3   default := 1
4   description := adjust to use more threads
5   rationale := needed for many-core systems
6   requirement := 1234
7   visibility := user
```


Reevaluate specifications (Recapitulation)

Task

In which situations should you reevaluate if a configuration setting (specification) is needed?

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

Goal

Reduction of all not-needed configuration settings (user view).

Semantic three-way merge (Recapitulation)

Ours:

```
1 slapd/threads/listener=4
2
3 slapd/threads/enable= \
4     yes # must be enabled for listener
5
```

Theirs:

```
1 slapd/threads/enable = on
2 slapd/threads/listener = 8
```

Origin:

```
1 slapd/threads/listener=8
2 slapd/threads/enable = true
```

Context-Awareness

- 1 Context-Awareness
- 2 Key Databases
- 3 History of Configuration Management

Khalil and Connelly [25] conducted a study where all users found context-aware configuration (very) useful. They learned that in 89 % of cases the mapping between activities and settings was consistent for individual users. In the study, context-aware configuration improved satisfaction, even if deduced settings sometimes were not appropriate. For example, a participant stated:

"I like how it changes state without you having to tell it to. I always forget to turn my cell [off] in class and turn it on after."

Definition (Recapitulation)

As adapted from Chalmers [10]:

***Context** is the circumstances relevant to the configuration settings of the application.*

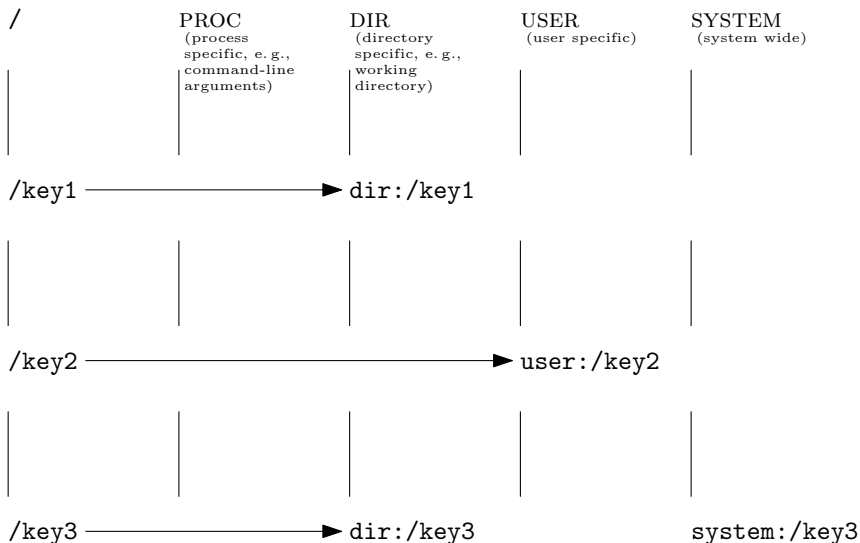
We extend the definition with:

***Context-aware configurations** are configuration settings that are consistent with its context. **Context-aware configuration access** is configuration access providing context-aware configuration.*

Types of Configuration (Recapitulation)

- Valid configuration** does not contradict the present validation specifications. With a valid configuration, applications can start but they may not do what the user wanted or may be inconsistent with context.
- Suitable configuration** is valid with respect to additional specifications from the user that describe the system the user requires [26].
- Optimal configuration** is optimal with respect to given optimization criteria. Optimization criteria are important if managing configuration of many computers but are rarely needed for configuration access discussed in this book.
- Context-aware configuration** is in accordance with its context. Unlike configuration settings, the context changes in ways outside of our control.

Cascading (Recapitulation)



Context-oriented Programming

One of the many systematic ways to write context-aware applications is called ***context-oriented programming*** [1, 5–8, 11, 12, 14, 18, 22–24, 28, 33–38]. Contrary to other techniques to improve context awareness, it focuses on the language level. Its run-time system is rather small, it does not need sophisticated frameworks, databases, or middleware. Context-oriented programming supports implementation of context-aware applications.

Contextual Values

Tanter [36] introduced a lightweight extension to context-oriented programming: **Contextual values** are variables whose values depend on the context in which they are read and modified. They *“boil down to a trivial generalization of the idea of thread-local values”*. The key idea is to use layers as *“discriminate amongst possible values, not only the current thread”* [36]. Side effects are limited to the respective context [30].

Contextual Values (Pseudocode)

```
1 void printBrowserConfig (Config config)
2 {
3     context.with("private")
4     {
5         println (config.keepHistory);
6     }
7     // same thread, different context:
8     println (config.keepHistory);
9
10    context.activate(currentLocation)
11 }
```

Introspection vs. Code Generation (Partly Recapitulation)

Implementation of contextual values might be in key database or in generated code. Advantages/Disadvantages?

- more techniques for performance improvements with code generation
- + specification can be updated live on the system without recompilation
- + tooling has generic access to all specifications
- + new features the key database (e.g., better validation) are immediately available consistently
- needed if context differs within same thread

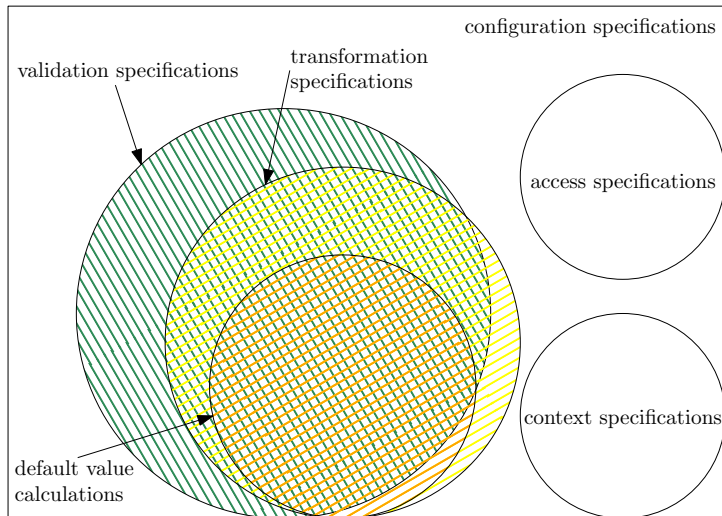
Implication

We generally prefer introspection, except for a very thin configuration access API.

Task

Break.

Types of Specifications (Recapitulation)



Keys as Contextual Values

- keys can be interpreted as contextual values [29, 31]
- we can make contextual values dependent on contextual values
- we can also use keys to describe requirements
- if we use a predefined path in Elektra for layers, we can activate context by writing to KDB
- this is implemented in “kdb elektrify-getenv”

Implication

The configuration can fully describe the context and the requirements.

Context Specifications

- Determine threads from CPUs:

```
1 [env/layer/cpu]
2   type := long
3 [slapd/threads/listener]
4   context := /slapd/threads/%cpu%/listener
```

- Determine vibration from sensors:

```
1 [phone/call/vibration]
2   type := boolean
3   context := /phone/call/%inocket%/vibration
```

- Determine proxy settings from network:

```
1 [env/override/http_proxy]
2   context := /http_proxy/%interface%/%network%
```

Key Databases

- 1 Context-Awareness
- 2 Key Databases
- 3 History of Configuration Management

Status Quo

Applications . . .

- usually consume configuration settings from configuration files, command-line arguments, and environment variables.
- sometimes have a single GUI or CLI for configuration settings.
- rarely have an API to access configuration settings.
- rarely consider context.
- rarely do in-depth validation.
- nearly never have an API to access configuration specifications.

Task

Think about applications you know. Discuss it with your neighbor.

Examples

- Postfix¹: CLI (Properties, CSV, and others)
- KDE²: GUI, CLI (INI)
- Libreoffice: GUI (XML)
- Firefox [21]: GUI (JavaScript and others)
- sudo: CLI (sudoers edited with visudo)
- X.org³: xorg.conf
- gpsd⁴: environment variables and command-line arguments

¹<http://www.postfix.org/OVERVIEW.html>

²<https://api.kde.org/frameworks/kconfig/html/>

³<ftp://www.x.org/pub/X11R6.7.0/doc/xorg.conf.5.html>

⁴<http://www.aosabook.org/en/gpsd.html>

Design Decisions

There are many ways to design configuration access but many decisions are only pragmatic and irrelevant with proper key/value abstraction.

Task

Which design decisions are there? Why are they (ir)relevant?

- Which configuration file format? (irrelevant due to key/values)
- Split up into multiple configuration files? (irrelevant due to 3-way merging)
- Where are the configuration files? (irrelevant due to mounting and resolver)
- Important: Introspection, Validation, Horizontal Modularity, Integration, Specification, API, Guarantees, ...

Key Databases (Usage)

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 %, $n = 218$)
- Freedesktop standards (20 %, $n = 205$)
- Windows Registry (13 %) (≤ 13 %, $n \geq 185$) [talk later]
- X/Q/GSettings (4 %, 11 %, 9 %)
- KConfig (5 %)
- dconf (7 %)
- plist (7 %)

Distributed Key Databases

Examples:

- Redis: in-memory with persistence and notification
- Zookeeper
- etcd:
 - not in-memory
 - get/set/watch interface via REST
 - distributed coordination [27]
 - needs configuration itself

Elektra

- is not only a key database but a specification language to describe a key database
- plugins implement the specification (could be distributed but focus is configuration files)
- is library based (no single point of failure, no distributed coordination needed)
- supports transactions (persisting whole KeySets at once)
- supports integration of existing configuration

History of Configuration Management

- 1 Context-Awareness
- 2 Key Databases
- 3 History of Configuration Management

Definition

Configuration Management:

- is a discipline in which configuration (in the broader sense) is administered.
- makes sure computers are assembled from desired parts and the correct applications are installed.
- ensures that the execution environment of installed applications is as required.

Definition

Configuration management tools:

- help people involved in configuration management.
- have means to describe the desired configuration of the whole managed system.
- try to converge the actual configuration to the desired one [9].

Challenging tasks in configuration management:

- inventory list
- installing packages
- monitoring
- add/replace machines
- maintaining files/databases/...
- *configuration file manipulation*

Cloning

It all started with:

- clone all files with dd, rdist, rsync or unison (“golden image”)
- then do necessary modifications with scripts or profiles
 - + works very good for many identical stateless machines
 - fails if differences between machines are too big

Scripts

First improvement: have a script to create the “golden image”.
Possible benefits:

- Documentation
- Customization (using configuration settings)
- **Reproducibility**: Reproduce creation using different operating system versions

Profiles

Profiles are groups of configuration settings between which the user can easily switch.

- by hostname, information EEPROM, manual selection, ...
- can be activated as context:

```
1 [%application%/profile]
2   type := string
3   opt := p
4   opt/long := profile
5   default :=
```

First four configuration management tools

Cloning, and then NIS/NFS, was state of the art for a long time, until in 1994 when *“the community nearly exploded with four new configuration systems”* [13]:

- lcfg** from Anderson [3]. The development of lcfg started first in 1991 [2, 3]. Nevertheless, its development still continues [4, 17].

- GeNUAdmin** from Harlander [15].

- omniconf** from Hideyo [16].

- config** from Rouillard and Martin [32].

Possible Benefits

- All advantages scripts have:
Documentation, Customization, Reproducibility
- Declarative description of the system
(Infrastructure as Code [20])
- Less configuration drift
- Error handling
- Pull/Push
- Reusability
- (Resource) Abstractions

Conclusion

- Context-awareness is a goal.
- Contextual values is a way to implement it.
- Many (distributed) key databases enable us to persist configuration settings.
- Definition and challenges in configuration management.
- Cloning: There and back again.

Outlook

- Challenges in Configuration Management
- Properties: self-describing, idempotent, round-tripping
- Validation
- Configuration management languages

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