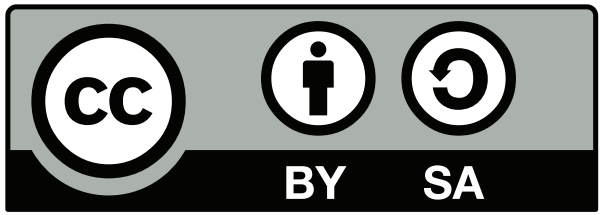
Configuration Management

Markus Raab

Institute of Information Systems Engineering, TU Wien

29.5.2018



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 Libary
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

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)

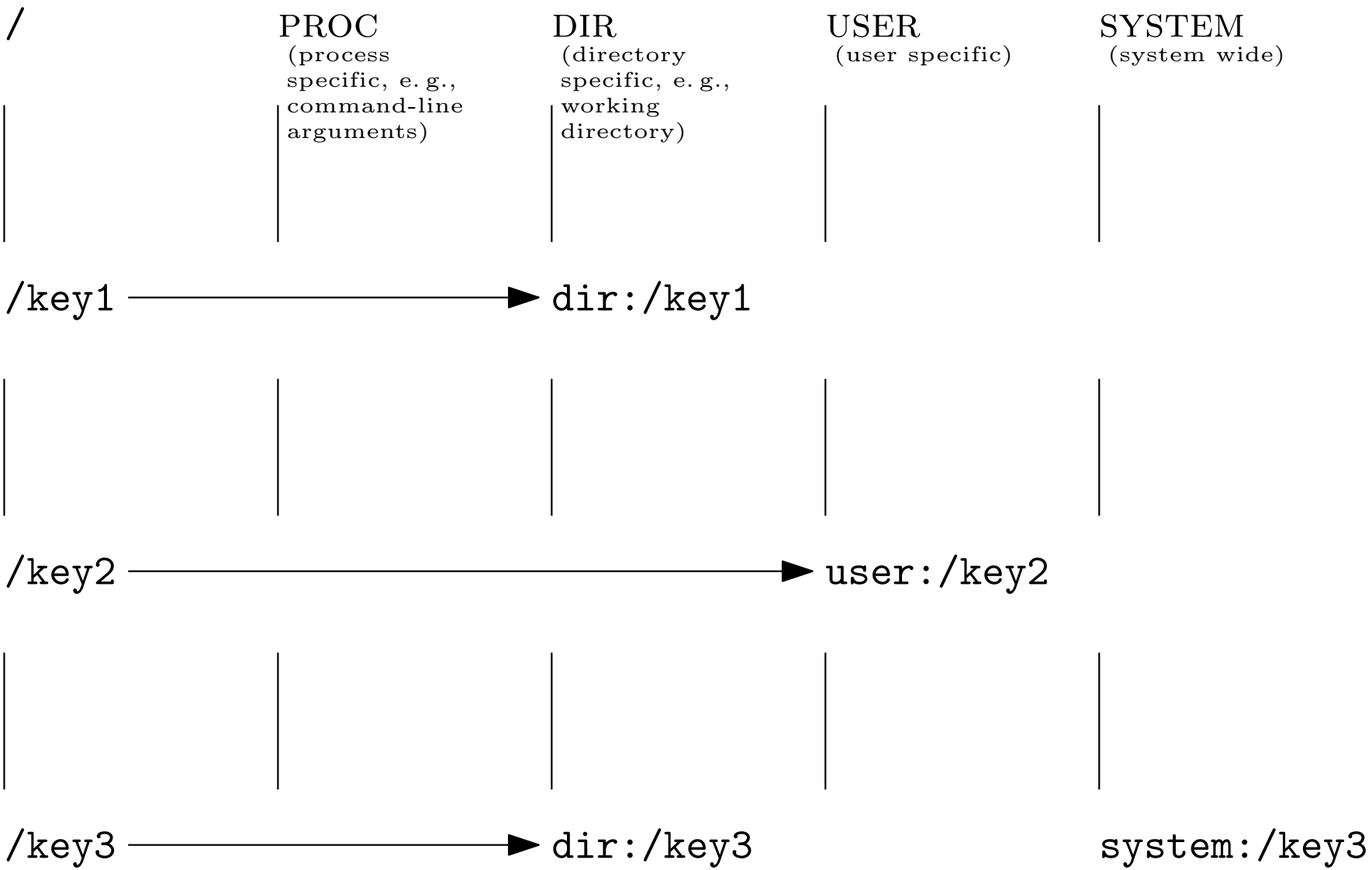
Valid configuration does not contradict the present validation specifications. With a valid configuration, applications can start but they may not do what the user wanted or may be inconsistent with context.

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 of having it in key database (with introspection)?

- – 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

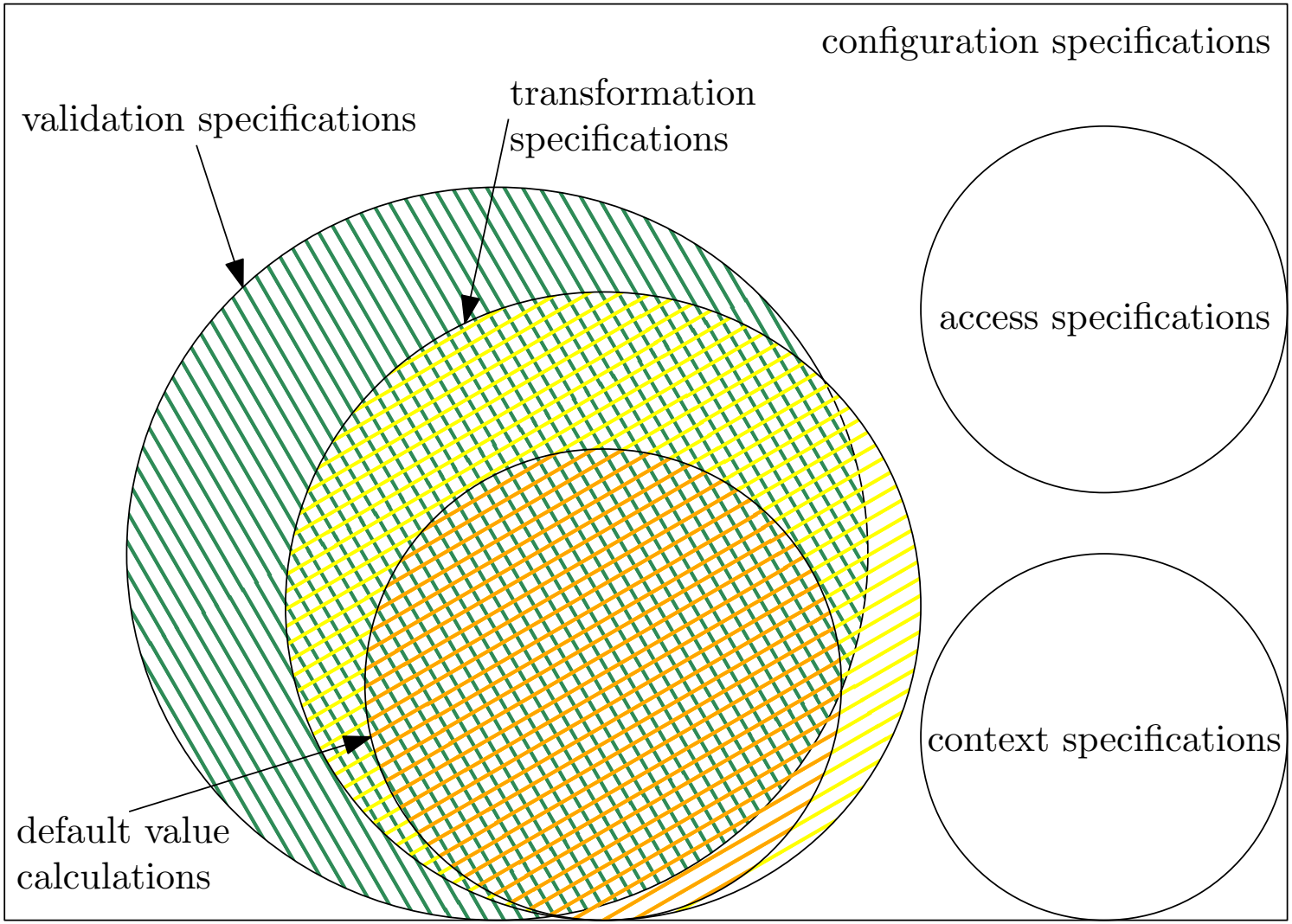
Implication

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/%inpocket%/vibration
```

- Determine proxy settings from network:

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

Key Databases

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

- Postfix[1]: CLI (Properties, CSV, and others)
- KDE[2]: GUI, CLI (INI)
- Libreoffice: GUI (XML)
- Firefox [21]: GUI (JavaScript and others)
- sudo: CLI (sudoers edited with visudo)
- X.org[3]: xorg.conf
- gpsd[4]: 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

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)
- **Reproducability**: 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, Reproducability
- 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

[1] Unai Alegre, Juan Carlos Augusto, and Tony Clark. Engineering context-aware systems and applications: A survey. *Journal of Systems and Software*, 117:55–83, 2016. ISSN 0164-1212. doi: 10.1016/j.jss.2016.02.010. URL http://www.sciencedirect.com/science/article/pii/S0164121216000467.

[2] Paul Anderson. Local system configuration for syssies. Technical report, CS-TN-38, Department of Computer Science, University of Edinburgh, Edinburgh, 1991.

[3] Paul Anderson. Towards a high-level machine configuration system. In *LISA*, volume 94, pages 19–26, 1994.

[4] Paul Anderson, Alastair Scobie, et al. Lcfg: The next generation. In *UKUUG Winter conference*, pages 4–7, 2002.

[5] Tomoyuki Aotani, Tetsuo Kamina, and Hidehiko Masuhara. Unifying multiple layer activation mechanisms using one event sequence. In *Proceedings of 6th International Workshop on Context-Oriented Programming*, COP'14, pages 2:1–2:6, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2861-6. doi: 10.1145/2637066.2637068. URL http://dx.doi.org/10.1145/2637066.2637068.

[6] Malte Appeltauer, Robert Hirschfeld, and Tobias Rho. Dedicated programming support for context-aware ubiquitous applications. In *Mobile Ubiquitous Computing, Systems, Services and Technologies, Second UBICOMM.*, pages 38–43. IEEE, 2008.

[7] Malte Appeltauer, Robert Hirschfeld, Michael Haupt, Jens Lincke, and Michael Perscheid. A comparison of context-oriented programming languages. In *International Workshop on Context-Oriented Programming*, COP '09, New York, NY, USA, 2009. ACM. ISBN 978-1-60558-538-3. doi: 10.1145/1562112.1562118. URL http://dx.doi.org/10.1145/1562112.1562118.

[8] Matthias Baldauf, Schahram Dustdar, and Florian Rosenberg. A survey on context-aware systems. *International Journal of Ad Hoc and Ubiquitous Computing*, 2(4):263–277, 2007.

[9] Mark Burgess. A site configuration engine. In *USENIX Computing systems*, volume 8, pages 309–337, 1995.

[10] Daniel Chalmers. *Contextual mediation to support ubiquitous computing*. PhD thesis, University of London, 2002.

[11] Pascal Costanza, Robert Hirschfeld, and Wolfgang De Meuter. Efficient layer activation for switching context-dependent behavior. In DavidE. Lightfoot and Clemens Szyperski, editors, *Modular Programming Languages*, volume 4228 of *Lecture Notes in Computer Science*, pages 84–103. Springer, 2006. ISBN 978-3-540-40927-4. URL `http://dx.doi.org/10.1007/11860990_7`.

[12] Anind K. Dey and Gregory D. Abowd. The what, who, where, when, why and how of context-awareness. In *CHI '00 Extended Abstracts on Human Factors in Computing Systems*, CHI EA '00, NY, 2000. ACM. ISBN 1-58113-248-4. URL `ftp://ftp.cc.gatech.edu/pub/gvu/tr/1999/99-22.pdf`.

[13] Rémy Evard. An analysis of UNIX system configuration. In *LISA*, volume 97, pages 179–194, 1997.

[14] Sebastián González, Nicolás Cardozo, Kim Mens, Alfredo Cádiz, Jean-Christophe Libbrecht, and Julien Goffaux. *Subjective-C*, pages 246–265. Springer Berlin Heidelberg, Berlin, Heidelberg, 2011. ISBN 978-3-642-19440-5. doi: 10.1007/978-3-642-19440-5_15. URL http://dx.doi.org/10.1007/978-3-642-19440-5_15.

[15] Magnus Harlander. Central system administration in a heterogeneous Unix environment: GeNUAdmin. In *LISA VIII Proceedings*, 1994.

[16] Imazu Hideyo. OMNICONF–making os upgrades and disk crash recovery easier. In *LISA VIII Proceedings*, 1994.

[17] Johannes Hintsch, Carsten Görling, and Klaus Turowski. A review of the literature on configuration management tools. 2016.

[18] Robert Hirschfeld, Hidehiko Masuhara, Atsushi Igarashi, and Tim Felgentreff. Visibility of context-oriented behavior and state in I. In *Proceedings of the 31th JSSST Annual Conference*, pages 2–1, 2014.

[19] 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.

[20] Waldemar Hummer, Florian Rosenberg, Fábio Oliveira, and Tamar Eilam. Testing idempotence for infrastructure as code. In David Eyers and Karsten Schwan, editors, *Middleware 2013*, pages 368–388, Berlin, Heidelberg, 2013. Springer Berlin Heidelberg. ISBN 978-3-642-45065-5.

[21] 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.

[22] Hong Jong-yi, Suh Eui-ho, and Kim Sung-Jin. Context-aware systems: A literature review and classification. *Expert Systems with Applications*, 36(4):8509–8522, 2009. ISSN 0957-4174. URL http://dx.doi.org/10.1016/j.eswa.2008.10.071.

[23] Tetsuo Kamina, Tomoyuki Aotani, Hidehiko Masuhara, and Tetsuo Tamai. Context-oriented software engineering: A modularity vision. In *Proceedings of the 13th International Conference on Modularity*, MODULARITY '14, pages 85–98, New York, NY, USA, 2014. ACM. ISBN 978-1-4503-2772-5.

[24] Roger Keays and Andry Rakotonirainy. Context-oriented programming. In *Proceedings of the 3rd ACM International Workshop on Data Engineering for Wireless and Mobile Access*, MobiDe '03, pages 9–16, New York, NY, USA, 2003. ACM. ISBN 1-58113-767-2. doi: 10.1145/940923.940926. URL `http://dx.doi.org/10.1145/940923.940926`.

[25] Ashraf Khalil and Kay Connelly. *Context-Aware Configuration: A Study on Improving Cell Phone Awareness*, pages 197–209. Springer Berlin Heidelberg, Berlin, Heidelberg, 2005. ISBN 978-3-540-31890-3. doi: 10.1007/11508373_15. URL `http://dx.doi.org/10.1007/11508373_15`.

[26] Manuele Kirsch-Pinheiro, Raúl Mazo, Carine Souveyet, and Danillo Sprovieri. Requirements analysis for context-oriented systems. *Procedia Computer Science*, 83:253–261, 2016. ISSN 1877-0509. doi: http://dx.doi.org/10.1016/j.procs.2016.04.123. URL `http://www.sciencedirect.com/science/article/pii/S1877050916301466`. The 7th International Conference on Ambient Systems, Networks and Technologies (ANT 2016) / The 6th International Conference on Sustainable Energy Information Technology (SEIT-2016) / Affiliated Workshops.

[27] Diego Ongaro and John K Ousterhout. In search of an understandable consensus algorithm. In *USENIX Annual Technical Conference*, pages 305–319, 2014.

[28] John Plaice and Blanca Mancilla. The cartesian approach to context. In *Proceedings of the 2nd International Workshop on Context-Oriented Programming*, COP '10, New York, NY, USA, 2010. ACM. ISBN 978-1-4503-0531-0. doi: 10.1145/1930021.1930024. URL http://dx.doi.org/10.1145/1930021.1930024.

[29] Markus Raab. Persistent contextual values as inter-process layers. In *Proceedings of the 1st International Workshop on Mobile Development*, Mobile! 2016, pages 9–16, New York, NY, USA, 2016. ACM. ISBN 978-1-4503-4643-6. doi: 10.1145/3001854.3001855. URL http://dx.doi.org/10.1145/3001854.3001855.

[30] Markus Raab. Unanticipated context awareness for software configuration access using the getenv API. In *Computer and Information Science*, pages 41–57. Springer International Publishing, Cham, 2016. ISBN 978-3-319-40171-3. doi: 10.1007/978-3-319-40171-3_4. URL http://dx.doi.org/10.1007/978-3-319-40171-3_4.

[31] 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.

[32] John P. Rouillard and Richard B. Martin. Config: A mechanism for installing and tracking system configurations. In *LISA*, 1994.

[33] Guido Salvaneschi, Carlo Ghezzi, and Matteo Pradella. Context-oriented programming: A software engineering perspective. *Journal of Systems and Software*, 85(8): 1801–1817, 2012. ISSN 0164-1212. URL http://dx.doi.org/10.1016/j.jss.2012.03.024.

[34] Hans Schippers, Tim Molderez, and Dirk Janssens. A graph-based operational semantics for context-oriented programming. In *Proceedings of the 2nd International Workshop on Context-Oriented Programming*, COP '10, New York, NY, USA, 2010. ACM. ISBN 978-1-4503-0531-0. doi: 10.1145/1930021.1930027. URL http://dx.doi.org/10.1145/1930021.1930027.

[35] Matthias Springer, Hidehiko Masuhara, and Robert Hirschfeld. Classes as layers: Rewriting design patterns with COP: Alternative implementations of decorator, observer, and visitor. In *Proceedings of the 8th International Workshop on Context-Oriented Programming*, COP'16, pages 21–26, New York, NY, USA, 2016. ACM. ISBN 978-1-4503-4440-1. doi: 10.1145/2951965.2951968. URL http://dx.doi.org/10.1145/2951965.2951968.

[36] Éric Tanter. Contextual values. In *Proceedings of the 2008 Symposium on Dynamic Languages*, DLS '08, pages 3:1–3:10, New York, NY, USA, 2008. ACM. ISBN 978-1-60558-270-2. doi: 10.1145/1408681.1408684. URL http://dx.doi.org/10.1145/1408681.1408684.

[37] Martin von Löwis, Marcus Denker, and Oscar Nierstrasz. Context-oriented programming: Beyond layers. In *Proceedings of the 2007 International Conference on Dynamic Languages*, ICDL '07, pages 143–156, New York, NY, USA, 2007. ACM. ISBN 978-1-60558-084-5. URL http://dx.doi.org/10.1145/1352678.1352688.

[38] Benjamin Hosain Wasty, Amir Semmo, Malte Appeltauer, Bastian Steinert, and Robert Hirschfeld. ContextLua: Dynamic behavioral variations in computer games. In *Proceedings of the 2nd International Workshop on Context-Oriented Programming*, COP '10, pages 5:1–5:6, New York, NY, USA, 2010. ACM. ISBN 978-1-4503-0531-0. doi: 10.1145/1930021.1930026. URL http://dx.doi.org/10.1145/1930021.1930026.