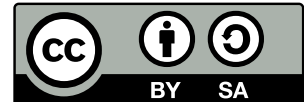


L10 Design of Configuration

Markus Raab

Institute of Information Systems Engineering, TU Wien

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Documentation

- 1 Documentation
- 2 Introspection
- 3 Code Generation
- 4 Introspection vs. Generation
- 5 Context-Awareness
- 6 Meeting
 - Recapitulation
 - Assignments
 - Preview

Learning Outcomes

Students will be able to

- design and document configuration settings and specifications.
- evaluate a configuration system and decide about use of
 - code generation.
 - introspection.
 - context-awareness.
- remember connections between the many different topics within CM.

Three Places

There are at least three places where documentation can be.

- ① In the CM code.
- ② In the specification (e.g., metadata “description”):

```
1 [slapd/threads/listener]
2  description:=adjust to use more threads
```
- ③ In comments of config files (e.g., metadata “comment”).

We will mostly talk about documentation of the specification.

Q: In detail, persons found it very important that (multiple choice, $n \geq 150$, “You want to configure a FLOSS application. How important are the following ways for you?”):

- 48 % documentation is shipped with the application
- 36 % configuration examples are shipped with the applications
- 17 % “google, stackoverflow. . . (looking for my problem)”
- 14 % looking at the website of the application
- 14 % use UIs that help them
- 14 % look into the source code
- 11 % “wiki, tutorials. . . (looking for complete solutions)”
- 5 % look into the configuration specification
- 2 % ask colleagues and friends

There are at least two forms of documentation necessary:

- Explanations
- Examples

Generation helps to avoid duplication:

Requirement

There must be a support for shipping correct documentation and examples generated from the configuration specifications.

Question

How to avoid duplication between description text and other parts?

- Render type and defaults into the documentation
- Render any other semantics into the documentation
- Render requirements and rationale into the documentation

Example

```
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
```


Semantics

Avoid describing semantics that easily can be specified:

```
1 [app/log/file]
2   description := path to file
```

Instead use:

```
1 [app/log/file]
2   check/path :=
```

Reevaluate specifications

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.

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?

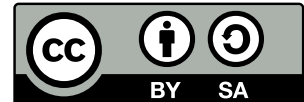
- Which configuration file format? (irrelevant due to key/values)
- Split up into multiple configuration files? (irrelevant due to 3-way merging)
- Where are the configuration files? (irrelevant due to mounting and resolver)
- Important: Validation, Modularity, Specifications, API, Guarantees, Docu,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

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Introspection

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Introspection

Question

What can introspection offer?

- unified get/set access to (meta*)-key/values
- GUI, web-UI can semantically interpret metadata
- access via applications, CLI, GUI, web-UI, ...
- access via any programming language (similar to file systems)
- access via any configuration management system

Internal Specification

For example, OWNER:

```
1 import org.aeonbits.owner.Config;
2
3 public interface ServerConfig extends Config {
4     int port();
5     String hostname();
6     @DefaultValue("42")
7     int maxThreads();
8 }
```

Question

Why do we need an external specification?

Intropection:

- needed as communication of producers and consumers of configuration
- the foundation for any advanced tooling like configuration management tools
- essential for ***no-futz computing*** Holland et al. [11]

External Specification

```
1 [port]
2 type := long
3 [hostname]
4 default := 42
5 [threads/max]
6 type := long
```

Advantages:

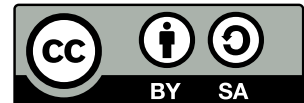
- are read and writable by other applications (introspection)
- we can generate the internal specification (code generation)
- we fulfill needs for configuration management tools

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Code Generation

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Current Challenges

Configuration access code (internal specification) usually has:

- code duplications and unsafe APIs
- hard-coded default values
- unexpected transformations (e.g., truncating of values)
- inconsistencies (e.g., case sensitivity)
- no introspection facilities (which keys and values are allowed?)

Example (Silent Overruling [28])

```
1 if (!strcasecmp(token, "on")) {  
2     *var = 1;  
3 } else {  
4     *var = 0;  
5 } /* src/cache_cf.cc from Squid */
```

Real-world example

PostgreSQL¹ has following duplications for its configuration settings:

- a global variable and an option record (struct)
- an entry in an example (postgresql.conf.sample)
- documentation in sgml
- in the source code of utils (in-source dump utils, and dozens of external configuration management tools)

Note: PostgreSQL has a clean implementation, and above list only shows limitations of systems without code generation.

¹http://doxygen.postgresql.org/guc_8c_source.html

Goal

Goal

Configuration settings should adhere the specification from source to destination.

For both applications and CM tools we want:

Requirement

The specification must enable code generation and inconsistencies must be ruled out during compilation.

KeySet Generation

Question

Idea: What if the configuration file format grammar describes source code?

$\langle \text{KeySet} \rangle ::= \text{'ksNew' } _ (' \{ \langle \text{Key} \rangle \text{' , } \leftarrow ' \} \{ \text{'_'} \} \text{'KS_END'});'$

$\langle \text{Key} \rangle ::= \text{'keyNew } _ (" ' \langle \text{key name} \rangle "' , \leftarrow ' [\langle \text{Value} \rangle] \langle \text{properties} \rangle \text{'KEY_END'})'$

$\langle \text{Value} \rangle ::= \{ \text{'_'} \} \text{'KEY_VALUE, } _ (" ' \langle \text{configuration value} \rangle "' , \leftarrow '}$

$\langle \text{properties} \rangle ::= \{ \{ \text{'_'} \} \langle \text{property} \rangle \text{' , } \leftarrow ' \}$

$\langle \text{property} \rangle ::= \text{'KEY_META, } _ ' \langle \text{property name} \rangle \text{' , } _ ' \langle \text{property value} \rangle \text{' '}$

Example

Example

Given the key `spec:/slapd/threads/listener`, with the configuration value 4 and the property `DEFAULT` \mapsto 1, GENELEKTRA emits:

```
1 ksNew (keyNew ("spec:/slapd/threads/listener",
2             KEY_VALUE, "4",
3             KEY_META, "default", "1",
4             KEY_END),
5     KS_END);
```

Finding

We have source code representing the settings. And if we instantiate it, we have a data structure representing the settings. Plugins emitting such “configuration files” are code generators.

Implementation Strategies

- Using print (only for very small generators)
- Using generative grammars

```
1 query = '{ ' >> *(pair) > '}' ;
2 pair = '{ ' >> key_name > '=' >> key_value >>
3         *('{ ' >> metakey_name > '=' >> metakey_value > '}' )
4         > '}' ;
```

- Using template languages (RubyERB, Cheetah, Mustache)

```
1 @for n in hierarchy.name.split('/') [1:-1]
2 namespace $support.nsnpretty($n)
3 {
4 class ${hierarchy.prettyclassname(support)}
5 {
6 typedef $support.typeof($hierarchy.info) type;
7 @if $support.typeof($hierarchy.info) != "kdb::none_t"
8 static type get(kdb::KeySet &ks, kdb::Key const& spec)
9 {
10     type value $support.valof($hierarchy.info)
11     Key found(ckdb::ksLookup(ks.getKeySet(), *spec,
12                             ckdb::elektraLookupOptions::KDB_0_SPEC));
13     return found.get<$support.typeof($hierarchy.info)>();
14 }
```

Which Configuration Access API?

```
1 long foo(slapd::Threads const & threads)
2 {
3     threads.listener++;
4     Context & c = threads.context ();
5     return threads.listener;
6 }
7
8 int main()
9 {
10     KeySet config;
11     Context c;
12     Environment env (config, c);
13     long x = foo (env.slapd.threads);
14 }
```

Which Configuration Access API?

In C, we use identifiers to be passed to the high-level API¹:

```
1 elektraGetLong (elektra , ELEKTRA_TAG_THREADS);
```

¹<https://www.libelektra.org/tutorials/high-level-api>

Other artefacts:

- APIs for type-safe CM code
- examples (e.g., defaults)
- documentation
- auto-completion/syntax highlighting/IDE support
- tooling (GUI, Web UI)
- parsing code (e.g., command-line parsing)

Guarantees by code generation:

- Every configuration setting is specified (essential for refactoring).
- (Data) type of source code and configuration settings match.
- Configuration access with defaults is always successful. Reason: We use defaults if everything else fails.

Finding

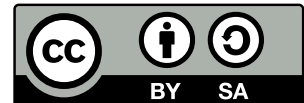
Guarantees for both CM and application code.

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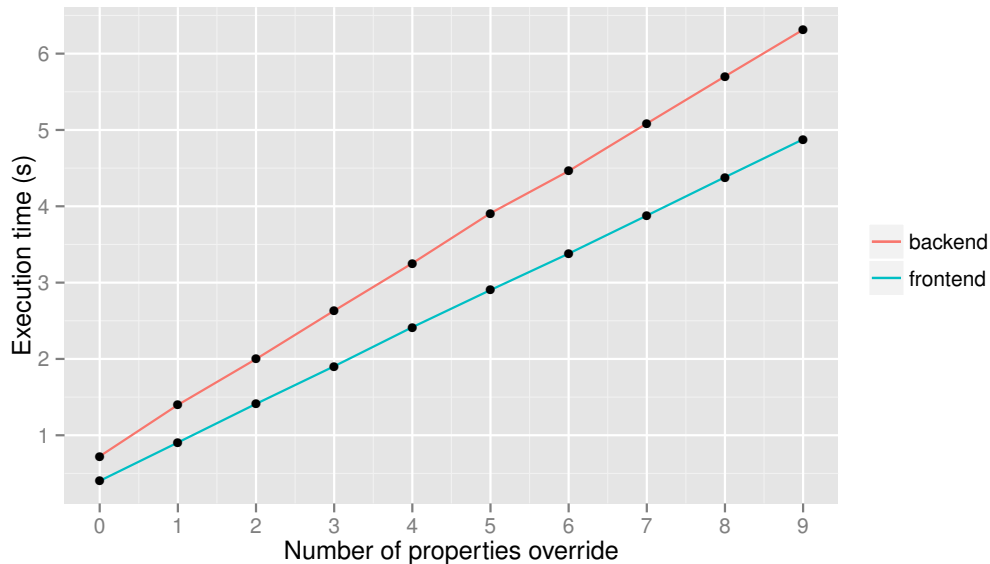
Introspection vs. Generation

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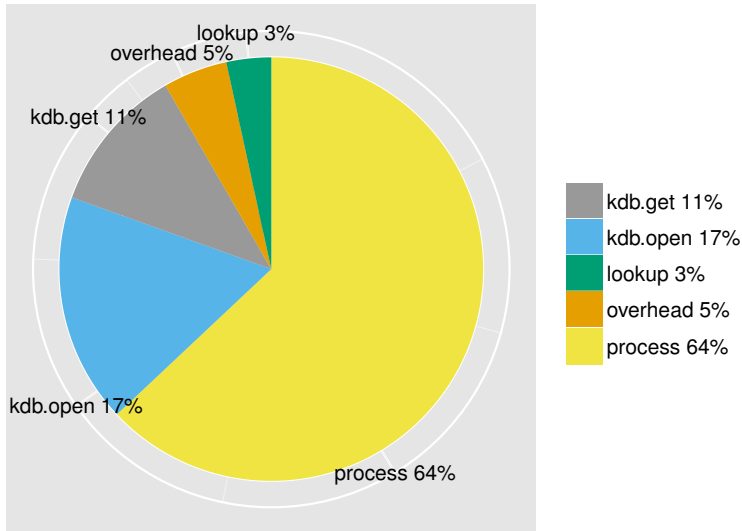
Limitations of introspection:

- no static checks
- no whole-program optimizations (API barriers)

Overhead without code generation (=backend) is 1.8x higher [18]:



But it might not matter because configuration access might not be a bottleneck [18], for example, a word counting application:



Use Cases of Elektra

- Embedded systems
 - OpenWRT (distribution)
 - Broadcom (blue-ray devices)
 - Kapsch (cameras)
 - Toshiba (TVs)
- Server
 - Allianz (insurance)
 - TU Wien
 - puppet-libelektra
 - Other Universities
- Desktop
 - Oyranos
 - LCDproc (in progress)
 - KDE

Introspection vs. Code Generation

Advantages of introspection:

- + 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
- more techniques for performance improvements with code generation
- code generation needed if context differs within same thread

Implication

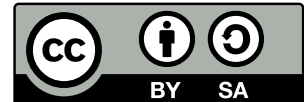
We generally prefer introspection, except for a very thin configuration access API.

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Context-Awareness

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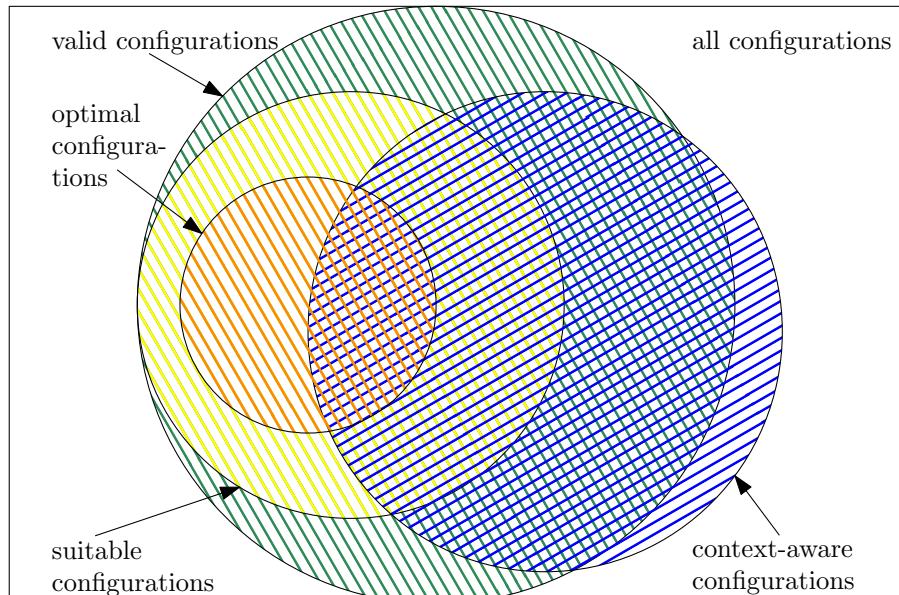
If you're a baker, making bread, you're a baker. If you make the best bread in the world, you're not an artist, but if you bake the bread in the gallery, you're an artist. So the context makes the difference.

— Marina Abramovic

Types of Configuration

- 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 [16].
- 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.

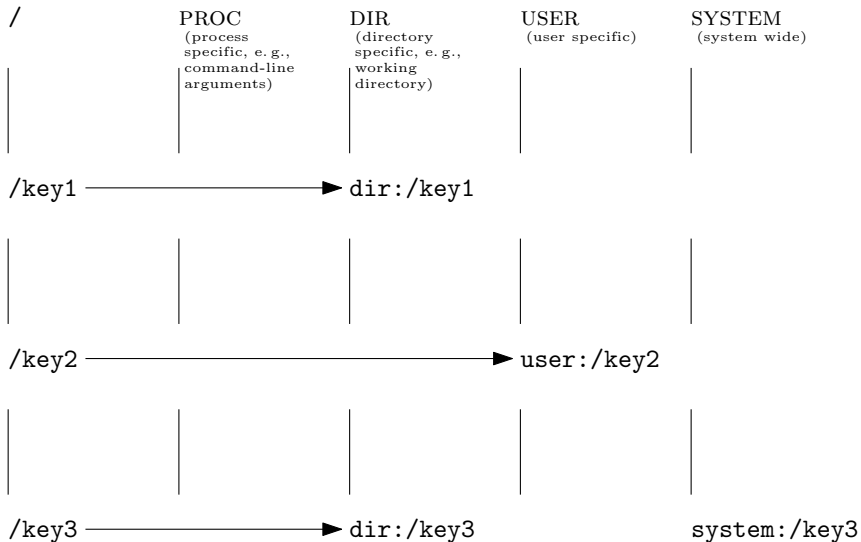
Types of Configurations



Khalil and Connelly [15] 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.”

Cascading (Recapitulation)



Definition

As adapted from Chalmers [6]:

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.

Context-oriented Programming

One of the many systematic ways to write context-aware applications is called ***context-oriented programming*** [1–5, 7–10, 12–14, 17, 22–27]. 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.

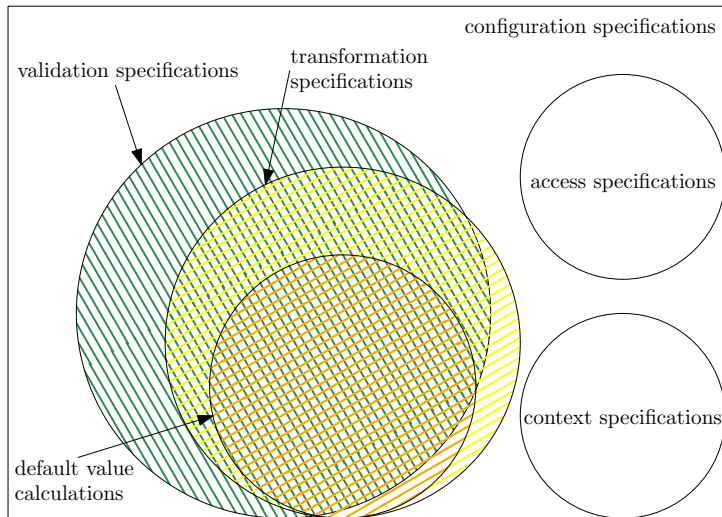
Contextual Values

Tanter [25] 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*” [25]. Side effects are limited to the respective context [20].

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 }
```

Types of Specifications (Recapitulation)



Keys as Contextual Values

- keys can be interpreted as contextual values [19, 21]
- 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%
```

Conclusion

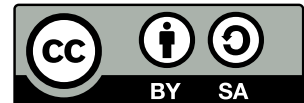
- Context-awareness is a goal.
- Contextual values is a way to implement it.
- Key databases enable us to persist context-aware configuration settings.

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Meeting

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Configuration Specification

Question

Explain following configuration specification:

```
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 := developer
```

Question

How to avoid duplication between description text and other parts?

- Render type and defaults into the documentation
- Render any other semantics into the documentation
- Render requirements and rationale into the documentation

Reevaluate specifications

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.

Introspection

Question

What can introspection offer?

- unified get/set access to (meta*)-key/values
- GUI, web-UI can semantically interpret metadata
- access via applications, CLI, GUI, web-UI, ...
- access via any programming language (similar to file systems)
- access via any configuration management system

Task

Break.

Which guarantees are possible with code generation?

- Every configuration setting is specified (essential for refactoring).
- (Data) type of source code and configuration settings match.
- Configuration access with defaults is always successful.
Reason: We use defaults if everything else fails.

Finding

Guarantees for both CM and application code.

Intropection vs. Code Generation

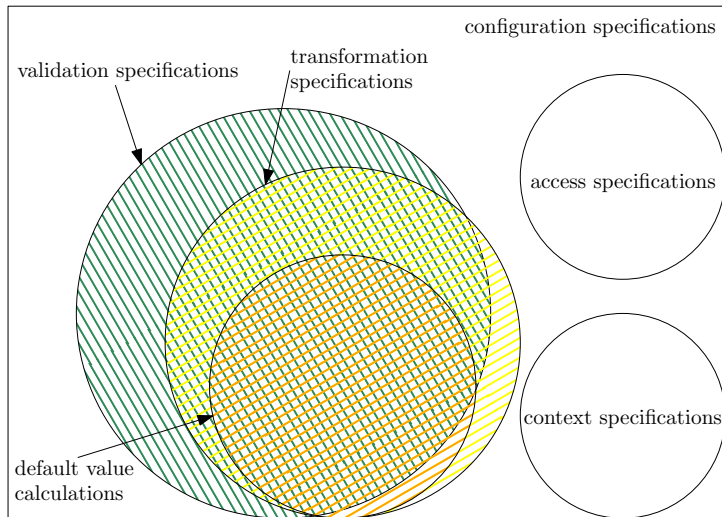
Advantages/disadvantages of intropection:

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- + new features the key database (e.g., better validation) are immediately available consistently
- more techniques for performance improvements with code generation
- code generation needed if context differs within same thread

Implication

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

Types of Specifications



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%
```

Learning Outcomes

Students will be able to

- design and document configuration settings and specifications
- evaluate a configuration system and decide about use of
 - code generation
 - introspection
 - context-awareness
- remember connections between the many different topics within CM

Task

Draw a big red, yellow or green (+) dot how you liked the topic.

Task

Break.

P3 Presentation

- be creative
- try something new
- hook (e.g. story, anecdote, challenge, offer, question, polls)
- strong message from own experience

Finalize PRs:

- Rebase PRs (+1P).
- Make CI happy.

Implication

You must be positive on every part (project, presentation) to be positive in the overall lecture!

LRE Recapitulation

Going full circle: How “everything” in CM connects.

- [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] 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>.
- [3] 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.

- [4] 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>.
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- [9] 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.
- [10] 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.
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