L04 Configuration Sources

Markus Raab

Institute of Information Systems Engineering, TU Wien

14.04.2021

This work is licensed under a Creative Commons *"Attribution-ShareAlike 4.0 International"* license.

Configuration Files

Learning Outcomes

Students will be able to

- differentiate between configuration sources
- unify configuration sources via specifications
- (calculate complexity of configuration settings)

Definition

A **configuration file** is a file containing configuration settings.

Definition

A ***configuration file*** is a file containing configuration settings.
A Web server configuration file:

```
1 port=80␣;␣comment
2 address=127.0.0.1
```

Question
What are keys? What are configuration values? What is metadata?

Definition

A **configuration file** is a file containing configuration settings.
A Web server configuration file:

```
1 port =80_;_comment
2 address =127.0.0.1
```

The configuration values are 80 and 127.0.0.1, respectively.
Other information in the configuration file is metadata for the
configuration settings (such as the comment).

Configuration File Formats

- CSV (comma-separated values)
- semi-structured
- programming language
- literate

CSV formats

- passwd: 3rd November, 1971
- passwd and group use : as separator
- are difficult to extend (e.g., GECOS)
- today mostly used for legacy reasons
- are replaced one-by-one (e.g., inetd, crontab)

Programming Language

- $+$ trivial for developers (source the file)
- $+$ above-overage quality of error message
- $-$ makes automatic change of individual values harder
- $-$ very hard to use for people who do not know the programming language
- $-$ does not separate code and data

Trends

- away from CSV
- towards general-purpose serialization formats (INI, JSON)
- human-read/writable (YAML, TOML)
- programming language as configuration file

Method

What do FLOSS developers say?

> *Q:* survey with 672 persons visiting, 162 persons
> completing the survey [4]

> *S:* source code analysis of 16 applications, comprising
> 50 million lines of code [4]

Why are so many formats present?

Q: "In which way have you used or contributed to the configuration system/library/API in your previously mentioned FLOSS project(s)?" [4]

- 19 % persons ($n = 251$) have introduced a configuration file format.
- 29 % implemented a configuration file parser.
- 15 % introduced a configuration system/library/API.
- 34 % used external configuration access APIs.

Multitude of Formats

- on every system a multitude of (legacy) configuration file formats exist
- the number grows fast
- thus applications usually have to deal with some legacy formats

Requirement

A configuration library must be able to integrate (legacy) systems and must fully support (legacy) configuration files.
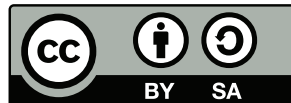
L04 Configuration Sources

Markus Raab

Institute of Information Systems Engineering, TU Wien

14.04.2021

This work is licensed under a Creative Commons *"Attribution-ShareAlike 4.0 International"* license.

Command-line Arguments

Is there something else?

- configuration files are the most researched of all configuration sources [2]
- but it is neither the most used nor most popular [4]

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 %, $n = 218$)
- *S:* API getenv is used omnipresently with 2,683 occurrences
- configuration files (74 %, $n = 218$))

Q: "What is your experience with the following configuration systems/libraries/APIs?"

- getenv (10 %, $n = 198$)
- configuration files (6 %, $n = 190$)
- command-line options (4 %, $n = 210$)
- X/Q/GSettings (41 %, 14 %, 35 %)
- KConfig (21 %)
- dconf (42 %)
- plist (32 %)
- Windows Registry (69 %)

Semantics

- 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)

L04 Configuration Sources

Markus Raab

Institute of Information Systems Engineering, TU Wien

14.04.2021

This work is licensed under a Creative Commons *"Attribution-ShareAlike 4.0 International"* license.

Environment Variables

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 %)

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.

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

L04 Configuration Sources

Markus Raab

Institute of Information Systems Engineering, TU Wien

14.04.2021

Abstractions

User View

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

Abstraction

Requirement

A configuration library must be able to integrate (legacy) systems and must fully support (legacy) configuration files.

How can we deal with the many formats?

Key-Value

A key-value pair is the simplest generic data structure [7]. While all these formats above have many differences, all of them represent configuration settings as **key-value pairs** [2, 3, 6, 8].

For configuration as program you need to execute them first.

KeySet (Recapitulation)

The common data structure between plugins:

KeySet   Key   metakey or property
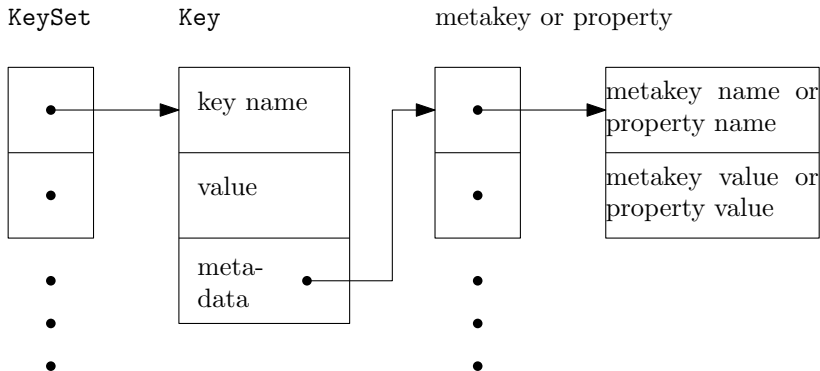
Mounting

Mounting integrates a backend into the key database [5]. Hence, ELEKTRA allows several backends to deal with configuration files at the same time. Each backend is responsible for its own subtree of the key database.
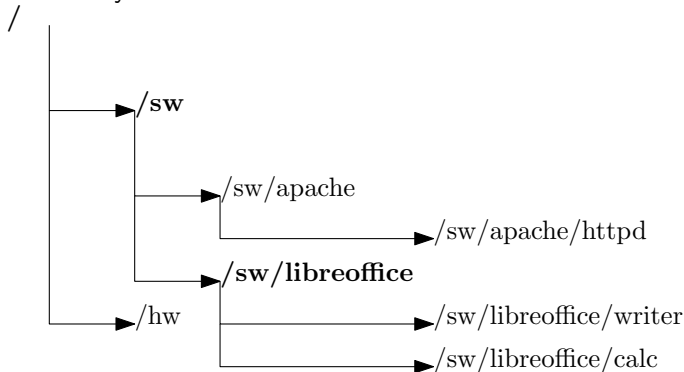
Elektra

```
1 [kdb/printversion]
2 description = "print version information"
3 opt = v
4 opt/long = version
5 opt/arg = none
```

- gopts puts Keys in the proc namespace
- https://www.libelektra.org/tutorials/
  command-line-options

```
kdb -v    kdb --version    VERSION=1 kdb
```

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.*

Plugins

Different backends can use different plugins:

/sw in the INI file config.ini

/sw/libreoffice in the XML file libreoffice.xml
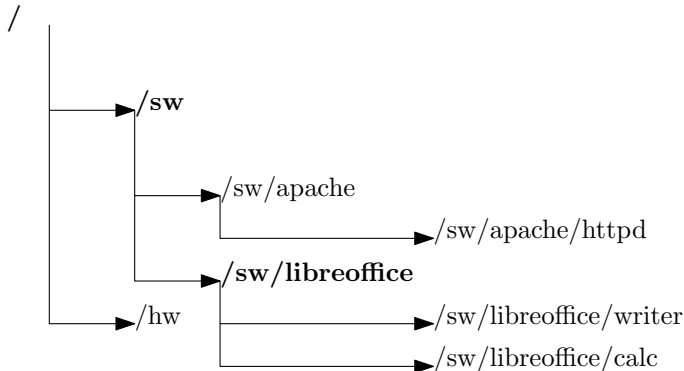
Cascading
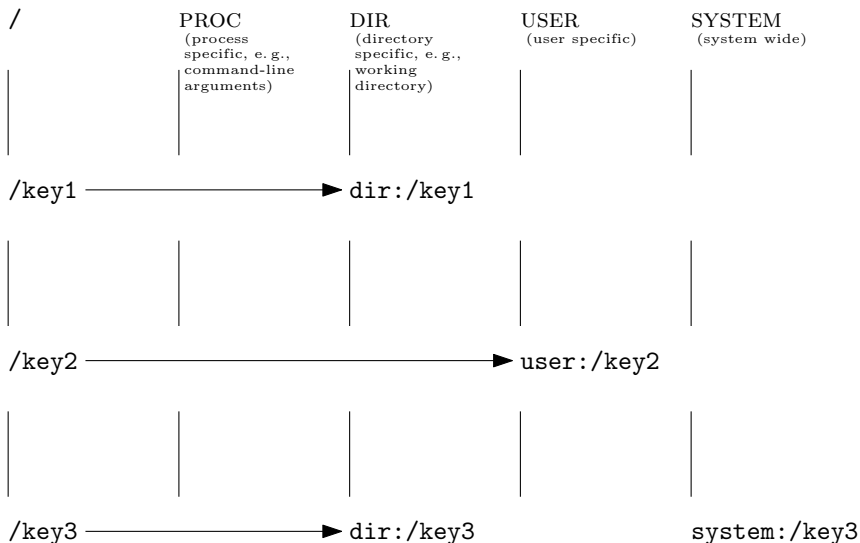
Conclusion

- 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

L04 Configuration Sources

Markus Raab

Institute of Information Systems Engineering, TU Wien

14.04.2021

This work is licensed under a Creative Commons *"Attribution-ShareAlike 4.0 International"* license.

Complexity

1. Configuration Files

2. Command-line Arguments

3. Environment Variables

4. Abstractions

5. Complexity
   - Trend
   - Calculation

6. Meeting
   - Recapitulation
   - Assignments
   - Preview

Configuration Files Command-line Arguments Environment Variables Abstractions **Complexity** Meeting
○○○○○○○○○○○○ ○○○○○○ ○○○○○○ ○○○○○○○○○○○○ ○○●○○○○○○ ○○○○○○○○○○○○○○○○

Trend

Trend Firefox
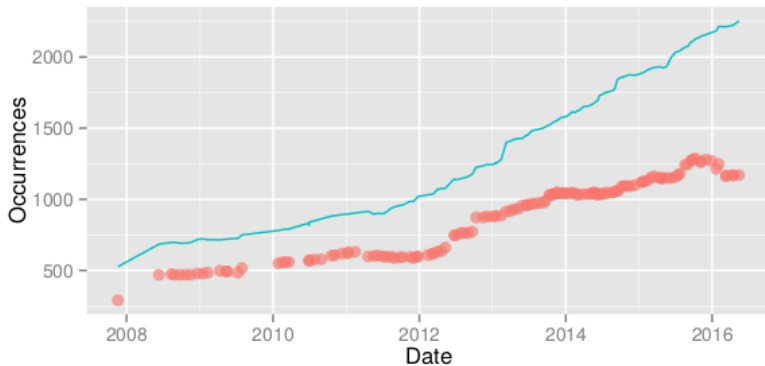
Trend Chromium

Trend Configuration Files

Xu et al. [9]

Configuration Files Command-line Arguments Environment Variables Abstractions **Complexity** Meeting
00000000000 000000 000000 000000000000 00000●0000 00000000000000000
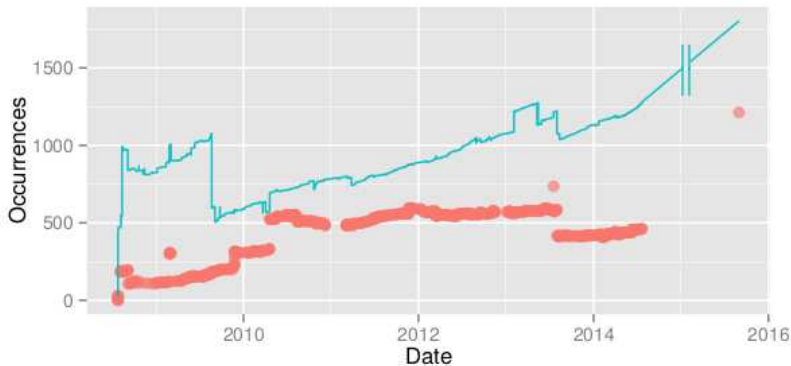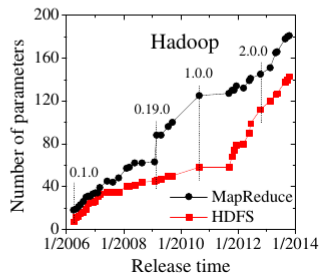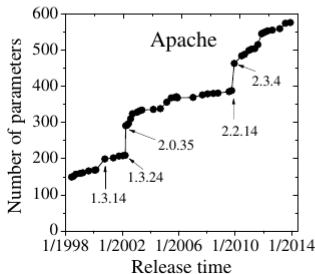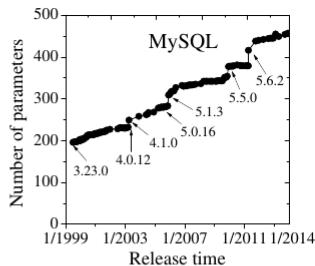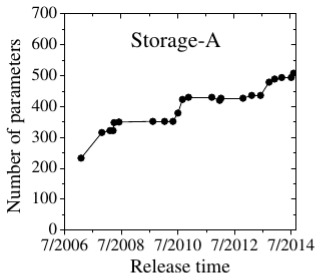
Calculation

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

Configuration Files Command-line Arguments Environment Variables Abstractions **Complexity** Meeting
○○○○○○○○○○○ ○○○○○○ ○○○○○○ ○○○○○○○○○○○○ ○○○○○○●○○○ ○○○○○○○○○○○○○○○

Calculation

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, . . .

Configuration Files   Command-line Arguments   Environment Variables   Abstractions   **Complexity**   Meeting
00000000000   000000   000000   00000000000000 0000000000 00000000000000

Calculation

Calculation of Complexity

Examples:

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

Configuration Files   Command-line Arguments   Environment Variables   Abstractions   **Complexity**   Meeting
0000000000   000000   000000   000000000000   0000000000   00000000000000

Calculation

Calculation of Complexity

Examples:

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

Calculation of Complexity

Examples:

- 600 boolean settings in Apache httpd (let us assume $n = 2$): $2^{600} \approx 10^{180}$
- 19 integer settings: $2^{32^{19}} = 2^{32 \cdot 19} = 2^{609} \approx 10^{183}$
- for 20 boolean and 20 enums with 5 possibilities:

Calculation of Complexity

Examples:

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

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

- for 20 boolean and 20 enums with 5 possibilities:

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

Calculation of Complexity (cont.)

Examples:

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

---

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

Calculation of Complexity (cont.)

Examples:

- an array with $1 - 20$ boolean settings: 2^{20}
- MySQL has 461 settings, of which 216 are non-simple types [9]
  (let us assume $n = \{3, 20\}$):

---

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

Calculation of Complexity (cont.)

Examples:

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

---

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

Calculation of Complexity (cont.) [2]

Examples:

- in Firefox resulting in 846 boolean options and 1,111 options of either integer or string, each with three values

Configuration Files   Command-line Arguments   Environment Variables   Abstractions   **Complexity**   Meeting
○○○○○○○○○○○○   ○○○○○○   ○○○○○○   ○○○○○○○○○○○○ ○○○○○○**○○○○**○ ○○○○○○○○○○○○○○○○○

Calculation

Calculation of Complexity (cont.) [2]

Examples:

- in Firefox resulting in 846 boolean options and 1,111 options of either integer or string, each with three values

$$2^{846} * 3^{1111} \approx 6.46 * 10^{259}$$

- LibreOffice

Configuration Files   Command-line Arguments   Environment Variables   Abstractions   **Complexity**   Meeting
0000000000   000000   000000   000000000000 00000**0000**● 00000000000000

Calculation

Calculation of Complexity (cont.) [2]

Examples:

- in Firefox resulting in 846 boolean options and 1,111 options of either integer or string, each with three values

$$2^{846} * 3^{1111} \approx 6.46 * 10^{259}$$

- LibreOffice

$$2^{4433} * 3^{31889}$$

L04 Configuration Sources

Markus Raab

Institute of Information Systems Engineering, TU Wien

14.04.2021

Meeting

Task

Do you have any questions?

Question

How can we share configuration settings?

Question

How can we share configuration settings?

Answer

- Implement support directly in application.
- Override/fallback links in specification.
- Calculate/transform values in specification.

Definition Configuration File

Configuration Files   Command-line Arguments   Environment Variables   Abstractions   Complexity   **Meeting**
○○○○○○○○○○○   ○○○○○○   ○○○○○○   ○○○○○○○○○○○○ ○○○○○○○○○○ ○○○○●○○○○○○○○○○

Recapitulation

Definition Configuration File

A **configuration file** is a file containing configuration settings.
A Web server configuration file:

```
1 port=80␣;␣comment
2 address=127.0.0.1
```

Question

What are keys? What are configuration values? What is metadata?

Configuration Files   Command-line Arguments   Environment Variables   Abstractions   Complexity   **Meeting**
0000000000   000000   000000   000000000000   0000000000   00000000000000

Recapitulation

Definition Configuration File

A **configuration file** is a file containing configuration settings.
A Web server configuration file:

```
1 port=80␣;␣comment
2 address=127.0.0.1
```

The configuration values are 80 and 127.0.0.1, respectively.
Other information in the configuration file is metadata for the
configuration settings (such as the comment).

Configuration File Formats

Task

What are the trends?   How can we deal with the many formats?

Configuration Files   Command-line Arguments   Environment Variables   Abstractions   Complexity   **Meeting**
○○○○○○○○○○○○   ○○○○○○   ○○○○○○   ○○○○○○○○○○○○   ○○○○○○○○○○   ○○○○○●○○○○○○○○○○

Recapitulation

Configuration File Formats

Task

What are the trends?

- away from CSV
- towards general-purpose serialization formats (INI, JSON)
- human-read/writable (YAML, TOML)
- programming language as configuration file

Task

How can we deal with the many formats?

- Key-value
- Mounting
- Plugins

Configuration Files   Command-line Arguments   Environment Variables   Abstractions   Complexity   **Meeting**
○○○○○○○○○○○○   ○○○○○○   ○○○○○○   ○○○○○○○○○○○○   ○○○○○○○○○○   ○○●○○○○●○○○○○○○○○

Recapitulation

Discussion

Task

What is your favourite configuration file format?

Task

Did you implement a configuration file parser and/or invented a
new configuration file format?

Task

Break.

Configuration Files Command-line Arguments Environment Variables Abstractions Complexity Meeting
○○○○○○○○○○○○ ○○○○○○ ○○○○○○ ○○○○○○○○○○○○ ○○○○○○○○○○ ○○○○○○○○●○○○○○○

Recapitulation

Semantics of Command-line Arguments

Configuration Files Command-line Arguments Environment Variables Abstractions Complexity **Meeting**
00000000000 000000 000000 000000000000 0000000000 00000000●000000

Recapitulation

Semantics of Command-line Arguments

- 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)

Configuration Files Command-line Arguments Environment Variables Abstractions Complexity **Meeting**
○○○○○○○○○○○○   ○○○○○○   ○○○○○○   ○○○○○○○○○○○○ ○○○○○○○○○○ ○○○○○○○○○●○○○○○

Recapitulation

Semantics of Environment Variables

Semantics of Environment Variables

- 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)

Configuration Files   Command-line Arguments   Environment Variables   Abstractions   Complexity   **Meeting**
○○○○○○○○○○○   ○○○○○○   ○○○○○○   ○○○○○○○○○○○○   ○○○○○○○○○○   ○○○○○○○○○○●○○○○

Recapitulation

Task

What are the differences between mounting and cascading?

Configuration Files Command-line Arguments Environment Variables Abstractions Complexity **Meeting**
○○○○○○○○○○○ ○○○○○○ ○○○○○○ ○○○○○○○○○○○○ ○○○○○○○○○ ○○○○○○○○○○○○○●○○○

Assignments

0.9.5 Release

- upgrade your installation to 0.9.5

0.9.5 Release

- upgrade your installation to 0.9.5
- read release notes
  `https://www.libelektra.org/news/0.9.5-release`

Configuration Files   Command-line Arguments   Environment Variables   Abstractions   Complexity   **Meeting**
○○○○○○○○○○○○   ○○○○○○   ○○○○○○   ○○○○○○○○○○○○   ○○○○○○○○○   ○○○○○○○○○○○○○●○○○

Assignments

0.9.5 Release

- upgrade your installation to 0.9.5
- read release notes
  https://www.libelektra.org/news/0.9.5-release
- rebase PRs

T1 Extra

Task

Calculate complexity of your teamwork and add to PR.

See scripts/complexity.rb

Configuration Files Command-line Arguments Environment Variables Abstractions Complexity **Meeting**
○○○○○○○○○○○○   ○○○○○○   ○○○○○○   ○○○○○○○○○○○○ ○○○○○○○○○○ ○○○○○○○○○○○○○○●○

Preview

Feedback

- Slides added
- Did TUWEL grading improve?

Configuration Files | Command-line Arguments | Environment Variables | Abstractions | Complexity | **Meeting**
○○○○○○○○○○○ ○○○○○○ ○○○○○○ ○○○○○○○○○○○○ ○○○○○○○○○○ ○○○○○○○○○○○○○○○●

Preview

Outlook

Will be online within this week:

- History of Configuration Management

Configuration Files Command-line Arguments Environment Variables Abstractions Complexity **Meeting**
○○○○○○○○○○○○ ○○○○○○ ○○○○○○ ○○○○○○○○○○○○ ○○○○○○○○○ ○○○○○○○○○○○○○○●

Preview

Outlook

Will be online within this week:

- History of Configuration Management
- CM Languages

Configuration Files   Command-line Arguments   Environment Variables   Abstractions   Complexity   **Meeting**
○○○○○○○○○○○○   ○○○○○○   ○○○○○○   ○○○○○○○○○○○○ ○○○○○○○○○○ ○○○○○○○○○○○○○○○●

Preview

Outlook

Will be online within this week:

- History of Configuration Management

- CM Languages

- CM Tools

[1] *getenv(3) Linux User's Manual*, March 2017.

[2] 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.

[3] Neal Lathia, Kiran Rachuri, Cecilia Mascolo, and George Roussos. Open source smartphone libraries for computational social science. In *Proceedings of the 2013 ACM Conference on Pervasive and Ubiquitous Computing Adjunct Publication*, UbiComp '13 Adjunct, pages 911–920, New York, NY, USA, 2013. ACM. ISBN 978-1-4503-2215-7. doi:

10.1145/2494091.2497345. URL
http://dx.doi.org/10.1145/2494091.2497345.

[4] Markus Raab and Gergö Barany. *Challenges in Validating FLOSS Configuration*, pages 101–114. Springer International Publishing, Cham, 2017. ISBN 978-3-319-57735-7. doi: 10.1007/978-3-319-57735-7_11. URL
http://dx.doi.org/10.1007/978-3-319-57735-7_11.

[5] Markus Raab and Patrick Sabin. Implementation of Multiple Key Databases for Shared Configuration.
ftp://www.markus-raab.org/elektra.pdf, March 2008. Accessed February 2014.

[6] Ariel Rabkin and Randy Katz. Static extraction of program configuration options. In *Software Engineering (ICSE), 2011 33rd International Conference on*, pages 131–140. IEEE, 2011.

[7] Thomas Strang and Claudia Linnhoff-Popien. A context modeling survey. In *First International Workshop on Advanced Context Modelling, Reasoning And Management at UbiComp 2004*, September 2004. URL http://elib.dlr.de/7444/.

[8] Tianyin Xu, Jiaqi Zhang, Peng Huang, Jing Zheng, Tianwei Sheng, Ding Yuan, Yuanyuan Zhou, and Shankar Pasupathy. Do not blame users for misconfigurations. In *Proceedings of the Twenty-Fourth ACM Symposium on Operating Systems Principles*, pages 244–259. ACM, 2013.

[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.