Towards Understanding and Analyzing Rationale in Commit Messages using a Knowledge Graph Approach

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MDEIntelligence Workshop
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Université de Montréal

POLYTECHNIQUE MONTRÉAL
UNIVERSITÉ D'INGÉNIERIE

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PhD topic :

Rationale extraction and management

Motivation: Understanding Rationale

For a **decision**, software/system developer has **rationale**
'Why' reasoning for their decision

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Rationale is *useful information* to deeply understand the system
Learn from mistakes, reuse solutions

Rationale in Code Commits

Scope: Code commit messages

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```
‘‘Fix:  Added check to prevent null pointer exception.’’
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‘‘changes’’

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Challenges:

- What is rationale *exactly*?
- Implicit or unrecorded

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- Ambiguous language
  - Especially past/future tenses
  - Non-native writers
- Need technical understanding

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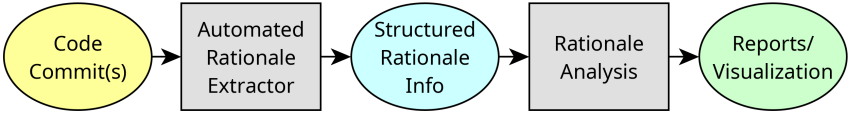
Research question:
How can we *structure* and *extract* rationale information from code commits?

Kantara: Rationale Framework

"*Kantara: a framework for end-to-end rationale reconstruction*"



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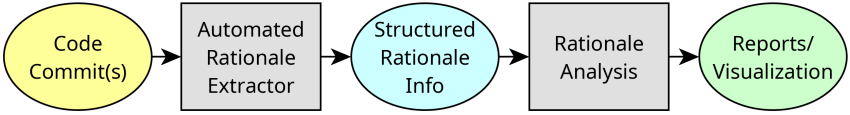

Purposes:

- As research to gain insight into rationale itself
- Allow developers to better understand presence of rationale in their software
  - Who, what, where, when
- Decide if a code commit has *insufficient rationale*
  - Flag or reject

Running Example: Linux OOM Subsystem

Linux kernel:

- Development is through Git commits
- Culture for motivating/describing changes
- Valuable (highest-quality?) source of rationale

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Out-of-Memory Killer subsystem:

- When Linux kernel runs out of memory
- OOM-Killer is called to avoid crashing
- Two broad steps:
  1. Select “best” task to kill
  2. Force task to release memory and exit
- Meaningful heuristics

Commit Example

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#	Sentence
0	signal: Use SEND_SIG_PRIV not SEND_SIG_FORCED with SIGKILL and SIGSTOP

Commit Example

#	Sentence
0	signal: Use SEND_SIG_PRIV not SEND_SIG_FORCED with SIGKILL and SIGSTOP
1	Now that siginfo is never allocated for SIGKILL and SIGSTOP there is no difference between SEND_SIG_PRIV and SEND_SIG_FORCED for SIGKILL and SIGSTOP.
2	This makes SEND_SIG_FORCED **unnecessary and redundant** in the presence of SIGKILL and SIGSTOP.
3	Therefore change users of SEND_SIG_FORCED that are sending SIGKILL or SIGSTOP to use SEND_SIG_PRIV instead.
4	This removes the last users of SEND_SIG_FORCED.

Creating a Labelled Rationale Dataset

Goal: Build a dataset of OOM-Killer commit sentences,
classified wrt rationale

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Procedure:

- Collect 410 commits (paper reports 180)
- Remove merge commits, filter code sentences
- Three authors label sentences
- Resolve conflicts in discussion

Sentence Classification

Sentence Classification

Label	Meaning
Inapplicable	Pre-processing error or bad sentences (i.e., does not contain English sentences)
Supporting Facts	A narration of facts used to support a decision
Rationale	Reason for a decision or value judgment
Decision	An action or a change that has been made, including a description of the patch behaviour

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- Obtained through piloting rounds and discussions
- **Multiple classifications per sentence**
- In disagreement, take classification union
- Fleiss kappa: Around 0.65 (fair to good agreement)

Classification Example

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0	Decision	signal: Use SEND_SIG_PRIV not SEND_SIG_FORCED with SIGKILL and SIGSTOP

Classification Example

0	Decision	signal: Use SEND_SIG_PRIV not SEND_SIG_FORCED with SIGKILL and SIGSTOP
1	Supporting Fact & Rationale	Now that siginfo is never allocated for SIGKILL and SIGSTOP there is no difference between SEND_SIG_PRIV and SEND_SIG_FORCED for SIGKILL and SIGSTOP.
2	Rationale	This makes SEND_SIG_FORCED unnecessary and redundant in the presence of SIGKILL and SIGSTOP.
3	Decision	Therefore change users of SEND_SIG_FORCED that are sending SIGKILL or SIGSTOP to use SEND_SIG_PRIV instead.
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OOM Subsystem Insights

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Decision summary phase ,
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Amount of rationale:

- **97.5%** of commits contain rationale
- About **40-50%** of sentences per commit contain rationale

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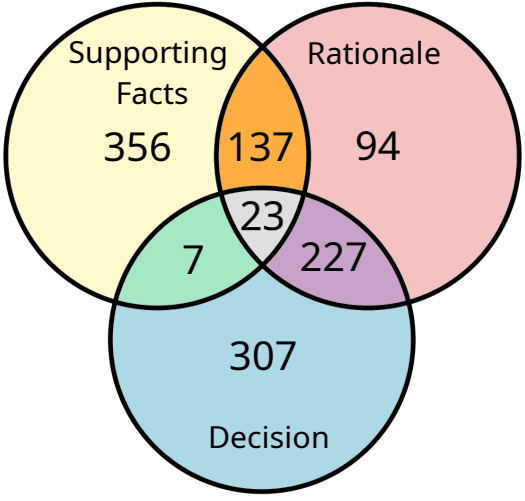

Automatic Classification of Sentences

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Binary classification: Logistic regression, decision tree, SVM
Multi-label classification: Random Forest, XGBoost, KNN

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XGBoost classification evaluation			
Label	**Precision**	**Recall**	**F1-score**
Decision	**0.76**	**0.69**	**0.72**
Rationale	0.62	0.41	0.49
Supporting Facts	0.64	0.68	0.66

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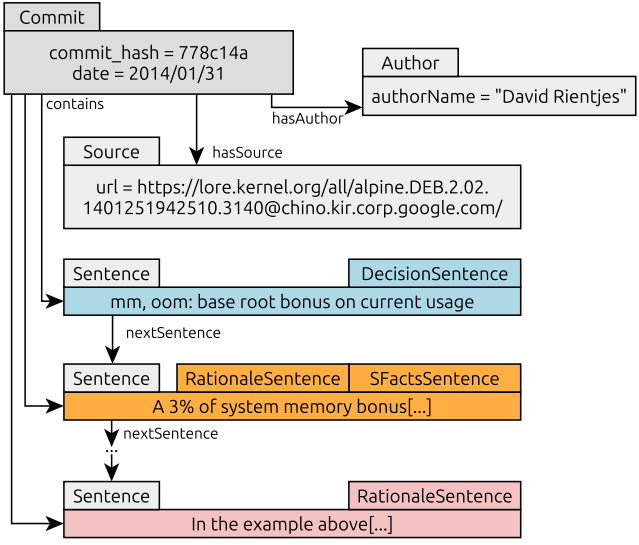
Insights:

- Overall poor performance
- Decisions easier to classify, rationale is harder

Rationale Info as a Graph

- Prior work modelled relationships between commits
- Here, we model the *sentences* as a *knowledge graph*



openCAESAR Framework

Elaasar *et al.*, “openCAESAR: Balancing agility and rigor in model- based systems engineering,” in Proceedings of SAM Conference, 2023

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Ontological Modelling Language (OML) for easily creating OWL ontologies and the knowledge graph

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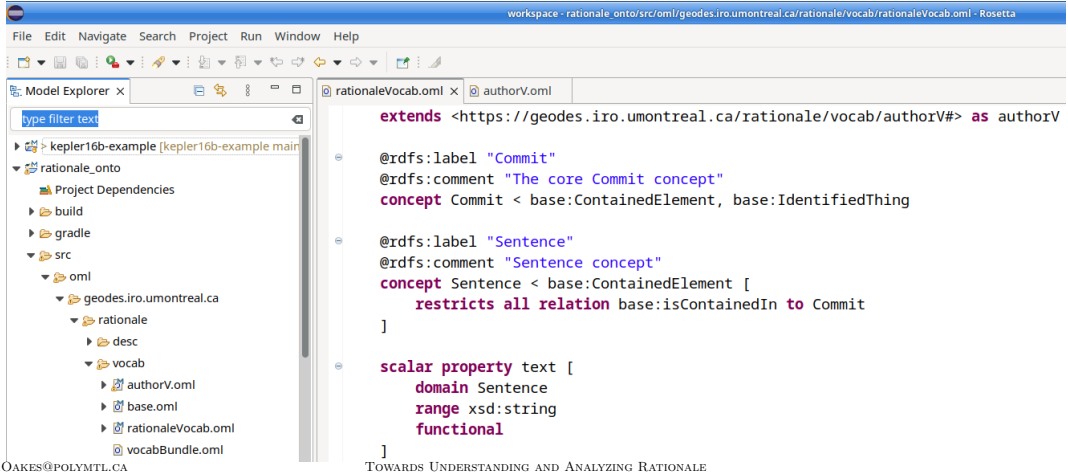
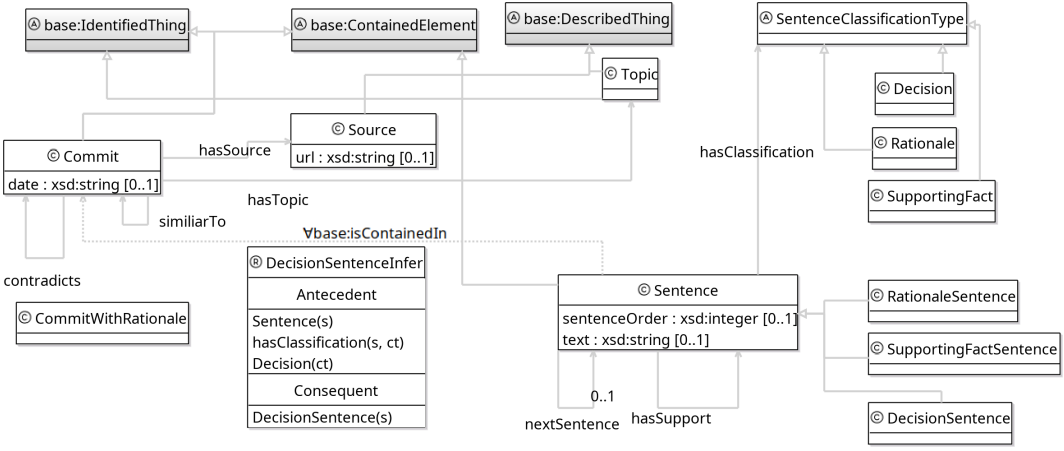


Ontology and Inferencing



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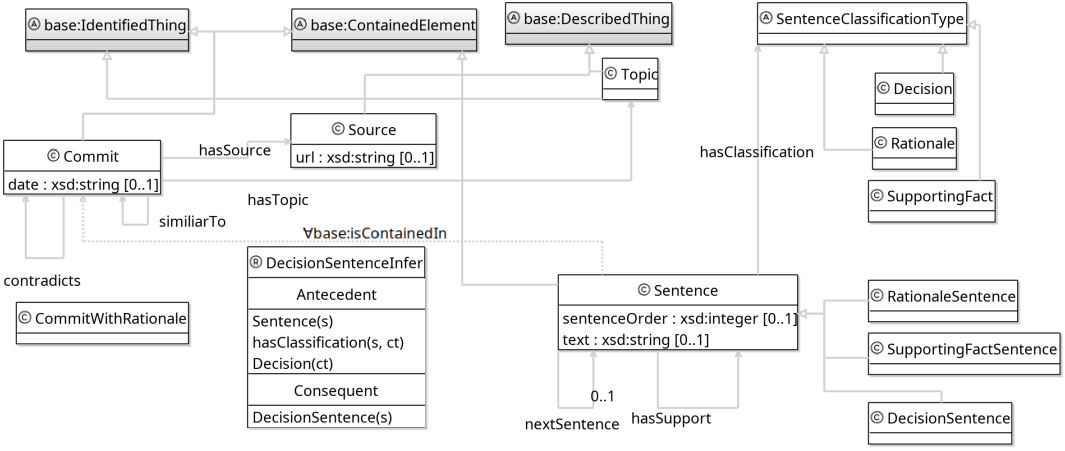

- Inferred multi-classification simplified analysis
- Easier to query for `CommitWithRationale`, `RationaleSentence`

Analysing Rationale Info

SPARQL queries on knowledge graph

SPARQL queries on knowledge graph

Implemented:

- Listing authors and their commits
- List of sentences containing rationale
- List of commits containing rationale (uses inference)


```
{
"author": { "value": "Michal Hocko" } ,
"commit_id": { "value": "c0" } ,
"text": { "value": "mm: reduce noise in show_mem for lowmem allocations" } ,
"isCommitWithRationale": { "value": "true" } ,
"isSentenceRationale": { "value": "true" } ,
"isSentenceDecision": { "value": "true" } ,
"isSentenceSupporting": { "value": "false" }
}
```

Visualization

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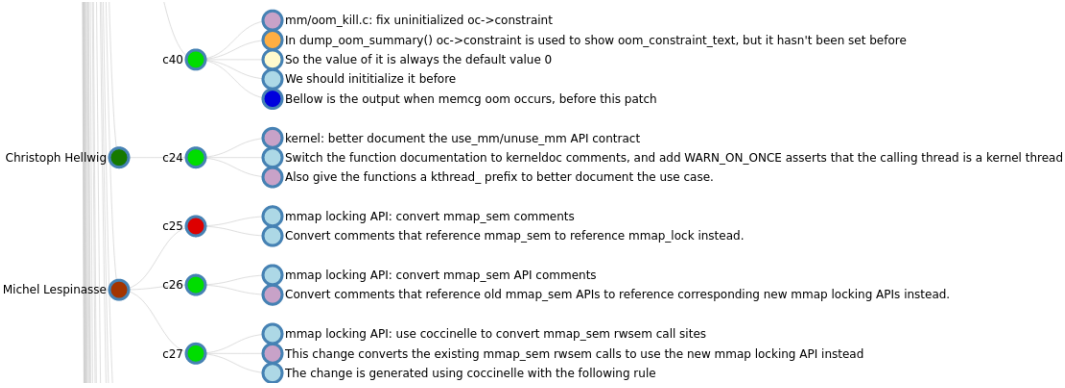

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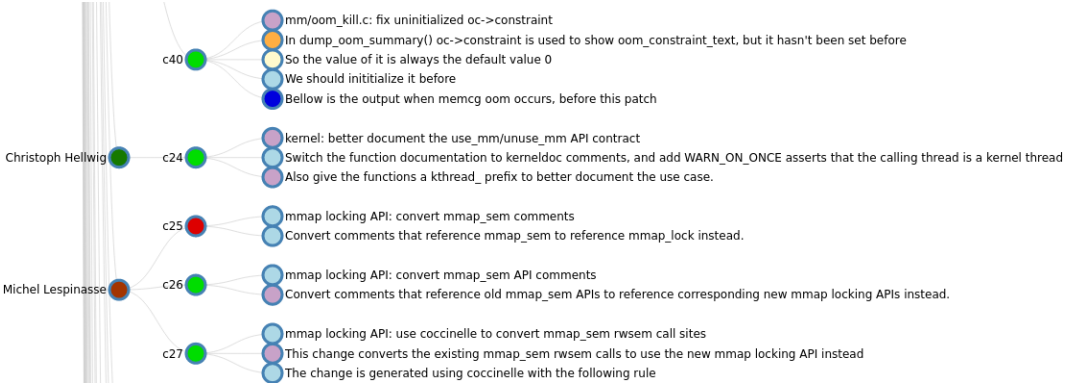

Intention:

- Allow developers/researchers to understand rationale presence
- Identify commits/subsystems/developers without sufficient rationale

Conclusion

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Summary:

1. Classification of sentences
   - Supporting fact, rationale, decision
2. Insights into rationale presence
   - 40% of commit, category overlap
3. Poor automatic classification
4. Structuring as knowledge graph, inferencing, and analysis
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Future work:

- Finish dataset
- Investigate indicators for rationale
  - Evolution over time
  - Developer characteristics
- Improve auto. classification
- Kantara as a pull request bot

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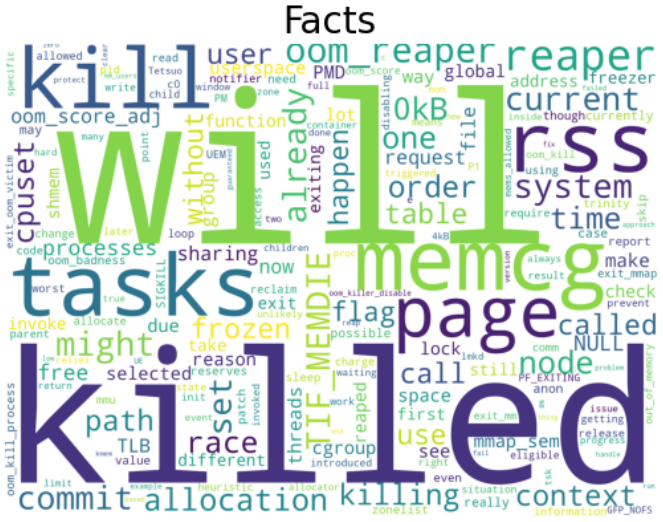
Facts
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oom_score_adj
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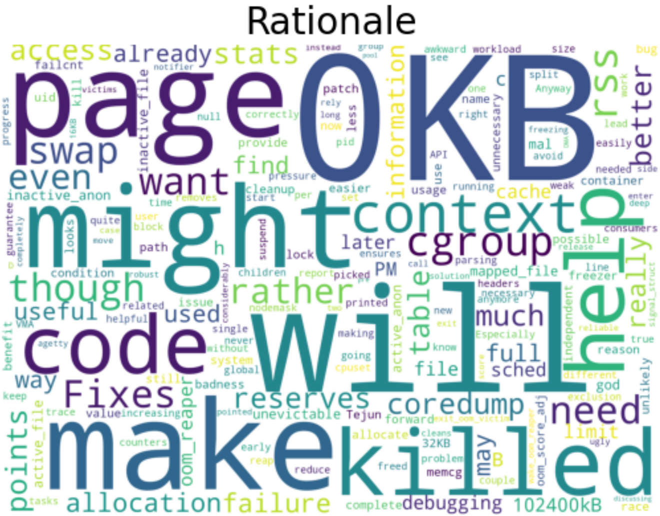
Rationale
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early
reduce
freed
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couple
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race
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workload
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notifier
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kill
uid
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correctly
provide
pressure
cleanup
start
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running
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consumers
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parsing
freezer
headers
necessary
anymore
Especially
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different
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exclusion
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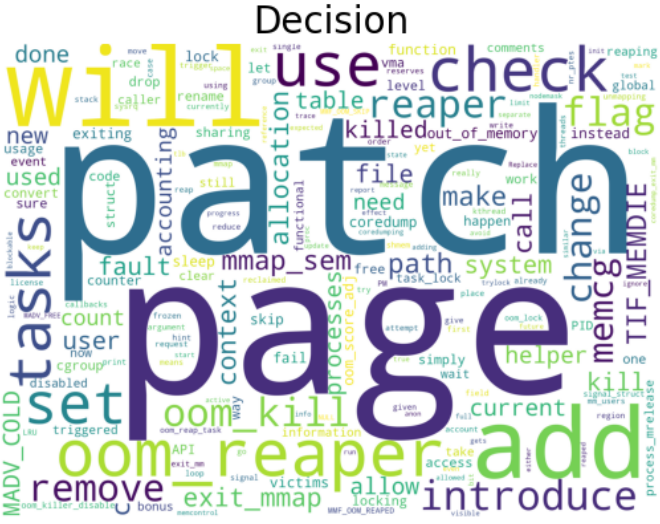
Decision
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oom_kill
reaper
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change
memcg
TIF_MEMDIE
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race
drop
caller
rename
table
killed
out_of_memory
instead
reaping
global
new
exiting
sharing
accounting
allocation
file
need
make
work
call
used
convert
sure
fault
sleep
clear
counter
mmap_sem
free
path
system
count
user
skip
fail
context
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oom_score_adj
helper
simply
wait
kill
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information
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disabled
cgroup
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allow
locking
victims
bonus
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happen
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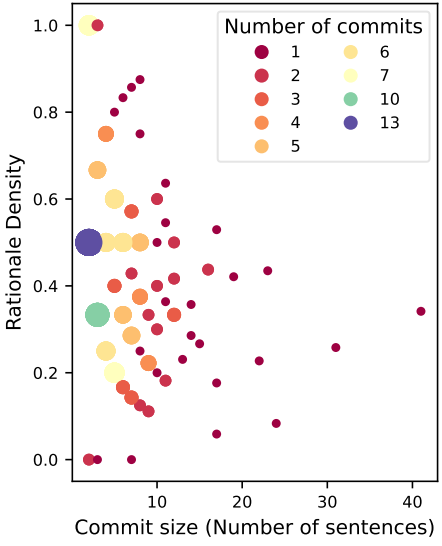
MMF_OOM_REAPED


Number of commits
1
2
3
4
5
6
7
10
13
Rationale Density
0.0
0.2
0.4
0.6
0.8
1.0
10
20
30
40
Commit size (Number of sentences)