Towards Formally Verified Rule Language Compilers

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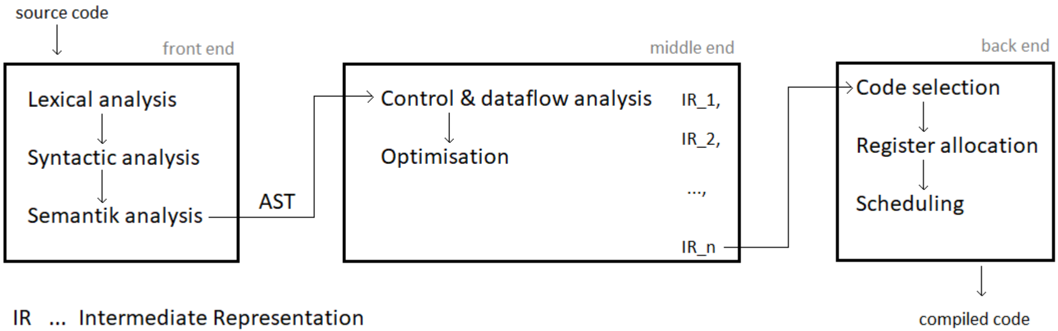
August 22, 2024

What is the problem

- optimisations need formal verification
  - search for a fixpoint may not terminate, e.g. Skolem chase
  - some algorithms optimize based on edge cases
- correctness guarantees should not compromise efficiency

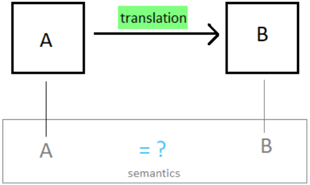
Short trip to the world of compilers



IR ... Intermediate Representation

Formally verified compilers

- 2 approaches
  - internally verified - directly from scratch
  - external verification aka. translation validation (more flexible)



- formalize representations; formalize transitions; show preservation of semantics

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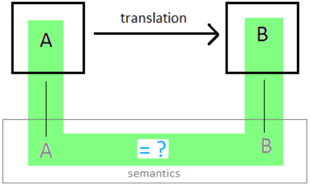

- formalize representations; formalize transitions; show preservation of semantics

Semantic preservation

- formalize representations; formalize transitions; show preservation of semantics
- theorem provers like Coq or Lean can be used

"If the compiler produces compiled code C from source code S, without reporting compile-time errors, then every observable behavior (B) of C is either identical to an allowed behavior of S, or improves over such an allowed behavior of S by replacing undefined behaviors with more defined behaviors." [2]

Semantic preservation

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- theorem provers like Coq or Lean can be used

$$S \texttt{ safe} \Rightarrow \forall B, S \Downarrow B \iff C \Downarrow B$$

Semantic preservation

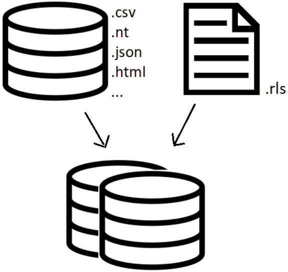
- formalize representations; formalize transitions; show preservation of semantics
- theorem provers like Coq or Lean can be used

$$\forall S, C, Comp(S) = \mathtt{OK}(C) \Rightarrow S \approx C$$

Rule reasoning systems

1. logic programming systems
2. KG and deductive database engines
3. specialised data-analytics systems
4. data management frameworks

according to *Nemo: Your Friendly and Versatile Rule Reasoning Toolkit* [0]



[1]

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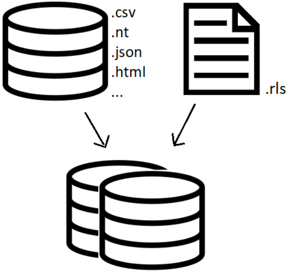
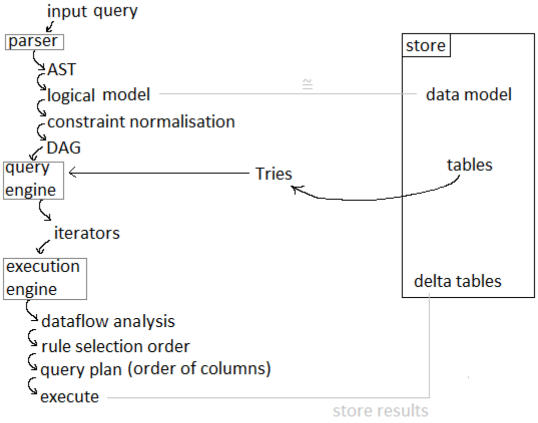
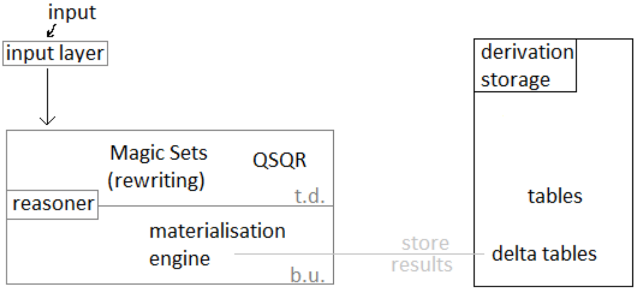


[1]

Nemo


input query
parser
AST
logical model
≅
constraint normalisation
DAG
query engine
Tries
iterators
execution engine
dataflow analysis
rule selection order
query plan (order of columns)
execute
store results
store
data model
tables
delta tables

VLog


input
input layer
Magic Sets
(rewriting)
QSQR
t.d.
reasoner
materialisation
engine
b.u.
store
results
derivation
storage
tables
delta tables

Soufflé

Vadalog

LogicBlox

What they have in common

todo

	nemo	VLog	Vadalog	LogicBlox	Soufflé
type	2, 3	2	2	3	3
data strct	tries	QSQR	?	treaps	tries
graph repr	DAG	magic sets	KG	?	B-tree
storage	delta tables	derivation storage	KG repos	workspaces	R.A.M
join	LFTJ	?	?	LFTJ	loop-based
reasoning	t.d.	t.d./b.u.	.	.	.

t.d. = top-down (query-driven reasoning)

b.u. = bottom-up (materialisation)

Concrete plans for verification

todo

- semi-naive evaluation (since it's optimized)
- LFTJ (since it's optimized)
- 1-parallel restricted chase
- (skolem chase)

References

[0] **classification of rule reasoning systems** from *Nemo: Your Friendly and Versatile Rule Reasoning Toolkit*, Alex Ivliev and Lukas Gerlach and Simon Meusel and Jakob Steinberg and Markus Krötzsch, https://iccl.inf.tu-dresden.de/w/images/f/fb/KR-2024-CR.pdf
[1] **database icon** https://linearicons.com/, created by https://perxis.com/ - https://cdn.linearicons.com/free/1.0.0/Linearicons-Free-v1.0.0.zip, CC BY-SA 4.0, https://commons.wikimedia.org/w/index.php?curid=77236210;
note icon SimpleIcon http://www.simpleicon.com/, CC BY 3.0 https://creativecommons.org/licenses/by/3.0, via Wikimedia Commons; changes were made to the graphics
[2] **definition of semantic preservation** taken from *CompCert - A Formally Verified Optimizing Compiler*, Leroy, Xavier and Blazy, Sandrine and Kästner, Daniel and Schommer, Bernhard and Pister, Markus and Ferdinand, Christian, https://inria.hal.science/hal-01238879/file/erts2016_compcert.pdf