Capturing Mathematical Knowledge in Drasil: the Case of Theories

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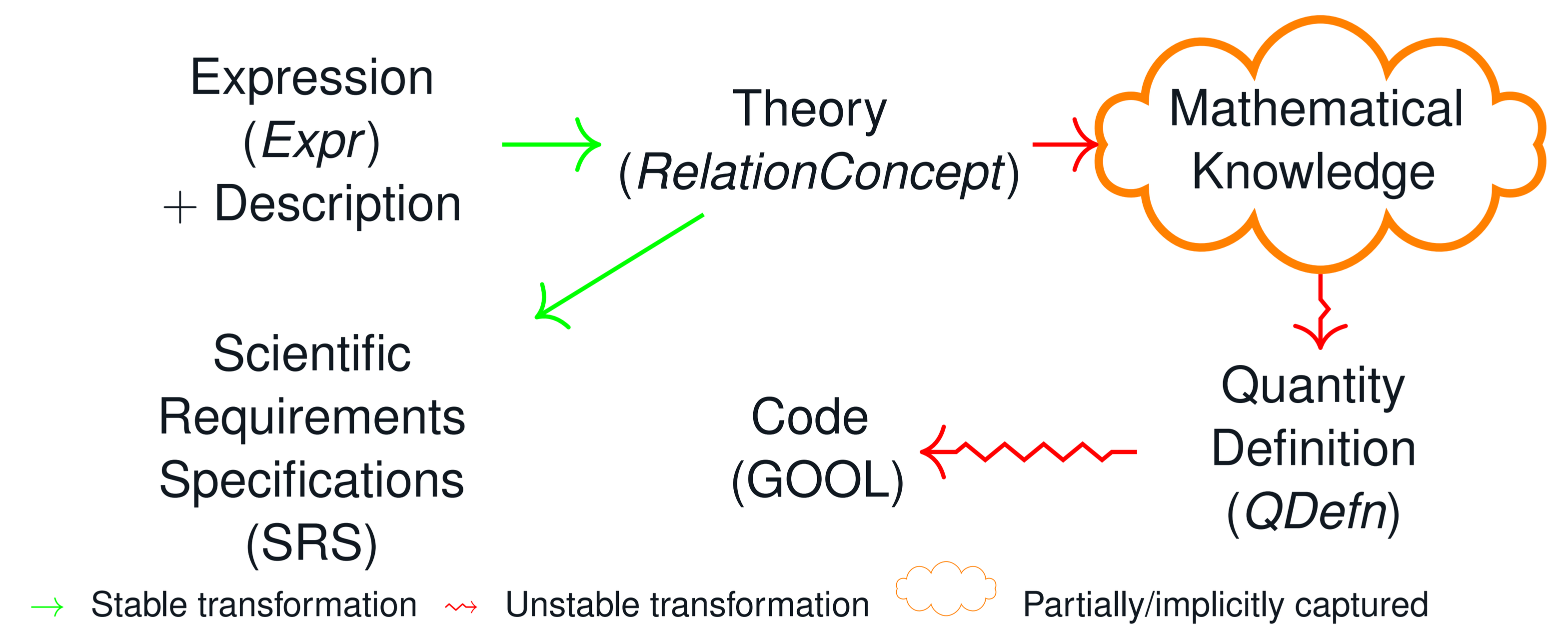
What is Drasil?

Drasil is a framework for generating families of software artifacts from a coherent knowledge base, following its mantra; "Generate All The Things!". Drasil uses a series of variably sized Domain-Specific Languages (DSLs) to describe various fragments of knowledge that domain experts and users alike may use to piece together fragments of knowledge into a coherent "story". Through forming some coherent "story" in a domain captured by Drasil, a representational software artifact may be generated. Drasil currently focuses on Scientific Computing Software (SCS), following Smith and Lai's Software Requirements Specifications (SRS) template as described in [4]. Behind the scenes of the SRS, a mathematical language is used to describe various theories, and have representational software constructed via compiling to Generic Object-Oriented Language (GOOL) [2]. Through encoding knowledge in Drasil, an increase in productivity (and maintainability) in building reliable and traceable software artifacts is observed [5], specifically in SCS [3]. Drasil's source code (Haskell), case studies, and documentation studies can be found on its website; `https://jacquescarette.github.io/Drasil/`.

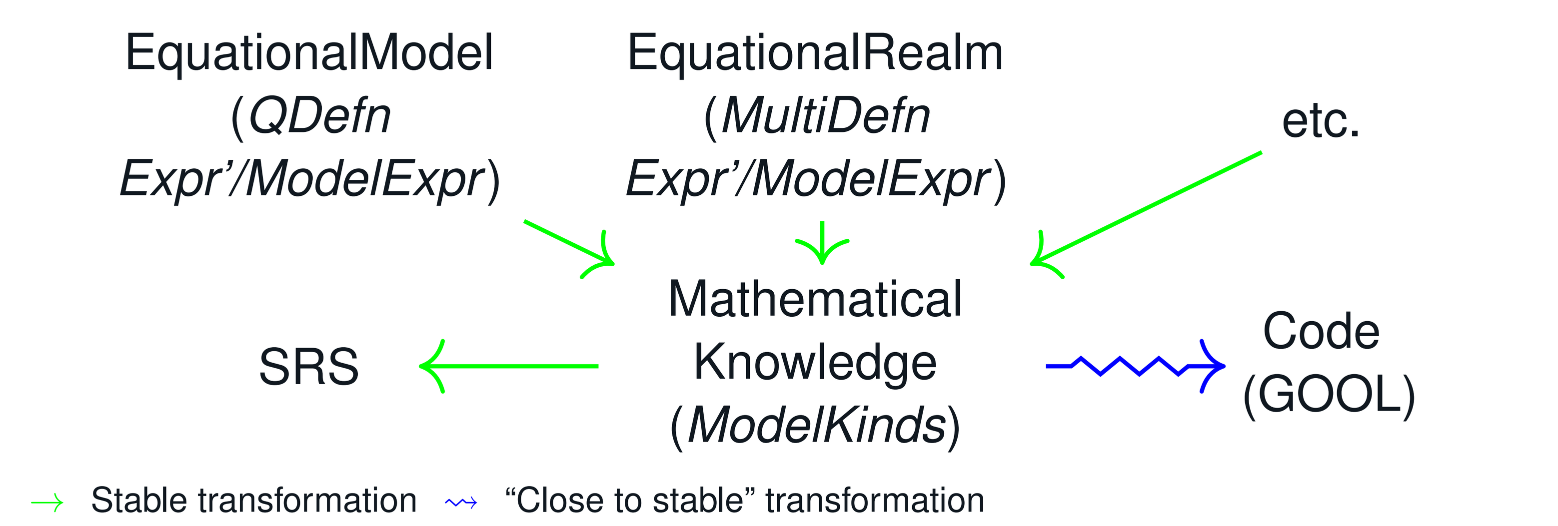
Research Motivation/Problem

- *Theories* are constructed using a natural English description and a single term from a single universal mathematical expression language.
  - Expressions must be precisely written in a manner "digestible" to the code generator so that a representational software code snippet can be constructed.
  - Not all expressions have definite values and are immediately usable in all programming languages.
- Only a handful of the case studies generate code, because...
  - Understanding of the expressions is weak and brittle as they don't expose sufficient information about the theories.
  - Software artifacts are validated, we must obey rigid rules of other languages.
  - Cognitive load of writing expressions in precise manners to accommodate the code generator would increase.

Mathematical Knowledge Flow



Capturing Mathematical Knowledge



What changed?

- More static validation! Safer generation!
- Expression language division: *Expr* $\longrightarrow$ *Expr'* $\cup$ *ModelExpr* $\cup$ *CodeExpr*
  - *Expr'*: Restricting the language to terms "well-understood", with a definite meaning and value.
  - *ModelExpr*: Restricting the language to terms with definite meanings, but not necessarily definite values.
  - *CodeExpr*: Restricting the language to terms that have a definite meaning and value to most general purpose programming languages, with some goodies for OOP.
- Created Typed Tagless Final (TTF) [1] encodings; Expression creation is just as easy as it ever was!

- Created a system of classifying *theories* (*ModelKinds*)
  - Increased the depth & breadth of knowledge contained.
  - First-class representation of theories, with their meaningful components fully exposed. No more brittle *cast*-like conversion of mathematical expressions (low info. density) to well-understood pieces of knowledge (high info. density).
  - Instances of theories usable in a wide variety of ways can be statically & reliably checked for validity.
  - Creating instances of theories comes with projectional editor-like ease.
- Improving productivity, stability, and flexibility in usage
- Current theory types:
  - *EquationalModel*: $x = f(a, b, c, \dots)$
  - *EquationalRealm*: $x = a \lor x = b \lor x = c \lor \dots$
  - *EquationalConstraints*: $a \land b \land c \land \dots$
  - *DEModel*: $\dots \frac{dy}{dx} \dots$

Conclusion & Future Work

- Through capturing and classifying mathematical knowledge, we earn significant gains in flexibility, usability, and productivity.
- *In progress*: Adding extra type information to expressions, allowing us to add type information to GOOL, and further improve static validity rules of various mathematical constructions.
- Teaching more theories to Drasil!

References

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[3] W. Spencer Smith. "Beyond Software Carpentry". In: *2018 International Workshop on Software Engineering for Science (held in conjunction with ICSE'18)*. 2018, pp. 32–39.

[4] W. Spencer Smith and Lei Lai. "A New Requirements Template for Scientific Computing". In: *Proceedings of the First International Workshop on Situational Requirements Engineering Processes – Methods, Techniques and Tools to Support Situation-Specific Requirements Engineering Processes, SREP'05*. In conjunction with 13th IEEE International Requirements Engineering Conference. Paris, France, 2005, pp. 107–121.

[5] Daniel Szymczak, W. Spencer Smith, and Jacques Carette. "Position Paper: A Knowledge-Based Approach to Scientific Software Development". In: *Proceedings of SE4Science'16 in conjunction with the International Conference on Software Engineering (ICSE)*. Austin, Texas, United States, May 2016.