

# CAPTURING MATHEMATICAL KNOWLEDGE IN DRASIL: THE CASE OF THEORIES

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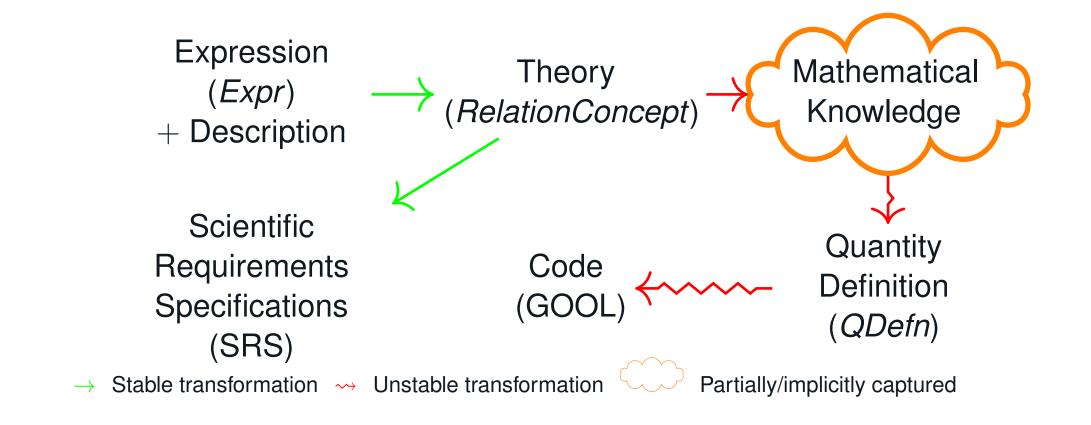
#### What is Drasil?

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/.

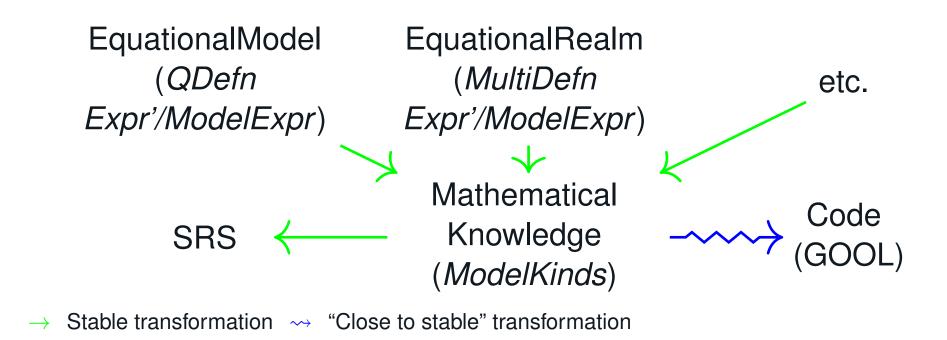
#### **Research Motivation/Problem**

- 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* → *Expr'* ∪ *ModelExpr* ∪ *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:
- Equational Model: x = f(a, b, c, ...)
- EquationalRealm:  $x = a \lor x = b \lor x = c \lor \dots$
- EquationalConstraints:  $a \wedge b \wedge c \wedge \dots$
- 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

- [1] Jacques Carette, Oleg Kiselyov, and Chung-chieh Shan. "Finally tagless, partially evaluated: Tagless staged interpreters for simpler typed languages". In: *Journal of Functional Programming* 19.5 (2009), pp. 509–543.
- [2] Jacques Carette, Brooks MacLachlan, and W. Spencer Smith. "GOOL: a generic object-oriented language". In: *Proceedings of the 2020 ACM SIGPLAN Workshop on Partial Evaluation and Program Manipulation*. 2020, pp. 45–51.
- [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.