First Committee Meeting

Progress Report

Jason Balaci

McMaster University

Oct. 21^{st}, 2021

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Who am I?

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- I am **Jason Balaci**

Me, Camping in Killarney Prov. Park, Fall 2019

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- Graduate of *McMaster University*, holding...
  - Hons. Actuarial and Financial Mathematics (B.Sc.)
  - Minor in Computer Science
- Currently pursuing a thesis-based Master's of Computer Science (M.Sc) at *McMaster University*, under the supervision of **Dr. Jacques Carette**.

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[1] https://academiccalendars.romcmaster.ca/preview_program.php?catoid=45&poid=23470&returnto=9166
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- Together, the courses completed satisfies the "Courses Requirement" as mentioned in the academic calendar[1] and the "Regulations for the Computer Science M.Sc. Program" document[2].

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- Attended a thesis defence to learn about what to expect from a thesis defence (and learn about their research).

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- Attended a thesis defence to learn about what to expect from a thesis defence (and learn about their research).
- Supervisory committee is formed, and we are currently having our first supervisory committee meeting.
    - *Supervisor*: Dr. Jacques Carette
    - Dr. Spencer Smith
    - Dr. Wolfram Kahl

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Preface

What is Drasil?

Drasil...

Drasil's Logo
[Carette et al., 2021b][Yggdrasil - Wikipedia, 2021]

[1] https://jacquescarette.github.io/Drasil/

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- Drasil currently focuses on building research software, generating Software Requirement Specification documents (SRS) in both LaTeX and HTML (with MathJaX), code to solve a problem, README files, Makefiles, graphs, etc.

Drasil Case Studies

[1] https://jacquescarette.github.io/Drasil/#Sec:Examples

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Drasil Case Studies

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  - **Slope Stability Analysis Program (SSP)** - Assessment of the safety of a slope (composed of rock and soil) subject to gravity, identifying the surface most likely to experience slip and an index of its relative stability (factor of safety).

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The Drasil website is also generated by Drasil!

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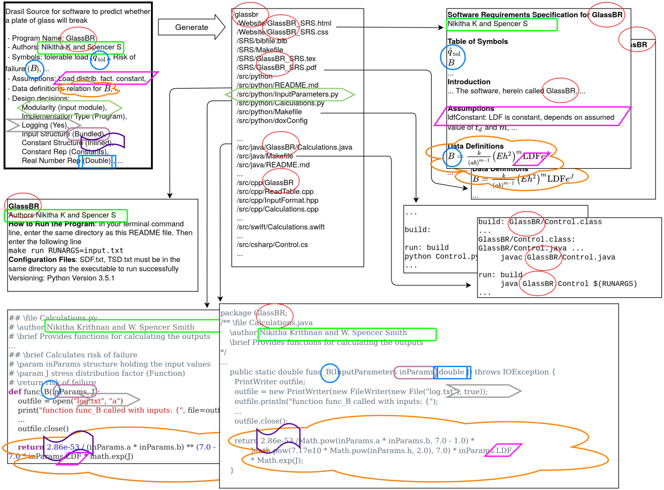
Taking a closer look at one of the examples: GlassBR

GlassBR Generates Code!



Knowledge flow from "knowledge-base"/source to artifacts, by Dr. Spencer Smith

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Generating view-only data (e.g., SRS documents) is considerably easier than generating artifacts that are "evaluated" in some way or another (e.g., compilation/interpretation/static analysis). These are largely different "printers".

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A few, notable, blocking problems:

- Confidently generating usable software artifacts without strong type information places significant stress on developers, resulting in a higher likelihood of bugs in artifacts.
- Existing "theories"/"*Models"[1] don't expose enough information. They must be enriched, so that we can better interact with, and understand them.

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Goal #1: Typed Expression Language

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- We want to ease developer cognitive load when writing expressions, as they will need to ensure their expressions are coherent, or else various problems (type, syntax, etc) can occur at runtime (of generated software artifacts).

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- Catches, within reason, all possible scenarios where an expression goes awry.
- Allows GOOL code generator to also become typed!
- Add extra functionality to existing expression languages safely, allowing for new data types to be introduced.
- Adding type information to expressions shouldn't be a burden!
- Decomposing/splitting vocabularies so that we can impose restrictions on allowed terms, while not causing problems for interoperability.

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    - Expr is intended to be "directly computable" language (e.g., an advanced calculator), expected to have a *total* conversion into code.
    - Created ModelExpr, which contains all other terms we might want to express, but won't necessarily be directly convertible into code. There are still a few operations left in Expr that need to be moved over, however.

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Current Progression

- Split core mathematical expression language (Expr) into 3 variants (Expr, ModelExpr, and CodeExpr)
  - Expr is intended to be "directly computable" language (e.g., an advanced calculator), expected to have a *total* conversion into code.
  - Created ModelExpr, which contains all other terms we might want to express, but won't necessarily be directly convertible into code. There are still a few operations left in Expr that need to be moved over, however.
    - Theories that rely on discussion of terms only found in ModelExpr may only have representational code generated if we have rich surrounding data (preferably also that generates said "ModelExpr"s, see goal #2).

Goal #1: Typed Expression Language

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  - CodeExpr is a clone of Expr, with a few extra functionalities for GOOL.
  - Created a “typed tagless final” [Carette et al., 2009] smart constructor encoding for writing expressions in Expr, and/or ModelExpr.

Goal #1: Typed Expression Language

What are the next steps?

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- Adjusting containers to allow for expressions with a type variable.
- Adding the final type signatures, using Haskell GADT syntax.

Assume we have a general concept consisting of $y = m \cdot x + b$, and a natural description “The equation of a line, with a constant, b, and a dependent and independent variable, y and x, respectively.”.

Goal #2: Theory Discrimination – “ModelKinds”

Problem Description

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- But if the equation were written slightly different (e.g. $y - b = m \cdot x$), generating code based on this "Relation"/Expr is significantly more tedious because we will need to solve for "y".

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- What if we want to change the symbols used? How do we know the "b" referred to in the equation is the same as the symbol "b" in the natural description?
- We're ignoring the obvious information that this is the equation of a line, and that this is just an alternative "Definition".

Goal #2: Theory Discrimination – "ModelKinds"

Problem Description, *cont.d*

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- "RelationConcepts" were heavily used in both displaying expressions, and code generation. They are essentially "Relation"s ("Expr"s) with a natural language description of them.

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- “RelationConcepts” were heavily used in both displaying expressions, and code generation. They are essentially “Relation”s (“Expr”s) with a natural language description of them.
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Problem Description, *cont.d*

- "RelationConcepts" were heavily used in both displaying expressions, and code generation. They are essentially "Relation"s ("Expr"s) with a natural language description of them.
- "RelationConcept"s don't contain enough information on their own to be a core component usable in general code generation.
- If the "shape" of the expressions are not uniform, then writing more "interpreters"/"views"/code generators for them required difficult pattern analysis. It's also not a total-conversion.

Goal #2: Theory Discrimination – “ModelKinds”

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- We should be able to easily add extra “ModelKind” variants.

Goal #2: Theory Discrimination – "ModelKinds"

Current Progression

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- Considerable number of "theories"/"*Models" have been restructured, but there are still many that are pending classification.
  - Most are best to be done once we have a typed expression language (so that we can better handle expressions that involve collections), and the rest are differential equation-related models (primarily Dong's domain).

Goal #2: Theory Discrimination – "ModelKinds"

What are the next steps?

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- Understanding what kinds of needs we have for "collections", pushing this information back into the typed expression language (once that is fully typed), and then creating model containers for these models.

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What are the next steps?

- Understanding what kinds of needs we have for “collections”, pushing this information back into the typed expression language (once that is fully typed), and then creating model containers for these models.
- For the differential equation-related models, we will need to build appropriate models for each possible kind.

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Fin.

Thank you!

Table of Contents

References I

Carette, J., Kiselyov, O., and Shan, C.-c. (2009).
Finally tagless, partially evaluated: Tagless staged interpreters for simpler typed languages.
Journal of Functional Programming, 19(5):509–543.

Carette, J., Smith, S., and Balaci, J. (2021a).
Pending publication: When capturing knowledge improves productivity.

Carette, J., Smith, S., Balaci, J., Hunt, A., Wu, T.-Y., Crawford, S., Chen, D., Szymczak, D., MacLachlan, B., Scime, D., and Niazi, M. (2021b).
Drasil.

Yggdrasil - Wikipedia (2021).
Yggdrasil.