Query-Driven Language Server Architecture using Second-Order Abstract Syntax

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- Multiple programming languages are implemented in Haskell [3], [4], [5].
- Only a half of the GitHub repositories for programming languages implemented in Haskell provide a language server [6].
- There exist frameworks for TypeScript (`Langium` [7]) and Python (`lsp-tree-sitter` [8]) that simplify integration with the LSP for new languages.
- However, to our best knowledge, there is no such framework for languages implemented in Haskell!

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- A promising approach is to work with the Second-Order Abstract Syntax (SOAS) [9] of a new language.

Solution

- Language servers share some features, such as "go to definition".
- We assume that some of these features can be implemented in a language-agnostic framework for implementing new languages in Haskell.
- A promising approach is to work with the Second-Order Abstract Syntax (SOAS) [9] of a new language.
- SOAS may allow to work with scope resolution ("go to definition"), variable bindings ("lookup the type on hover"), and substitution ("rename all occurences") in a language-agnostic way.

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- We plan to implement in Haskell a language-agnostic framework that simplifies integration of new languages with LSP.
- The framework will primarily be based on the `free-foil` [10] (SOAS manipulation), `BNFC` [11] (parsing), `lsp` [12] (library for building LSP) packages.

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- We will measure for both approaches and compare:
  - The lines of code required for integration and some other complexity metrics.
  - The performance of the server on a large (probably generated) code base (approx. 10KLoC).

Review the literature

- Read papers on SOAS [9], Foil [15] and Free foil [16].
- Read the `free-foil` package documentation [10].

Preliminary results

- We created a repository [17] for the thesis work.
- We implemented a parser and pretty-printer of STLC as defined in [18] using BNFC.

Practice with Free Foil

- Complete exercises on AST manipulation provided by Nikolai.
- Complete these exercises using Free foil.

Type checker and interpreter for Simply typed lambda calculus (STLC)

- Implement a type checker and interpreter for STLC.
- Features:
  - Single module on the input and the output.
  - Use BNFC for parsing and pretty-printing.
  - Use Free Foil and Template Haskell.
  - Show error location in the code.

Language server for STLC

- Implement a language server and a simple VS Code extension for STLC.
- Use the `lsp` [12] package.
- Features:
  - Go to definition.
  - Type on hover.
  - Maybe something else that makes sense for STLC.

Type checker and interpreter for Stella Core

- Implement a type checker and interpreter for Stella Core.
- Features:
  - Single module on the input and the output.
  - Use BNFC for parsing and pretty-printing.
  - Use Free Foil and Template Haskell.
  - Show error location in the code.

Language server for Stella Core

- Implement a language server, and a simple VS Code extension for Stella Core.
- Use the `lsp` [12] package.
- Features:
    - Type and documentation on hover.
    - Autocompletion.
    - Inlay (type) hints.
    - (Un)folding scopes.
    - InfoView - a separate panel that shows context (what is in scope, the type of the current expression or goal)
    - Something else.

[1] "Language server protocol."
Available at https://en.wikipedia.org/w/index.php?title=Language_Server_Protocol&oldid=1236113985.

[2] "Lsp implementations."
Available at https://microsoft.github.io/language-server-protocol/implementors/servers/.

[3] "Search results on github.com for "programming language language:haskell"."
Available at https://github.com/search?q=programming+language+language%3Ahaskell&type=repositories.

[4] "Hackage packages in the "formal languages" category."
Available at
https://hackage.haskell.org/packages/#cat:Formal%20Languages.

[5] "Hackage packages in the "language" category."
Available at https://hackage..haskell.org/packages/#cat:Language.

[6] “Search results on github.com for "language.lsp.server language:haskell".” Available at `https://github.com/search?q=Language.LSP.Server+language%3Ahaskell&type=code`.

[7] “Langium.” Available at `https://langium.org`.

[8] “neomutt/lsp-tree-sitter.” Available at `https://github.com/neomutt/lsp-tree-sitter`.

[9] M. Fiore and D. Szamozvancev, “Formal metatheory of second-order abstract syntax.”

[10] “free-foil package on hackage.” Available at `https://hackage.haskell.org/package/free-foil`.

[11] “Bnfc package on hackage.” Available at `https://hackage.haskell.org/package/BNFC`.

[12] "lsp package on hackage."
Available at https://hackage.haskell.org/package/lsp.

[13] "Simply typed lambda calculus."
Available at https://en.wikipedia.org/w/index.php?title=Simply_typed_lambda_calculus&oldid=1252118159.

[14] "fizruk/stella: Structurally typed extensible language for learning ACCPA."
Available at https://github.com/fizruk/stella.

[15] D. Maclaurin, A. Radul, and A. Paszke, "The foil: Capture-avoiding substitution with no sharp edges," in *Proceedings of the 34th Symposium on Implementation and Application of Functional Languages*, pp. 1–10, ACM.

[16] N. Kudasov, R. Shakirova, E. Shalagin, and K. Tyulebaeva, "Free foil: Generating efficient and scope-safe abstract syntax." Available at https://arxiv.org/pdf/2405.16384.

[17] "A repository for the ms thesis query-driven language server architecture using second-order abstract syntax."
Available at `https://github.com/deemp/query-driven-free-foil/`.

[18] J. Dunfield and N. Krishnaswami, "Bidirectional typing."

Thank You