Mnemosyne:
A Functional Language for Systems Programming

CMPSC600 Senior Thesis Proposal

Hawk Weisman

Department of Computer Science
Allegheny College

November 20th, 2015

Proposal

To implement and evaluate a prototype compiler for the Mnemosyne programming language.

- Mnemosyne is a functional language for systems programming, with compile-time automatic memory management.
- But what does that mean?

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- **Functional programming** models computation as the evaluation of functions [12, 28]
  - **It focuses on** immutability, purity, and function composition

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- **Functional programming** models computation as the evaluation of functions [12, 28]
  - **It focuses on** immutability, purity, and function composition
  - **Advantages:** expressiveness [10, 12], modularity [10, 12], safety

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- Mnemosyne features:
  - **Homoiconic syntax** like Lisp [24, 26].
  - **Strong, static types** like Haskell [9, 11, 14]
  - **Pattern matching** like Haskell and MLs [11, 14, 16, 18, 21]
  - **Compile-time memory management** like Rust's [2]
  - **Eager and lazy evaluation** at the programmer's discretion

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- **Systems programming** is the implementation of software that provide services to other software [20, 22].

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- **Systems programming** is the implementation of software that provide services to other software [20, 22].
- High quality systems are necessary for high quality applications.

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- **Systems programming** is the implementation of software that provide services to other software [20, 22].
- High quality systems are necessary for high quality applications.
- But there are some significant challenges in this field [2, 22]

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- Almost all systems programming today is done in C [7, 22]

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- Almost all systems programming today is done in C [7, 22]
- **Why?** C manages memory at compile-time

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- Almost all systems programming today is done in C [7, 22]
- **Why?** C manages memory at compile-time
  - Most languages use garbage collection (GC) [1]
  - GC is unsuitable for most low-level systems [7, 8, 22]
  - C manages memory manually (`malloc()`/`free()`) [8, 15, 22]

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- **Manual memory management leads to errors** such as buffer overflows, memory leaks, and null pointer dereferences [7, 22]
- **What if there was another way?**

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- Mnemosyne manages memory automatically at compile time
- **How?**

What is Mnemosyne?

A functional language for systems programming, with compile-time automatic memory management.

- Mnemosyne manages memory automatically at compile time
- **How?**
  - Stack allocation [3, 6, 19]
  - Lending and ownership analysis [19]
  - Controlled mutability [19]

Mnemosyne Syntax

Calculating factorials

```
(def factorial (fn ( -> int int )
    ((factorial 0) 1)
    ((factorial n) ( * n (factorial (- n 1))))
)))
```

Mnemosyne Syntax

Syntactic sugar

- Inspired by Scheme RFI 110 [27]
- Always reduceable to homoiconic S-expressions
  - Indentation-delimited expressions (I-expressions)
  - Curly-infix expressions (C-expressions)
  - Neoteric expressions (N-expressions)

Mnemosyne Syntax

Syntactic sugar

```
defn factorial { int -> int }
    (factorial 0) 1
    (factorial n) {
        n * factorial({n - 1})
    }
```

Methods

Manganese, the Mnemosyne compiler, is implemented in Rust

- **Combinator parsing** [4, 5, 13, 25] using `combine` and `combine-language`
- **Analysis** including type checking and lifetime analysis [19, 23]
- **Code generation** using `librustc-llvm` [17]

Methods

Assessing Mnemosyne's correctness

- **Unit and integration testing** to validate the compiler implementation
- **Demonstration** by implementing example code, including parts of the prelude
- **Benchmarking** compiled Mnemosyne binaries

Questions?

For more information:

- **Sample Mnemosyne code** if there's time
- **Complete source code:**
  `https://github.com/hawkw/mnemosyne`

References I

David H. Bartley. “Garbage Collection”. In: *Encyclopedia of Computer Science*. Chichester, UK: John Wiley and Sons Ltd., pp. 743–744. ISBN: 0-470-86412-5.

Jim Blandy. *Why Rust?* 1st ed. 1005 Gravenstein Highway North, Sebastopol, CA 95472.: O’Reilly Media, Inc, Sept. 2015. ISBN: 978-1-491-92730-4.

Erik Corry. “Optimistic Stack Allocation for Java-like Languages”. In: *Proceedings of the 5th International Symposium on Memory Management*. ISMM ’06. Ottawa, Ontario, Canada: ACM, 2006, pp. 162–173. ISBN: 1-59593-221-6.

Nils Anders Danielsson. “Total Parser Combinators”. In: *SIGPLAN Not.* 45.9 (Sept. 2010), pp. 285–296. ISSN: 0362-1340.

Richard A Frost, Rahmatullah Hafiz, and Paul Callaghan. “Parser combinators for ambiguous left-recursive grammars”. In: *Practical Aspects of Declarative Languages*. Springer, 2008, pp. 167–181.

Chris Hanson. “Efficient Stack Allocation for Tail-recursive Languages”. In: *Proceedings of the 1990 ACM Conference on LISP and Functional Programming*. LFP ’90. Nice, France: ACM, 1990, pp. 106–118. ISBN: 0-89791-368-X.

References II

Chris Hawblitzel et al. “Low-level linear memory management”. In: *Proceedings of the 2nd workshop on Semantics, Program Analysis and Computing Environments for Memory Management*. 2004.

Matthew Hertz and Emery D. Berger. “Quantifying the Performance of Garbage Collection vs. Explicit Memory Management”. In: *Proceedings of the 20th Annual ACM SIGPLAN Conference on Object-oriented Programming, Systems, Languages, and Applications*. OOPSLA ’05. San Diego, CA, USA: ACM, 2005, pp. 313–326. ISBN: 1-59593-031-0.

Paul Hudak and Joseph H Fasel. “A gentle introduction to Haskell”. In: *ACM Sigplan Notices* 27.5 (1992), pp. 1–52.

Paul Hudak and Mark P. Jones. *Haskell vs. Ada vs. C++ vs. Awk vs. ... An Experiment in Software Prototyping Productivity*. Research Report YALEU/DCS/RR-1049. New Haven, CT: Department of Computer Science, Yale University, 1994.

Paul Hudak et al. “Report on the programming language Haskell: a non-strict, purely functional language version 1.2”. In: *ACM SIGPLAN notices* 27.5 (1992), pp. 1–164.

John Hughes. “Why functional programming matters”. In: *The Computer Journal* 32.2 (1989), pp. 98–107.

References III

Graham Hutton and Erik Meijer. *Monadic parser combinators*. Tech. rep. NOTTCS-TR-96-4. 1996.

Simon L Peyton Jones. *Haskell 98 language and libraries: the revised report*. Cambridge University Press, 2003.

Brian W Kernighan, Dennis M Ritchie, and Per Ejeklint. *The C programming language*. Vol. 2. Prentice-Hall Englewood Cliffs, 1988.

Neelakantan R. Krishnaswami. "Focusing on Pattern Matching". In: *SIGPLAN Not.* 44.1 (Jan. 2009), pp. 366–378. ISSN: 0362-1340.

Chris Lattner and Vikram Adve. "LLVM: A Compilation Framework for Lifelong Program Analysis & Transformation". In: *Proceedings of the International Symposium on Code Generation and Optimization: Feedback-directed and Runtime Optimization*. CGO '04. Palo Alto, California: IEEE Computer Society, 2004, pp. 75–. ISBN: 0-7695-2102-9.

Luc Maranget. "Warnings for pattern matching". In: *Journal of Functional Programming* 17.03 (2007), pp. 387–421.

References IV

Nicholas D. Matsakis and Felix S. Klock II. "The Rust Language". In: *Proceedings of the 2014 ACM SIGAda Annual Conference on High Integrity Language Technology*. HILT '14. Portland, Oregon, USA: ACM, 2014, pp. 103–104. ISBN: 978-1-4503-3217-0.

Thomas Narten. "Systems Programming". In: *Encyclopedia of Computer Science*. Chichester, UK: John Wiley and Sons Ltd., pp. 1739–1741. ISBN: 0-470-86412-5.

Martin Odersky et al. *The Scala language specification*. 2004.

Jonathan Shapiro. "Programming Language Challenges in Systems Codes: Why Systems Programmers Still Use C, and What to Do About It". In: *Proceedings of the 3rd Workshop on Programming Languages and Operating Systems: Linuistic Support for Modern Operating Systems*. PLOS '06. San Jose, California: ACM, 2006. ISBN: 1-59593-577-0.

Patrick G Sobalvarro. "A lifetime-based garbage collector for LISP systems on general-purpose computers". PhD thesis. Massachusetts Institute of Technology, 1988.

Gerry Sussman, Harold Abelson, and Julie Sussman. *Structure and interpretation of computer programs*. MIT Press, Cambridge, Mass, 1983.

References V

S Doaitse Swierstra. "Combinator parsers: From toys to tools". In: *Electronic Notes in Theoretical Computer Science* 41.1 (2001), pp. 38–59.

Luke VanderHart and Stuart Sierra. "Macros and Metaprogramming". In: *Practical Clojure*. Springer, 2010, pp. 167–178.

David Wheeler and Alan Gloria. *Sweet-expressions (t-expressions)*. Tech. rep. SRFI-110. 2006.

David S. Wise. "Functional Programming". In: *Encyclopedia of Computer Science*. Chichester, UK: John Wiley and Sons Ltd., pp. 736–739. ISBN: 0-470-86412-5.