

Minimalist Syntax and Mathematics

A practical approach to Hopf-Algebraic Minimalism in the Classroom

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Introduction and Motivations

What: Math and Linguistics at Grinnell College

- Absence of math & linguistics classes at Grinnell and comparable institutions
- Cf. integration of mathematics into Biology, Physics, Psychology.



So What: Mathematical Literacy

What are linguists missing by not having mathematics in their toolbox?

- Disciplinary level: precision of hypotheses and modeling for new hypotheses
- Subdisciplinary level:
 - Phonetics: Recent success in statistical models (esp. Neural Networks)
 - Typology: Clustering models and numerical analysis.
 - Syntax: Generative models, algebraic representations, etc.
 - ...and much more!

Now What: A Course on MCB

- A followup to a standard UG Syntax course, ideally after a Mathematical Linguistics course
- Critically compares two mathematical approaches to minimalist syntax
- Practices proving statements from mathematical axioms and stating hypotheses
- Offers a starting point for integrating math into linguistics courses at Grinnell and elsewhere

Course Syllabus

Year Overview

Unit 1 Scientific Modeling

- ① Types of Scientific Models
- ② Examples of Scientific Models

Unit 2 Models of Syntax

- ① Examples in Generative Linguistics
- ② The Minimalist Program and its Models

Unit 3 Comparative Review

- ① Chomsky's New Minimalism
- ② Constituency (Merge)
- ③ X-Linguistic Similarities (Features)
- ④ Word Order (Linearization)
- ⑤ Grammaticality (Filtering)
- ⑥ Paraphrases (Possible Derivations)

Unit 1: Scientific Modeling

Takeaways:

- ① A mathematical model is a type of scientific model
- ② Models are dogmatic. No model is a perfect model.
- ③ A mathematical model can be evaluated on its expressive power, cost, and empirical soundness.
- ④ A mathematical model is defined by its objects and axioms.

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Unit 2: Models of Syntax

Takeaways:

- 1 There exist many models of syntax, particularly in generative linguistics.
- 2 Chomsky's Hierarchy is a method of evaluating a grammar's expressive power.
- 3 "Minimalism" is not one theory, but a guiding set of principles for several models of syntax.

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Unit 3: Comparative Review

Takeaways:

- 1 “New minimalism” is Chomsky’s recent revision of the Minimalist Program.
- 2 Ed Stabler’s “Computational Minimalism” and Marcolli, Chomsky, and Berwick’s Hopf-Algebraic Minimalism are two approaches to modelling the minimalist program.
- 3 Computational minimalism aligns closer to the “90s formulation” of minimalism, whereas Hopf-Algebraic minimalism aligns closer to “New minimalism.”

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Optional Unit: Mathematical Prerequisites

Course equivalences:

- MAT-322 “Advanced Topics in Abstract Algebra”

Covers:

- Elementary Category Theory
- Algebras, Bialgebras, Hopf Algebras, and Universal Algebras
- Modules over Algebras

Optional Unit: Minimalist Prerequisites

Course equivalences:

- LIN-216 “Syntax”
- LIN-375 “Advanced Linguistic Analysis” in Syntax
- LIN-295/LIN-395 Special Topic in Syntax

Covers:

- P&P Architecture
- Governor-Binding Theory
- 90s Minimalism

Formatted Examples

Example Essay Prompt

In three double-spaced pages, answer the following:

- What is the SMT? How does it relate to the miracle creed?
- Are you convinced by the concept of the miracle creed? Why or why not?
- Give one example for and one example against the existence of the miracle creed in your area of interest. E.g. in Mathematics, one may write about complex-analytic series expansions and Gödel's incompleteness theorem.

You may cite “The Miracle Creed and SMT” [3], *Merge and the Strong Minimalist Thesis* [4], or other resources should you find them useful.

Example Worksheet Questions

On the \mathbb{Q} -vector space of workspaces $\mathcal{WS} := \mathcal{V}(\mathcal{F}_{S\mathcal{O}_0})$, Marcolli, Chomksy, and Berwick define a product \sqcup , coproduct Δ , antipode S , and unit and counit ϵ, η . Prove that these operations compatibly form a Hopf Algebra. That is, show that the hexagon

$$\begin{array}{ccccc} & \mathcal{WS} \otimes \mathcal{WS} & \xrightarrow{S \otimes \text{id}} & \mathcal{WS} \otimes \mathcal{WS} & \\ \Delta \nearrow & & & & \searrow \sqcup \\ \mathcal{WS} & \xrightarrow{\epsilon} & \mathbb{Q} & \xrightarrow{\eta} & \mathcal{WS} \\ \Delta \searrow & & & & \nearrow \sqcup \\ & \mathcal{WS} \otimes \mathcal{WS} & \xrightarrow{\text{id} \otimes S} & \mathcal{WS} \otimes \mathcal{WS} & \end{array}$$

commutes.

Example Lecture Notes Excerpt

Forthcoming...

Future Directions

Extending this research

- 1 Looking at other institution's programs
- 2 Getting linguistics student feedback
- 3 Reaching out to academics in math of language community.

A course for Grinnell

- Navigate the mathematical requirement
- Perhaps a more general math of language curriculum?
- Finalize syllabus into 14-week schedule



A course for the public

- GitHub repository with syllabus, this presentation, and PDF scans of lecture notes
- Please submit pull requests!!
- Everything is licensed under MIT (free to use with accreditation provided)
- Let's develop mathematical literacy in linguistics as a community

It's your turn!



Figure: GitHub Repository: [andrewfargo/NewMinimAlgFrm](#).

Bibliography I

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- [4] Noam Chomsky et al. *Merge and the Strong Minimalist Thesis*. Elements in Generative Syntax. Cambridge University Press, 2023.
- [5] Matilde Marcolli, Noam Chomsky, and Robert C. Berwick. *Mathematical Structure of Syntactic Merge*. Linguistic Inquiry Monographs. The MIT Press, 2025.
- [6] Marcolli Matilde, Riny Huijbregts, and Robert C. Berwick. “Modeling Externalization”. In preparation.

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