Compositional methods for health modeling

Dates: August 2-5, 2022 (three lecture days & one-day hackathon with student-driven projects)
Structure: Remote (via Zoom)
Further information: compositionalbootcamp@usask.ca
A no cost event.

Instructors

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Summary

Description
Dynamic models in infectious disease and health and healthcare more generally integrate information and processes across many domains. Model modularity serves as a key enabler for smooth and flexible coordination between domains --- for instance, between pathogen transmission, human behavior, and genomic data. Such modularity allows domain experts to independently build and refine clearly delineated model components which are composed into a single complex model. This approach divides the complexity of model building into two factors: the development of submodels by domain experts and the integration of the submodels into the whole. Applied category theory, the mathematics of composition, tackles this second challenge. Composing models using the tools of applied category theory provides visual transparency for stakeholders, formal analyzability, alignment between types of model heterogeneity (e.g., modular stratification), and opportunities for optimization and parallelization. In this course, we will show how these mathematical tools and their implementation in the open-source AlgebraicJulia programming environment can be used to rapidly develop transparent dynamic models in health, with a particular emphasis on models of infectious diseases.

Beyond teaching these fundamental advances in modeling methodology and theory, the course will explore the strong application potential for these platforms, where students will gain experience in use of existing toolsets that make practical a variety of types of compositional modeling. These tools include interactive application programming interfaces as well as browser-based interactive, collaborative, graphical user interfaces for compositional modeling. Examples model will be drawn from conditions such as COVID-19, measles, pertussis, and other infectious, zoonotic and chronic diseases.

Audience
The intended audience is mathematical epidemiologists and dynamic modelers for infectious diseases, health and health care seeking to learn about emerging methods and tools, based on applied category theory, for constructing large-scale models efficiently, reliably, and modularly. Experience with standard mathematical infectious disease models (e.g., compartmental, stock and flow, agent-based, stochastic), as well as programming experience in a language such as Julia, Python, or R, will be helpful. Specific prior knowledge of applied category theory or the Julia programming language will not be assumed.

Deliverables
Students will be provided with lecture notes and slides, exercises, Jupyter notebooks, and a library of example models taught in the course. Such online contents will also link to a series of video lectures published on the Topos Institute YouTube channel.

Venue
This event will take place on Zoom. Registered participants will be sent Zoom links prior to the event.

Topics
ACT concepts

- Modular modeling
    - Decorated/structured cospans
    - Colimits as a tool for gluing together models
    - Compositional and modular model stratification
- Hierarchical modeling
    - Operads
    - Directed and undirected wiring diagrams
    - Operadic composition of structured multicospans, ODEs, PDEs, and discrete-time dynamical systems
- Categorical databases for domain-specific modeling languages
    - Graphs
    - Petri nets
    - Stock and flow diagrams

Tools

- Julia programming language
- Catlab and the AlgebraicJulia ecosystem (AlgebraicPetri, AlgebraicDynamics, AlgebraicStockFlow)

Anticipated Schedule

The following gives the anticipated schedule for the event. The defaults of the schedule remain under discussion, and we anticipate aspects of timing evolving. *All times given are Saskatchewan Time (GMT-6).*

Tuesday, August 2

9:00 **Vision for ACT + support for epidemiological modeling**
9:30 **Graphs and C-sets**
10:30 *Break*
11:00 **Introduction to Petri nets**
12:00 *Lunch*
12:30 **(Algebraic) Julia Install (optional)**
13:30 **Julia Basics**
14:00 **Julia Plotting**
14:30 **Julia ODEs**
15:00 *Coffee*
15:30 **AlgebraicJulia Overview**
16:00 **AlgebraicJulia Graph + Petri**
16:30 **Create and run a Petri net**
17:00 *End of Day*

Wednesday, August 3

9:00 **Coproducts**
9:30 **Pushouts**
10:00 **Cospan Composition**
10:30 *Health break*
11:00 **UWDs**
12:00 *Lunch*
13:30 **Composing Petri nets**
15:00 *Health break*
15:15 **Overview of Stock-Flow**
15:45 **Coding with Stock-Flow**
16:30 **Introduction to Collaborative Compositional Graphical Stock-Flow Systems**
17:00 *EOD*

Thursday, August 4

9:00 **Limits**
9:30 **Stratification**
10:00 **Pullbacks of Petri Nets**
10:30 *Health break*
11:00 **Machines in Algebraic Dynamics**
12:00 *Lunch*
13:30 **Hackathon:** Team formation
14:00 **Hackathon:** Brainstorming
14:30 **Hackathon:** Setting expectations and goals
15:00 *Health break*

15:30 **Hackathon:** TA & instructor-facilitated work
17:00 *EOD*

Friday, August 5
9:00 **Hackathon:** TA & instructor-facilitated work
10:30 *Health break*
11:00 **Hackathon:** TA & instructor-facilitated work
12:00 *Lunch*
13:30 **Hackathon:** TA & instructor-facilitated work
15:00 *Health break*
15:30 *Demonstrations*
16:30 **Bootcamp Closeout**
17:00 *EOD*

Acknowledgments

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