MODELCOLLAB: SOFTWARE FOR COMPOSITIONAL MODELING

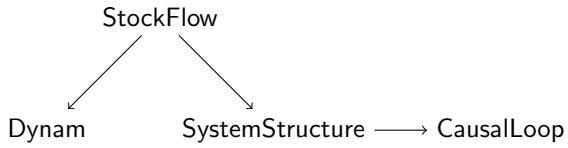
JOHN C. BAEZ, XIAOYAN LI, NATHANIEL D. OSGOOD

System Dynamics [7] is a popular framework for studying the behaviour of nonlinear complex systems through computer simulations. It is widely used in business, economics, epidemiology and other fields. Because System Dynamics is based on diagrams that are easily understood by nonmathematicians, it lends itself to "community based modeling" [5], an approach where modelers solicit knowledge and critique from diverse community members. However, its reliance on diagrams for representing model structure and reasoning about model behavior also makes System Dynamics a natural candidate for applying techniques from category theory.

In this talk we demonstrate some new features of ModelCollab [6], our collaborative System Dynamics software tool based on category theory. We focus on features connected to functorial semantics. ModelCollab now implements three kinds of diagrams that are fundamental to System Dynamics:

(1) A **causal loop diagram** is a graph with vertices representing 'variables' and directed edges called 'links' which indicate whether one variable affects another. Loops in this diagram represent feedback loops. Links are labeled with polarities (+/-), and when links compose, the polarity for the composite is given by the rule of signs. There is no distinction between whether the variables are 'stocks' (e.g. an amount of money held in a bank) or 'flows' (e.g. income per year).
(2) In **system structure diagram** variables are divided into three kinds: stocks, flows, and 'auxiliary variables'. Each flow is drawn as an edge from one stock to another. There are also (optionally polarity-labeled) 'links' that go from variables to variables that they affect.
(3) A **stock and flow diagram** is a more refined version of a system structure diagram, where we label each flow or auxiliary variable with a function saying exactly how it depends on the variables linked to it. A stock and flow diagram can be systematically converted to a system of first-order ordinary differential equations describing how the stocks change with time.

Each kind of diagram is an object in its own category. From a stock and flow diagram, ModelCollab can functorially extract a dynamical system—that is, a system of first-order ordinary differential equations—and solve these equations. From a stock and flow diagram, it can also functorially extract the underlying system structure diagram—and from that, it can functorially extract the underlying causal loop diagram. Thus, ModelCollab implements the following diagram of categories and functors:



ModelCollab lets users working on different web browsers collaboratively draw and work with all three kinds of diagrams. Additionally, all three diagrams can be made 'open' using the mathematics of structured and decorated cospans [2], allowing users to build larger diagrams from smaller open pieces.

While ModelCollab relies on the AlgebraicJulia system for scientific computing with categories [1, 8], its users need no knowledge of Julia or category theory. It can be used with a standard browser, without any need to install further software. Thus, it meets a prime goal of community based modeling: enabling as many commmunity members and domain experts as possible to become involved in the modeling process. We plan to train the next generation of Systems Dynamics modelers in the use of ModelCollab, continue to expand its publicly available library of models, extend its capabilities, and apply it to modeling projects, particularly in the fields of public health and climate change.

References

[1] AlgebraicJulia: Bringing compositionality to technical computing. Available at https://www.algebraicjulia.org.

[2] J. C. Baez, X. Li, S. Libkind, N. D. Osgood and E. Patterson, Compositional modeling with stock and flow diagrams, to appear in *Proceedings of Applied Category Theory 2022*.

[3] J. C. Baez, X. Li, S. Libkind, N. D. Osgood and E. Redekopp, A categorical framework for modeling with stock and flow diagrams, to appear in *Mathematics for Public Health*, Springer.

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[5] P. S. Hovmand, *Community Based System Dynamics*, Springer, 2014.

[6] ModelCollab: A web-based application for collaborating on simulation models in real-time using Firebase. Available at https://github.com/UofS-CEPHIL/modelcollab.

[7] J. D. Sterman, *Business Dynamics*, McGraw-Hill, 2000.

[8] Stockflow.jl. Available at https://github.com/AlgebraicJulia/StockFlow.jl.