Approximate Inference for Human Understanding of Complex Physical Systems

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Overview
This project will investigate the accuracy and fit to human data of approximate forms of inference for predicting how physical systems behave.

Background
Understanding complex physical scenes is extremely challenging computational problem, but one that people appear to do quite well (Battaglia et al., 2013; Sanborn, et al., 2013). To do this properly requires the incorporation of background knowledge of physics with uncertainty about the noisy sensory information that people receive. Because of the complexity, it may be that people only consider some of the information when making a decision.

A potential project is to focus on a particular three-ball system of colliding objects in which the outcome of interest is predicting the path of one of the objects following collisions. The project would potentially involve three tasks. First, implementing an "ideal observer" model that takes account of all of the information of the colliding objects and combines it with Newtonian mechanics to make the best possible response (e.g., Sanborn et al., 2013). Second, implement more restricted versions of the model that approximate the ideal observer but use less information. Third, compare both model types to human data that has previously been collected in this task.

Other ideas for projects involve more complex systems of colliding objects, how people understand the properties of liquids, how towers collapse, or the behavior of animate and inanimate objects. These projects would require more background reading.

Prerequisites and Future Prospects
Students interested in this project should be able to program in Matlab and have a working knowledge of Newtonian mechanics, Bayesian inference, and the approximations necessary to solve difficult inference problems. This project could project lead to PhD work on this topic as there is a large literature in psychology on how people understand these systems, but a relative lack of statistical models of how they do so.

References

Battaglia PW, Hamrick JB, Tenenbaum JB (2013). Simulation as an engine of physical scene understanding, *Proceedings of the National Academy of Sciences*, 110 (45), 18327-18332.

Sanborn, A. N., Mansinghka, V. K., & Griffiths, T. L. (2013). Reconciling intuitive physics and Newtonian mechanics for colliding objects. *Psychological Review, 120,* 411-437.