Humans may have intuitive physics engine

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Abstract

Intuitive physics is crucial to humans, guiding our decision-making by offering insight into potential consequences of our actions. However, the underling mechanism of human intuitive physics remains unclear. Researchers debate on the existence of the intuitive physics engine in human. In this essay, we explore the hypothesis concerning the potential existence of an intuitive physics engine in humans by reviewing the achievement of probabilistic simulation methods and model-based approaches in computer science. We will discuss some distinctions between intuitive physics engines in human and physics engines employed in computer science.

1 Introduction

Intuitive physics constitutes a fundamental facet of human cognitive and reasoning abilities [8]. Kubricht et al. [4] defined the term "intuitive physics" as "the knowledge underlying the human ability to understand the physical environment and interact with objects and substances that undergo dynamic state changes, making at least approximate predictions about how observed events will unfold." The concept of intuitive physics plays a significant role in human interactions with the environment, offering insight into potential consequences of our actions in the physical world and guiding our decision-making. For instance, we instinctively avoid stacking dishes in the kitchen, recognizing the risk of them toppling and shattering. Cognitive scientists and computer science researchers are actively pursuing an understanding of the underling mechanism governing human intuitive physics and the implementation of intuitive physics with computational methods.

Recent advances in computer graphics have equipped us with high-quality physics engines, facilitating highly accurate and realistic simulations of the physical world. This leads us to contemplate whether humans possess an intuitive physics engine that enables them to simulate the outcomes of specific scenarios and take appropriate actions.

In my perspective, I support the hypothesis that humans possess an intuitive physics engine. This essay aims to substantiate the strong likelihood of the existence of an intuitive physics engine by presenting findings in computer science (Sec. 2). Nonetheless, it is important to clarify that the intuitive physics engine in humans is not the same with the physics engines utilized in computer science, that we shall delve into in Sec. 3.

2 Intuitive physics in computer science

2.1 Models with physics engine

Research in the domain of intuitive physics within computer science has a longstanding history, marked by the emergence and predominance of three distinct methodologies: heuristic approaches, probabilistic simulation methods, and learning-based methods[4]. Heuristic approaches adhere to an "if" paradigm, as they are rule-based. However, as the complexity of scenarios increases, devising rules for a heuristic model can become a tedious task, indicating that the implementation of intuitive physics through heuristic approaches is impractical. In contrast, probabilistic simulation methods and learning-based methods exhibit the ability to generalize across a wide spectrum of scenarios.

Probabilistic simulation methods leverage physics engines equipped with Newtonian dynamics to perform forward simulations for inference. Battaglia et al. [1] demonstrated this concept in their IPE model(an exemplar of a probabilistic simulation model), which was employed to predict the stability of block towers. The IPE model takes multiple samples as input, drawn from their respective probabilistic distributions, and then simulates the outcomes of these input variations. Subsequently, it draws conclusions regarding the potential number of falling blocks and the direction of their fall. Another probabilistic simulation model was used to simulate the dynamics of fluids[3]. Both of these models exhibited similar performances to humans' on these tasks, demonstrating that intuitive physics of humans may share some properties with probabilistic simulation methods.

Duan et al. [2] emphasised the significance of physics engine within the context of learning-based methods. Their work categorizes intuitive physics tasks into three primary categories: prediction, inference, and causal reasoning. In prediction tasks, the physics engine plays a pivotal role by executing forward simulations. In inference tasks, the physics engine contributes to these tasks through an "analysis by synthesis" approach.

The importance of physics engine and simulation has been illustrated through these probabilistic simulation models and learning-based models above. In computer science, intuitive physics models equipped with physics engines have exhibited similar performance (both in successful cases and failures) across various tasks when compared to human performance. This remarkable correlation strongly suggests the plausible existence of an intuitive physics engine in humans.

2.2 Model-based methods for intuitive physics

Researchers have pursued the achievement of intuitive physics through both model-based and model-free methodologies. As previously mentioned, model-based approaches have demonstrated human-like performance, strongly suggesting the existence of an intuitive physics engine. In contrast, model-free methods primarily rely on experiential learning, lacking explicit models.

Battaglia et al. [1] emphasised that feedback-driven and model-free methods play a limited role in the context of intuitive physics. Additionally, research has indicated that models with uncertainty about dynamics, which is a property of models, outperform models with perceptual uncertainty in terms of human-like performance[6]. These findings lead to the inference that model-based methods are essential to the field of intuitive physics within computer science, and the presence of an intuitive physics engine may similarly be fundamental to human intuitive physics, given that models equipped with physics engines exhibit performance similar to human capabilities. It is noteworthy, however, that model-free methods can still contribute to intuitive physics by serving as prior expectations gained from experiential learning[6].

3 Discussion

We establish the potential existence of an intuitive physics engine in humans by drawing from successful methodologies in computer science. However, it is important to recognize that this does not imply a direct parallel in the implementation of an intuitive physics engine in humans when compared to the physics engines employed within computer science. While they both operate on the shared principle of providing approximate, probabilistic, and incomplete outcomes[5], distinctions exist between the intuitive physics engine in humans and the physics engine in computer science.

Abstract representations In a study on human core knowledge, Spelke and Kinzler [7] highlighted that human knowledge about number can be abstract, and humans can understand the concept of number even when specific numerical terms are absent from their vocabularies. Given that it is still unknown how humans represent physical properties (both observable and latent properties) in mind, it is plausible to hypothesize that humans employ abstract representations for these properties. However, the utilization of abstract representations presents a notable challenge in computer science, primarily due to the utility and reliance on physics engines.

Implicit dynamics While research has indicated that human intuitive physics aligns with the results of stochastic Newtonian dynamics, the precise dynamic laws governing human intuitive physics remain unknown. As highlighted by Smith and Vul [6], the predominant source of uncertainty in human intuitive physics stems from the uncertainty about dynamics. Hence, we propose a hypothesis suggesting that human intuitive physics adheres to a form of implicit dynamics without explicit representation.

Complex structure Human intuitive physics is rooted in a highly intricate neural system composed of billions of neurons. This intricate neural architecture offers the potential for abstract representations and implicit dynamics, posing significant implementation challenges in computer science due to their computational demands and associated costs.

4 Conclusion

In this essay, we have explored the hypothesis concerning the potential existence of an intuitive physics engine in humans. We have substantiated this hypothesis by drawing upon research from the field of intuitive physics within computer science. The achievement of probabilistic simulation methods and model-based approaches strongly suggest the likelihood of an intuitive physics engine in humans. Subsequently, we delve into the distinctions between the intuitive physics engine in humans and the physics engines utilized in computer science, including abstract representations, implicit dynamics, and complex structure.

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