CoRe Essay 2
Intuitive physics

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Abstract

This paper critically examines the concept of an Intuitive Physics Engine (IPE) in humans, a theoretical framework suggesting that humans possess an inherent capability to understand and predict physical interactions in their environment. The paper contrasts this notion with alternative theories and computational models, and examines its relation with two machine learning mechanisms: Learning from Dynamics and Learning from Intuition. Through a case study involving magic tricks, the paper also explores the potential of commonsense reasoning in artificial intelligence (AI) systems.

1 Introduction

The notion of an IPE within humans posits an inherent capability to swiftly and accurately apprehend the physical dynamics of the surrounding environment[3]. It is conjectured to underpin our capacity for predicting outcomes of physical interactions, adjudicating on stability of structures, foreseeing trajectories, among other spontaneous physical judgments. This concept has been broadly inspired by observations of human behavior, and particularly the ability to make complex judgments about physical occurrences nearly instantaneously.

However, the premise of an inherent IPE within humans has not gone unchallenged. Several counter-arguments and alternative theories have been put forth, questioning the existence of an IPE, its functionality, or even the extent to which it might be innate or acquired. Critics argue that what is perceived as an intuitive understanding of physics may instead be a result of learned experiences over time. They point towards the limitations and inaccuracies in human predictions about physical interactions, especially in unfamiliar or complex scenarios, as evidence against the existence of a robust internal physics engine.

Moreover, the comparison between human cognition and computational physics engines employed in AI and robotics unveils a spectrum of disparities. While computational models require extensive data and computational resources to approximate physical predictions, it's argued that humans operate under a different paradigm, which might not be solely accounted for by an IPE.

This essay endeavors to dissect the arguments against the notion of a human IPE, explore alternative explanations for human aptitude in physical reasoning, and scrutinize the comparative analysis between human cognition and artificial physics engines.

2 Machine Reasoning

In this section, I am going to discuss two common machine learning mechanisms[2] and show the relation with humans' IPE.

2.1 Learning from Dynamics

In this approach, the model first learns the underlying dynamics of a physical system and then uses this information to predict the outcome of a task. When the model was supplied with accurate dynamics directly from a simulator, it performed significantly better than other learning mechanisms. This served as an upper bound for Learning from Dynamics performance. When the dynamics were predicted by the model itself, the performance was not as good as when ground-truth dynamics were used. This suggests that errors in dynamics prediction can significantly affect the reasoning process.

2.2 Learning from Intuition

The model directly learns to predict the outcome of a task based on the initial conditions, without any intermediate step of learning the dynamics. It can be more computationally efficient as it don't need to simulate or understand the underlying dynamics. For many real-world applications where a good-enough prediction is sufficient, Learning from Intuition can be a more practical choice. Also, it is less sensitive to errors in dynamics prediction, making them potentially more robust in certain scenarios.

2.3 Relation with humans' IPE

The two approaches, Learning from Dynamics and Learning from Intuition, address a fundamental question in the field of cognitive reasoning: Do humans possess an IPE for understanding the world around them? If human cognition operates on the basis of Learning from Dynamics, wherein individuals construct and reason upon a world model that captures the underlying physical laws, then the answer would affirmatively be "yes." Conversely, if human cognition is primarily guided by Learning from Intuition, wherein reasoning is conducted directly from initial conditions to outcomes without the mediation of a dynamic model, then the answer would be "no." This dichotomy serves as a critical framework for investigating the mechanisms underlying human cognitive reasoning in the context of physical interactions.

3 Humans may not have Intuitive Physics Engine

3.1 Humans are not good dynamics predictors

It has been postulated that humans possess an IPE enabling them to predict physical interactions with both precision and swiftness. However, a closer examination reveals that human predictions concerning dynamic systems often fall short of accuracy, especially when faced with complex or novel scenarios. Several studies[4, 1] have shown that humans tend to oversimplify dynamic systems, relying on heuristics which, although useful in familiar settings, prove erroneous in more complicated or unfamiliar situations. Furthermore, the consistency in prediction errors across different demographics suggests a systematic limitation in our intuitive understanding of dynamics. These findings challenge the notion of an inherent, accurate IPE within humans, and suggest that our ability to predict physical dynamics may be more dependent on learned experiences and heuristic shortcuts than on an innate physics engine.

3.2 Humans excel at analogy

One of the remarkable facets of human cognition is the ability to draw analogies, which plays a vital role in our understanding and interaction with the physical world. Unlike a rigid physics engine which operates under fixed principles, humans have the ability to extrapolate knowledge from one domain to another, often discovering novel insights through analogical reasoning. This ability to form and exploit analogies enables humans to tackle new problems and adapt to new environments swiftly. It can be argued that this analogical reasoning, coupled with experiential learning, forms the basis of our aptitude in physical reasoning, rather than an innate IPE. The flexibility and adaptability inherent in analogical reasoning present a stark contrast to the fixed and predetermined nature of a physics engine, suggesting a different mechanism underpinning our physical intuition. By embracing a more analogy-driven model of human cognition, we might not only arrive at a more accurate understanding of human physical reasoning but also inspire new approaches in AI and robotics, fostering machines that think more like humans and less like traditional physics engines.

4 Case Study: Magic Show

Magic shows[5] serve as an enthralling playground to explore violations of commonsense principles, which are typically deeply ingrained in both human and potential artificial cognition. Through carefully crafted illusions, magicians lead the audience to believe in occurrences that contravene basic physical laws. Analyzing such violations in a structured manner can provide insights into the commonsense reasoning capacities required by AI systems to navigate and understand the real world akin to humans.

4.1 Rubber Pencil Magic Trick

The rubber pencil magic trick is a simplistic yet effective illusion where a rigid pencil appears to transform into a flexible rubber entity when vibrated at a particular frequency. At the core of this illusion is the violation of commonsense understanding of material properties — a wooden pencil is expected to remain rigid, and any deviation from this expectation strikes as a surprise.

4.2 Spoon Bending Illusion

The spoon bending illusion is another elementary yet captivating trick, where a metal spoon appears to bend through mere gentle strokes. This trick fundamentally challenges the commonsense understanding of solid material properties and the amount of force required to alter such materials' shape.

4.3 Relation with AI

If an AI can be surprised by the above magic shows, then it must have already equipped with a rudimentary understanding of material properties and physical laws. The surprise element in the illusion could serve as a trigger for the AI to re-evaluate its understanding, delve deeper into the nuances of visual perception, and the limitations therein.

For example in the first scenario, by analyzing the discrepancy between visual input and expected physical behavior, an AI can refine its understanding and potentially develop a more nuanced interpretation of sensory data, akin to the process of discerning optical illusions. In the second scenario, by hypothesis generation and testing, AI could generate a better hypothesis to explain observed discrepancies, like potential mechanisms behind the apparent bending. Testing these hypotheses against known laws and further observations helps in refining common sense understanding.

5 Conclusion

While the concept of an IPE provides a compelling framework for understanding human cognition, it may not be the sole or even the primary mechanism underlying our ability to understand and interact with the physical world. Alternative explanations like learned experiences and analogical reasoning offer a more nuanced understanding, which not only challenges the existing paradigm but also has implications for the development of more human-like AI systems.

Also, several case studies show that AI has the ability to learn from the violation of commonsense. If AI systems can be surprised by such illusions, it suggests that they have a rudimentary understanding of physical laws, opening avenues for further refinement and learning.

References

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