The physics engine in humans' brain

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Abstract

This essay explores the concept of an "intuitive physical engine" (IPE) in human cognition, focusing on our innate understanding of the physical world and our ability to predict object behaviors. It discusses the proposal of an IPE as a cognitive mechanism akin to computer engines used in video games, highlighting its architecture and function. The essay also delves into the evidence supporting the existence of IPE, drawing from neuroscience studies that examine brain regions associated with physical scene understanding. These studies provide compelling evidence of IPE's presence in human brains.

1 Introduction

Humans are able to experience and understand the physical environment around them and make basic predictions about objects and substances on how they are going to move in the future. The ability underlying such activities is termed intuitive physics. It has been an active topic for several decades and has been reinvigorated in recent years by the development of approaches linked to artificial intelligence[5].

The term "intuitive physical engine" is proposed as a cognitive mechanism similar to computer engines that simulate rich physics in video games and graphics[2]. It shows a fast and robust approach to analyzing and simulating complex 3D physical scenes and has been highly discussed in recent years.

Naturally, here comes a question. Do humans have physical engines in their brains? If so, how do they work? About the existence, our answer is yes. In this essay, we are going to point out evidence and discuss further possible mechanisms.

2 Intuitive physical engine(IPE)

When we are placed in a physical environment, as human beings, we are curious not only about "what is where by looking"[1], but also "why it happens" and "how it is going to happen". We can predict the water will spill out of the cup if it is knocked over and we know the curve of a ball if it is kicked by a player. We can not accomplish this feat by object recognition. Following Newtonian physics principles seems to be a possible approach, however, we would not do any force analysis when we make such a prediction.

During past years game engine has been developed and can build up a virtual environment that stimulates real-world physical movements[4]. Human judgments are driven by a similar built-in engine that has got high-level architecture akin to the game engine that can stimulate rigid body dynamics and collision called intuitive physical engine(IPE)[7].

The engine works follow the architecture shown in Figure1[2]. It takes input which can be in the form of image, language, etc. Then the input is stimulated from time t to time $t + n$. Finally, IPE outputs the prediction results on what will happen at time $t + n$.

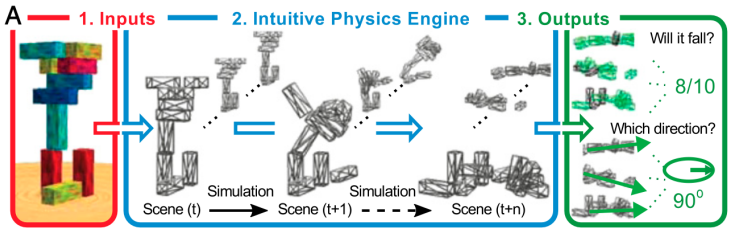

Figure 1: Architecture of IPE

The IPE is a model-based engine in order to achieve a robust performance. Is it possible that the stimulation is based on model-free, data-driven approaches? Which depends heavily on learning from past experience. It appears unlikely for several reasons: such an approach would need to be versatile enough to handle diverse real-world situations while remaining simple enough to be learned from individuals' limited experiences. It would also necessitate additional mechanisms to determine which features and strategies are suitable for specific contexts. Additionally, it would struggle to account for how people tackle new tasks in unfamiliar environments and how their comprehension of the physical world interacts with their extensive language, reasoning, imagination, and planning abilities.

In order to illustrate it, let us look at a gun-shooting example(Figure 2). Imagine someone is shooting a watermelon with a pistol and the watermelon explodes at the same moment when the trigger is pulled. You have never seen a bullet flying because it is too fast to be captured by eyesight. Putting ballistic gelatin between the pistol and the watermelon will show the trajectory of the bullet. We infer the trajectory simulation without past experience but with an abstract from ballistic gelatin.

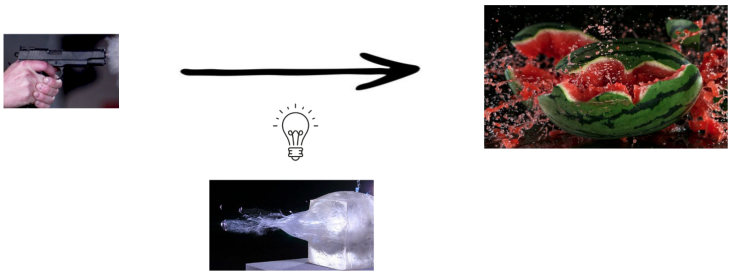

Figure 2: Aquire trajectory stimulation from ballistic gelatin

2.1 Evidence for the existence of IPE

We pointed out a possible architecture of IPE and discussed its mechanism briefly in the past section. How can we be sure that IPE really exists? The most intuitive evidence we consider is from neuroscience. Here we ask whether the brain has a region or set of regions that engage in fast intuitive physical inference. The study by Fisher et al(2016) focuses on this question.

In the study they conducted 3 experiments, focusing on physical and nonphysical judgments, physical versus social interactions, and passive viewing of physical events. They take videos as visual input and the results of fMRI responses of candidates show strong evidence that physical scene understanding engages a systematic set of brain regions[3]. However, their study has opened up a new question, do the brain regions reported here explicitly code for physical properties, such as masses, forces, or materials?

In order to answer this question, Sarah et al. conducted 3 similar experiments and using fMRI observed candidates[6]. They designed the 3 experiments specifically for mass inference and included invariance dimensions used for mass decoding. In the results they showed using fMRI decoding methods that the candidate brain regions for physical inference contain information about mass in 25/26 subjects tested and the brain regions previously implicated in intuitive physical reasoning represent mass in an invariant manner that would be expected for an intuitive physics engine.

Despite the data arguing against the possibility that physical scene understanding is carried out by a purely domain-specific system, these studies show exciting evidence of the existence of IPE in

human brains. Consider an analogy with GPUs in computers. GPUs have since become indispensable for applications, such as computer vision, deep neural network training, and indeed, real-time approximate physics simulation in computer games. Although it is not engaged by many other software applications it is not a completely general system.

2.2 Conclusion

In this essay, we discuss the existence of an intuitive physical engine(IPE) in human brains and propose a possible stimulation-based architecture of the engine. There might be another working mechanism due to the ultrahigh speed at human beings response to a novel physical engine which is much faster than stimulation. Moreover, evidence of IPE's existence can be found among infants and their development.

Overall, the study of intuitive physical engines can be broadly inspired by psychophysics, neuroscience, and game engineering. On the other hand, it can also provide new ideas for these fields, which is a question worth exploring.

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