Artificially Intelligent Physics Solver: This AI Understands Newton's Law

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Abstract—Artificial Intelligence (AI) is transforming many fields including science. At the intersection of physics and Artificial Intelligence, this paper explores if AI can understand the laws of physics? Specifically, this paper conceptualized and implemented a working prototype of a Deep Learning module that seem to understand Newton's third law of motion. The progress in AI is so fast, it has now exceeded human performance in specific tasks, mainly due to the progress in deep neural networks. In this paper, a Google BERT neural network model was trained using transfer learning technique on a synthetic dataset of simple physics problems within the scope of solving Newton's third law problems that requires understanding of concepts such as action and reaction, magnitude and direction forces, simple concepts of vectors in physics problems. The results are presented in this paper. Results demonstrate AI could solve simple physics problems within the specific context of Newton's third law assuming certain boundaries on the language model of the word problems. A working prototype of this AI can be accessed at the given website. This paper also contributes the source code for reproducible results. This novel idea can be extended to more science topics. Applications of this interdisciplinary area of AI and physics have impact not just in areas of robotics and computational physics, but also in how science uses AI in the future. In future, more areas of science can benefit from the novel method contributed in this paper.

Keywords: Artificial Intelligence, Deep Learning, Computational Physics, Laws of Physics, Natural Language Understanding, Transfer Learning

INTRODUCTION

The progress in the field of Deep Learning in the recent few years is amazing. Artificial Intelligence (AI) is the new electricity, as per Prof Andrew Ng from Stanford University. AI is transforming many fields including science,

Authored by 2018 Turing Award winners, Deep Learning (LeCun, 2015) is a seminal review of the potential of the AI technologies. The impact of AI on science is enormous. of the five most highly cited papers in Nature, three are related to AI in 2019 (Crew, 2019).

Fig. 1: Novel Method to Model Physics Problems as AI Models

AI Physics Challenge and a Solution (Summary of this work)

Challenge: Can AI understand and solve physics word problems for say Newton's 3rd law?

Fig. 2: Summary of this Paper's Contribution. Results Reproducible at URL

THE SCIENCE OF LEARNING MACHINES: NEURAL NETWORKS AND THE HUMAN BRAIN

Machines ability to learn like humans is a key trait inspired by how neurons in human brain works (Sarah, 2018). Deep Learning methods are apt in handling specific tasks rather than generic tasks. For instance Patel (2019) demonstrates AI progress in a specific task of medical image diagnosis. Both Mass (2019) and Levine (2019) demonstrates progress in understanding natural language.

OBJECTIVE OF THE PAPER: CAN AI UNDERSTAND LAWS OF PHYSICS?

Nature physics paper (Buchanan, 2019) highlights the power of AI in physics. At the intersection of AI and physics, new themes are emerging such as Physics enhanced AI (O'Driscoll, 2019). While AI is being applied in science in many ways, this paper sets out to get an answer to this challenge: Is it possible for an AI to understand the laws of physics? Is it possible for an AI to understand word problems and solutions in a specific context of Newton's law? The specific challenge addressed in this paper is clearly presented in Figure 2.

This AI understands Newton's law! How it works is illustrated here, essentially on the lines of language modelling by BERT, this one attempts physics modelling

Neural network architecture for modelling of Newton's law by a neural network.

Multiple attention mechanisms solve the problem similar to how an human will solve it

Fig. 3: Novel Method for Modelling Newton's Law as BERT Inspired AI Models is Proposed

METHODS

HOW TO SOLVE THE CHALLENGE: POSSIBILITY OF A NOVEL METHOD

How to build an AI that understands and solves problems in Newton's laws? For the challenge presented in section 1.2, this paper attempts with a novel approach: By mapping the challenge into a Deep Learning method of supervised classification task using state of art language modelling neural networks such as Google BERT (Devlin, 2018), a reasonable result is in the realm of feasibility.

CHOICE OF SCOPE OF CHALLENGE: WHY NEWTON'S 3RD LAW?

Given that Deep Learning has proven to be apt for specific tasks, a specific scope is considered for this experiment. A random choice of Newton's 3rd law is used in this experiment, though any law could be used. This paper aims to solve physics questions, that are simple yet challenging the fundamentals of modelling physics concepts using AI. For instance, can the proposed AI understand the concept of magnitude and direction of a force vector in Newton's 3rd law? The challenge is because the AI needs to understand the concepts involved in the law, the objects involved in the

context, and identify the action and reaction. The dataset listed in Figure 3 clearly scopes up the boundaries of the challenge taken in this paper.

NOVEL METHOD OF SOLVING THE CHALLENGE: AI ATTENTION CAN MODEL SCIENCE QUESTIONS!

Deep Learning based Attention models as a key technique to solve the science challenge is being proposed in this paper. Attention models (Vaswani, 2017) has demonstrated breakthrough results in the recent years such in Google

translate (Ramati, 2018), Transformer networks (Mohamed, 2019), and more recently in Google BERT (Devlin, 2018). As shown in Figure 3, any science word problem can be handled as a text classification problem. The key technique now is to transform a neural network that understand natural english language (Jacob, 2018) into one that understands physics models. This transformation is realized using transfer learning method in this paper, as proposed in Figure 3. As proposed, Encoders in top of the BERT network would understand physics concepts and hence can model physics word problems. Figure 4 discusses the approach to design an AI model.

Fig. 4: Key Ideas in Designing the AI Model to Solve Word Problems in Science

RESULTS AND DISCUSSION

Results demonstrated in this paper are

1. It is feasible for an AI to solve the challenge in Figure 3 within scope listed in section 2.2.
2. Results & screenshots in Figure 5 are reproducible by readers at this URL.
3. Novel method for AI to learn Newton's law via BERT attention is established (Figure 3)

Fig. 5: Results of an AI Physics Classifier that Distinguishes Solutions as Right or Wrong

CONTRIBUTION AT INTERSECTION OF AI & PHYSICS

This paper makes an important and new contribution at the intersection of Physics and AI. Specifically, as clearly presented in Figure 2, the core contribution is on how to develop a neural network that automatically learns physics laws by scanning through solved problems (provided as datasets in Figure 3). As demonstrated in Figure 3 and Figure 5, this AI can learn scientific laws, automatically deducing simple formulas between action and reaction, can understand and verify the correctness of magnitude and direction of the force vectors. This AI has been shown to be capable of identifying the pairs of objects interacting in Newton's law such as gun & bullet, tennis racket & ball pairs, as illustrated in Figure 3 and Figure 7.

KEY RESULTS: AI ATTENTION MODELS CAN SOLVE SIMPLE WORD PROBLEMS IN NEWTON'S LAW!

Key result is development of breakthrough AI model that understands physics word problems. The results demonstrate that it is feasible for AI to understand physics laws and solve simple problems framed as simple sentences as depicted in Figure 5, within certain boundary conditions listed in section 3.4. By just looking at examples of solved problems, this AI can automatically learn physics concepts, understand the law of science, apply it solve simple problems in physics, and even apply the physics laws when a new problem set is presented. The novel method depicted in Figure 3 was implemented in TensorFlow. A live working demo of this AI is demonstrated in this URL. A specific screenshot of this working prototype is shown in Figure 2.

SOURCE CODE OF THE NOVEL METHOD

This AI is developed with Tensorflow Deep Learning framework using Keras. This source code can be accessed at this URL, <https://sites.google.com/view/aiforphysics>

REPRODUCIBILITY OF RESULTS

To enable quick reproducibility of the results demonstrated in Figure 4, viewers are encouraged to visit to this URL, <https://sites.google.com/view/aiforphysics>. The experiments can be repeated and the results could be validated quickly.

DISCUSSION ON THE NOVEL AI METHOD CONTRIBUTED

Fig. 6: Attention Modelling is at the Core of the Novelty

The core contribution is the novel to develop a neural network that automatically learn physics laws. The amazing result presented in section 3.2 was realized by the approach articulated in section 2.3. Deep Learning Attention models (Vaswani, 2017) is the heart of the method that produced this breakthrough result. This can be validated by observing the BERT visualization in Figure 1 and 6 for word problems in physics. One can observe in Figure 6, the head #1 of 11th encoder connects bullet to gun, while the head #11 of 11th encoder of BERT pays attention to the magnitude of applied force to compute the reaction force. Attention models learns with Query, Key mechanism, and this fundamental idea is brought out in Figure 1.

DISCUSSION ON ACCURACY OF AI AND ASSUMPTIONS

The boundary conditions were discussed in section 2.2. In addition, like other machine learning solutions, the test distribution and training distribution can't be different. In this specific case, the training dataset is synthesized programmatically, hence can be improved. Given programmatically created dataset, this binary text classifier based on BERT with 12 layers achieved a training accuracy over 95%. Validation accuracy could vary based on the test data's similarity to the training dataset.

CONCLUSION

The paper demonstrated the feasibility of developing a neural network that could understand, solve and validate certain type of word problems in physics laws. Attention models hold a key to understanding concepts of the physics laws, and Query Key mechanisms can attend to relevant values to validate the physics statements. While the result was demonstrated with one of the Newton's laws, it could be extended to model more topics in science. This paper contributed by conceptualizing the challenge, designing a novel method to model physics laws with attention based neural networks, and demonstrated with a working prototype. The novel AI technique implemented in source code is contributed online for reproducibility. Readers are encouraged to visit the online website, <https://sites.google.com/view/aiforphysics> to check out a live demo of AI that understands Newton's 3rd law.

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