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XXXI SIC

Salão UFRGS 2019 — Conhecimento o Formação o Inovação

21 . 25 . OUTUBRO . CAMPUS DO VALE

ON THE REASONING CAPABILITIES OF LANGUAGE MODELS

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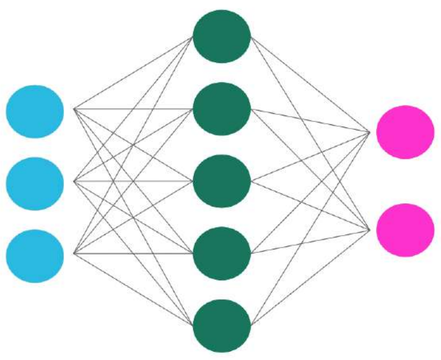
INTRODUCTION

DEEP LEARNING

Machine learning systems acquire their own knowledge, extracting patterns from raw data, consequently such systems don't need to be told (pre-programmed) how to perform their tasks. The hierarchy of concepts allows the computer to learn complicated concepts by building them out of simpler ones. **Deep learning** leverages computational power to build deeper concept hierarchies from large datasets, being able to tackle complicated tasks with super-human performance.[1]



GPT-2

Recently, **OpenAI** "trained a large-scale unsupervised language model which generates coherent paragraphs of text"[2] called **GPT-2**, based on a transformer model. The machine learning and natural language processing communities have been positively impressed with the model's capability of sustaining long-term consistency throughout sentences. On the other hand, some researchers expressed concerns that GPT-2 is merely memorizing an extensive dataset of texts instead of effectively reasoning about what it says.

Currently, OpenAI released 3 out of their 4 trained models for the general public, with 124, 345 and 774 million parameters. Due to their concerns on malicious applications of the technology, their biggest model, with **1,5 billion parameters**, has not been released to the general public yet, although some researchers have already tried to reproduce it[3] (with an estimated cost of **$50,000**). Our project, then, attempts to go further and investigate whether the model can reason about different things than what it was created for.

METHODS

TASKS

We developed some tasks to be solved by the model, described below. Each task is accompanied by the set of abilities we deem are required to solve it:

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FIRST ORDER LOGIC SOLVER (FOL)

Represent semantical proof structure (through natural deduction) as a graph similar to an Abstract Syntax Tree.

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LINEAR SYSTEMS SOLVER

Learn to compute matrix properties (such as determinant), generating a step-by-step guide towards the solution.

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MATHEMATICAL READING AND SOLVING

Learn to evaluate texts as symbolic expressions and manipulate them, to achieve the final result.

MODELS

We used the already released GPT-2 trained models[4] to leverage the semantics knowledge, such that we just need to learn the specifics for each task. As a baseline, we will train the tasks without the pre-trained parameters, to see if the semantics learned by the basic model help in the writing ability needed on the second and third task.

PRELIMINARY RESULTS

The research has not been finished yet, as a metric to measure how well is GPT2 predicting the tasks proposed above. Nevertheless, some of the models were already trained, and some examples can be seen below, acomppanied by an example which was generated by the original GPT2 model:

Why is investing in science important?

The first word that comes to mind when thinking about science is "important". I think the term "important" has been used for many, many years in order to identify the people (and people's organisations) who "matter" to those in power. What science really means is "useful for our common society and survival". Science helps us in understanding and controlling our environment, and how to improve it.

(((((y => b) => (z => a)) => ((b => y) => (z => (y => a))))).

proof.
1 assume (y => b) => z => a.
2 assume (b => y) => z => y => a.
3 assume (a => a).
4 a => a. =>E 2,3
5 z => y => a. =>E 1,3
6 a => z => y => a. =>E 5,4
7 z => y => a. =>E 6,5
8 y => a. =>E 7,6
9 a. =>E 8,2
10 b => z => y => a. =>E 4,2
11 z => y => a. =>E 10,9
12 y => a. =>E 11,7
13 a. =>E 12,6
14 therefore z => a. =>I 3,13
15 therefore y => z => a. =>I 2,14
16 therefore (u => x => z => y => a) => y => z =>a. =>I 1,15

Given the following equation, we want to solve it

-1/1x - 3/1y - 3/1z = 13/1
1/1x + 1/1y + 1/1z = - 5/1
0/1x - 1/1y + 0/1z = 1/1

First we write a matrix with the equation coefficients, and a vector with the solutions:
- 1 / 1 , - 3 / 1 , - 3 / 1
1 / 1 , 1 / 1 , 1 / 1
0 / 1 , - 1 / 1 , 0 / 1

1 3 / 1 , - 5 / 1 , 1 / 1

We calculate the matrix determinant to see if it is singular or not
As the determinant is 2, the matrix is NOT singular, so we can procceed.

[...]

REFERENCES:

[1] Goodfellow, Ian; Bengio, Yoshua; Courville, Aaron; (2016), 'Deep Learning'.
[2] Radford et Al. (2018), 'Language Models are Unsupervised Multitask Learners'.
[3] Gokaslan, Aaaron; Cohen, Vanya; (2019), 'GPT-2: We Replicated GPT-2 Because You Can Too'.
[4] Shepherd, N; (2019), 'Github: GPT2; in https://github.com/nshepperd/gpt-2'.

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