Electronics and Computer Science
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An AI Approach to Chaotic Physicl Systems:

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Second examiner: **TBD**

Progress report submitted for the award of
Bachelors of Science

Abstract

Physical laws are generalisation established through empirical observations of the physical world. It has taken humans centuries to discover, requires huge amounts of research, repeated experiments and plenty of scientists to produce an universally accepted law in the scientific community. Thanks to recent advances in neural networks and increased computational power, we can now train models to replicate and fasten our discovery of physical laws such as the laws of motion,also including chaotic systems such as the double pendulum, drastically shortening the time required to find new physical laws. Furthermore human's have a cognitive bias when looking at data, find it difficult to spot patterns in chaotic systems. This report explores how an AI without any bias or prior knowledge views the physical world, how it is capable of spotting chaotic patterns and how it is a tool that can reduce the time taken to make new discoveries.

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My work did not involve human participants, their cells or data, or animals.

ECS Statement of Originality Template, updated August 2018, Alex Weddell aiofficer@ecs.soton.ac.uk

Contents

1 Introduction:

1.1 Goals:

It took humans centuries to derivie physical laws, can this process be sped up through AI, by feeding it data and letting the model derive complex laws for us. I aim to derive physical laws, from experimental data. I will explore deriving simpler physical laws such as acceleration without air resistance, and move onto to complex chaotic systems such as pendulums, and explore how an unbiased AI views the physical world, compared to humans who's views of physical systems are naturally biased through systematic learning.
Can this lead to perhaps different prespectives of viewing the physical world around us, allowing for further progress?

1.2 Scope:

- Aim to derive simple laws of motions (ie acceleration) through AI frameworks.

- Move onto more complex systems such as pendulums, and initially explore smaller initial values, moving onto larger initial values, thereby increasing the chaos, and difficulty of spotting patterns.

- To explore using various AI techniques, (Graph Neural Networks, Deep learning, Neural Networks) in combination with no prior knowledge and observe how and in what form the physical laws are derived.
- Simulate physical data required using pymunk, and perhaps use real world data from physics labs.

2 Literature Review:

2.1 Introduction:

Humans have spent millennia observing the world around us, creating concepts that describe the variables in the physical world, such as mass and force, to derive the laws of motion. In physics, like with all human endevaours, new discoveries and ways of thought are based upon previous works, creating a natural bias in the way we humans approach new problems. All exisiting theories, are therefore somewhat biased, this combined with our pre-existing bias in our biological brains, can introduce some hurdles in our future progress [1,2].

In the 17th Century, Kepler had gotten his hands on the word's most precise data tables on the orbits on planets, using this and his intellect, he spent close to half a decade, and after numerous unsucessful attempts, he had began a scientific revolution at the time, describing Mar's orbit to be an ellipse [3]. In essence, scientists throughout history, much like Kepler, have spent a great deal of time, discovering the right expressions to match the relevent data they have, this at it's core is symbolic regression. Now, a few centuries later, with exponential increases in orders of magnitude in our capability to perform calculations through computers, the process of discovering natural laws and the way to express them, has to some extent resisted automation.

One of the core challenges of physics and artificial intelligence, is finding analytical relations automatically, discovering a symbolic expression that accurately matches the data from an unknown function. This problem, due to it's nature, is most certainly NP-hard [4] in principle. The vastness of the space of mathematical constants, further adds to the difficulty. This literature review aims to present the recent advances in deriving expressions and laws through data, how we can avoid human bias by seeking solutions without prior assumptions and describing the various tools and techniques used to achieve this. Then it will introduce the 3-body problem and explore how artificial intelligence is being used to find faster and more efficient solutions.

2.2 Acceleration:

$$\mathcal{F} = m \cdot a$$

2.3 Double Pendulum Laws:

2.4 3 Body Problem:

2.5 4 Body Problem: ?????

2.6 Conclusion:

2.7 Symbolic Regression:

2.8 Neural Networks:

2.9 Symbolic Neural Networks:

2.10 Linear Systems:

2.11 Double Pendulum, Chaotic System:

3 Progress:

placeholder

4 Project Planning:

placeholder

5 Project Management:

5.1 Risk Assessment:

Issue	Impact	Prob	Risk	Mitigation
Unexpected delays and accidents	3	3	7	Include contingency plans and a 3 week break between major stages of the project, to allow for unexpected incidents.of the project, to allow for unexpected incidents.
Unable to generate enough experimental data due to lack of computational power.	4	1	14	Explore alternate more efficient ways of simulating data, consider using cloud infrastructure or potentially the Universities HPC facilities.
Challenges learning the double pendulum laws and the derivation.	2	4	5	Seek other resources from the Physics Department to learn the Physics required. Look up explanations online to learn.
Interpretability Challenges	3	2	10	Challenges in interpreting how the model works, can be mitigated through visualising the data, plotting results and through seeking ways to explain the model.

5.2 Project Planning:

A Gantt chart along with a rough outline of the relevent dates for various submission was made towards the beginning of this project, this alose included contengency planning and short yet frequent breaks every couple weeks.

blah blah

5.3 Gantt Chart:

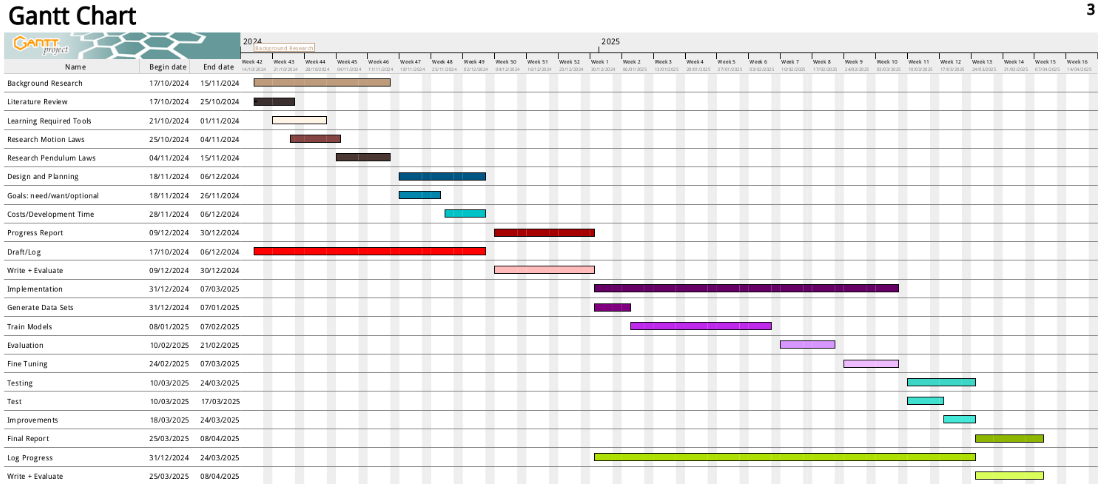
Part3Project 20 Oct 2024

Tasks 2

Name	Begin date	End date
Background Research	17/10/2024	15/11/2024
Literature Review	17/10/2024	25/10/2024
Learning Required Tools	21/10/2024	01/11/2024
Research Motion Laws	25/10/2024	04/11/2024
Research Pendulum Laws	04/11/2024	15/11/2024
Design and Planning	18/11/2024	06/12/2024
Goals: need/want/optional	18/11/2024	26/11/2024
Costs/Development Time	28/11/2024	06/12/2024
Progress Report	09/12/2024	30/12/2024
Draft/Log	17/10/2024	06/12/2024
Write + Evaluate	09/12/2024	30/12/2024
Implementation	31/12/2024	07/03/2025
Generate Data Sets	31/12/2024	07/01/2025
Train Models	08/01/2025	07/02/2025
Evaluation	10/02/2025	21/02/2025
Fine Tuning	24/02/2025	07/03/2025
Testing	10/03/2025	24/03/2025
Test	10/03/2025	17/03/2025
Improvements	18/03/2025	24/03/2025
Final Report	25/03/2025	08/04/2025
Log Progress	31/12/2024	24/03/2025
Write + Evaluate	25/03/2025	08/04/2025

Part3Project 20 Oct 2024

Gantt Chart 3



6 Bibliography:

[1] C. Wood Powerful 'Machine Scientists' Distill the Laws of Physics From Raw Data. Quanta Magazine, 2022.

[2] M. Schmidt and H. Lipson, Distilling Free-Form Natural Laws from Experimental Data. Science, 324, 5923, 2009.

[3] A. Koyr´e, The Astronomical Revolution: Copernicus- Kepler-Borelli (Routledge, 2013).

[4] A Computational Inflection for Scientific Discovery by Hope, Tom and Downey, Doug and Weld, Daniel S. and Etzioni, Oren and Horvitz, Eric