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Neural Networks: Enhancing Smart Systems with Machine Learning

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RESEARCH REPORT

The present report approaches a way to improve smart systems. Through artificial intelligence applied in the mechanical engineering field, it provides a consistent algorithm that can reads data, trains the machine and provides results about the situation and what to do with it. It will be studied two cases, one of them using machine learning classical techniques to determine the forces applied to a unnamed aerial vehicle and other using deep learning techniques like neural networks in the structural health monitoring area.

Complete after the research is done.

Keywords: machine learning, structural health monitoring, unnamed aerial vehicle

LIST OF FIGURES

LIST OF ABBREVIATION

AI Artificial Intelligence 1, 2

BD Big Data 2

DL Deep Learning 1, 2

IoT Internet of Things 2

ML Machine Learning 1, 2

NN Neural Network 1, 2

SHM Structural Health Monitoring 1–3

UAV Unnamed Aerial Vehicle 1–3

CONTENTS

1 INTRODUCTION

The use of Artificial Intelligence (AI) is very present nowadays [26, 33, 34]. This area of statistics neither is new nor started just now with the autonomous cars and voice assistants [31], but it is clear that in the last years it has been increasingly gaining more popularity. This happens mainly because of the advances that the World Wide Web has been had over the years [27, 12], since dial-up internet connection, back in the eighties, until now, with broadband internet and smartphones equipped with 5G connection. Another factor is that in the past, the cost to get a large capacity of storage memory was significantly more expensive than it is now, what makes today cheaper and easy to get memory to store information [18]. With the amount of data available, the evolution of internet and storage capacity, now it is not difficult to obtain, keep and analyze databases to make decisions [14].

AI application is everywhere and today, more than ever, it is easy to realize that. Either to get multimedia recommendations on streaming platforms, like occurs at Netflix, YouTube, Spotify, and so many others platforms [11], or to make predictions on the financial market and sports betting [30, 23, 21], AI is there behind the scenes making all the magic happen. Evidently there is nothing really magical about them, it is pure mathematics combined with a programming language that produces the algorithm capable of doing those things [19, 3, 35, 36]. The launch of ChatGPT–3, and shortly thereafter ChatGPT–4, has shown the power of those technologies and how they can change the way people do things [9, 8, 28, 5].

Getting into the smart systems application, the use of AI is widely used to Structural Health Monitoring (SHM), which is heavily used in the aerospace and civil fields, [4, 43]. The level and the complexity of the AI to be applied to monitor the structure, whether is going to use Deep Learning (DL) and Neural Network (NN) or simpler methods of Machine Learning (ML) like regressions, is determined by the problem itself and the results desired [15]. In some cases, the standards methods use numerical techniques and they may not be feasible, especially when there is a huge data to be analyzed. Thus, taking the AI road is an alternative to get the needed results for the monitoring in a more practical way [38, 39].

Still in this context, but in the field of Unnamed Aerial Vehicle (UAV), the use of AI can be combined to integrate UAV through wireless communication networks [25] what

can be useful in the agriculture sphere [1] with technologies like Internet of Things (IoT) [41, 40]. Also, the use of the AI can be subtle, such as the use of a built-in MATLAB function to make a simple NN to determine the final pose of a UAV based on the initial pose and the forces applied on it [16], or can be more sophisticated, like the use of ML and DL algorithms to predict materials properties, design new materials, discover new mechanisms and control real dynamic systems [20, 2].

It is clear, therefore, that AI can transit into different fields, such as entertainment, business, health care, marketing, financial, agriculture, engineering, among others [37, 44, 13, 42, 29, 32, 17]. The use of the Big Data (BD) can not only make it clear the scenario to be studied, but also to support making strategical decisions [22, 24]. The internet and hardware improvement [6], alongside the facility to storage data with accessible costs, encourages the AI use due to the benefits it can provide.

1.1 Objective

To develop an AI algorithm based on NN to apply in smart systems. The studied cases are:

- determination of the forces used to move an UAV based on its initial and final pose; and
- crack detection on railways through computational graphing[1] from images captured by UAV for SHM.

[1] Image recognition

2 METHODOLOGY

This chapter deals with the history, the main concepts and some practical cases of SHM inside the industry and academic area. Next, in the dynamic field, it will be studied the main mechanical concepts to get the necessary understanding to a UAV motion as well the basics to know how a UAV can be controlled. Then, it will be shown the mathematics behind the algorithms of deep learning that will be implemented in the Chapter 3. Finally, the way how the algorithms are going to be implemented and the tools necessary to achieve the desired neural network.

2.1 Structural Health Monitoring

2.1.1 Definition

According to Balageas et al. [7], the SHM main purpose is to provide, during the life of a structure, a diagnosis of: the state of the constituent material; the different parts of the structure; and the full assembly of each part that makes the structure as a whole. It is an improved way to make non-destructive evaluation. It can be applied in several areas such as civil infrastructure, like bridges and buildings; aerospace, like airplanes and spaceships; and mechanical, like machines.

Figure 2.1.1. SHM and human nervous system analogy. Source: Blanckenstein [10]

It also can be associated as an analogy to the human nervous system, as shown in the Fig. 2.1.1. Just like the sensors send a signal to the central processor, the human senses

send a signal to the brain to make the recognition of what is happening.

2.1.2 Brief History

The history goes back to the 1960s, when researches...

$$\mathscr{L}\{f(x)\} = \lim_{\theta \to 0^+} \int_{\theta}^{\infty} f(x)\, \exp(-st)\, dt \tag{2.1.1}$$

2.2 UAV Dynamics

2.3 Neural Networks

2.4 Toolbox

3 RESULTS AND DISCUSSION

4 CONCLUSION

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