São Paulo State University
School of Engineering of Ilha Solteira

Neural Networks: Enhancing Smart Systems with Machine Learning

Gabriel D. Silva

Student

Douglas D. Bueno

Advisor

Research Report – Iniciação Científica

UNESP

Ilha Solteira – SP

2023

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

CONTENTS

1 INTRODUCTION

The use of Artificial Intelligence (AI) is very present nowadays (Lee, 2020; Poola, 2017; Rabunal and Dorado, 2006). This area of statistics neither is new nor started just now with the autonomous cars and voice assistants (Muthukrishnan et al., 2020), 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 (Leiner et al., 2009; Cohen-Almagor, 2011), 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 (Goda and Kitsuregawa, 2012). With the amount of data available, internet and the evolution of storage capacity, now it is not difficult to obtain, keep and analyze them to make decisions (Duan et al., 2019).

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 (Chan-Olmsted, 2019), or to make predictions on the financial market and sports betting (Milana and Ashta, 2021; Kollár, 2021; Hubáček et al., 2019), 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 (Goodfellow et al., 2016; Aurélien, 2022; Raschka, 2015; Raschka et al., 2022). 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 (Biswas, 2023b,a; Lund and Wang, 2023; Baidoo-Anu and Owusu Ansah, 2023).

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, (Azimi et al., 2020; Ye et al., 2019). 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 (Farrar and Worden, 2012). In some cases, the standards meth-

ods use numerical techniques and they may not be viable, 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 (Smarsly et al., 2007; Sun et al., 2020).

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 (Lahmeri et al., 2021) what can be useful in the agriculture sphere (Ahirwar et al., 2019) with technologies like Internet of Things (IoT) (Verdouw et al., 2016; Tzounis et al., 2017). 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 (Geronel et al., 2023), 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 (Guo et al., 2021; Assilian, 1974).

It is clear, therefore, that AI can transit into different fields, such as entertainment, business, health care, marketing, financial, agriculture, engineering, among others (Ruiz-Real et al., 2020; Yu et al., 2018; Davenport and Kalakota, 2019; Verma et al., 2021; Mhlanga, 2020; Pannu, 2015; Ghatrehsamani et al., 2023). 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 (Jeble et al., 2018; Kościelniak and Puto, 2015). The internet and hardware improvement (Baji, 2018), 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 cases to be studied are:

- based on the dynamics of an UAV, to determine the relation of forces used to move it through its initial and final pose; and
- crack detection on railways from images captured by UAV for SHM.

2 METHODOLOGY

This chapter deals with the mathematics behind the algorithms that will be implemented in the Chapter 3. Naturally, the theory here explained can be implemented in any programming language, however in this research all the code will be done with Python, using the PyTorch framework for ML, and MATLAB, using its built-in functions.

3 RESULTS AND DISCUSSION

4 CONCLUSION

BIBLIOGRAPHY

Ahirwar, S., R. Swarnkar, S. Bhukya, and G. Namwade (2019, January). Application of Drone in Agriculture. *International Journal of Current Microbiology and Applied Sciences 8*(01), 2500–2505.

Assilian, S. (1974). *Artificial Intelligence in the Controle of Real Dynamic Systems*. Ph. D. thesis, Queen Mary University of London.

Aurélien, G. (2022). *Hands-on Machine Learning with Scikit-Learn, Keras, and TensorFlow*. O'Reilly Media, Inc.

Azimi, M., A. Eslamlou, and G. Pekcan (2020, May). Data-Driven Structural Health Monitoring and Damage Detection through Deep Learning: State-of-the-Art Review. *Sensors 20*(10), 2778.

Baidoo-Anu, D. and L. Owusu Ansah (2023). Education in the Era of Generative Artificial Intelligence (AI): Understanding the Potential Benefits of ChatGPT in Promoting Teaching and Learning. *SSRN Electronic Journal*.

Baji, T. (2018, March). Evolution of the GPU Device widely used in AI and Massive Parallel Processing. In *2018 IEEE 2nd Electron Devices Technology and Manufacturing Conference (EDTM)*, Kobe, pp. 7–9. IEEE.

Biswas, S. S. (2023a, March). Potential Use of Chat GPT in Global Warming. *Annals of Biomedical Engineering*.

Biswas, S. S. (2023b, March). Role of Chat GPT in Public Health. *Annals of Biomedical Engineering*.

Chan-Olmsted, S. M. (2019, October). A Review of Artificial Intelligence Adoptions in the Media Industry. *International Journal on Media Management 21*(3-4), 193–215.

Cohen-Almagor, R. (2011, April). Internet History:. *International Journal of Technoethics 2*(2), 45–64.

Davenport, T. and R. Kalakota (2019, June). The potential for artificial intelligence in healthcare. *Future Healthcare Journal 6*(2), 94–98.

Duan, Y., J. S. Edwards, and Y. K. Dwivedi (2019, October). Artificial intelligence for decision making in the era of Big Data – evolution, challenges and research agenda. *International Journal of Information Management 48*, 63–71.

Farrar, C. R. and K. Worden (2012). *Structural Health Monitoring: A Machine Learning Perspective*. John Wiley & Sons.

Geronel, R. S., R. M. Botez, and D. D. Bueno (2023, January). Dynamic responses due to the Dryden gust of an autonomous quadrotor UAV carrying a payload. *The Aeronautical Journal 127*(1307), 116–138.

Ghatrehsamani, S., G. Jha, W. Dutta, F. Molaei, F. Nazrul, M. Fortin, S. Bansal, U. Debangshi, and J. Neupane (2023, January). Artificial Intelligence Tools and Techniques to Combat Herbicide Resistant Weeds—A Review. *Sustainability 15*(3), 1843.

Goda, K. and M. Kitsuregawa (2012, May). The History of Storage Systems. *Proceedings of the IEEE 100*(Special Centennial Issue), 1433–1440.

Goodfellow, I., Y. Bengio, and A. Courville (2016). *Deep Learning*. MIT Press.

Guo, K., Z. Yang, C.-H. Yu, and M. J. Buehler (2021). Artificial intelligence and machine learning in design of mechanical materials. *Materials Horizons 8*(4), 1153–1172.

Hubáček, O., G. Šourek, and F. Železný (2019, April). Exploiting sports-betting market using machine learning. *International Journal of Forecasting 35*(2), 783–796.

Jeble, S., S. Kumari, and Y. Patil (2018, January). Role of Big Data in Decision Making. *Operations and Supply Chain Management: An International Journal*, 36–44.

Kollár, A. (2021, March). Betting models using AI: A review on ANN, SVM, and Markov Chain. Preprint, Open Science Framework.

Kościelniak, H. and A. Puto (2015). BIG DATA in Decision Making Processes of Enterprises. *Procedia Computer Science 65*, 1052–1058.

Lahmeri, M.-A., M. A. Kishk, and M.-S. Alouini (2021). Artificial Intelligence for UAV-Enabled Wireless Networks: A Survey. *IEEE Open Journal of the Communications Society 2*, 1015–1040.

Lee, R. S. T. (2020). *Artificial Intelligence in Daily Life*. Singapore: Springer Singapore.

Leiner, B. M., V. G. Cerf, D. D. Clark, R. E. Kahn, L. Kleinrock, D. C. Lynch, J. Postel, L. G. Roberts, and S. Wolff (2009, October). A brief history of the internet. *ACM SIGCOMM Computer Communication Review 39*(5), 22–31.

Lund, B. D. and T. Wang (2023, February). Chatting about ChatGPT: How may AI and GPT impact academia and libraries? *Library Hi Tech News*.

Mhlanga, D. (2020, July). Industry 4.0 in Finance: The Impact of Artificial Intelligence (AI) on Digital Financial Inclusion. *International Journal of Financial Studies 8*(3), 45.

Milana, C. and A. Ashta (2021, May). Artificial intelligence techniques in finance and financial markets: A survey of the literature. *Strategic Change 30*(3), 189–209.

Muthukrishnan, N., F. Maleki, K. Ovens, C. Reinhold, B. Forghani, and R. Forghani (2020, November). Brief History of Artificial Intelligence. *Neuroimaging Clinics of North America 30*(4), 393–399.

Pannu, A. (2015). Artificial Intelligence and its Application in Different Areas. *4*(10).

Poola, I. (2017). How Artificial Intelligence in Impacting Real life Everyday. *International Journal for Advance Research and Development 2*(10), 96–100.

Rabunal, J. R. and J. Dorado (Eds.) (2006). *Artificial Neural Networks in Real-Life Applications*. Hershey PA: Idea Group Pub.

Raschka, S. (2015). *Python Machine Learning*. Packt Publishing Ltd.

Raschka, S., Y. H. Liu, V. Mirjalili, and D. Dzhulgakov (2022). *Machine Learning with PyTorch and Scikit-Learn: Develop Machine Learning and Deep Learning Models with Python*. Packt Publishing Ltd.

Ruiz-Real, J. L., J. Uribe-Toril, J. A. Torres, and J. De Pablo (2020, October). Artificial Intelligence in Business and Economics Research: Trends and Future. *Journal of Business Economics and Management 22*(1), 98–117.

Smarsly, K., K. Lehner, and D. Hartmann (2007). Structural Health Monitoring based on Artificial Intelligence Techniques. In *Computing in Civil Engineering (2007)*, pp. 111–118.

Sun, L., Z. Shang, Y. Xia, S. Bhowmick, and S. Nagarajaiah (2020). Review of Bridge Structural Health Monitoring Aided by Big Data and Artificial Intelligence: From Condition Assessment to Damage Detection. *Journal of Structural Engineering 146*.

Tzounis, A., N. Katsoulas, T. Bartzanas, and C. Kittas (2017, December). Internet of Things in agriculture, recent advances and future challenges. *Biosystems Engineering 164*, 31–48.

Verdouw, C., S. Wolfert, and B. Tekinerdogan (2016, January). Internet of Things in agriculture. *CABI Reviews 2016*, 1–12.

Verma, S., R. Sharma, S. Deb, and D. Maitra (2021, April). Artificial intelligence in marketing: Systematic review and future research direction. *International Journal of Information Management Data Insights 1*(1), 100002.

Ye, X., T. Jin, and C. Yun (2019, November). A review on deep learning-based structural health monitoring of civil infrastructures. *Smart Structures and Systems 24*(5), 567–585.

Yu, K.-H., A. L. Beam, and I. S. Kohane (2018, October). Artificial intelligence in healthcare. *Nature Biomedical Engineering 2*(10), 719–731.