# Smart Monitoring for SLA-type 3D Printer using Artificial Neural Network

Danielle Jaye S. Agron*, Cosmas Ifeanyi Nwakanma†, Jae-Min Lee‡, and Dong-Seong Kim§
Networked Systems Laboratory, Department of IT Convergence Engineering,
Kumoh National Institute of Technology, South Korea.
{danielleagron*,cosmas.ifeanyi†, ijmpaul‡, dskim§}@kumoh.ac.kr

***Abstract*—In additive manufacturing, a relatively high oxygen concentration inside a Stereolithography Apparatus (SLA-type) of three dimensional (3D)-printer during the operation have high risk of degrading the quality of the product. Monitoring such level of oxygen is still an open challenge to solve in the additive manufacturing industry. This paper presents a design of a collaborative sensor system that monitors the normal oxygen level during the printing process. Furthermore, a self organizing map (SOM) which is a form of artificial neural network(ANN) to cluster the oxygen concentration to reach the critical level was proposed. Results of the ANN performance is 96%.**

***Index Terms*—ANN, machine learning, real time monitoring, remaining useful life, 3D Printing.**

## I. Introduction

Nowadays, 3D printing has been implemented in many industry [1]. One type of a 3D printer is a metal laser additive manufacturing printer and one variation of it is the StereoLithography Apparatus (SLA), this technology uses an ultraviolet (UV) laser to turn light-sensitive resin into solid 3D objects layer-by-layer from bottom to top. However, SLA printer may be the fastest additive manufacturing technology for functional, durable prototypes and end-use parts but there are a lot of wasted materials, time and money because of some printing failures. Some of the existing problem includes the high concentration level of oxygen inside the 3D-printer produced during operation. The allowable oxygen concentration to preserve the highest quality of the printed product is 0.2% if it violates the threshold value then, it escalates the risk on having high porosity on the printed product [2].

Recent trend in condition monitoring is the application of digital twin and machine learning approaches. Such approach involve real time monitoring and classification of remaining useful life (RUL) of applications and devices or what is rightly called prognostics and health management (PHM). Chief among the machine learning approaches are support vector machine (SVM), artificial neural network (ANN) [3]. In [3], an echo state network (ESN) was adopted and shown to have superior performance over other machine learning algorithms like SVM. The drawback was also acknowledged in the work of [4] where in SVM was only used in classifying a good or bad print of work done. The need for more robust means of remaining useful life monitoring can not be overemphasised. This paper adopted the use of ANN to help in real time prediction of the threshold of the oxygen and prompting action if threshold for refill is detected. Most works in the area of combining neural networks with 3D printing monitoring appears to be faced with challenges and look promising as a research direction due to numerous challenges identified such as dataset limitations, adoption of unified application programming interfaces (APIs), hardware limitations and expertise [5].

To the best of our knowledge, this is the first time a work is done in the area of using ANN to predict of the level of oxygen inside the 3D printer within acceptable threshold. Motivated by the works of [6], this paper attempts to develop an ANN to monitor the threshold level of oxygen in SLA-type 3D printer. The rest of the paper is organized as follows. Section II discuss the system architecture of the 3D printer and the ANN of the proposed system. Section III demonstrated the preliminary results while Section IV is the conclusion of the paper.

## II. System Architecture

In this paper, the effectiveness of using Artificial Neural Networks (ANN) to predict the future errors that may occur during the printing process was presented. The error that we are referring to is the abundance of oxygen present inside the 3D printer that leads to the degradation of quality of the product. In order to do that, an oxygen sensor is strategically placed inside the SLA 3D printer and it is connected to a data acquisition device (DAQ) to collect the data from the sensor and feeds it on a computer to process it (See Fig. 1).

The data are filtered and logged in the local database, a comparison of the acquired data and the threshold value that indicates whether the condition of the printing environment whether it is normal or in critical/alarming condition. If the data collected is found to have an error or is strained, the system activates an alarm that sends a warning to the administrator about the irregularities on the values acquired by the sensors. These values may lead to conclusions that (1)

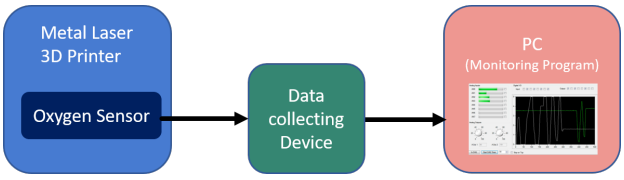


Fig. 1: Monitoring System Test Design

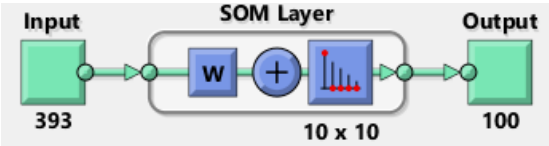


Fig. 2: Neural network trainer showing number of input, SOM layer and number of desired output.

imbalance of oxygen level, (2) the sensors are not working properly. Else, it continues its normal operation. Afterwards, the progress in printing is checked so that until the printing is not yet finish, it continues gathering data.

When the neural network foreseen a pattern of data input that may lead to violating the threshold values, it issues a signal to activate the motor that is assigned to flush the gas inside the 3D printer. The self-organizing map is chosen for the process because it is widely use for the real time data because of its fast conversion rates characteristic even with a non-linear data inputs. SOM identifies similar samples or data. It is a form of dimension reduction or nonlinear generalization of principal component analysis. Similar data are clustered together helping to reduce the dataset dimension. This is a step towards dataset pre-processing for ANN.

## III. Experiment and Data Clustering using Self Organizing Map

The sensors involved in this experiment is a sensor with analog voltage output. The threshold values set on this experiment is -3V and 3V. The sensor connected on DAQ device that is dedicated for signal conditioning, reading analog signal input from the sensor. Fig. 2 represents the overall system flow of the neural network. After logging the data on local database, the values are stored as a feature vector in internal matrix and then each feature vector is normalized and scaled to [10,10]. The vectors are stored as an input vector to the classifier afterwards, the classification process starts until convergence, the total Epoch size was 200. The data is clustered and collected using MATLAB R2019b self organising map (SOM).

The neural network system model detailing the total number of input, SOM layer and output cluster. Fig. 3 is the SOM Neighbor weight distances representing the variation in the value of the oxygen. The orange neighborhood cluster are the values that violated the threshold values, while the yellow clusters are the acceptable values for the oxygen level. The boundaries represent when value is deviating from threshold as shown in the result Fig. 4.

## IV. Conclusion

This work presented a preliminary system framework for the the monitoring of SLA-type 3D printer and proposed the use of ANN for threshold prediction to intelligently take decision of activating the flushing motor. It is a future research direction to enhance the framework and the neural network model to reflect complex and real testbed scenario. For the future development of the monitoring program, error detecting

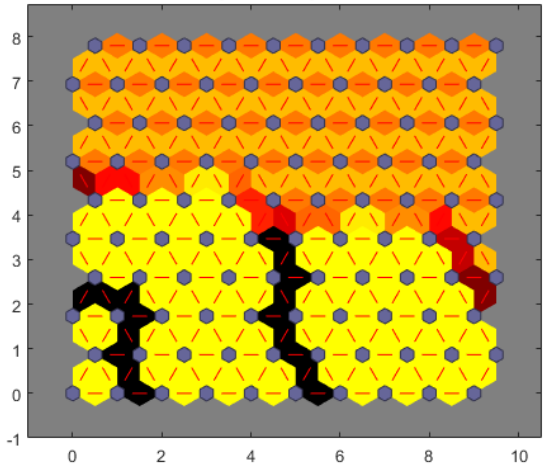


Fig. 3: Self-Organizing Map (SOM) Cluster of Datatset showing the SOM Neighbor Weight Distances based on the values of dataset and how close they are to the threshold.

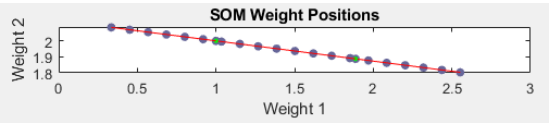


Fig. 4: Threshold Position using the SOM

paradigm will be implemented on the project using state-of-the-art machine learning algorithms and computer vision technology that reinforce integrity of the monitoring program.

## Acknowledgment

This research was supported by the MSIT(Ministry of Science and ICT), Korea, under the Grand Information Technology Research Center support program(IITP-2020-2020-0-01612) supervised by the IITP(Institute for Information communications Technology Planning Evaluation).

## References

[1] J. Sorocki and I. Piekarz, "Low-cost microwave components' fabrication in hybrid technology of laminates and additive manufacturing on an example of miniaturized suspended directional coupler," *IEEE Access*, pp. 1–1, 2020.

[2] H. Guo, R. Lv, and S. Bai, "Recent advances on 3d printing graphen-based composites," *Nano Materials Science*, vol. 1, no. 2, June 2019. [Online]. Available: https://doi.org/10.1016/j.nanoms.2019.03.003

[3] S. Zhang, K. He, D. Cabrera, C. Li, Y. Bai, and J. Long, "Transmission condition monitoring of 3d printers based on the echo state network," *Appl. Sci.*, vol. 9, no. 3058, July 2019. [Online]. Available: https://doi.org/10.3390/app9153058

[4] U. Delli and S. Chang, "Automated process monitoring in 3d printing using supervised machine learning," in *46th SME North American Manufacturing Research Conference, NAMRC 46, Texas, USA*, vol. 26, no. 2018. USA: Elsevier Procedia Manufacturing, August 2018. [Online]. Available: https://doi.org/10.1016/j.promfg.2018.07.111

[5] X. Qi, G. Chen, Y. Li, X. Cheng, and C. Li, "Applying neural-network-based machine learning to additive manufacturing: Current applications, challenges, and future perspectives," *Engineering*, vol. 5, no. 4, pp. 721–729, 2019. [Online]. Available: https://doi.org/10.1016/j.eng.2019.04.012

[6] Y. Banadaki, N. Razaviarab, H. Fekrmandi, and S. Sharifi, "Toward enabling a reliable quality monitoring system for additive manufacturing process using deep convolutional neural networks," *arXiv*, March 2020. [Online]. Available: https://arxiv.org/abs/2003.08749