# Design of a Fault-Detection System for FDM-type 3D Printer using Temporal Convolutional Network

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***Abstract*—In the process of additive manufacturing, the devices used to print usually encounter errors and problems that are not easily detected by the device operator. Undetected errors can cause serious damage to the 3D printer and leads to the output being counted as reject, thus leading to both loss in time and resources. The research focuses on the development of a device to monitor the process of 3D printing. The design applies temporal convolutional networks (TCN) to train the device to identify whether certain measurements of the 3D printer will lead to errors in output. The prototype serves as an attachment to the 3D printer and displays measurements and if they are within the safe values.**

***Index Terms*—Additive manufacturing, 3D printer, machine learning, Smart monitoring, Temporal convolutional network.**

## I. Introduction

Additive manufacturing is the process of generating tangible objects through a layer-by-layer approach. There are various methods for additive manufacturing, some of which us plastic while others use metal [1], [2]. The procedure is performed in the development of prototypes, as the use of factory-grade equipment may be costly and is not ideal in prototype development. When developing a certain product, the agile design methodology for hardware development requires several iterations and rework of a product [3]. If engineers were to manufacture the product the same way as they perform mass production, the process would take long and would cost much more than the use of additive manufacturing methods. Though additive manufacturing is ideal for prototype development, it is not an ideal approach for mass production.

In the development of prototypes using additive manufacturing, the process takes a lot of time to complete. The process involves a layer-by-layer approach and a small component can take even more than 6 hours. Due to the time consuming process, additive manufacturing operators cannot be expected to watch over the whole process. The machine is often left to complete the print cycle with very minimal supervision. During the printing process, errors in the printing process may occur. Small defects and imperfections in the print can compile and later lead to more serious problems, leaving the output print as a reject or simply waste. If such occurs, both time and money are lost in the process. Furthermore, bad output may result to damage in the machine, thereby causing more problems in the future.

Due to the time consuming process, manual supervision of the additive manufacturing process is not deemed ideal. The need for a smarter solution to monitor the process is established. In this research, the development of a monitoring system is recommended. This research aims to explore the use of TCN to develop a device that can detect errors during the printing process and halt it [4], [5].

In this paper, the researchers elaborate their plans for the the implementation of a smart monitoring device that shall be used to detect faulty prints during the additive manufacturing process. The device shall consist of sensors for monitoring environmental parameters, as well as machine learning algorithms to differentiate faulty from quality print.

## II. Methodology

The formulation and conceptualization of this study was derived from the underlying cause of prototyping waste in time and resources – lack of a device to properly monitor if the 3D printer is still operating at normal conditions. The 3D printing process is very intricate and a slight error in the process would lead the print output to be unusable. Fig. 1 shows the conceptual framework of the design. The design aims to obtain input from the temperature, air quality, and interior of the 3D printing chamber and the sound produced by the printer extruder. From the processed data, temporal convolution networks will be applied to obtain threshold values that may be attributed to the printer being in safe working conditions. The process then leads to a comparison and a notification if the print quality is still optimal.

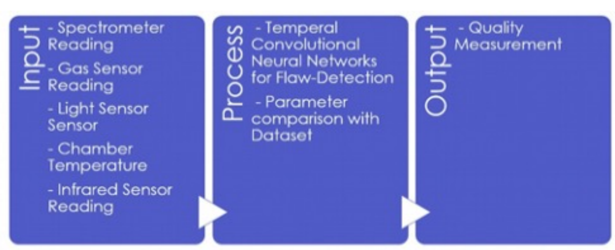


Fig. 1: Conceptual Framework

### A. Hardware Design

The formulation and conceptualization of this study was derived from the underlying cause of prototyping waste in time and resources – lack of a device to properly monitor if the 3D printer is still operating at normal conditions. The 3D printing process is very intricate and a slight error in the process would lead the print output to be unusable. Figure 1 shows the conceptual framework of the design. The design aims to obtain input from the temperature, air quality, and interior of the 3D printing chamber and the sound produced by the printer extruder. From the processed data, temporal convolution networks will be applied to obtain threshold values that may be attributed to the printer being in safe working conditions. The process then leads to a comparison and a notification if the print quality is still optimal.

In the development of the system, the schematic diagram in Fig. 2 shall be used for the wiring of the sensors. The National Instruments (NI) USB-6001 shall be used as the microcontroller of the device. The NI USB-6001 is low-cost data acquisition device that allows connections through its various digital and analog input/output pins.

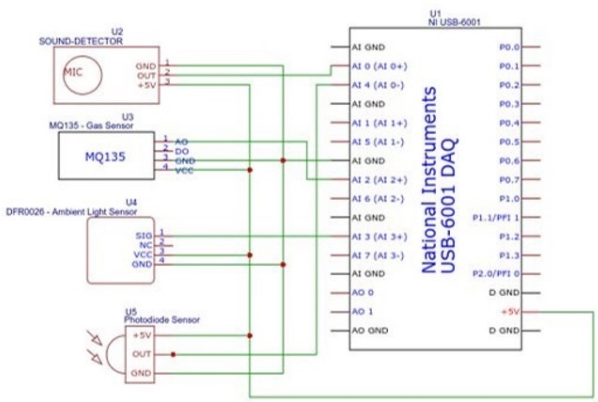


Fig. 2: Conceptual Framework

### *B. Temporal Convolutional Networks*

Temporal Convolutional Networks or TCN is a deep learning algorithm that was first used in video-based action segmentation. The process consists of two steps – collecting low-level features through convolutional neural networks (CNN) and using a recurrent neural network (RNN) for obtaining high-level temporal information from the low-level features [6].

The TCN is the preferred algorithm in this research as the size it is able to take in is variable. TCN can take any length as input and output the same length as output. Furthermore, its architecture is casual in a sense that the future data and past data do not interfere. In summary, its operational model is simply the integration of a one-dimensional fully-convolutional network (FCN) and casual convolutions.

### *C. Software Development*

In the software development phase of this research, LabVIEW will used. LabVIEW is a systems engineering software used for testing, measurement, and control. The LabVIEW provides the ability to program graphically using block diagrams. LabVIEW will used to obtain readings from the sensors using the NI USB-6001. The measurements from the sensors will initially graphed using a time-series model and studied from there.

## III. Testing

To initially test out the device to be developed, sensor readings will be obtained after running the device during the operational mode of a 3d printer. From the results, different values will be seen from the temperature, sound, light, and gas sensors. For the analysis of the values, the next step of the design would be to obtain a threshold value to use, as a means to determine whether or not the 3D printer is still in a stable condition. Furthermore the next steps would include performing a t-test and comparing the results obtained from the device with manual observations made by the researchers.

## IV. Conclusion and Recommendation

The paper outlines the plans for the development of the device. The next steps in this research would involve the implementation of the plans discussed. The main objective is to develop the a device capable of monitoring the operational status of a 3D printer was developed. The results from the t-test must prove the effectiveness of the application of TCN in obtaining proper threshold values in determining whether or not a 3D printer is in proper operational condition. Future works would include applying modifications to the algorithm and exploring other applicable algorithms to be used to improve the accuracy of the system to be developed. Furthermore, a mechanism for automatically halting the operation of a 3D printer in the event of operational failure is recommended. As of this design, detection and notification of the status was only considered.


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