Artificial neural networks in the context of additive manufacturing

Introduction and Background

Additive manufacturing allows the production of lighter and stronger parts by depositing a chosen material layer upon layer, in precise geometrical shapes. This process is now being used for the aerospace, military and defence, medical, and automotive fields [1].

Artificial Neural Networks consist of three types of layers: an input layer of neurons (or nodes), one or more hidden layers of neurons, and a last layer of output neurons. These layers are interconnected by the nodes, as shown in Figure 1. Each connection has an associated weight, which helps determine the significance of the given variable.

To find new materials, materials scientists are now looking towards artificial neural networks (ANN). ANNs are Machine Learning algorithms based on the model of human neurons. Scientists are using these models to find complex relationships between the machine parameters and the material properties. This will make choosing the materials easier and cheaper, as by changing the machine parameters we can predict what properties the material will have.

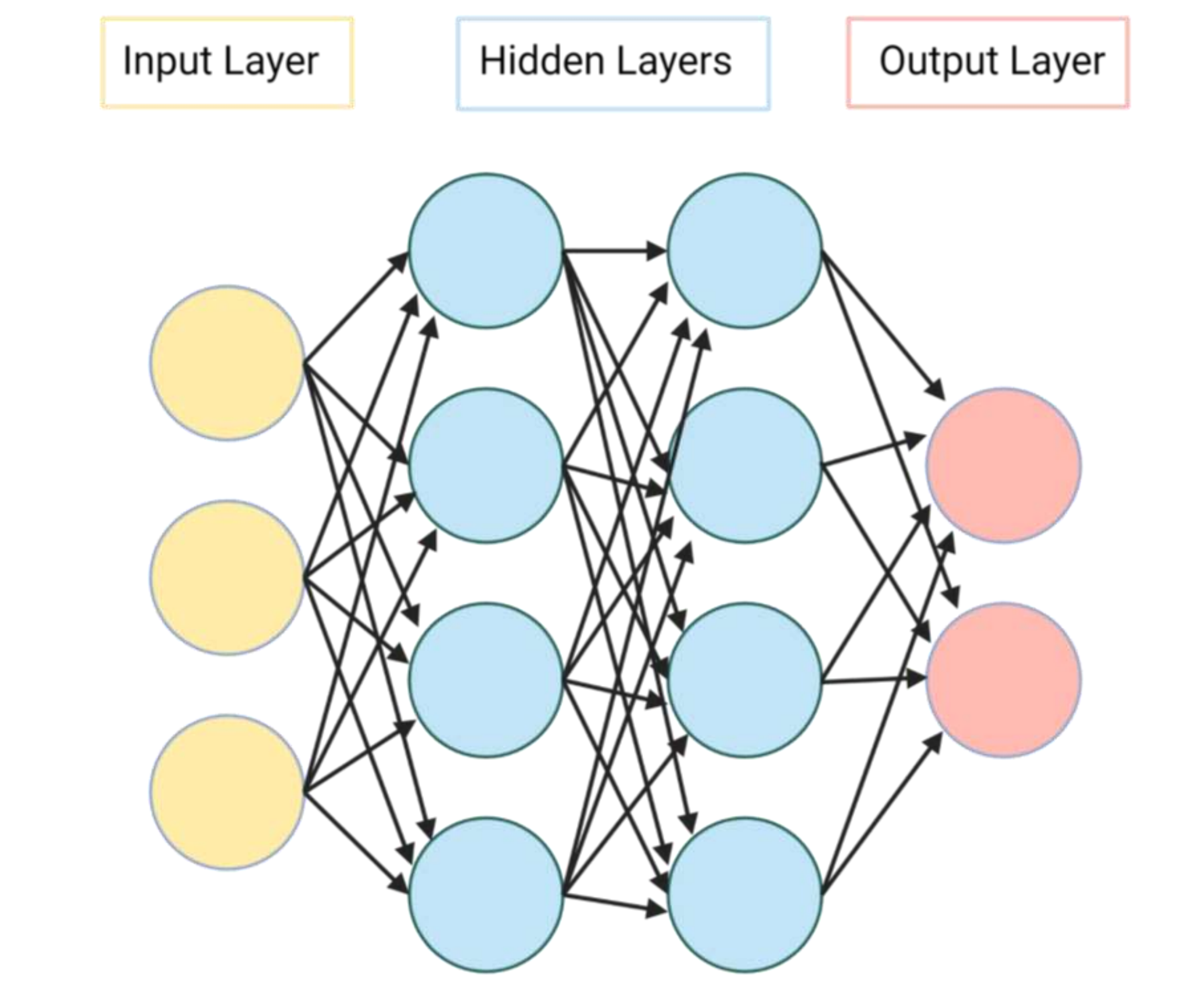

Figure 1. Representation of an Artificial Neural Network

Aims and Objectives

- To use an ANN model to find the correlation between input (machine parameters) and output (mechanical properties) in the context of additive manufacturing process
- To train and validate the ANN model with research data from an additive manufacturing process

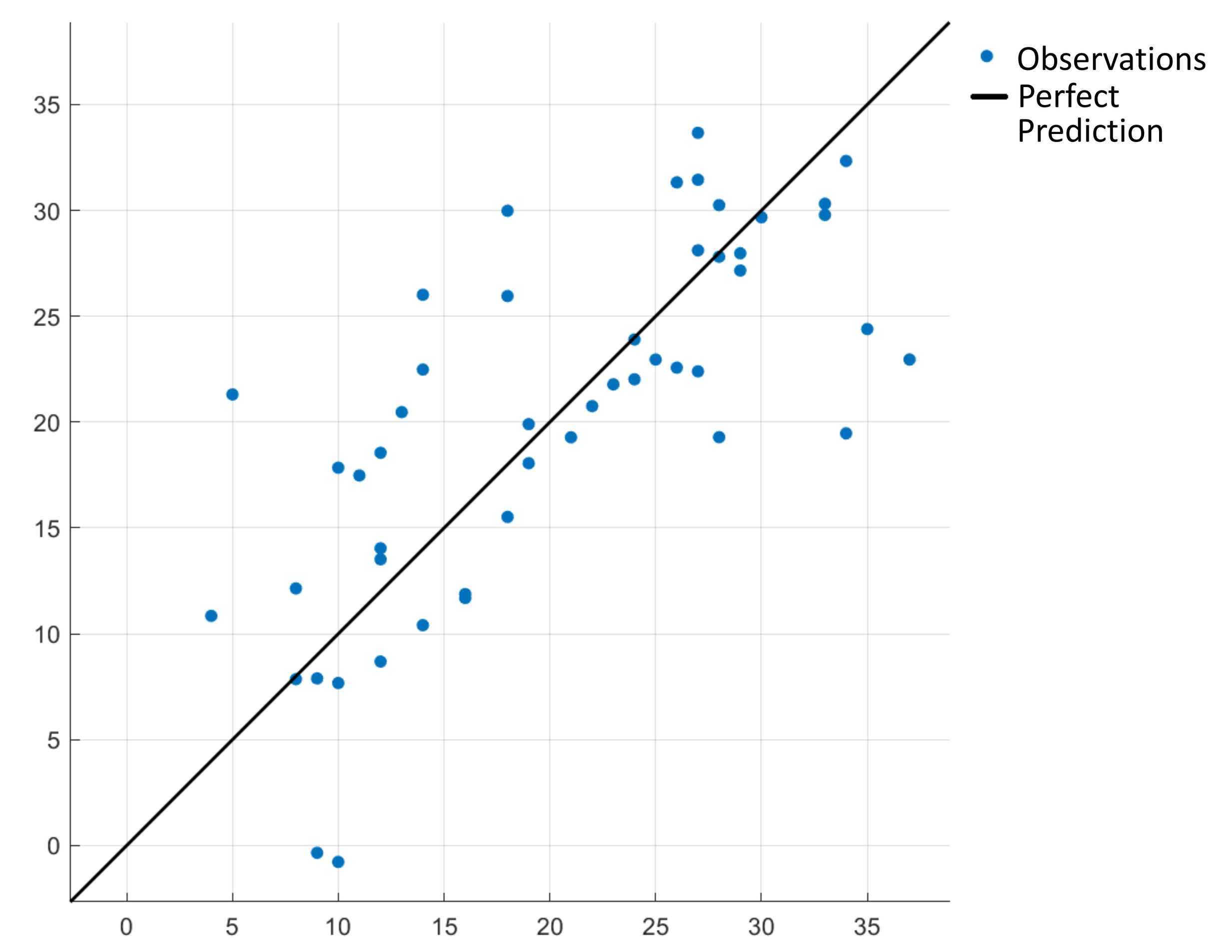

Figure 2. Predicted tensile strength values (Y-axis) in comparison to the actual values (X-axis).

Methodology

The Artificial Neural Network was created with MATLAB built-in functions, as it is a faster way of seeing the end result, whilst being able to modify the neural network parameters.

The chosen network for this problem is a two-layer feedforward neural network, where the information always moves in one direction, forward. The model has been trained with the Levenberg-Marquardt algorithm, and the dataset has been split as 70-30. 70% used for training the model, and 30% used for validating (15%) and testing it (15%).

The final ANN model will be created using a python based model using the final parameters that best suit the neural network previously created in MATLAB.

Results

After training and testing the model with various parameters, the best results were found using the following hyperparameters: number of fully connected layers: 1 (with the size being 133), activation function: none, iteration limit: 1000, regularization strength (Lambda): 0.0034025.

The training performance was measured with R-Squared, which gave a value of 0.53 (this value is lower than expected and has to do with the dataset only containing 50 data points). The model was validated using the 10-fold Cross-Validation statistical method, where k = 10.

Figure 2 illustrates the model performance where the X-axis shows the true response, and the Y-axis the predicted response.

The input parameters (machine parameters) used are: layer height, wall thickness, infill density, nozzle temperature, bed temperature, print speed, and fan speed. The output parameter (material property) predicted is the ultimate tensile strength.

Conclusions and Future Work

The model created with MATLAB shows there is a correlation between the ultimate tensile strength and the layer height, wall thickness, infill density, nozzle temperature, bed temperature, print speed, and fan speed.

There are still improvements being made in the additive manufacturing field. Therefore, we will need to make sure all factors and parameters are considered and appropriately tested.

Many other parameters can be modified and that may affect the ultimate tensile strength, some in a more direct way, and others will not make a difference.

Acknowledgements

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[1] Frazier, W.E. Metal Additive Manufacturing: A Review. *J. of Materi Eng and Perform* **23,** 1917–1928 (2014).

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