Bilkent University

Department of Computer Engineering

Design Project

Machine Learning for Machining Processes of Three-Dimensional Parts

Project Specifications Report

Project Members: Irmak Akyeli, Denizhan Kemeröz, Alp Üneri, Bulut Gözübüyük, Tuva Tanay Işıksal

Supervisor: Prof. Dr. Uğur Güdükbay

Jury Members and Project Evaluators: Dr. Shervin Arashloo and Dr. Hamdi Dibeklioglu.

Oct 11, 2021

This report is submitted to the Department of Computer Engineering of Bilkent University in partial fulfillment of the requirements of the Senior Design Project course CS491/2.

Contents

1. Introduction

In this part of the report we will be introducing the project by giving a description of it and as well delving deep into the constraints of the project.

1.1 Description of the Project

The project will be an application of machine learning (ML) techniques in the field of machining process identification (MPI). ML is defined as a branch of artificial intelligence (AI) and computer science that focuses on the use of data sets and algorithms to mimic the way humans are able to learn on computer systems [1]. ML algorithms, often called models, are fed data from data sets that gradually get better and better in their accuracy in the same ways that humans would [1]. For example, an ML model may be constructed to identify how many faces are in a picture that is supplied. In order to do this the model would have to be trained using a known data set, which involves feeding the model data on which the aspect in question is known, and the model would then gradually get better and better at identifying how many faces there are in a supplied picture. After sufficient training, the model would be able to identify the number of faces within a picture with great confidence.

MPI is a novel area of research that aims to automate the manufacturing of mechanical parts by automatically deciding whether the part in question would be able to be manufactured using the manufacturing plants in place in an effort to make the manufacturing process more time and cost effective and to reduce the amount of faults that may occur during manufacturing [2]. Our project will investigate the applicability of ML and especially convolutional neural networks (CNNs) for MPI means. A CNN is a deep learning model that takes in an input image and by assigning importance such as learnable weights and biases to various aspects or objects within the image is able to differentiate images within a number of categories the aspects/objects within the image can belong to [3].

We will be trying to come up with an ML model that will be used to automate the processes of determining the type of manufacturing processes (additive versus subtractive manufacturing) to be used, the producibility of three-dimensional models, and cost estimation. Additive manufacturing is when processes build objects by adding materials layer by layer to form the desired product, while subtractive manufacturing is when materials are removed from an already existing object to come up with the part that is needed [4]. We are planning on developing a deep learning framework for determining which type of machining processes are suitable for producing a machine part and the producibility of these parts using the selected machining process for the provided three-dimensional models.

The machining operations we will consider are turning, milling, and drilling. Turning is a machining operation in which a work piece is rotated while the cutting piece moves in a linear motion to achieve the desired shape, which is often cylindrical [5]. A lathe machine is usually used for turning purposes [5]. Drilling is a machining operation in which a drill press or a tapping machine is used to create a round hole in a workpiece [5]. Lastly, milling is a machining operation that involves using many multi-point rotary cutters to remove material from an object to achieve the desired outcome [5]. Our end product will also be able to determine which operations are to be performed in order to attain the desired part if the part is able to be produced using the available producing plant. Another stage for the parts that are producible using the selected machining process and the operations selected is the estimation of the cost of the production of the parts for different material properties and costs input to the system.

1.2 Constraints of the Project

In this section of the report we will be delving into the constraints of the project in more detail.

1.2.1 Economic Constraints

Our project will be able to automate a number of processes within the creation of a specific part within a given manufacturing plant, and will thus be able to reduce costs for the people involved in the creation of the selected part. This will be in the form of not having to employ people whose roles are to do the processes that will be automated by our project, and will therefore create an economic incentive for people involved in manufacturing and the creation of parts to use our project.

1.2.2 Environmental Constraints

Our project will be able to reduce the number of mistakes or mishaps that may happen during the manufacturing of specific parts. As these mistakes or mishaps result in inefficiencies in the use of the manufacturing plant, which in turn result in the manufacturing plant's use going to waste, generating unnecessary pollution to the environment, our project will be able to benefit the environment by reducing or completely eliminating these mistakes and mishaps.

1.2.3 Social Constraints

Our project will be able to automate some of the processes that are undertaken during the production of specific parts. These automations are likely to either remove the people who were doing the processes which are to be automated from employment or have their efforts focused elsewhere. Thus, our project will have a social impact on the people who are now manually performing the processes which our project is going to be used to automate.

1.2.4 Political Constraints

Our project will be able to be used in large manufacturing plants to increase the efficiency of the plant. As large manufacturing plants are usually used in service of government affiliated companies, our project will be able to in a roundabout way help the government by increasing the efficiency of manufacturing plants affiliated with them. No other political constraints have been linked to our project.

1.2.5 Manufacturability Constraints

Our project will be used to automate some of the processes involved in the manufacturing of certain parts at manufacturing plants. Thus, we will be increasing the efficiency of said manufacturing plants and will as well be reducing the likelihood of mistakes or mishaps from occurring.

1.2.6 Sustainability Constraints

Our project will be increasing the sustainability of manufacturing plants by automating certain processes and thus lowering the risk of mistakes or mishaps from occurring. Our project will also be a sustainable project as the machining operations our project will be based on have been around for many years and are likely to be around for much more. Even if new machining operations are introduced, use of these current machining operations will likely not dwindle as they are core operations, the other machining operations that are to be introduced will likely be used as supplements to these already existing ones. In addition, with sufficient data provided, any new feature can be added to the existing models with additional training therefore the system can stay up-to-date without extra work.

1.2.7 Ethical Constraints

Our project will be used to automate certain processes to be done in the manufacturing of parts. This will likely lead to the people who are doing those jobs manually to be left without anything to do. This will lead to one of two scenarios: either they will be let go and lose their job, or they will be reassigned to do some different type of work. This issue would go into the broader issue of AI replacing menial human jobs, and is an ethical concern. However, those who are in favor of progress such as our group members recognize the fact that such regrettable consequences are part of progress and innovation, and will pursue the project regardless.

1.2.8 Professional Constraints

As stated in the previous constraint, our project is likely to either cause employees to be let go or reassigned, which are the professional constraints associated with our project.

2. Requirements for the Project

In this section of the report we will be discussing the requirements of the project in detail. We will first start with the functional requirements and move on to discuss the non-functional requirements.

2.1 Functional Requirements

In this section of the report we will be discussing the functional requirements of the project in detail. We will first be focusing on the functionalities of the model that will be trained before it reaches the user, and will then be delving into the functionalities that the end user will have access to.

2.1.1 Functionalities of the ML Model

The model would be able to be trained by supplying it with data in the mode of binvox files. The model will have to first be sufficiently trained in order to then be able to predict and perform operations on user supplied parts.

This training process requires long computations and depending on the CPU used can have a runtime of as little as two seconds for each epoch on an NVIDIA RTX 30 series with a total of 15 hours to completely train the model. However, it should be noted that this training will be done only once and before the project reaches its end user. Thus, the length of the duration of this process will not be of issue to the end user.

2.1.2 Functionalities of the User

The main functionality of our project from an end user perspective is the trained model being able to predict the user supplied part models and accurately determine whether it is able to be produced using the given manufacturing plant, what materials will be necessary to produce the part, the method of manufacturing and the machining operations that will be required to manufacture the part, and the estimated cost that will be required to produce this part. In order to do this, the user will be able to supply to our program an STL file, have it transformed into a binvox file, have this transformed into a numpy array, fed into the model, and have the respective output be produced. The user will be able to supply models in the form of STL files and will be able to view this model turned into a binvox file and the output resulting from the given input. The model will then predict whether a part of the given model can be manufactured using the given manufacturing plant or not, what method and manufacturing and machining operations will be used to manufacture the part, and the estimated cost of doing so.

2.2 Non-Functional Requirements

In this section of the report we will be discussing the non-functional requirements of the project in detail.

2.2.1 Usability

As our end-product will only have to be used by professionals within the field of manufacturing, we will not be required to cater to a general audience when creating our project. Thus, we can assume that the people using our project will be familiar with the technical terms within our project such as turning, drilling, and milling, and we will not be required to provide a description of such terms. We will also be able to assume some level of expertise on the abilities of the people using our project to be able to interact with computer systems, as we are expecting the large majority of our users to be engineers. As such, we will be able to assume the users will be familiar with using systems such as the one we will develop, and can be more relaxed in the way we approach the user interface elements et cetera.

2.2.2 Supportability

Our project will be able to be run on any system that runs Python3 excluding 3.8+ as it does not support the Tensorflow library that we are using for our CNN models, and we will be focusing on the interoperability of the underlying Python fundamentals to establish the supportability of our project.

2.2.3 Reliability

We aim for our ML models to be able to be accurate to a very high degree after sufficient training. We at the moment are unable to estimate the size of the data set that will be required to achieve this, but we will be putting the bar at around 95% to be able to call the model accurate.

2.2.4 Efficiency

As the model will have to be trained only once for it to be able to output accurate classifications, efficiency will not be the biggest non-functional requirement in our project. We will be putting more emphasis on our project producing more accurate results and will be ruling in favour of losing efficiency for this aim if need be.

2.2.5 Security

As there is no sensitive information that is to be stored or processed in our project, there are no security concerns for data leak or any such considerations. Therefore, no encryption or any other method of obfuscation will be necessary in our project.

2.2.6 Scalability

Our project will be taking into consideration the machining operations of turning, drilling, and milling. Thus, it will have to be scaled if need be to have any other machining operations that are to be incorporated. We cannot comment at this time how easy or difficult it will be as we do not yet have the model, but we are assuming it will be easier to implement such a scaling to our project.

3. References

[1] “What is machine learning?”. https://www.ibm.com/cloud/learn/machine-learning. [Accessed: Oct 9, 2021]

[2] “Identifying manufacturability and machining processes using deep 3D convolutional networks”. https://www.sciencedirect.com/science/article/pii/S1526612521001201. [Accessed: Oct 9, 2021]

[3] ”A Comprehensive Guide to Convolutional Neural Networks”. https://towardsdatascience.com/a-comprehensive-guide-to-convolutional-neural-networks-the-eli5-way-3bd2b1164a53. [Accessed: Oct 9, 2021]

[4] “Additive vs. Subtractive Manufacturing”. https://formlabs.com/blog/additive-manufacturing-vs-subtractive-manufacturing/. [Accessed: Oct 9, 2021]

[5] “Machining Processes: Turning, Milling, and Drilling”. https://trimantec.com/blogs/t/machining-processes-overview. [Accessed: Oct 9, 2021]