Bilkent University

Department of Computer Engineering

Senior Design Project

Machine Learning for Machining Processes of Three-Dimensional Parts

Project High Level Design Report

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Contents

1. Introduction

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 using ML 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 number 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 workpiece 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.

1.1 Purpose of the System

The main purpose of the system will be to determine whether a part whose three dimensional model is supplied can be manufactured or not using a given manufacturing plant. The system will also be used to determine using which machining operations the part can be manufactured if it can be manufactured, and the estimated cost for doing so. The project will be aimed at replacing the human workers that are currently used to make such determinations, instead using our project to perform them.

1.2 Design Goals

We have several design goals when it comes to our projects, and these are usability, supportability, reliability, efficiency, security, and scalability.

1.2.1 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.

1.2.2 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.

1.2.3 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.

1.2.4 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 favor of losing efficiency for this aim if need be, since our training will only need to be done once before the product is usable.

1.2.5 Security

As there is no sensitive information that is to be stored or processed in our project, there are no security concerns for data leaks or any such considerations. Therefore, no encryption or any other method of obfuscation will be necessary for our project. We will not be having any sessions or storing the models provided on our system.

1.2.6 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 scaling to our project. We can have one main model with the basic functionality and other additional functionality can be added on top of this model.

1.3 Definitions, Acronyms and Abbreviations

In this section of the report we will be providing the definitions of acronyms and abbreviations that we will be using throughout the report.

1.3.1 Artificial Intelligence (AI)

Artificial Intelligence is a branch of computer science that is concerned with building smart machines capable of performing tasks that typically require human intelligence.

1.3.2 Machine Learning (ML)

Machine learning is defined as a branch of 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].

1.3.3 Machining Process Identification (MPI)

Machining process identification is the operation of deciding whether the part in question would be able to be manufactured using the manufacturing plants in place. Augmenting MPI with ML is a novel area of research performed in an effort to make the manufacturing process more time and cost-effective and to reduce the number of faults that may occur during manufacturing [2].

1.3.4 Convolutional Neural Networks (CNN)

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]. There are different dimensional CNNs, such as two dimensional and three dimensional CNNs. We will be using a three dimensional CNN throughout our project.

1.4 Overview

Our project will be an ML project, specifically using three dimensional CNNs to determine for a given three dimensional model of a part that is to be manufactured whether it can be manufactured using a given manufacturing plant or not, the machining operations that would be required to manufacture the part if it can be manufactured, and the estimated cost that it would require to do so. Our project will be under the novel area of research MPI.

2. Current Software Architecture

We currently have a system that takes in STL files and successfully converts them to binvox files. We also have a machine learning model that takes in a three-dimensional part model and predicts whether it can be manufactured using subtractive manufacturing and if it can be produced, the machining processes that would be required to produce the desired part. We have a desktop application that takes an STL file, shows the model, converts it to binvox, and also shows the converted model.

3. Proposed Software Architecture

In this section of the report we will be going over the proposed software architecture of our system, delving into our subsystem decomposition, hardware/software mapping, persistent data management, access control and security, global software control, and boundary conditions.

3.1 Overview

We will be sticking to a modified version of the Model-View-Controller design pattern while decomposing our system into subsystems. Our project will not require any additional hardware to run. We do not have any persistent data that has to be maintained throughout our project. Our project does not have any security risks associated with it. Our project will work in a strictly sequential manner, therefore we do not have any global software control. We will have three boundary conditions; initialization, termination, and exception handling.

3.2 System Models

In this section of the report, we will be discussing the use cases and the scenarios of our system, and will as well be providing UML diagrams for the system.

3.2.1 Scenarios

Scenario	Uploading the STL File
Participating Actor	User, system
Flow of Events	The user selects an STL file to upload to the system. The selected STL file is uploaded to the system.
Entry Condition	The user presses the “Upload STL File” button.
Exit Condition	The user presses the “Upload” button.
Quality Requirements	The system must not allow the user to upload any other type of file. The system must accurately save the STL file.

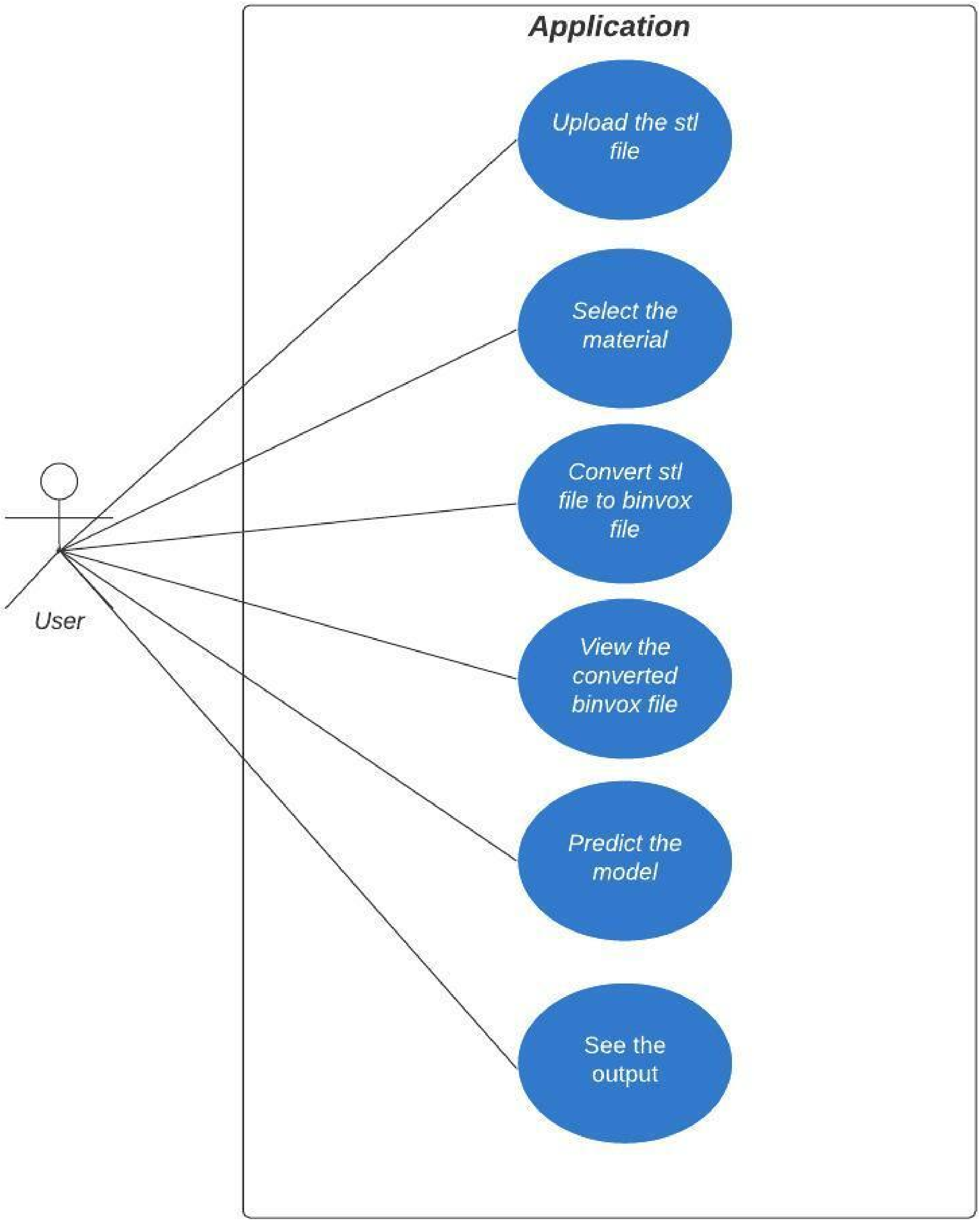
Scenario	Selecting the Material
Participating Actor	User, system
Flow of Events	The user views the available types of material within the system.

	The user selects a material out of the displayed list.
Entry Condition	The user presses the “Select Material” button.
Exit Condition	The user presses the “Proceed” button.
Quality Requirements	There must be a suitable number of materials that the user can choose from.

Scenario	Convert the STL file into BinVox and Display the Model
Participating Actor	User, system
Flow of Events	The supplied STL file is converted into BinVox. The BinVox model is displayed to the user. The user checks the converted BinVox model.
Entry Condition	An STL file must be uploaded and a material must be chosen. The user presses the “Convert to BinVox and View Model” button.
Exit Condition	The user either presses the “Confirm” or the “Go Back” button.
Quality Requirements	The BinVox model must be displayed clearly. The BinVox model must be able to be viewed in a three-dimensional manner with the user being able to rotate the model et cetera.

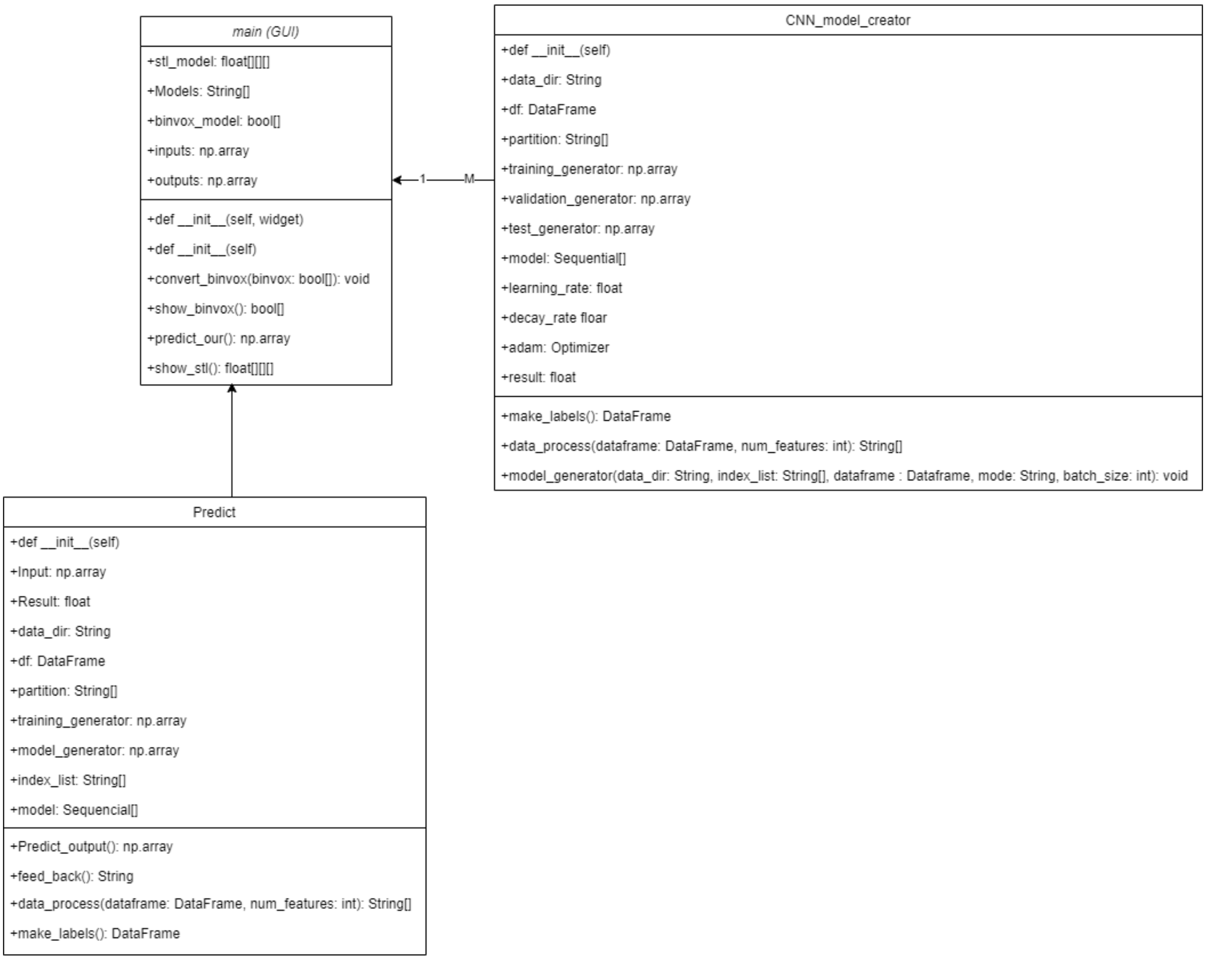
Scenario	Predict the Model and Display the Results
Participating Actor	User, system, display
Flow of Events	The user asks for the system to predict the BinVox model and display the results. The system does so.
Entry Condition	A BinVox file that has been approved by the user must be present within the system. The user presses the “Predict Model and Display the Results” button.
Exit Condition	The user presses the “Close” button.
Quality Requirements	The system must be able to predict the model with sufficient accuracy (above 95%).

3.2.2 Use Case Model



The use cases within the model are explained in detail under the “Scenarios” section.

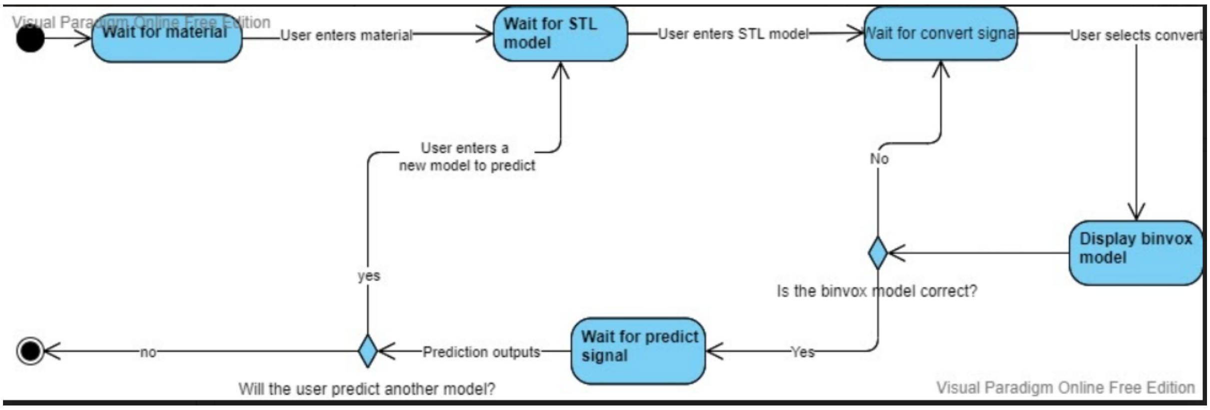
3.2.3 Object and Class Model



3.2.4 Dynamic Models

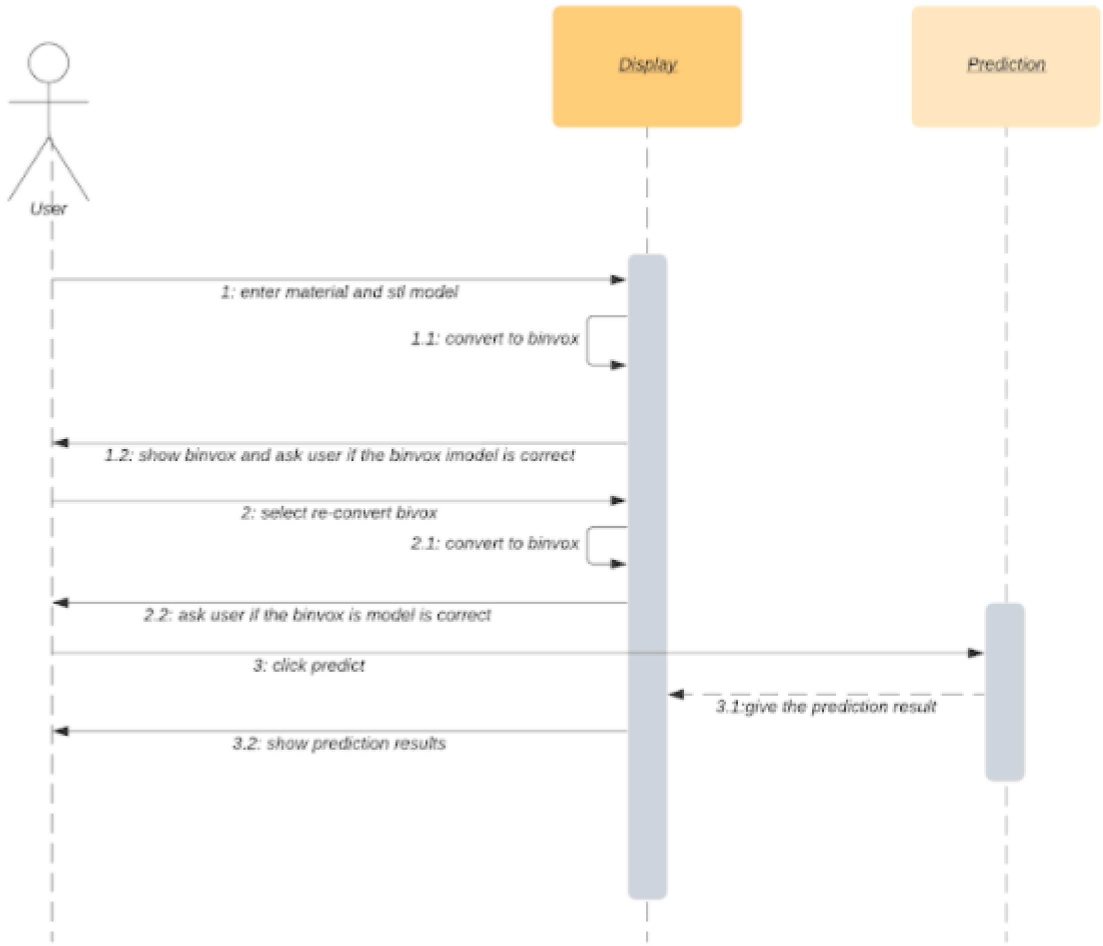
In this section, we will be discussing the state machine diagram, the sequence diagram, and the activity diagram of our system.

3.2.4.1 State Machine Diagram



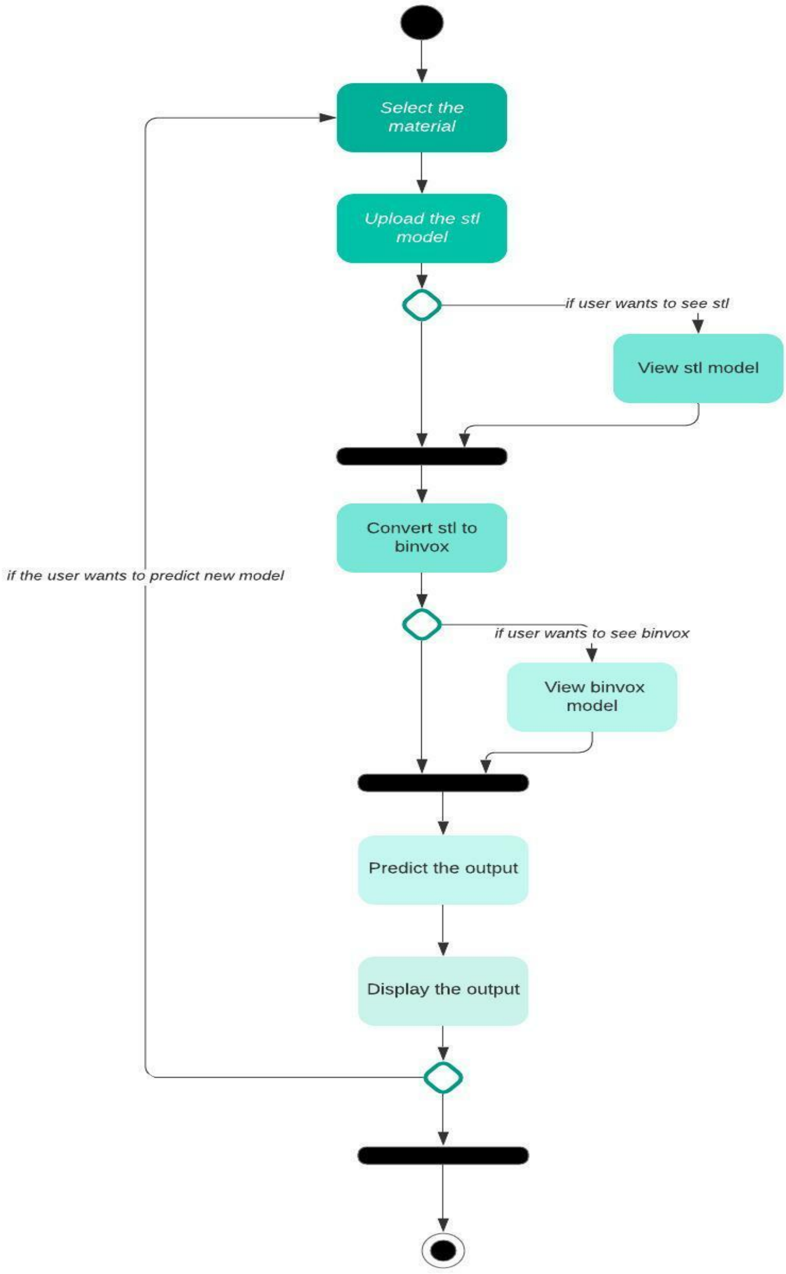
The application starts with the user selecting a material from the list of materials that are available within the system. The user then uploads a three-dimensional model of the part that is to be manufactured in the format of an STL file. Next, the system converts this file into BinVox format and displays this file for the user to check. The user then either confirms the BinVox file or goes back to reconvert the file into BinVox. Next, the user clicks the predict button and the system predicts and displays the results. If the user wishes to predict another model, they press the button to go back to the main menu and go through the explained process once more.

3.2.4.2 Sequence Diagram



The user first chooses the material that the part will be made out of from a list of materials available within the system and uploads an STL model to the system. This is done through the GUI. This STL file is then converted into a BinVox model and this model is shown to the user. If the user spots any problems within the model and wishes to reconvert it into BinVox he does so using the GUI. After the user confirms the model, they click the "Predict and Display Results" button via the GUI and the system predicts the model using the machine learning backend of the system. The machine learning model then passes the results to the display, and they are shown to the user over the GUI.

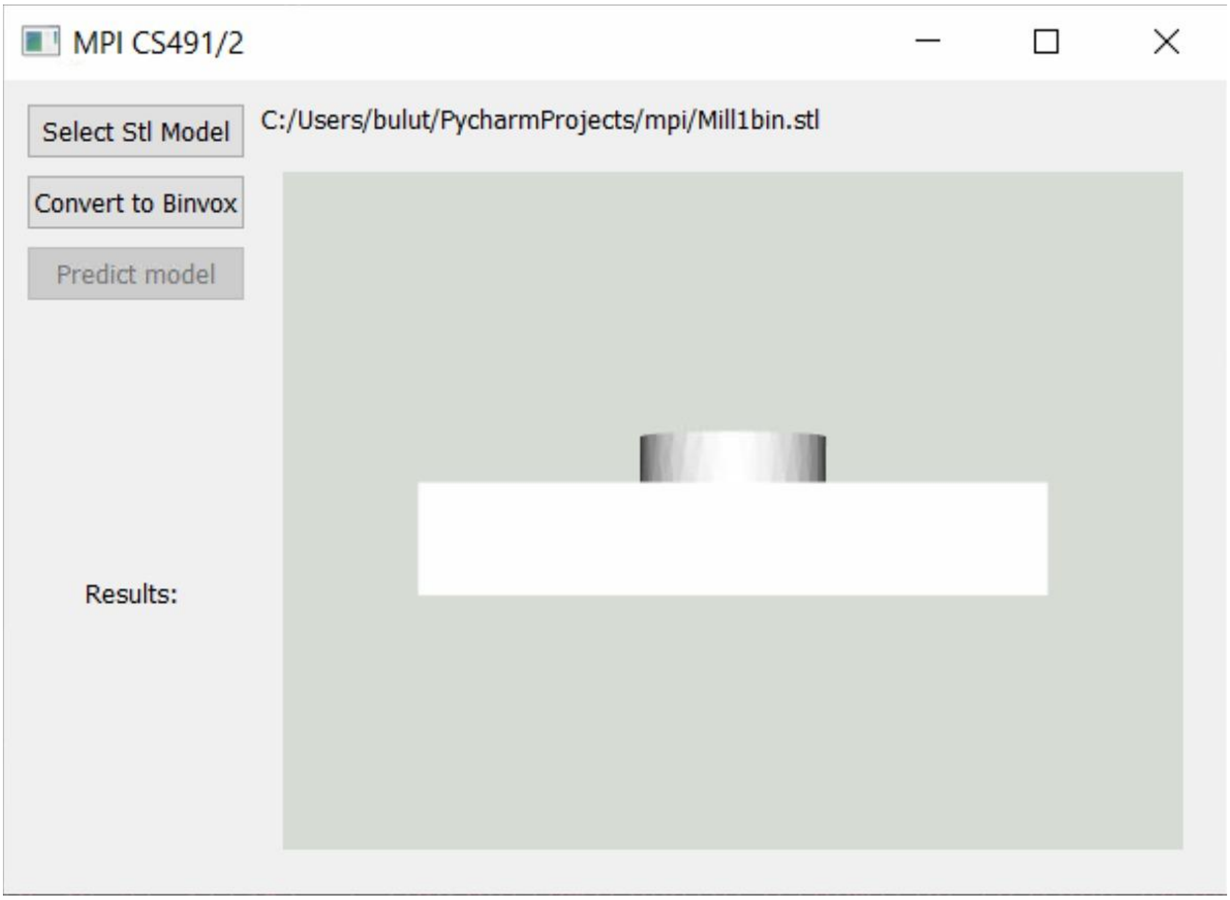
3.2.2.3 Activity Diagram,



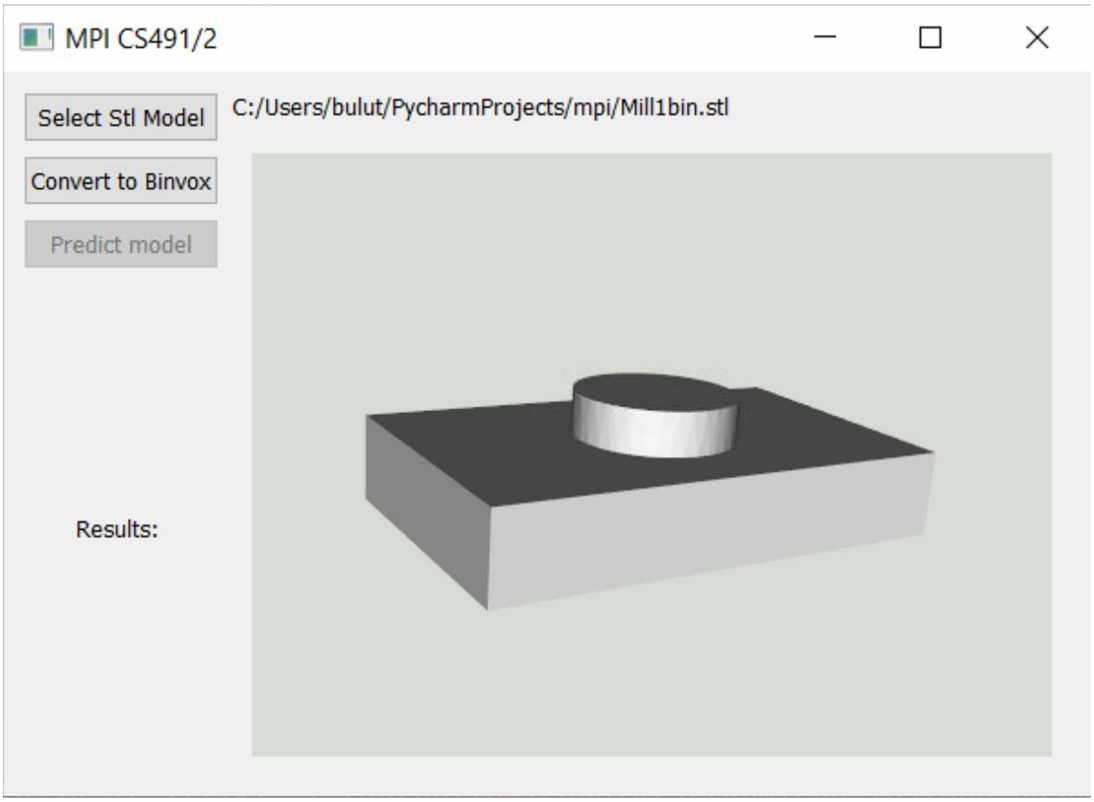
The user will first select the material that the part will be made out of out of a list of materials that are available within the system. Next, the user will upload an STL file to the system and will be able to view it if they wish to do so. The user will next convert this STL file into BinVox format, and will likewise be able to view the BinVox model should they want to. Next, the system will predict the model and display the output. If the user wishes to predict another model, the process will start once more.

3.2.5 User Interface

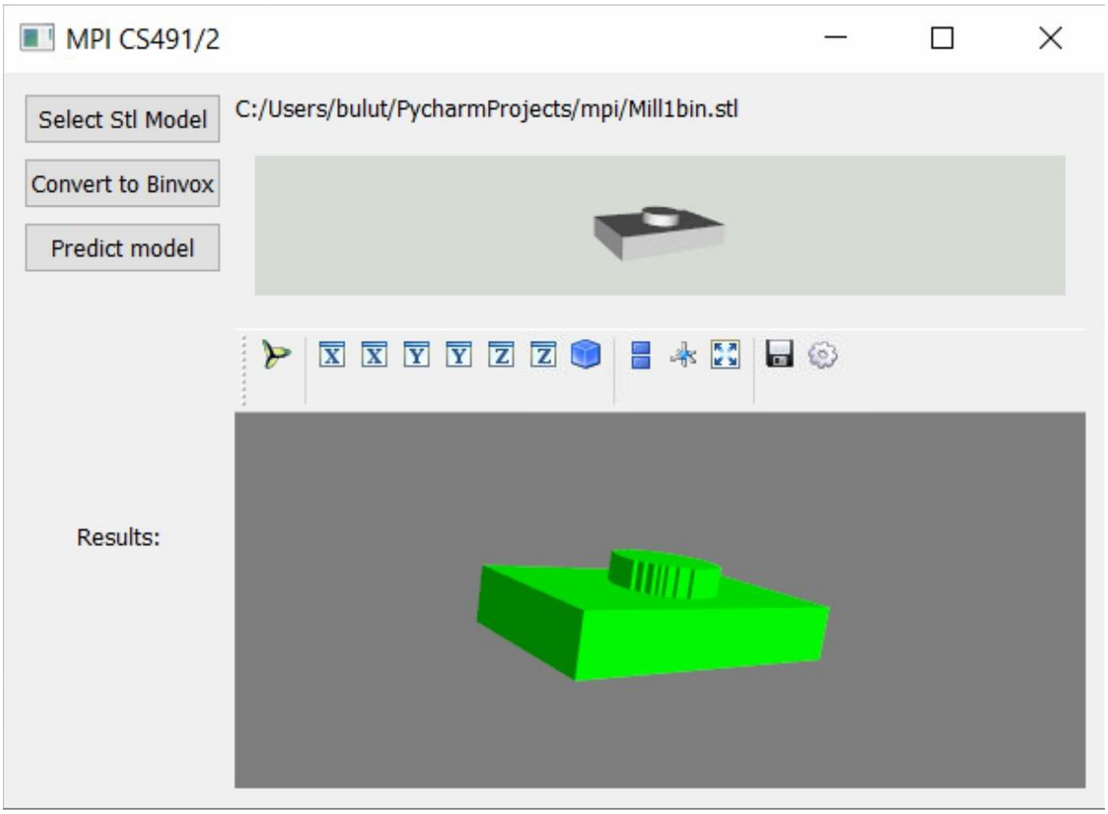
Our UI will have four main components, on the top left we will have the material selection and STL file upload sections, on the bottom left we will have the buttons for the use-cases of our program, on the top right we will have the prediction results, and on the bottom right we will have our model viewers.



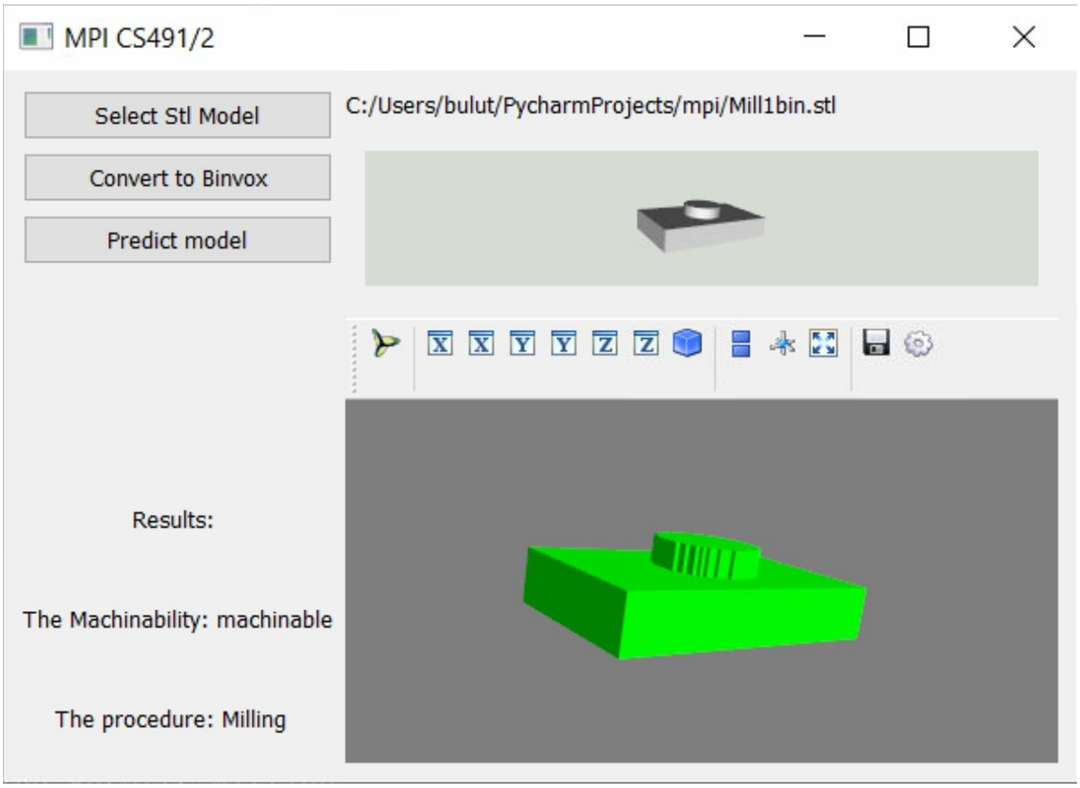
After selecting stl file



Available to see stl model from every view



After converting the stl model to binvox



After predicting the results

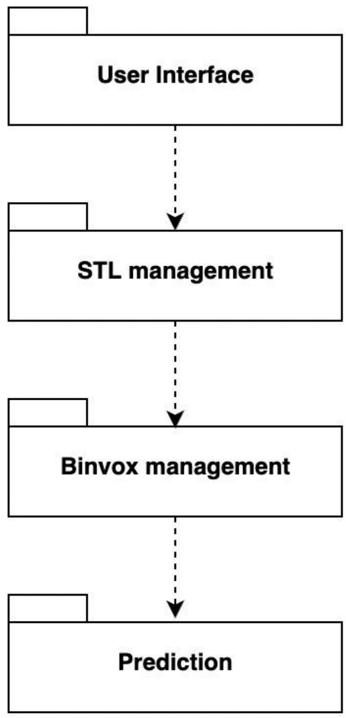
3.3 Subsystem Decomposition

Our system will be divided into three subsystems, called the UI Management Subsystem, Core Logic Subsystem, and the File Management Subsystem. In our subsystem decomposition we have decided to follow a design approach inspired by both the Model-View-Controller design pattern and the layered approach, however we have not stuck to either of them fully. We have essentially decomposed the system into a subsystem that implements both the Model and the Controller in the MVC approach as one subsystem (our Core Logic Subsystem) and a separate View subsystem (our UI Management Subsystem). We have as well a third subsystem that will be handling the uploading of STL files onto our system and the saving of the BinVox files onto the hard drive of the user, called the File Management Subsystem.

The services associated with these subsystems will be elaborated further on Section 4. However, the following is a quick summary rundown of the main functionalities of the three subsystems.

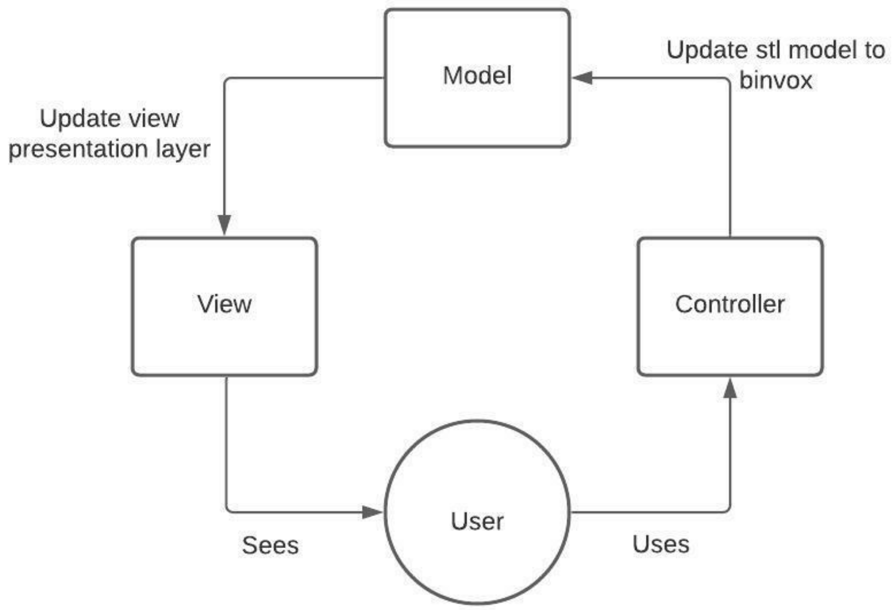
3.3.1 UI Management Subsystem

This is the subsystem that corresponds to the View subsystem in the MVC design pattern. The main service this subsystem will provide is creating and managing the GUI of our project. It will have different components such as STL and Binvox model viewers and a prediction output viewer screen.



3.3.2 Core Logic Subsystem

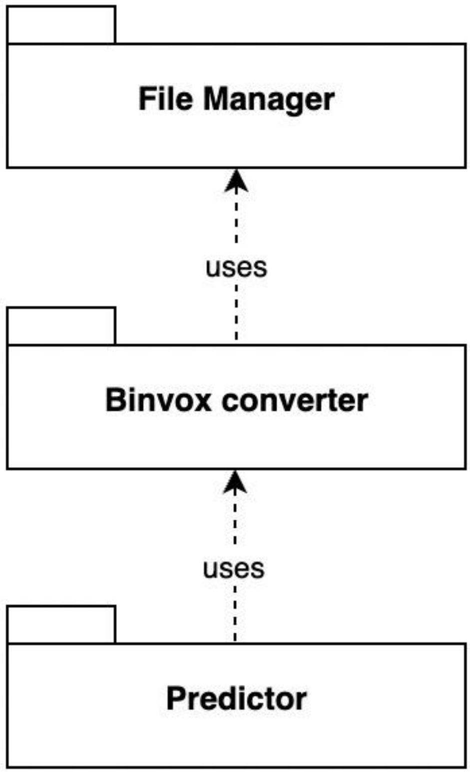
This is the subsystem that corresponds to the Model and the Controller subsystems in the MVC design approach. As our project is of a relatively compact scale, we have decided not to separate these into two subsystems and establish a communication between them but have rather decided to do it all in one subsystem. This subsystem will mainly be responsible for two use-cases; converting the supplied STL model into Binvox format and predicting the Binvox model.



MVC paradigm

3.3.3 File Management Subsystem

This is the subsystem that will be responsible for the uploading of the STL files onto our system by the user and the saving of the Binvox files that have been created by conversion from the STL files onto the hard drive of the user. We have decided to have this as a separate subsystem as we believe these functionalities do not really fall under any of the categories in the MVC design model. This will be a fairly basic and simple subsystem.



3.4 Hardware/Software Mapping

We will be implementing our project using the Python programming language. Our project will not require any additional hardware on top of the standard keyboard/mouse set up to be run. For the most part, users will only have to interact with our project using the mouse.

Our ML model will have to be trained before our product is ready to be used, but this will only have to be done once before it is ready. In order to speed up this process of training our model, a computer with high specs would be preferable. However, since this training will only have to be done once and out of the sight of the users, it is possible to train our model on virtually any machine.

We will be using the hard disk space of the user to store our files such as our trained ML model. We will not require any installation process before the user is able to run our project.

3.5 Persistent Data Management

Our project will not require any complex data storage system or database in order to be used. We will be dealing with a couple types of files as part of our project, namely STL and Binvox files. The users will have the option to upload any STL files and have them converted to Binvox as well as view these Binvox files. These files will be stored on the hard drive of the user and our system will not be handling any persistent data when it comes to these files. If a user wishes to save one of their files onto their hard drive, they will be able to do so, yet our project will not check for any persistent data when doing so.

3.6 Access Control and Security

There will be no networking component to our project. As such, we will have a minimal attack surface to our program. We will not be storing any sensitive data on our system either, so sensitive data leakage will not be an issue. We will not have any login or authentication system to our project, as we do not require one. Our project will essentially be an STL to Binvox converter and a predictor of several attributes on a Binvox file. It does not have any surface for any meaningful attacks.

3.7 Global Software Control

Our project will be run in a strictly sequential fashion, as shown in our state machine diagram in our analysis report. Since we do not have any concurrent events, our global software control will be easy. We will be moving in sequential order through our use-cases.

Our system will move from one use-case to another via the user clicking a button. Therefore our system will be event-driven. We are not going to be using separate threads for each event, our program will run in its entirety as a single thread and by extension process.

3.8 Boundary Conditions

In this section of the report, we will be discussing the boundary conditions of our project. We have three boundary conditions; initialization, termination, and exception handling.

3.8.1 Initialization

Our project will not require any installation process to be usable. We will only require that the user has the appropriate Python version and packages. The system will be created whenever our executable is executed. Upon launching our program, the user will be met with the main screen. On this screen they will be able to select a material to work with and will as well be able to upload an STL model. From this point onwards they will have the ability to view the given STL model, convert the model to Binvox, view the Binvox model, and predict the Binvox model.

3.8.2 Termination

The user will be able to terminate the program at any time by clicking the exit button. Once they do so, the system will terminate. During this termination process, the system will check if there are any ongoing predictions, and will ask the user if they wish to terminate mid-prediction or not. If they wish to do so the system will cancel the prediction and quit. If not the system will abort the termination and move on as usual.

3.8.3 Exception Handling

If the user tries to upload a file that is not in STL format when trying to upload an STL model, the system will reject the file. Further, if there are any exceptions that present themselves during the conversion of an STL file into Binvox format, during any predictions or while attempting to view a model, the system will display an appropriate error message and terminate. Since we do not have any persistent data that is to be stored on our project, it is okay for our system to simply terminate after displaying an appropriate error message.

4. Subsystem Services

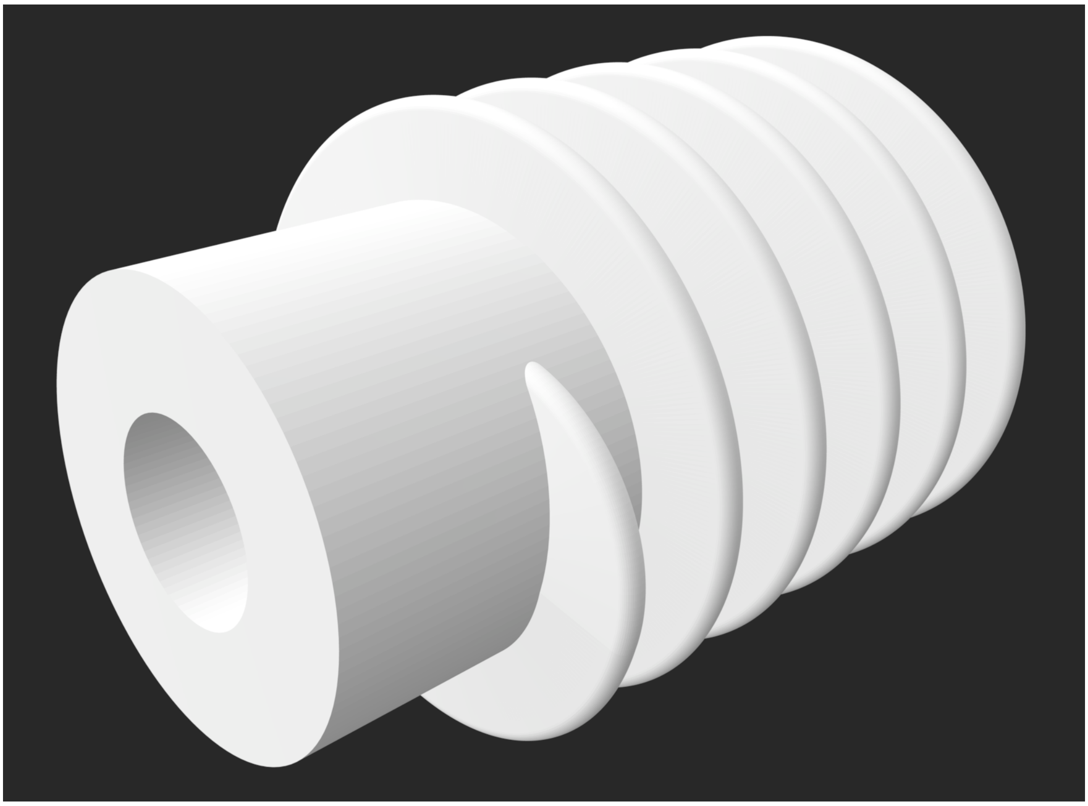
In this section, we will be discussing in more detail the services of the subsystems that we have outlined under Section 3.2 of our report. Here, we will delve into further discussion regarding the services of our subsystems.

4.1 UI Management Subsystem

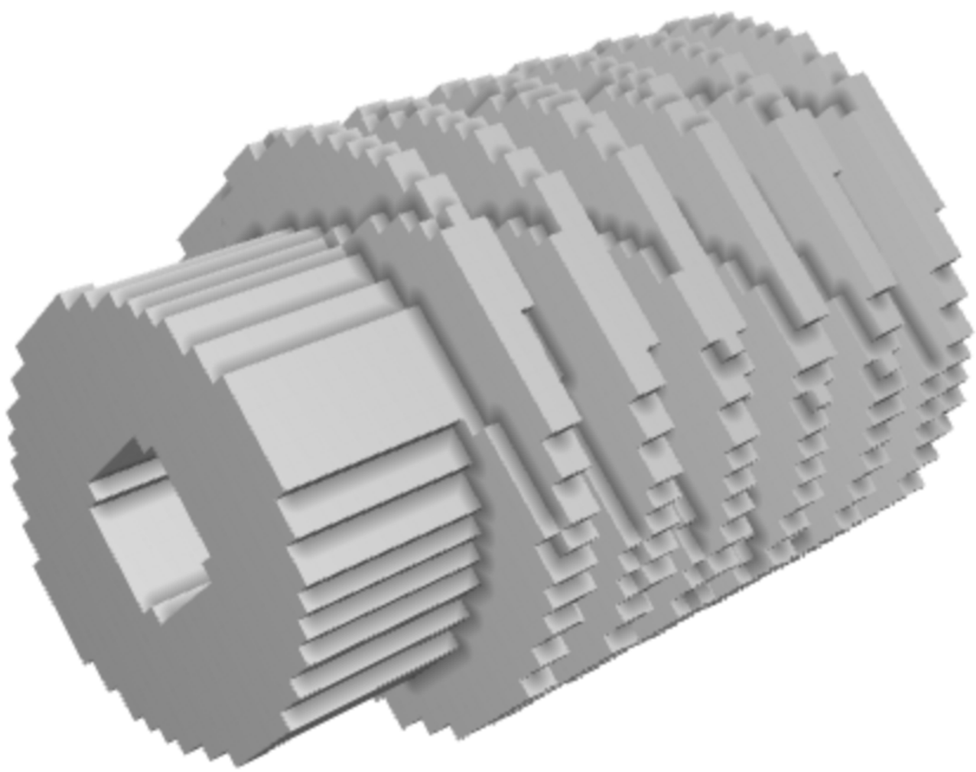
As previously discussed, this subsystem will be tasked with handling the creation and the management of the GUI of our project.

4.1.1 Viewing STL and Binvox Models

This will be the main functionality of this subsystem. One of our core use-cases is allowing the user to view STL and Binvox models. This subsystem will be responsible for the displaying of such models. It will display these models on a separate window in a three dimensional manner with the user being able to rotate the model in any direction they please as well as zoom in and out to the model.



Example of a stl model



Example of a binvox

4.1.2 Viewing Core Screens of the System

This will be the secondary functionality of this subsystem. As the subsystem corresponding to the View subsystem in the MVC design approach, this subsystem will be responsible for the creation and the displaying of all the screens within our project.

4.2 Core Logic Subsystem

This is the subsystem of our project that corresponds to the Model and Controller subsystems within the MVC design paradigm. As previously stated, since our project is of a relatively compact size we have decided not to split this into two separate subsystems in favor of more rapid communication and deployment.

4.2.1 Converting STL Files into Binvox Format

This will be the secondary feature of this subsystem. It is a prerequisite that has to be performed before the main feature of the subsystem and as well the main feature of our project is able to be performed. This subsystem will be tasked with taking the STL file supplied by the user and successfully converting it into Binvox format. The user will then be able to assess the correctness of the Binvox model using the UI Management Subsystem and proceed to the main feature of our program if they are satisfied with the conversion.

4.2.2 Predicting Binvox Models

This will be the main feature of this subsystem and as well our project. This subsystem will be tasked with implementing the prediction feature of our system, which is our main feature. Given a Binvox model of a part that is to be manufactured and a manufacturing plant, our project will be able to predict whether the given part can be manufactured, with which machining operations it can be manufactured if it can be manufactured, and the estimated cost of doing so. This subsystem will be using the trained ML models of our project in order to predict these and display the results.

4.2.3 Training CNN Models

The training of the 3D CNN models consists of adding different layers of Keras Library Sequential model layers, manipulating parameters and optimizing the result. In our case we used a few different model layering for our different prediction models, in which all layers serve different purposes to obtain the best result possible. These systems are highly dependent on the training data and require a great number of them to train with. For the moment our training depends on the data that we took from [2] and we plan to later on add more taken from different sources to differentiate the functionalities of our project. The training of models is done once as mentioned previously and this part of the code will not be included in the source code provided to future clients.

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv3d (Conv3D)              (None, 29, 29, 29, 32)    11008
_________________________________________________________________
conv3d_1 (Conv3D)            (None, 29, 29, 29, 32)    128032
_________________________________________________________________
conv3d_2 (Conv3D)            (None, 29, 29, 29, 64)    55360
_________________________________________________________________
max_pooling3d (MaxPooling3D) (None, 15, 15, 15, 64)    0
_________________________________________________________________
flatten (Flatten)            (None, 216000)            0
_________________________________________________________________
dropout (Dropout)            (None, 216000)            0
_________________________________________________________________
dense (Dense)                (None, 128)               27648128
_________________________________________________________________
dropout_1 (Dropout)          (None, 128)               0
_________________________________________________________________
dense_1 (Dense)              (None, 16)                2064
_________________________________________________________________
dense_2 (Dense)              (None, 21)                357
=================================================================
Total params: 27,844,949
Trainable params: 27,844,949
Non-trainable params: 0
```

Example layers of the first CNN model, feature classification.

4.3 File Management Subsystem

This subsystem will be tasked with managing the upload and save features of our project. It will be tasked with allowing the user to upload STL files onto the system and saving Binvox files onto the hard drive of the user.

4.3.1 Uploading STL Files onto the System

The user will be able to upload an STL file containing the three dimensional model of the part they wish to predict onto the system. This subsystem will be in charge of this functionality.

4.3.2 Saving Binvox Files onto the Hard Drive of the User

The user will as well be able to convert these STL files it uploads onto the system into Binvox format and save them onto their hard drive. This subsystem will be in charge of saving the Binvox files onto the hard drive of the user.

5. Consideration of Various Factors in Engineering Design

The four main factors that we deliberated on are algorithmic efficiency, memory cost, the accuracy of the model, and the time required to predict the attributes for the parts. The first two are common to all software engineering solutions, and we have decided that we would be in favor of algorithmic efficiency as opposed to lowering memory cost, and would make trade-offs in order to speed up our processes even when it means more memory would be required. We have chosen to do so because our training of the model takes quite a bit of time with a large number of epochs and a sizable amount of time per each epoch. Therefore, we have chosen to try and speed this process up as much as we can even though it might mean we would have to utilize more memory to do so. One can argue that because we only need to train the model once before providing it to the user we would not necessarily have to worry about the time it would take to complete the training of the model. However, as during testing we might change qualities about the model in an effort to increase its accuracy, and would have to train it every single time, we have chosen to favor algorithmic efficiency as opposed to a lowered memory cost. One may also argue that since the training has to only be done once the memory cost will only have to be paid once, so it is not a big problem to favor algorithmic efficiency.

The other two factors we considered are the accuracy of the model when predicting a part, and the time it takes for the model to predict a part. We would ideally like the accuracy of the model to be as high as possible, and the time it takes to predict a model to be as low as possible. We have decided that the accuracy threshold for our model in order to be considered a success is 95%, and we have decided that it can take up to a minute's time for the model to predict a part that is given, depending on the size of the part.

6. Teamwork Details

In this section of the report we will be discussing the measures we have taken as a team to ensure we are contributing and functioning effectively as a team, we have created a collaborative and inclusive environment, and have taken leadership roles as well as shared leadership effectively within the team.

6.1 Contributing and Functioning Effectively on the Team

We have briefly discussed how we are trying to move the project simultaneously in two activities of development, the first being the actual implementation of the project and the second being the writing of the reports and the documentation of the project within the previous section of the document. This allows us to effectively separate team members and assign them to one or the other of these two activities, ensuring that everyone knows what to do and that they have other team members that they can ask for help if they get stuck. In addition to this, we are having weekly meetings with both only the group members and as well meetings with our project supervisor and innovation expert. During the group member only meetings we are focusing on task allocation for the week and ensuring that everyone has a task that they are to do, everyone knows what this task assigned to them is and that the tasks for the week have been distributed in a fair manner among the group members. In the meetings with the project supervisor and the innovation expert present, we are presenting what we have done during the previous week and will be asking them to give us some feedback on the things that we have done over the previous week. We are also asking for guidance on the direction that the project is going in and whether we are on the right track or not. We have as well created two WhatsApp groups, one with just the project members and the other with the innovation expert and the project supervisor for easier and faster communication on matters that do not require a meeting. This is how we are planning to ensure proper teamwork throughout the project.

6.2 Helping Create a Collaborative and Inclusive Environment

As mentioned previously, we are having weekly meetings both only as the group members and with our innovation expert and project supervisor. This helps create a collaborative and inclusive environment as everyone is able to see each other weekly and discuss what tasks they have been doing throughout the week et cetera. It also helps that every group member knows that there will be a weekly meeting, which makes it so members are more determined to get their work that has been assigned to them done, making it so the weekly meetings serve as a pseudo-deadline for the team members. One other thing is that we have meetings with only the group members present as well as those with our innovation expert and project supervisor present. This helps make it so we can have more informal meetings with just the group members present and more formal meetings with our innovation expert and project supervisor present. The informal meetings allow for faster communication and more rapid assignment of tasks, while the formal meetings help us keep track of where we are under supervision. We also have two separate WhatsApp groups, one with and one without the innovation expert and project supervisor. This helps us communicate more directly and set up meetings easier. We also have a Google Drive in which we keep our resources and work on our reports collaboratively on a Google Docs document. We also have a Discord server with our team members where we can post deadlines and communicate more effectively. We are also using GitHub as a means of working collaboratively on our coding activities. All these tools and services we use as well as our meetings help us create a more collaborative and inclusive working environment.

6.3 Taking Lead Role and Sharing Leadership on the Team

We have Irmak as our impromptu leader, as this was her summer internship project before we have picked it up as our senior design project as a team together, therefore she is more knowledgeable when it comes to the terminology or the inner workings of the code et cetera, although throughout the semester we have all more or less caught up to where she is right now. She is also the one that usually contacts the project supervisor and innovation expert to set up meetings as she has known them longer and has had a professional relationship with them prior to us choosing this as our senior design project. However, when it comes to decisions such as how a segment of the code or the report should be written, we discuss the possible alternatives as a team either during one of our meetings or through our WhatsApp group. Every member has an equal say when it comes to these decisions, with those members who are more knowledgeable regarding the topic in which the decision is being made having more of a leadership role. Bulut is our member of the team that is the most experienced in using Python, therefore he has more of a leadership role in the coding side of things. Alp is the member that usually spends the most time on the reports, therefore he is more of a leader when it comes to those. Irmak is more of a leader when it comes to communicating with the project supervisor and innovation experts as well as administrative decisions, Denizhan is more involved with the user interface elements of the project and Tanay is more involved when it comes to the design aspects of our application.

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