FUNDAMENTALS OF ARTIFICIAL NEURAL NETWORK FOR MANUFACTURING ENGINEER USING PYTHON LANGUAGE WITH GUI DEVELOPMENT AND EXECUTABLE CONVERSION

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Abstract: This book is accomplished as result of a long term local and international collaboration between Smart Manufacturing Research Institute (SMRI) at Universiti Teknologi MARA in Shah Alam, Faculty of Mechanical and Manufacturing Enginering at Universiti Tun Hussein Onn Malaysia in Batu Pahat, University of Applied Sciences in Osnabrück, Germany and Fraunhofer Institute for Mechatronic Systems Design in Paderborn, Germany. The structure of this book is as follows: Chapter 1 discusses the overview of artificial intelligence, artificial neural networks, and the basic ideas behind machine learning. A perceptron concept is presented as a simple computing element with selected activation function. Some standard loss functions are introduced with its mathematical equations. This chapter also outlines the standard backpropagation method and Levenberg-Marquardt algorithm. At the end of the chapter, a step-by-step backpropagation example is described to work through simple neural networks' mathematical ideas gently. Chapter 2 introduces python programming languages. Some of the python applications are shown. In addition, Package Management System is also briefly presented. Chapter 3 deliberates essential information on Jupyter and Spyder integrated development environment to code the ANN program. Chapter 4 is aimed to design graphical user interface using Qt designer and to add functionalities to GUI project. This chapter teaches how to use different widgets such as QLabel, QCheckBox, QLineEdit, etc. Chapter 5 provides an overview of the ANN application in the manufacturing processes. Some of the applications are outlined in the chapter. The case study of resistance spot welding with ANN application is explained following quality issue. The dataset acquired for the training of the ANN model is shown in this chapter. The ANN applications produced the result, and the advanced recommendation of the ANN is proposed. Chapter 6 shares the future outlook of artificial intelligence application in manufacturing data analytic.

Keywords: Neural, method, data analytic, development

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Table of Contents

List of Figures

List of Tables

Preface

It has become a common goal for manufacturing companies to use data to improve quality and productivity of product and process. With the data generated by machines, insights into production process can be made visible and transparent, and factors which will impact production speed or quality can be identified and anticipated. The key enabler here is Artificial Intelligence which transforms traditional production floor into data-driven intelligence and interconnected production modules.

It remains a challenge for many manufactures, especially smaller ones, to start the first step from the ideation of an AI use case, potential assessment, until the successful implementation of AI solutions. In particular, writing a program and creating an application tool are not the skills of manufacturing engineers. This book is written to answer the challenges of manufacturing engineers to predict quality with artificial neural network supported by a self-executable application tool.

This book is accomplished as result of a long term local and international collaboration between Smart Manufacturing Research Institute (SMRI) at Universiti Teknologi MARA in Shah Alam, Malaysia, UTHM- Fraunhofer IEM Innovation Lab (innovationlabs.my) at Universiti Tun Hussein Onn in Batu Pahat, Malaysia, University of Applied Sciences in Osnabrück, Germany and Fraunhofer Institute for Mechatronic Systems Design in Paderborn, Germany. The structure of this book is as follows: **Chapter 1** discusses the overview of artificial intelligence, artificial neural networks, and the basic ideas behind machine learning. A perceptron concept is presented as a simple computing element with selected activation function. Some standard loss functions are introduced with its mathematical equations. This chapter also outlines the standard backpropagation method and Levenberg-Marquardt algorithm. At the end of the chapter, a step-by-step backpropagation example is described to work through simple neural networks' mathematical ideas gently. **Chapter 2** introduces python programming languages. Some of the python applications are shown. In addition, Package Management System is also briefly presented. **Chapter 3** deliberates essential information on Jupyter and Spyder integrated development environment to code the ANN program. **Chapter 4** is aimed to design graphical user interface using Qt designer and to add functionalities to GUI project. This chapter teaches how to use different widgets such as QLabel, QCheckBox, QLineEdit, etc. **Chapter 5** provides an overview of the ANN application in the manufacturing processes. Some of the applications are outlined

in the chapter. The case study of resistance spot welding with ANN application is explained following quality issue. The dataset acquired for the training of the ANN model is shown in this chapter. The ANN applications produced the result, and the advanced recommendation of the ANN is proposed. **Chapter 6** shares the future outlook of artificial intelligence application in manufacturing data analytic.

In order to describe the chapters clearly, this book is also furnished with Appendices which include installation of Python and related libraries using anaconda and pip, application of Jupyter notebook and Spyder IDE for artificial neural network, development of GUI using pyqt5 and Qt designer, "signal and slot" or function development for GUI and executable (exe) file conversion.

It is expected that by having read and understood the contents of the book, manufacturing engineer can have a clear and better understanding on the application and implementation of ANN using open-source software Python and hence be able to develop GUI for easy visualization and presentation of important information.

Acknowledgement

First and foremost, the authors would like to praise and thank the almighty God for His showers of blessing and for providing constant motivation as well as courage at each stride to step forward with confidence and self-belief in writing this book.

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Prof. Ir. Ts. Dr.-Ing. Yupiter HP Manurung CEng IMechE, IWE

Chapter One

Artificial Intelligence and Neural Network with Example

The heart of Industrial Revolution (IR) 4.0 is the integration of innovative technology into traditional manufacturing process which can enable fast response on fault detection, system diagnosis, time-to-market, and product quality as well as efficiency and waste reduction. Among the innovative technologies are advanced data analysis, high performance computation, Internet of Things (IoT) and artificial intelligence (AI). The constant push for productivity improvement and cost optimization is driving many industries to revisit the possibility of using manufacturing data to become more efficient by using AI.

This first chapter deals with the fundamental of AI which has revolutionized many industrial sectors. AI has become more developed and advanced leading to more application and accessibility across various applications including manufacturing sector. The AI functionality has resulted in a massive impact in the way that products are manufactured with more efficiency, less human error and better output quality. At the end of this chapter, an example of Artificial Neural Network (ANN) with backpropagation method and optimizers is discussed comprehensively.

1.1 Artificial Intelligence – An Overview

Artificial Intelligence (AI) is a subset of data science and a branch of computer sciences that emphasizes machine intelligence development that behaves like human beings. In many existing book (J. C. Flowers., 2018; T. Taulli., 2019; X. Neapolitan, Richard E. Jiang., 2018; W. Ertel., 2017; Y. E. Bulut., 2018), AI normally includes activities of speech recognition, problem-solving, learning, and planning. For speech recognition, it is a technology that transforms human speech into a format that is useful for computer applications. Using the technology, it has the

Chapter Two

Python Programming Language and Package Management System

There are many programming languages used for data analysis in various industries. Python language is one of the most popular high level and accessible programming languages available due to simplified syntax and uncomplicated structure that gives more emphasis on natural language (Tariq Rashid., 2016). Python codes can be easily written and executed relatively much faster than other programming languages. Some of the key advantages compared to other proprietary programming language like Programmable Logic Controller (PLC) are that Python is free and open-sourced which can reduce risks, cost of implementation and running on licensing and upgrade or maintenance. Furthermore, it also provides large standard library and programming support as well as work on cross platform such as Windows, Mac, Linux, Raspberry Pi and others.

In recent years, Python programming skill is in extremely high demand in manufacturing industries involving data science and analytics which are used for prediction and evaluation of quality, maintenance, safety and warranty as well as for computer vision, sale forecasting and many more. Adding Internet of Things (IoT) in manufacturing production environment can generate voluminous amounts of data which consequently require strong knowledge, expertise and good command of programming to manage the data.

Package Management System (PMS) has important function for data scientist as utility to simplify the tasks of locating, installing, upgrading and removing Python packages. This Python utility can determine whether the most recent version of software packages is installed on a system and can install or upgrade the package from a local or remote host. Hence, the selection of PMS is crucial and should be defined before the actual programming is due to commence.

Chapter Three

Integrated Development Environment for Python

An integrated development environment (IDE) is a software application that provides comprehensive features to computer programmers for developing software. IDE enables programmer to write code in a script, validate the output by running the code and view the result in the output window. The selection of the best IDE is subjective at which Python programmer needs to consider basic recommendation before deciding on the right selection of IDE. At the beginner level, it is always a good idea to start with an IDE that comprises basic features to discover the environment and functionality as well as to become familiar before proceeding to the advanced level. If the user wishes to learn how a particular feature works, it can be found at the support window inside the IDE or run single-liner code in the console. There are various sophisticated IDEs available to be selected such as Jupyter Notebook, Spyder, Atom, Pycharm, Pydev and others. Using a suitable IDE will enhance programmer's interaction with Python. Two of them which are Jupyter Notebook and Spyder will be presented and discussed.

3.1 IDE using Jupyter Notebook

Jupyter Notebook is an incredibly versatile IDE for writing and iterating Python code. Rather than rewriting the entire program, the user can write lines of code and execute them one by one. In case that any adjustment is required, the user can return back to the same slot, make an edit and rerun the program.

Jupyter Notebook is based on IPython which is an interactive Python interpreter that uses the REPL (Read-Eval-Print-Loop) paradigm to execute Python code in the terminal. The IPython kernel performs the computations and interfaces with the front-end Jupyter Notebook GUI. Additionally, it enables multilingual support for

Chapter Four

Development of Graphical User Interface using PYQT5 and QT Designer with Example and Executable Conversion

The user interface (UI) has morphed into an essential part of our daily lives allowing users to interact with computers or electronic devices through graphical icons instead of text-based command labels or navigation. It can be said that UI acts as a gateway between users and our programs and application. A UI is developed to make human-computer interaction simpler. The users must run and monitor the computer to fulfil a purpose; simultaneously, the machine must guide the human's decision-making process. UIs can be used in some ways, from smartphone apps, web servers, heavy machines and even kitchen appliances. A good UI is responsible for assisting an individual in obtaining the desired outcome while also making system operation smoother, more effective, and welcoming.

A Graphical User Interface (GUI) can be defined as a system of interactive visual components for computer program application and software. A GUI displays objects that convey information and represents actions that can be taken by the user. The objects might change colour, size or visibility when the user interacts with them. The graphical objects can be like icons, cursors, and buttons which are sometimes enhanced with sounds or visual effects like transparency and drop shadows. Hence, the computer can be used without prior knowledge of commands (C. Hope., 2021). This chapter would concentrate on designing GUI, which uses a computer's graphical capability to construct visual controls on the screen by using PyQt5 and Qt designer.

Chapter Five

Application of ANN in Manufacturing with Case Studies

Manufacturing is a collection of interconnected operations and activities for the manufacturing industries, such as product design, material selection, planning, distribution, inspection, management, and product marketing. This chapter deals with applications of ANN in manufacturing which begins with a brief description of major applications in this field. In order to apply the theories described in previous chapters, two case studies are presented. The first case study has an objective to predict quality of most-commonly used Resistance Spot Welding process in automotive industry, while the second case study is aimed for investigating the parameters in cleaning process of manufactured products.

5.1 General Application of ANN in Manufacturing

A lot of neural network research has been done to see how applying neural network strategies to manufacturing processes will help shorten response times, improve product efficiency, make manufacturing systems more efficient, and improve the intelligence of multiple manufacturing systems. The application area of neural networks in manufacturing is extensive which covers nearly all of the fields spreading from the design phase through simulation, process planning, scheduling, control, monitoring to quality assurance.

As a result of new production technology, manufacturing processes have changed significantly. Industries are now attempting to achieve and retain world-class status by automation enabled of advanced computer programs. AI is broadly implemented to assist human efforts in advanced industrial systems environments, where decision-making is becoming exceedingly complex and daunting. On the other hand, neural networks can learn, respond to changes, and imitate human thought processes with

Chapter Six

Implementation Planning of Industrial Artificial Intelligence Projects

AI and data analytics are key technologies in current digitization efforts. However, companies still have huge problems to identify their benefit and use. One of the main reasons is the need to involve many different stakeholders like IT specialists, engineers, data scientists and management. This requires a communication across different domains.

In this chapter, an Analytics Canvas is proposed which is a semi-formal specification technique for describing analytics use case and the necessary data infrastructure. As a method for system architects, the Canvas allows a clear description and differentiation of the roles of stakeholders in an analytics project as well as their points of contact. Thus, it can be used as a basis for transparent interdisciplinary communication. The Analytics Canvas uses an intuitive, visual representation of existing and future requirements along five layers in an analytics project and provides concrete modelling rules. Based on specific use cases, the typical approach in defining analytics projects is illustrated by using the Canvas.

The chapter is structured as follows, namely, Section 6.1 describes the brief motivation of data analytics. After the problem analysis (Section 6.2), current methods and process models in the context of digitization and analytics projects will be presented in Section 6.3. Section 6.4 represents the main contribution in which Analytics Canvas and its application to several used cases will be discussed. The chapter ends with a conclusion and an outlook.

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APPENDIX 1:
INSTALLATION OF PYTHON AND LIBRARIES USING ANACONDA

Appendix 1 consists of steps and procedures to install related software, libraries and tool for the application of ANN using Anaconda. The procedures are as follows:

1. Installation of Anaconda

   Anaconda is a free and open-source distribution of Python and R programming languages for scientific computing that aims to simplify package management and deployment. All the other packages, libraries and tools can be installed from:

   - https://www.anaconda.com/
   - Select "Individual edition" and click "Download"
   - Install according to Operating System (Windows, MacOS or Linux) as shown in Fig. A1.1. For windows, run the "Anaconda3-2020.07-Windows-x86_64.exe" file from download directory.

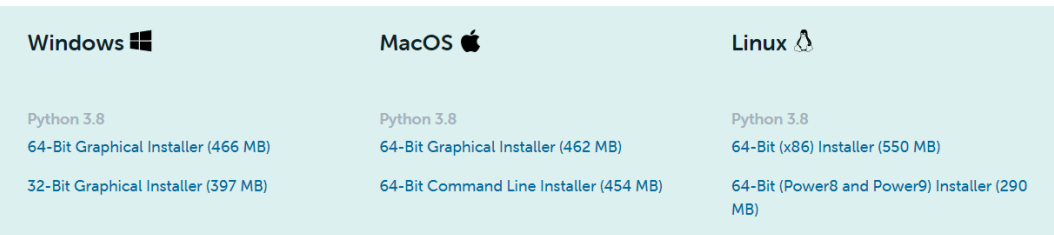


Figure A1.1: List of operating system compatible with Anaconda

   - During setup, click "Next" and "Agree" on the license agreement page as shown in Fig. A1.2

APPENDIX 2:
INSTALLATION OF PYTHON AND LIBRARIES USING PIP

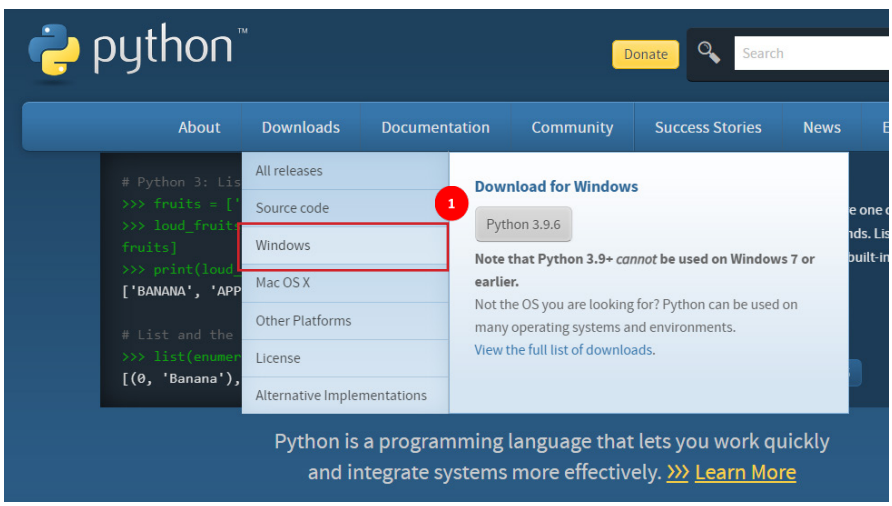
This appendix consists of steps and procedures to install related software, libraries and tool for the application of ANN using PIP. The procedures are as follows:

1. Installation of the full installer.

Using the full installer is the best option for a fully-fledged Python programming environment because it provides a greater degree of flexibility and control over the installation process.

Step 1: Download the Full Installer.

1. Open a browser window and navigate to the Python.org download page for Windows[5].
2. Under the "Python Releases for Windows" heading, click the link for **Python 3.7.9**.
3. Select either *Windows x86-64 executable installer for 64-bit* or *Windows x86 executable installer for 32-bit* depending on system bit processor. Note: The version of python used in this tutorial reduces the compatibility issues instead of using the latest version of python. Hence, 64-bit processor and Python 3.7.9 are used.



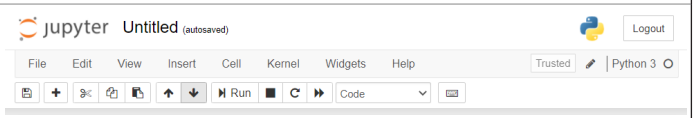
[5] https://www.python.org/downloads/windows/

APPENDIX 3: APPLICATION OF JUPYTER NOTEBOOK FOR ARTIFICIAL NEURAL NETWORK

This Appendix consists of basic programming concepts to write Python programs. Basic example of codes to develop ANN using Jupyter Notebook is presented at the end of this Appendix.

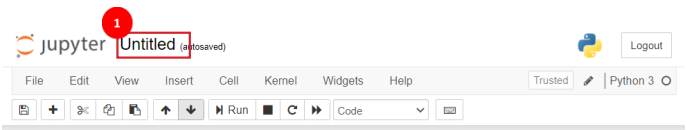
A. Basic Features

Step 1: Open Jupyter Notebook

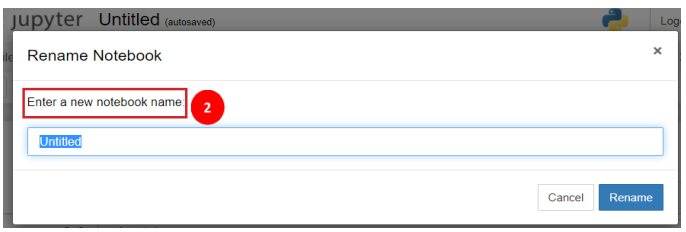


Step 2: Rename the file

1. Click on the **Untitled**
2. Type new name of the file



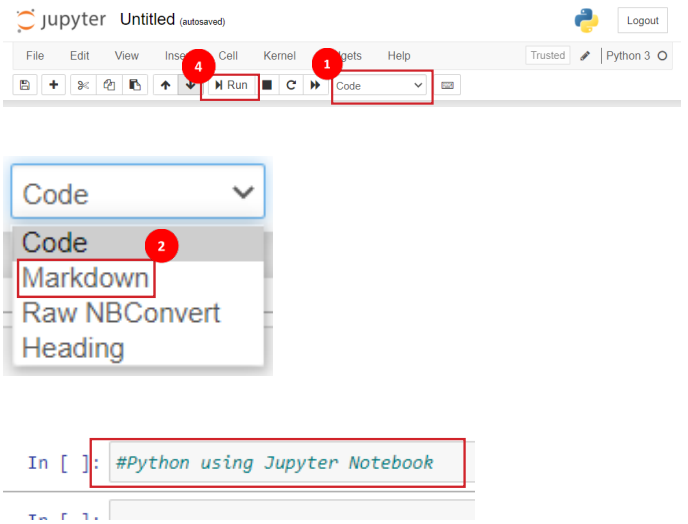
Next page



Step 3: Change type of code as text

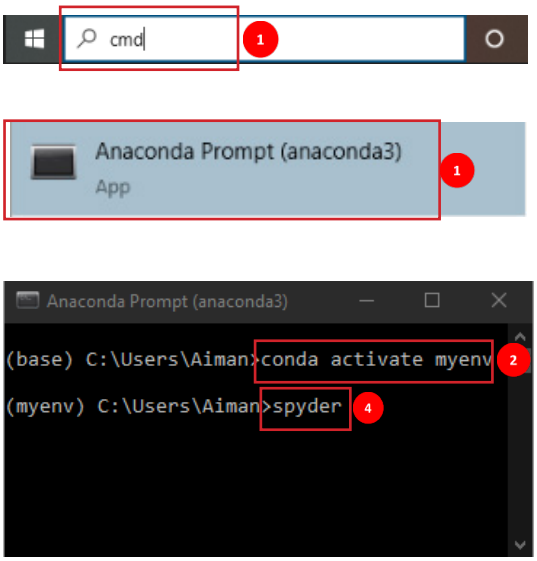
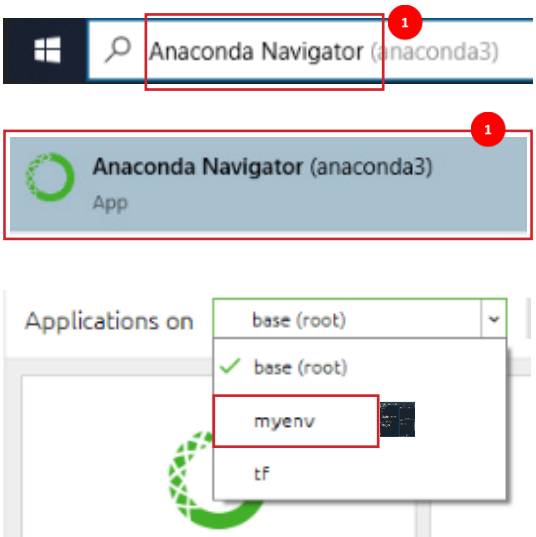
1. Click on the **Code**
2. Select **Markdown**
3. Type text, then click **Shift+Enter**
4. **Shift+enter** or **RUN** to execute the code.

**Besides markdown, # also can be used as comments. Hash symbol is used to write comments to explain the steps in a program



APPENDIX 4: APPLICATION OF SPYDER IDE FOR ANN

There are two options in launching Sypder which are:
Option 1 = Using Anaconda Prompt with command "Spyder"
Option 2 = Using Anaconda Navigator with respected environment

<table>
<tr>
<td>OPTION 1: Anaconda Prompt
1. Search Anaconda prompt (anaconda3) on Start menu.
2. Launch the Anaconda prompt (anaconda3).
3. Inside the terminal, activate the environment (Preferred).
4. Type "spyder" inside the anaconda prompt to launch the Spyder ide.</td>
<td> 
</td>
</tr>
<tr>
<td>OPTION 2: Anaconda Navigator
1. Search Anaconda Navigator on start menu.
2. Launch the Anaconda Navigator (anaconda3).
3. Inside the Anaconda Navigator, on the "Applications on", select the myenv environment. Make sure that it is not base (root).
4. Click launch to launch the Spyder.</td>
<td> 
</td>
</tr>
</table>

APPENDIX 6: "SIGNAL AND SLOT" OR FUNCTION DEVELOPMENT FOR GUI

This Appendix will show the steps how to develop the functions within GUI. It is also known as a unique "Signal and Slot" mechanism in dealing with events. This mechanism is to create communication between objects. While a signal is emitted when a particular event occurs, a slot can be in any Python callable. Figure A5.1 below is the example on the expected result of functional GUI.

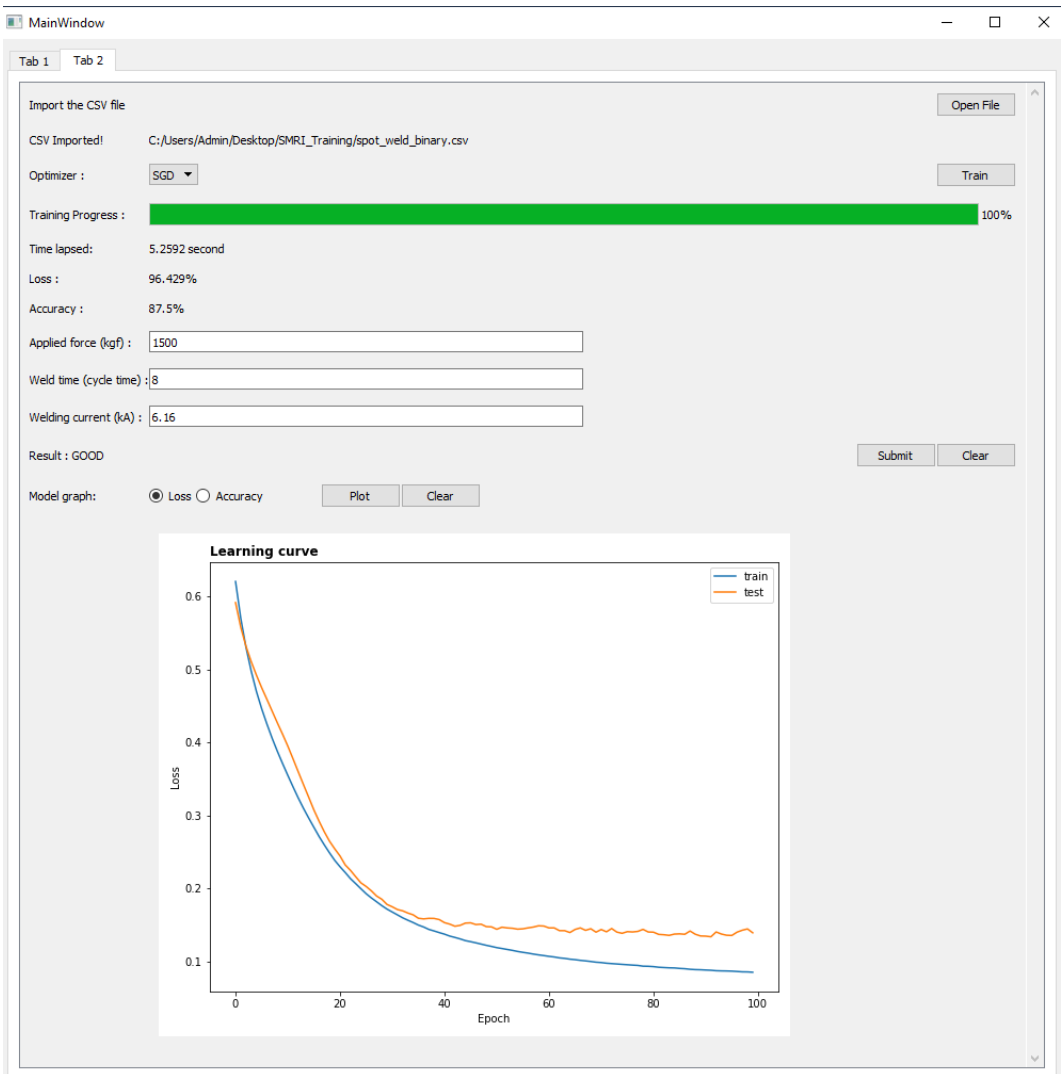


Figure A5. 1: Example of finished GUI

APPENDIX 7: EXECUTABLE (exe) FILE CONVERSION

7.1 Developing executable using Pyinstaller in Anaconda environment

This chapter will teach on how to convert the program made in python file into an executed file (.exe). Pyinstaller will be used to convert the python file to .exe file. Anaconda prompt will be used as a platform to convert the python file.

Step 1: Installing the pyinstaller.

1. Open the Anaconda command prompt and activate the conda environment.
2. Type "**conda install -c conda-forge pyinstaller**".

Note: Please skip this step **if Pyinstaller is already installed** inside your environment. Please activate the environment first using "**conda activate nameofyourenvironment".**

Anaconda prompt

(base) C:\Users\Aiman> conda activate myenv 1

(myenv) C:\Users\Aiman> conda install -c conda-forge Pyinstaller 2

Step 2: Converting the python file to the executed file.

1. Make sure the environment contains activated Pyinstaller.
2. Make sure that you are on the same directory with your python script. If not, use the command "**cd <paste your python script directory>** and click enter/return.
3. This step will convert your python script to **.exe**. The "**-p DIR**" is referred to as a path to search for imports. Paste the directory of the **TensorFlow** file. TensorFlow file is usually located at **C:\Users\Admin\anaconda3\envs\<yourenvironment>\Lib\site-packages**.
4. The user can add an icon for the application. The icon must be in .ico format which can be converted from any type of image file such as png and others from the internet. This command will add the icon to the converted python file. After the "--icon=", paste the directory of the icon which is in .ico format and add \<icon name>.ico at the end of this line.
5. At the end of the line, replace the "**YOURFILENAME**" with your python file name to be executed.
6. Once the process is completed, three folders and a spec file will be generated.

Note: Please change <yourenvironment> to your environment's actual name where the TensorFlow is installed.

Biography

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CEng IMechE, IWE/EWE/SFI, VDI, MIEM

Yupiter HP Manurung is a full Professor at School of Mechanical Engineering in Universiti Teknologi MARA (UiTM) Shah Alam, Malaysia and former Director of Smart Manufacturing Research Institute (SMRI). He is also a Professional Engineer (Ir-BEM), a Professional Technologist (Ts-MBOT), a Chartered Engineer (CEng-IMechE) and member of Association of German Engineer (VDI) who received his A-Level, BSc, MSc and PhD in Manufacturing Technology from German universities. Additionally, he is a certified International/European/German Welding Engineer (IWE/EWE/SFI) and Laser Technologist as well as Laser Safety Officer from German Research Institutes. He has been supervising bachelor students and postgraduate researchers, some of them are students or researchers from China, German and Austrian Universities. With his postgraduate students and international research partners from Germany, Austria, Tunisian, Cyprus, Ukraine and Switzerland, he has been publishing high-impact scientific publications in various international journals and conferences on Advanced Welding Technology, Virtual Manufacturing, Metal Additive Manufacturing and Weld Fatigue Integrity with financial support from national and international research grant such as E-Science, FRGS, DAAD, Erasmus+, ASEA UNINET, GIP and SRP with various industries. He is an examiner of postgraduate thesis from all over the world, a reviewer of various international scientific journals and an evaluator of national and international research grants. Since 2016, he is an international research fellow at Professorship of Virtual Production Engineering in Technical University Chemnitz in Germany.

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Index

FUNDAMENTALS OF
ARTIFICIAL NEURAL NETWORK
FOR MANUFACTURING ENGINEER
using Python Language with GUI Development and Executable Conversion

This book is accomplished as result of a long term local and international collaboration between Smart Manufacturing Research Institute (SMRI) at Universiti Teknologi MARA in Shah Alam, Faculty of Mechanical and Manufacturing Enginering at Universiti Tun Hussein Onn Malaysia in Batu Pahat, University of Applied Sciences in Osnabrück, Germany and Fraunhofer Institute for Mechatronic Systems Design in Paderborn, Germany. The structure of this book is as follows: Chapter 1 discusses the overview of artificial intelligence, artificial neural networks, and the basic ideas behind machine learning. A perceptron concept is presented as a simple computing element with selected activation function. Some standard loss functions are introduced with its mathematical equations. This chapter also outlines the standard backpropagation method and Levenberg-Marquardt algorithm. At the end of the chapter, a step-by-step backpropagation example is described to work through simple neural networks' mathematical ideas gently. Chapter 2 introduces python programming languages. Some of the python applications are shown. In addition, Package Management System is also briefly presented. Chapter 3 deliberates essential information on Jupyter and Spyder integrated development environment to code the ANN program. Chapter 4 is aimed to design graphical user interface using Qt designer and to add functionalities to GUI project. This chapter teaches how to use different widgets such as QLabel, QCheckBox, QLineEdit, etc. Chapter 5 provides an overview of the ANN application in the manufacturing processes. Some of the applications are outlined in the chapter. The case study of resistance spot welding with ANN application is explained following quality issue. The dataset acquired for the training of the ANN model is shown in this chapter. The ANN applications produced the result, and the advanced recommendation of the ANN is proposed. Chapter 6 shares the future outlook of artificial intelligence application in manufacturing data analytic.

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For more information, please scan the code