**Technology Design Project – COS 60011**

**Deliverable 1**

**Individual Research Report**

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# Acknowledgement to Country

Today’s modern-day Melbourne and Swinburne University of Technology are situated in what was originally the Kulin Nation of the past. As a Swinburne student, who is truly grateful and proud to study at this esteemed institution, I would like to humbly pay my deepest respects to the Wurundjeri People of this nation who are the traditional owners of these lands. Additionally, I sincerely thank the students, alumni, partners, and guests of Swinburne who are from Aboriginal and Torres Strait Islander backgrounds. It is my honor and I feel proud to recognize and acknowledge the link of spirituality, history, and culture of this place to the Wurundjeri country.

# 1. Introduction

Machine learning (ML) is a groundbreaking method that allows computers to learn from data and make judgements without requiring explicit programming. Many current applications rely on machine learning, particularly recommendation algorithms, which are critical in directing user choices across a wide range of areas, from movies and books to products and services.

This report focuses on the learnings and knowledge acquired through research, for the implementation of a car recommendation system using a Deep Feedforward Neural Network, also known as a Multi-Layer Perceptron (MLP). The report will cover the basics of machine learning and neural networks, delve into the specifics of deep MLPs and backpropagation, and outline the steps involved in implementing this model in a recommendation system.

# 2. Machine Learning and Neural Networks

## 2.1 Understanding Machine Learning

Machine learning is a subset of artificial intelligence (AI) where algorithms learn from data to make predictions or decisions. The primary goal is to allow computers to find patterns in data autonomously and improve over time. There are three main types of machine learning:

* **Supervised Learning**: The model is trained on labeled data, where the input-output pairs are known. The aim is to learn a mapping from inputs to outputs.
* **Unsupervised Learning**: The model is trained on unlabeled data, where the goal is to identify patterns or groupings within the data.
* **Reinforcement Learning**: The model learns by interacting with an environment, receiving rewards or penalties based on its actions, and using this feedback to improve its performance.

In this project, supervised learning is used to predict car recommendations based on user preferences.

## 2.2 Introduction to Neural Networks

Neural networks are computational models inspired by the human brain's structure and function. They consist of layers of interconnected nodes, or neurons, which process data through a series of weighted connections.

Figure 1: Basic Structure of a Neural Network

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[Input Layer] ---> [Hidden Layer 1] ---> [Hidden Layer 2] ---> ... ---> [Output Layer]

* Input Layer: Receives the raw data features (e.g., car attributes).
* Hidden Layers: Intermediate layers where the data undergoes complex transformations. The more hidden layers, the deeper the network.
* Output Layer: Produces the final output, which in this case would be the car recommendations.

Each connection between neurons has an associated weight, and each neuron has an activation function that determines whether it should "fire" or pass on its signal. The learning process involves adjusting these weights to minimize the difference between the predicted output and the actual target.

# 3. Deep Feedforward MLP with Backpropagation

## 3.1 Understanding the Deep Feedforward MLP

A Deep Feedforward MLP is a type of neural network where connections between neurons do not form cycles. Data flows in one direction—from the input layer, through several hidden layers, to the output layer. The depth of the network (number of hidden layers) allows it to capture complex patterns in the data.

Figure 2: Deep Feedforward MLP Architecture

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[Input Layer]

|

[Hidden Layer 1]

|

[Hidden Layer 2]

|

...

|

[Output Layer]

In a car recommendation system, the input layer might include features such as car body type, budget, and fuel efficiency. The hidden layers learn combinations of these features to produce the most relevant car recommendations in the output layer.

## 3.2 Backpropagation

Backpropagation is the algorithm used to train deep neural networks. It involves two main phases: forward pass and backward pass.

Forward Pass: The input data is fed through the network, layer by layer, until it reaches the output layer, where a prediction is made.

Backward Pass: The error between the predicted output and the actual target is calculated. This error is then propagated back through the network, and the weights are adjusted to minimize this error.

The backward pass relies on a mathematical technique called gradient descent, which finds the minimum of a function by iteratively moving in the direction of the steepest descent.

## 3.3Mathematical Representation of Backpropagation:

Forward Pass Equation:

y^=σ(W⋅X+b)

y^​=σ(W⋅X+b)

Where:

y^y^​ = Predicted output

WW = Weights matrix

XX = Input features

bb = Bias term

σσ = Activation function (e.g., ReLU, sigmoid)

Loss Function (Cross-Entropy Loss):

L(y^,y)=−∑i=1nyilog⁡(y^i)

L(y^​,y)=−i=1∑n​yi​log(y^​i​)

Where:

LL = Loss function

yy = Actual output

y^y^​ = Predicted output

Gradient Descent Update Rule:

Wnew=Wold−η⋅∂L∂W

Wnew​=Wold​−η⋅∂W∂L​

Where:

ηη = Learning rate

∂L∂W∂W∂L​ = Gradient of the loss function with respect to the weights

# 4. Implementation in the Car Recommendation System

## 4.1 Dataset Preparation

The dataset for this car recommendation system includes 15 features and 30,000 records. These features encompass various car attributes, such as body type, budget, fuel efficiency, and brand value.

Steps for Data Preparation:

One-Hot Encoding: Categorical variables (e.g., car body type) are converted into binary vectors to be used as inputs for the neural network.

Normalization: Numerical features (e.g., budget, fuel efficiency) are scaled to a common range to improve the model's performance.

## 4.2 Model Architecture

The deep MLP designed for this system consists of the following layers:

Input Layer: Receives the 15 input features from the dataset.

Hidden Layers: Four hidden layers with 256, 128, 64, and 32 neurons, respectively, using the ReLU activation function to introduce non-linearity.

Output Layer: A softmax layer that outputs the probabilities for each car recommendation.

Figure 3: Detailed Model Architecture

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[Input Layer] -> [Dense Layer (256 ReLU)] -> [Dropout] -> [Dense Layer (128 ReLU)] -> [Dropout] ->

[Dense Layer (64 ReLU)] -> [Dropout] -> [Dense Layer (32 ReLU)] -> [Output Layer (Softmax)]

Dropout layers are included to prevent overfitting, and batch normalization is applied after each hidden layer to stabilize the learning process.

## 4.3 Method of Implementation

Data Preparation: The dataset is pre-processed with one-hot encoding and normalization.

Model Initialization: The deep MLP is initialized with the specified architecture.

Training: The model is trained using backpropagation and gradient descent, adjusting weights to minimize the loss function.

Deployment: The trained model is integrated into a Streamlit web application, where users can input their preferences and receive car recommendations.

# 5. Summary and Conclusion

This report has explored the application of a Deep Feedforward MLP in a car recommendation system. Through a detailed explanation of machine learning, neural networks, and backpropagation, it has outlined the implementation steps necessary to build a robust recommendation engine. The deep MLP's ability to learn from complex data and produce accurate predictions makes it a powerful tool in modern recommendation systems.

# 6. References

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