ABSTRACT

One of the biggest problems humanity faces today is that our adverse effects on the environment are much greater than the steps taken to mend them. One such step or process is waste management. Waste management begins with reducing the production of consumer waste; the waste caused by product materials. Consumer waste can be reduced by choosing sustainable product materials.

To choose sustainable product materials, the product designer must take into account not only environmental factors but mechanical and economic factors as well to ensure the maximum efficiency of the chosen material with respect to the product requirements. It is often difficult to accurately weigh the various properties of the materials and derive the most optimal material that adheres to all the objectives of the product.

A cohesive machine learning solution of differential evolution (DE) and back propagation neural networks (BPNs) is proposed to optimize the Pareto product material selection. This approach has been validated by an application that can select the most optimal material given a list of potential materials for a product. The application has been created such that it will assist product designers during the planning stages of product designing.

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CHAPTER 1

INTRODUCTION

1.1 OVERVIEW

This report discusses the result of the work done in development of "Pareto Optimization of Product Material Selection: Artificial Neural Networks & Differential Evolution Approach" using machine learning and python. It aims at the development of an application that assists product designers choose a sustainable product material.

1.2 BACKGROUND AND MOTIVATION

India is one of the places in the world where the most garbage is disposed of. India's urban population of 429 million citizens produce 62 million tonnes of garbage annually. Studies have shown that higher income levels and increased urbanization mean more waste is generated. Of all the waste, the total packaging waste is 32 million tonnes per annum (predominantly single use plastics). This shows a definite link between consumerism and waste. Unless something is done about this consumer waste, WEF Report estimates that by 2050 there will be more plastic in the ocean than fish. The field that deals with waste is known as waste management.

The most troublesome objective of waste management is reducing the production of waste.

1.3 LITERATURE SURVEY

Various scientific journals were analyzed to further investigate and understand the domains of waste management, material selection, and machine learning. Many papers offered an insight that was parallel to the motivation of this project, and existing working systems were understood.

In 2009, a system was created to select sustainable materials for bottled beverages.It used Genetic Algorithm and Artificial Neural Networks to select a material based on multiple objectives like minimizing cost and adverse environmental effects. Environmental impacts were calculated by LCA method (Life Cycle Assessment Method). Material selection was explored and multicriteria decision making methods were studied to gather background knowledge.

Material selection using Linear Assignment method helped formulate a basic understanding of the process needed to select a product material.Based on the drawbacks of the existing system, papers were read to find an improvement to the Genetic Algorithm. In this process many algorithms were touched upon till Differential Evolution was found to have superior command over the decision space.

Then, the working of Artificial Neural Networks, Differential Evolution and Genetic Algorithm were separately studied in various papers. Insight like the general activation function for a neural network being a sigmoid function was gathered. It was also learned that differential evolution's extent of application to neural networks is still being studied.

1.4 Problem Statement

The materials a product is made of can not just be determined based on environmental factors. The product designer will have to consider mechanical and economic factors as well. There will be specific objectives based on what the product is built to do it's purpose. This type of multiobjective optimization of product material selection been done previously using genetic algorithms and artificial neural networks. However, this solution is not the most optimal.

1.5 Goal and Vision

` The goal is to develop an application for product designers to determine the best product materials based on various objectives. This application should give the highest accuracy possible and provide a better insight to the product designer. The product designer can select a list of potential materials he or she is considering from a friendly GUI and get an output of the most optimal material.

The vision is to use differential evolution (a better evolutionary algorithm for Pareto optimization in comparison to genetic algorithms) with back propagation neural networks to select the optimal material.

1.6 Application Validation

The validity of the application will be tested by applying it to the selection of materials for the product, kitchen cutlery specifically knives, forks, and spoons.

CHAPTER 2

REQUIREMENT ANALYSIS

This phase of the project was carried out to understand the current available solutions to product materials selection, their drawbacks, the requirements of products material determination, how materials are selected, understanding various properties of materials, research into parameters, the product designing process, data needs, algorithm requirements, etc.

2.1 REQUIREMENT SPECIFICATION

2.1.1 User Characteristics

The user that interacts with the application is a product designer. A product designer understands the relationship between art, science and technology. They will spend their time planning, designing and modeling products, producing prototypes and conducting rigorous testing. During the planning stage itself, the designer will brainstorm a list of potential materials that can be used. This is where the application can be utilized by the designer.

The designer will interact with a GUI that presents a form with a list of materials. He or she can select the candidate materials they are considering. On submitting the form, one optimal material from the list will be displayed as the output. It is assumed that the designer has no specific knowledge about the materials. This means that toxic materials or otherwise unusable materials way be entered by the designer as input.

2.1.2 Functional Requirements

Actor: User

Input: Selecting Checkboxes as Input

Description: User provides input that gets processed in the background and instant result will be returned.

2.1.3 Dependencies

Modern modules of Python 3.6 have been used to develop the frontend and backend of the application. The modules Numpy and Pandas are used to develop the backend, and PyQt5 is used for the frontend. PyInstaller is used to combine the necessary modules and run the application on a click by generating an .exe file.

2.1.4 Performance Requirements

The performance of the model was tested using the manually calculated data of few materials. The LCA parameters were fetched and processed to compare the output of the model and to determine the performance.

2.1.5 Hardware Requirements

This application can be run on any laptop or PC with a fairly decent CPU like an Intel Core i3, 2GB RAM, Windows or Ubuntu Operating System, and Python should be installed.

2.1.6 Constraints and Assumptions

Application assumes that user knows the “English” language and is designing a product that is made of only one material.

2.2 FEASIBILITY STUDY

The feasibility study is a process executed to determine if the actualization of the application is possible with the available resources.

2.2.1 Economic Feasibility

The economic analysis is to determine the benefits and savings that are expected from the application and compare them with cost. The system is economically feasible, as most designers possesses the hardware and software resource required for the functioning of the application. Any additional resources, if required, can also be easily acquired.

2.2.2 Technical Feasibility

The application's backend centres around data, and the type of data required is attainable from public sources. The model built for processing is technically applicable as well.

2.2.3 Operational Feasibility

The user will not see the machine learning part of the application. The application just requires a user friendly interface, which it has.

2.2.4 Behavioral Feasibility

In today's world, computers are an inevitable entity, therefore the application requires no special efforts thus it will be widely accepted.

CHAPTER 3

DESIGN

The detailed implementation of the application for kitchen cutlery material selection based on the feasibility study is split into 3 modules; the dataset, the model (integrated algorithm), and the GUI.

3.1 DATA DESIGN

The dataset utilized by the application is a collection of public numeric data about the properties split into three main divisions, and under them are different parameters as follows:
Mechanical Properties

- Young's Modulus
- Shear Modulus
- Poisson's Ratio
- Elastic Modulus
- Tensile Strength
- Compressive Strength
- Hardness
- Density
- Economical Properties
- Price of Raw Material
- Price of Recycle
- Environmental Properties
- Embodied Energy
- Embodied Carbon
- Average Recycle Content
- Acidification Potential
- Global Warming Potential
- Toxicity