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Optimizing Washing Machine Efficiency with a Fuzzy Logic Control System using Python

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Abstract:

Washing clothes is an essential part of our daily routines. Traditionally, clothes were cleaned by hand, but with technological advancements, machines have taken over these manual tasks, making life more convenient. Among these innovations is the washing machine, designed to save water, energy, and time. To enhance efficiency, a **Fuzzy Logic Control System** was developed to optimize washing processes based on user needs.Fuzzy logic, a type of reasoning that handles approximate information rather than binary true or false values, is widely utilized today, especially in Artificial Intelligence to mimic human-like decision-making in automated systems. Applications of fuzzy logic span various domains such as air conditioners, unmanned aerial vehicles, satellites, traffic control systems, transmission systems, and anti-lock braking systems (ABS).In the context of washing machines, Python provides a streamlined approach to implementing fuzzy logic, addressing some of the limitations encountered with MATLAB. In this Python-based system, inputs like **fabric type**, **dirt level**, and **load size** determine outputs such as **wash time**, **spin speed (RPM)**, **drying time**, and **water temperature**. The goal is to minimize the time, power consumption, and water usage while ensuring optimal wash quality. Simulation results demonstrate that this approach significantly enhances wash efficiency and performance.

Keywords: Python; Fuzzy logic system; Artificial Intelligence; Rule Viewer; MATLAB.

I. INTRODUCTION

Python was first designed in 1980 and it was a high-level interpreted programming language. Python was released in the year 1991 by Guido Van Rossum at Centrum Wiskunde and Informatica (CWI) in Netherland. For his continuous efforts in the development and central role in deciding the correct direction, he was given the title, “Benevolent Dictator for Life” (BDFL) by the Python community.

Python is an easy and powerful programming language. It is helpful for the beginners. It can perform complex mathematics and handle large data and files. It increases the reduction of memory usage and time complexity.

Python was first implemented using C language hence it was called C Python initially. The main advantage of Python is that, it does not use many symbols such as semi colon and curly braces in looping statements. Python uses indentation to indicate a block of code and hence it is easy to read and understand. Python has the major features relating to Object-Oriented Programming concepts.

Python 2.0 was first released on 16th October, 2000 with innovative features and developments like Garbage collector for cycle detecting for memory management and also supports Unicode.

Python 3.0 was released on 3rd December, 2008 after conducting several tests. But many of its feature have been back ported. Python 2.7 was reported by the Python community for Sunset date that is End of Life (EOL) date, but was postponed to 2020 because of many people concern that it cannot be easily forward-ported to Python 3 within the stipulated time periods.

Python finds its application over several domain such as Artificial Intelligence, Machine Learning, Deep Learning, Web Development, installers, security systems, etc.

In this paper, we use Fuzzy Logic Controller for liquid level maintaining and control. Previous approaches for Fuzzy Logic Control was designed in MATLAB. But here we have programmed Fuzzy Logic Control using Python for easy, precise and compact structure of program.

II. FUZZY LOGIC SYSTEM

Fuzzy logic control is a concept which helps the computers to make decision like human. It works on the basis of conditional statement. Most of the people do not know how much time is required for washing clothes in order to overcome these issues, Fuzzy logic controller (FLC) based washing machines are designed in such a way it offers better performance and low cost.

The Fuzzy logic controller for liquid level monitoring in washing machine was designed using the Fuzzy logic concept in Python.

Washing machine developed based on Fuzzy logic rules will be helpful in washing procedures by sensing the amount of dirt, type of dirt etc. The Fuzzy logic system used in washing time will not only reduces the energy consumption (including electricity and water) but also helps the users to save finances in commercial boundary. The application of Fuzzy logic controllers has more dynamic range when compared to the conventional PID controller.

The conditions inside the machine are monitored by sensors. The fuzzy logic also has a feature of ‘one touch control’. The fuzzy logic also checks the amount of dirt and grease direction of the spinning, the detergent and water to be added and so on. The reloading takes place to correct the direction of spin. Neuro fuzzy logic system has inbuilt optical sensors which detect the type of fabric used by the user.

The washing machines incorporate optical sensors to find light permeability of water in washer tank, a device that converts light rays to electrical signal. The optical sensors detect change in light beams. A point at which there is no change of color in the water is known as saturation point. There is no

logic or formula to determine the relationship between volumes of clothes and dirt and also the time needed to wash. The structure of washing machine controller has not let itself to ancient methods as the input and output are not clear.

The principle of sensor is that the light is transmitted through a water sample and the amount of light passed through it is proportional to the amount of soil. The increase in soil levels leads to decrease in amount of light transmitted is measured by the turbidity sensor to find out the turbidity. The decisions on how long to wash in all cycles are given to the dishwasher controller based on turbidity measurements. These decisions are carried out on the basis of the comparison of clean water and wash water turbidity. Using this strategy to make decisions, we can conserve energy on lightly soiled loads by washing as long as necessary.

III. PROPOSED DESIGN

The main work of washing machine is to clean the dirty clothes and other fabrics without any damage. For that, we give a particular input according to the properties of the cloth to produce output such as heavy wash or soft wash, time of washing and so on. In relation to that, 27 principles for washing time and 27 principles for water temperature are proposed and used to design this Fuzzy Logic Control System using Python. To achieve these advantages in an economical way, this washing machine uses fuzzy logic system with some of these three major input parameters:

1. Weight of Fabrics
2. Stains category
3. Type of Fabric

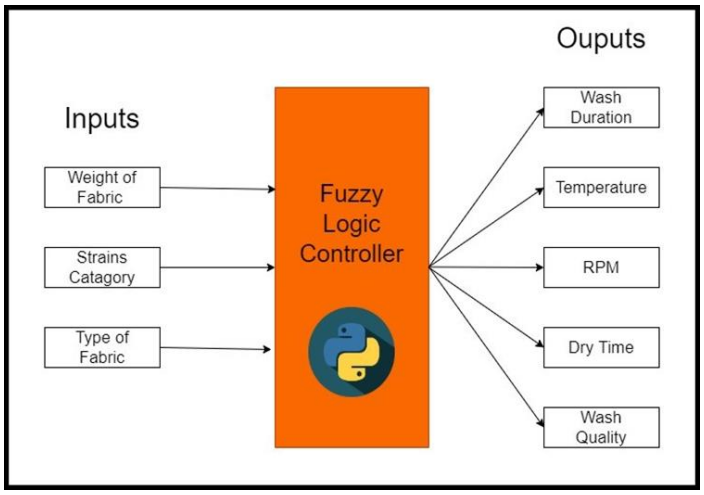

Fig 1. Fuzzy logic Inputs and Outputs System

The FLC processes the input information and produces five outputs which are:

1. Wash Duration
2. Temperature
3. RPM
4. Dry Time
5. Wash quality

A. Algorithm for our Fuzzy logic system:

BEGIN < FUZZY LOGIC > (FAB_TYPE, DIRT_TYPE, WEIGHT)

IF FAB_TYPE=SILK AND DIRT_TYPE= LIGHTLY_SOILED AND WEIGHT = BELOW_10KG THEN

PRINT WASH STASTICS

ELSE IF FAB_TYPE = SILK AND DIRT_TYPE=LIGHTLY_SOILED AND WEIGHT=10_TO_15KG THEN

PRINT WASH STATISTICS

ELSE IF FAB_TYPE = SILK AND DIRT_TYPE=LIGHTLY_SOILED AND WEIGHT=ABOVE_15 KG THEN

PRINT WASH STATISTICS

ELSE IF FAB_TYPE = SILK AND DIRT_TYPE=NORMALLY_SOILED AND WEIGHT=BELOW_10KG THEN

PRINT WASH STATISTICS

ELSE IF FAB_TYPE = SILK AND DIRT_TYPE=NORMALLY_SOILED AND WEIGHT=10_TO_ 15 KG THEN

PRINT WASH STATISTICS

---- ----------

ELSE IF FAB_TYPE = COTTON AND DIRT_TYPE=NORMALLY_SOILED AND WEIGHT=10_TO_15KG THEN

PRINT WASH STATISTICS

ELSE IF FAB_TYPE = COTTON AND DIRT_TYPE=NORMALLY_SOILED AND WEIGHT=ABOVE_15KG THEN

PRINT WASH STATISTICS

ELSE IF FAB_TYPE = COTTON AND DIRT_TYPE=HEAVILY_SOILED AND WEIGHT=BELOW_10KG THEN

PRINT WASH STATISTICS

ELSE IF FAB_TYPE = COTTON AND DIRT_TYPE=HEAVILY_SOILED AND WEIGHT=10_TO_15KG THEN

PRINT WASH STATISTICS

ELSE IF FAB_TYPE = COTTON AND DIRT_TYPE=HEAVILY_SOILED AND WEIGHT=ABOVE_ 15KG THEN

PRINT WASH STATISTICS

B. Python code for our Fuzzy logic system:

Fuzzy rules have been involved in the modeling of washing machines. The whole system which we have made is developed by using Python. The code for our FLC system is as follows:

```
list1=[]
def result():
#Silk
  print("------")
  print("OUTPUT")
  print("------")
 Rule 1:  if((list1[0]=="silk")and(list1[1]=="lightly  soiled")and(list1[2]=="below_10kg")):#1
    print("Wash Duration   - 0.35 h")
    print("Temperature - 30c")
    print("RPM         - 400")
    print("Dry Time    - Quick")
    print("Quality     - Good")
    input("Press Enter key to exit...")
 Rule 2:  elif((list1[0]=="silk")and(list1[1]=="lightly soiled")and(list1[2]=="10_to_15kg")):#2
    print("Wash Duration - 0.47 h")
    print("Temperature - 30c")
    print("RPM         - 600")
    print("Dry Time    - Intermediate")
    print("Quality     - Good")
    input("Press Enter key to exit...")
 Rule 3: elif((list1[0]=="silk")and(list1[1]=="lightly soiled")and(list1[2]=="above_15kg")):#3
    print("Wash Duration  - 0.50 h")
    print("Temperature - 40c")
    print("RPM         - 600")
    print("Dry Time    - Intermediate")
```

```
        print("Quality     - Best")
        input("Press Enter key to exit...")
```

```
    Rule 25: elif((list1[0]=="cottan")and(list1[1]=="heavily soiled")and(list1[2]=="below_10kg")):#25
        print("Wash Duration  - Long")
        print("Temperature -  60c")
        print("RPM         - 1000")
        print("Dry Time    - Intermediate")
        print("Quality     - Good")
        input("Press Enter key to exit...")
    Rule 26: elif((list1[0]=="cottan")and(list1[1]=="heavily soiled")and(list1[2]=="10_to_15kg")):#26
        print("Wash Duration   - 1.18")
        print("Temperature -  60c")
        print("RPM         - 1200")
        print("Dry Time    - Long")
        print("Quality     - Best")
        input("Press Enter key to exit...")
    Rule 27: elif((list1[0]=="cottan")and(list1[1]=="heavily soiled")and(list1[2]=="above_15kg")):#27
        print("Wash Duration - 2.10 h")
        print("Temperature - 60c")
        print("RPM         - 1200")
        print("Dry Time    - Long")
        print("Quality     - Good")
        input("Press Enter key to exit...")
def fun():
    list1.append(str(input("Enter the Fabric_type:").lower()))
    list1.append(str(input("Enter the Stain_category:").lower()))
    list1.append(str(input("Enter the Fabric_Weight:").lower()))
```

```
    print(list1)
    if(((list1[0]=="cottan")or(list1[0]=="silk")or(list1[0]=="woolen"))and
       ((list1[1]=="lightly soiled")or(list1[1]=="normally soiled")or(list1[1]=="heavily soiled"))and
       ((list1[2]=="below_10kg")or(list1[2]=="10_to_15kg")or(list1[2]=="above_15kg"))):
       settings=str(input("Do you want to Change the Settings (YES OR NO):").lower())
       if(settings=="yes"):
          list1.clear()
          fun()
       elif(settings=="no"):
          result()
    else:
       print("Given input is wrong try again")
       list1.clear()
       fun()
fun()
```

C. Resultant values of our washing machine's FLC python code:

The decision of the fuzzy logic controller is made using previously stored data in the database. The principles which we use in this paper is derived from the logical thinking, data taken from daily usage, and experimentation of the system in a controlled environment. The set of principles used here to derive the output are based on the Fuzzy logic system using python code are given below:

```
Python 3.8.5 (tags/v3.8.5:580fbb0, Jul 20 2020, 15:43:08) [MSC v.1926 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>>
========== RESTART: C:\Users\Raja\Desktop\p n.py ==========
Enter the Fabric_type:silk
Enter the Stain_category:lightly soiled
Enter the Fabric_Weight:below_10kg
['silk', 'lightly soiled', 'below_10kg']
Do you want to Change the Settings (YES OR NO):no
------
OUTPUT
------
Wash Duration   - 0.35 h
Temperature - 30c
RPM         - 400
Dry Time    - Quick
Quality     - Good
```

```
Python 3.8.5 (tags/v3.8.5:580fbb0, Jul 20 2020, 15:43:08) [MSC v.1926 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>>
========== RESTART: C:\Users\Raja\Desktop\p n.py ==========
Enter the Fabric_type:silk
Enter the Stain_category:lightly soiled
Enter the Fabric_Weight:10_to_15kg
['silk', 'lightly soiled', '10_to_15kg']
Do you want to Change the Settings (YES OR NO):no
------
OUTPUT
------
Wash Duration - 0.47 h
Temperature - 30c
RPM         - 600
Dry Time    - Intermediate
Quality     - Good
```

```
Python 3.8.5 (tags/v3.8.5:580fbb0, Jul 20 2020, 15:43:08) [MSC v.1926 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>>
========== RESTART: C:\Users\Raja\Desktop\p n.py ==========
Enter the Fabric_type:silk
Enter the Stain_category:lightly soiled
Enter the Fabric_Weight:above_15kg
['silk', 'lightly soiled', 'above_15kg']
Do you want to Change the Settings (YES OR NO):no
------
OUTPUT
------
Wash Duration  - 0.50 h
Temperature - 40c
RPM         - 600
Dry Time    - Intermediate
Quality     - Best
```

```
Python 3.8.5 (tags/v3.8.5:580fbb0, Jul 20 2020, 15:43:08) [MSC v.1926 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>>
========== RESTART: C:\Users\Raja\Desktop\p n.py ==========
Enter the Fabric_type:cottan
Enter the Stain_category:heavily soiled
Enter the Fabric_Weight:below_10kg
['cottan', 'heavily soiled', 'below_10kg']
Do you want to Change the Settings (YES OR NO):no
------
OUTPUT
------
Wash Duration  - Long
Temperature -  60c
RPM         - 1000
Dry Time    - Intermediate
Quality     - Good
```

```
Python 3.8.5 (tags/v3.8.5:580fbb0, Jul 20 2020, 15:43:08) [MSC v.1926 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>>
========== RESTART: C:\Users\Raja\Desktop\p n.py ==========
Enter the Fabric_type:cottan
Enter the Stain_category:heavily soiled
Enter the Fabric_Weight:10_to_15kg
['cottan', 'heavily soiled', '10_to_15kg']
Do you want to Change the Settings (YES OR NO):no
------
OUTPUT
------
Wash Duration   - 1.18
Temperature -  60c
RPM         - 1200
Dry Time    - Long
Quality     - Best
Python 3.8.5 (tags/v3.8.5:580fbb0, Jul 20 2020, 15:43:08) [MSC v.1926 32 bit (Intel)] on win32
Type "help", "copyright", "credits" or "license()" for more information.
>>>
========== RESTART: C:\Users\Raja\Desktop\p n.py ==========
Enter the Fabric_type:cottan
Enter the Stain_category:heavily soiled
Enter the Fabric_Weight:above_15kg
['cottan', 'heavily soiled', 'above_15kg']
Do you want to Change the Settings (YES OR NO):no
------
OUTPUT
------
Wash Duration - 2.10 h
Temperature - 60c
RPM         - 1200
Dry Time    - Long
Quality     - Good
```

The above input and output can be represented in a table for an easy understanding of how it works:

TABLE I

R. No	**Linguistic Inputs**			**Linguistic Outputs**				
	Type of Clothes	**Degree of Dirtiness**	**Mass of Cloth Load**	**Wash Time**	**Temperature**	**RPM**	**Dry Time**	**Wash Quality**
1	Silk	lightly soiled	Below_10kg	0.35 h	$30^{*}c$	400	Quick	Good
2	Silk	lightly soiled	10_to_15 kg	0.47 h	$30^{*}c$	600	Intermediate	Good
3	Silk	lightly soiled	Above_15kg	0.50 h	$40^{*}c$	600	Intermediate	Best
4	Silk	normally	Below_1	0.50 h	$30^{*}c$	400	Long	Medium

		soiled	0kg					
5	Silk	normally soiled	10_to_15 kg	1.18 h	$30^{*}c$	800	Quick	Good
6	Silk	normally soiled	Above_15kg	1.18 h	$40^{*}c$	600	Long	Medium
7	Silk	heavily soiled	Below_10kg	0.50 h	$30^{*}c$	800	Intermediate	Good
8	Silk	heavily soiled	10_to_15 kg	1.18 h	$40^{*}c$	800	Quick	Best
9	Silk	heavily soiled	Above_15kg	2.10 h	$40^{*}c$	800	Quick	Best
10	Woollen	lightly soiled	Below_10kg	0.47 h	$40^{*}c$	600	Long	Medium
11	Woollen	lightly soiled	10_to_15 kg	0.50 h	$40^{*}c$	800	Intermediate	Good
12	Woollen	lightly soiled	Above_15kg	1.18 h	$40^{*}c$	800	Quick	Good
13	Woollen	normally soiled	Below_10kg	0.50 h	$40^{*}c$	600	Intermediate	Medium
14	Woollen	normally soiled	10_to_15 kg	1.18 h	$40^{*}c$	600	Intermediate	Medium
15	Woollen	normally soiled	Above_15kg	1.18 h	$60^{*}c$	800	Quick	Best
16	Woollen	heavily soiled	Below_10kg	1.18 h	$60^{*}c$	800	Quick	Best
17	Woollen	heavily soiled	10_to_15 kg	1.18 h	$60^{*}c$	1000	Quick	Good
18	Woollen	heavily soiled	Above_15kg	2.10 h	$60^{*}c$	1200	Quick	Good
1	Cotto	lightly	Below_1	0.47 h	$40^{*}c$	400	Intermediate	Good
2	Cotto	lightly	10_to_15	0.50 h	$40^{*}c$	600	Intermediate	Good

0	n	soiled	kg					
21	Cotton	lightly soiled	Above_15kg	1.18h	$40^{*}c$	800	Quick	Best
22	Cotton	normally soiled	Below_10kg	0.50 h	$40^{*}c$	600	Intermediate	Best
23	Cotton	normally soiled	10_to_15 kg	1.18h	$40^{*}c$	800	Quick	Best
24	Cotton	normally soiled	Above_15kg	2.10 h	$40^{*}c$	1000	Quick	Good
25	Cotton	heavily soiled	Below_10kg	1.18h	$60^{*}c$	1000	Quick	Good
26	Cotton	heavily soiled	10_to_15 kg	1.18h	$60^{*}c$	1200	Quick	Best
27	Cotton	heavily soiled	Above_15kg	2.10 h	$60^{*}c$	1200	Quick	Good

Here in this table, three types of clothes are taken into consideration. They are silk, woollen and cotton. They have the weight of 10 to 15 kg from lightly soiled to heavily soiled. Using these three parameters, the output such as the temperature ranging from 30 to 60 degree Celsius, RPM ranging from 400 to 1200, washing time differing from quick to long and washing quality ranging from medium to best. These outputs produced from inputs are calculated on the basis of fuzzy logic controller system which is programmed on python for use of a greater number of criteria and also to reduce the power consumption. Thus, the best fit of output is produced by the FLC system for the given input and to reduce the water consumption and power consumption.

IV. RESULTANT AND SIMULATION

Consider any type of material or cloth to be used for washing. The mass of the cloth and the degree of dirtiness comes into consideration. When these things are given as an input to the system, that is the washing machine, the fuzzy logic system working in it measures how much temperature it should be maintained while washing, what is the RPM which it has to run, the time of washing and the quality of wash using sensors are calculated and produced as the output.

These can be visualized using graph simulation as given below:

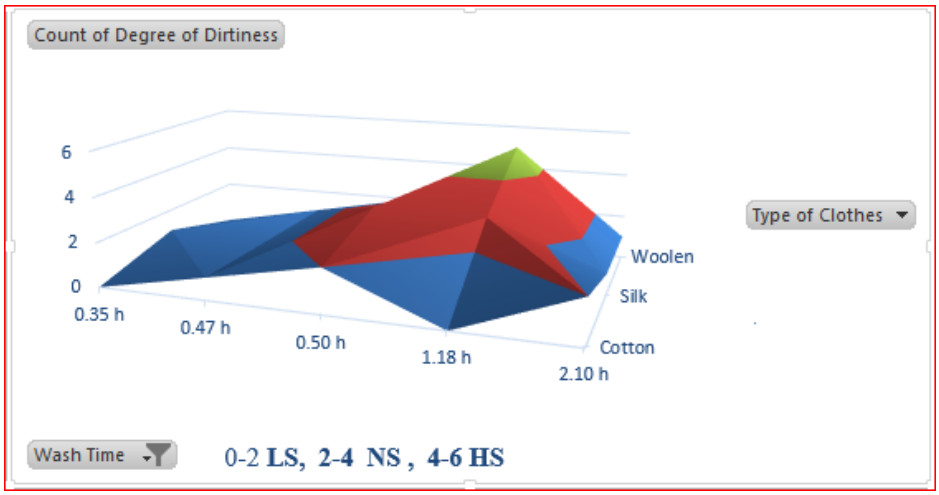

Fig 2. Degree of dirtiness vs Types of clothes based on Washing time

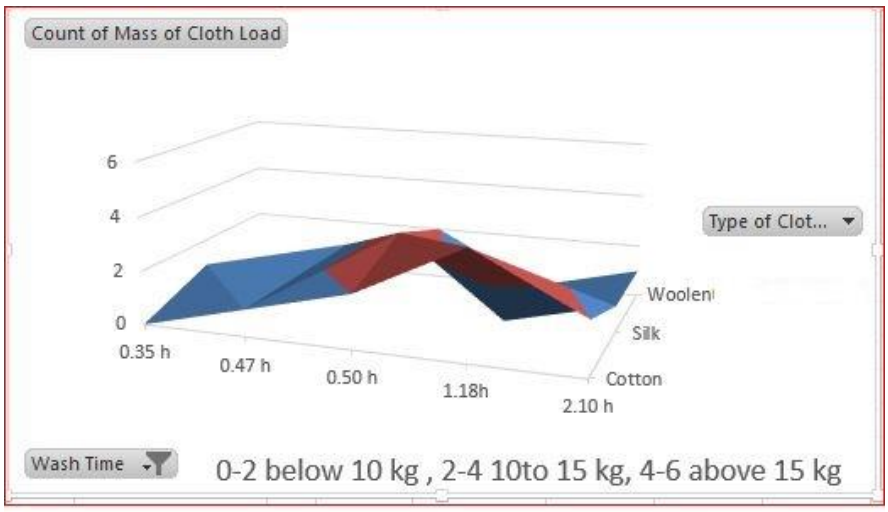

Fig 3. Mass of cloth load vs Types of clothes based on Washing time

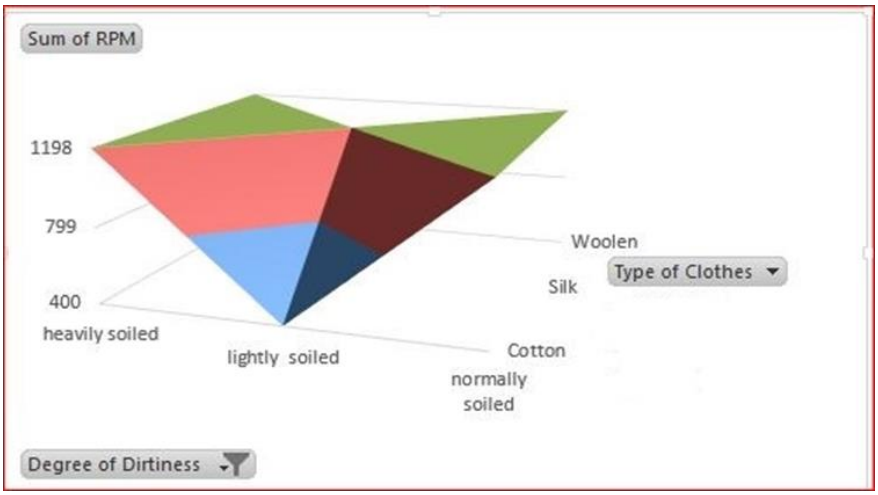

Fig 4. RPM vs types of clothes based on degree of dirtiness

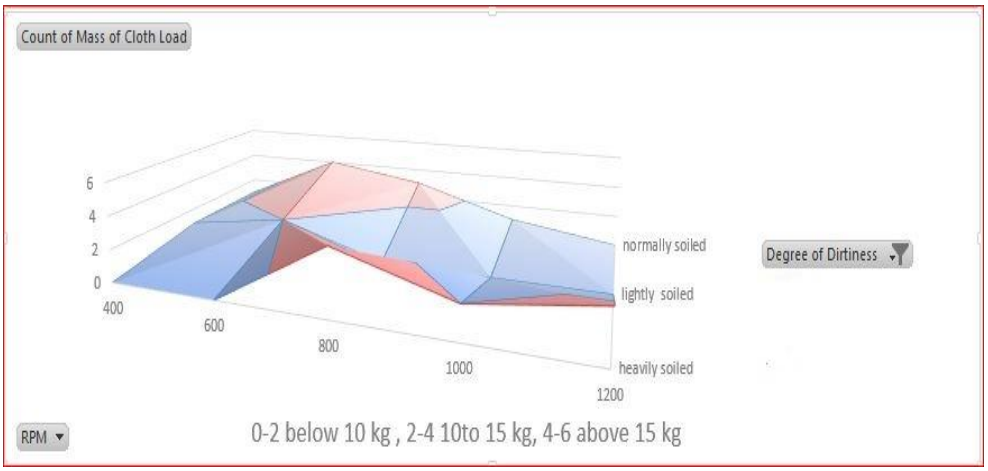

Fig 5. Mass of cloth load vs Degree of dirtiness based on RPM

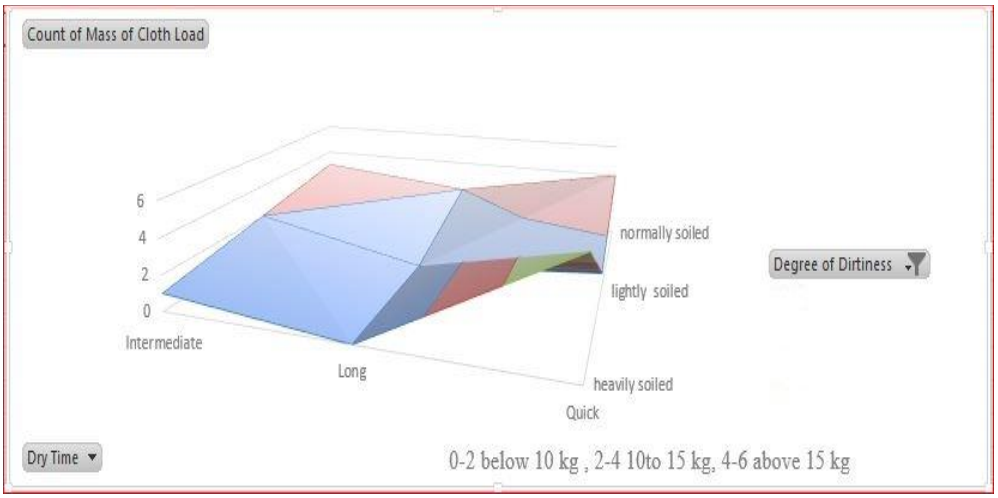

Fig 6. Mass of cloth load vs Degree of dirtiness based on Dry time

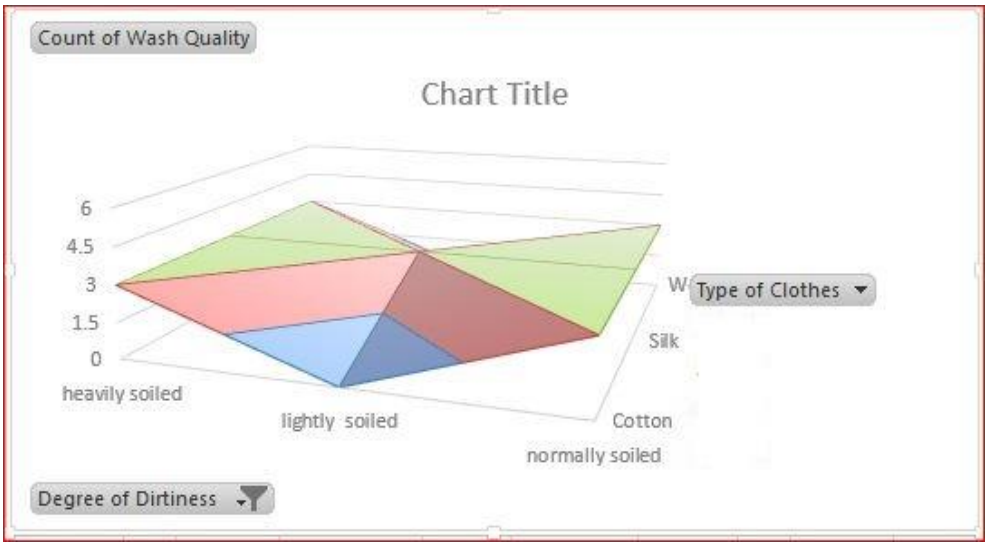

Fig 7. Count of Wash quality vs types of clothes based on degree of dirtiness

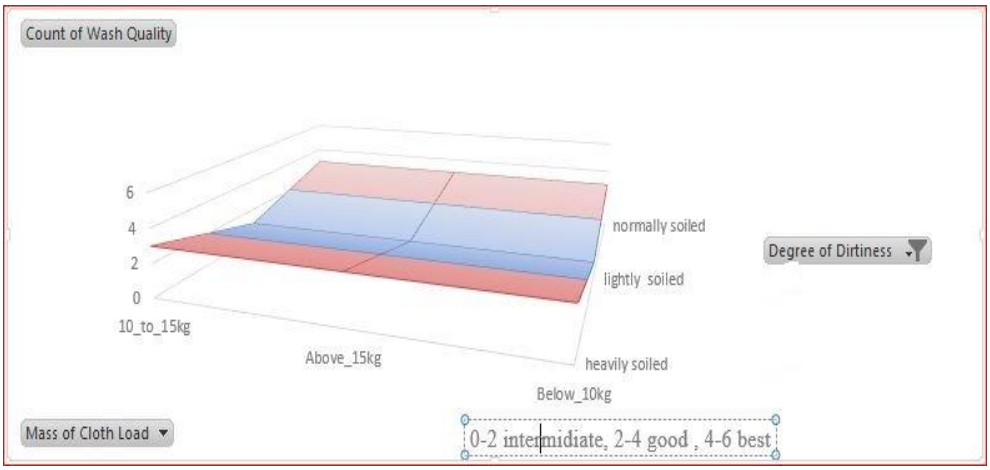

Fig 8. Wash quality vs Degree of dirtiness based on Mass of cloth load

V. CONCLUSION

By using Fuzzy Logic, we have designed an automatic washing machine controller to assess the quality of wash based on parameters namely dry/rinse time and drum rotation speed / RPM. The wash quality index is a performance measure to accurately determine the working efficiency of a washing machine at given load. The use of Fuzzy Logic Controller using Python automatically detects the necessary RPM for given input load and accordingly presumes the average rinse time of the load, thereby calculating the wash quality index. This system manages the time, saves water consumption and electricity consumption. This automatic control systems depicts the advantages of Fuzzy Logic Controller over traditional washing machine. Thus, Fuzzy logic control systems in Python provides great advantages and provides more solutions for problems that cannot be solved by MATLAB environment by reducing the disadvantages such as time management, processing speed and restricted number of input values and etc. So, Python would be the best solution to solve these problems.

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