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Energy Saving Monitoring Using Fuzzy Logic for Computing Lab

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ABSTRACT

The important issue for societies, enterprises and governments is to improve energy efficiency and reduce energy demand consumed by large number of computers and servers that could have an extensive impact on the environment. ICT creates many environmental issues such as high consumption of electrical energy from large number of computers and other I.T equipment's. I.T industry has invented that Green Information Communication Technology (GICT) is a good way to treat with the major environmental and energy related problems faced by every country because it improves overall energy productivity while also maintaining the healthy energy consumption. In this paper, a brief overview on Green ICT implementation in IIUM computer lab by the help of energy audit in ICT lab, survey questionnaires and interview sessions. The paper will contribute by presenting the prototype which is based on energy saving monitoring by using Fuzzy Logic algorithm. Moreover, in this paper we will also giving our recommendations on Green ICT practices.

Key words: Green Information Communication Technology, Green Computer Lab, Energy Saving Monitoring System.

1. INTRODUCTION

Computer is one of the most widely used machines ever invented. Its usage requires substantial amount of electricity whether to power the system unit and monitor, recharge batteries, or print. A single computer consumes between 95 and 650 watts of electricity daily depending on its usage [Osch and Avital, 2010]. Information and Communication Technology (ICT) uses huge amount of electricity and the high consumption of electrical energy from large number of computers and ICT equipment puts a heavy load on grid stations and causes emissions of Green-house gas [R. Steven Patrick, 2015]. However, ICT, at the same time, can also play a role in helping to reduce further gas emission caused by its usage [Agarwal, 2013].

The education sector has benefited tremendously from the use of ICT in providing quality education. Nevertheless, ICT power consumption devices, ICT equipment and Greenhouse emissions are becoming serious issues among ICT professionals in education institutions [Suryawanshi and K.Narkhde, 2012]. Awareness of the environmental impact caused by ICT excess usage has led the education sector to adopt Green ICT in their computer and research labs. The primary goal behind Green ICT in education sector is to control the energy consumption, along with monitoring the energy consumption; at the same time, also control the continuous increasing requirements for capacity and performance of resources [George Paul, 2010].

Many past studies concerning energy monitoring and consumption in computing systems were related to households and commercial buildings [Suryawanshi and K.Narkhde, 2012]. Their focus were on measuring power consumption for different machines analyzing relationships between power consumption and performance of different machines [A. Hindle, 2012], In 2011, Robert C. Meurant implemented GICT Practices in Microsoft and resulted in 27percent drop in the usage of power that is used by desktop computers. He also implemented graphical user interface web, where users can access data and monitor energy consumption on the LCD screen and using different browsers on their PC'S [Robert C. Meurant, 2011]. Computing systems' energy monitoring and consumption study in educational institutions is still lacking. Research in this area is needed as recent studies have shown that most of the time desktop computers in computer labs remain idle when not in use; and normally, in classroom, the average CPU idleness is at 97.9 percent, while the average unused memory is at 42.1 percent [Lungu, 2014]. With many educational institutions facing financial constraints, it is imperative that the institutions seriously look into saving energy and monitoring their computing systems' energy consumption to reduce their energy billings, and at the same time, reduce the harmful impact of computing systems on the environment. This led to our two (2) research questions which are:

1. How to measure computer energy consumption in a computer lab? and
2. What elements are required in the development of an energy saving monitoring system?

This paper presents the energy audit we conducted to measure computer energy consumption in computer labs of a chosen educational institution and proposes a model of energy saving monitoring using fuzzy logic for a computer lab. The rest of the paper is organized as follows: Section 1 presents an overview of related research works. Section 2 explains the research method used in the research. Section 3 presents our proposed research model. Section 4 discusses the energy audit we conducted to measure energy consumption in computer labs while Section 5 presents our prototype for energy saving monitoring using fuzzy logic model. The last section, Section 6, concludes the paper and highlights future works for the research.

2. RESEARCH METHOD

In addressing the two (2) research questions, the research followed several phases, specifically, 1) literature review, 2) energy audit, and 3) model development.

2.1 Literature Review

A review and analysis of research works were carried out on publications related to Green ICT that were published from year 2001 to 2018. The purposes of this phase are:

1. To examine gaps in existing research related to Green ICT implementation;
2. To identify problems and formulate research questions;
3. To find out about Green ICT practices; and
4. To learn about ways of capturing and measuring computer energy consumption; and
5. To identify elements important in Energy Saving Monitoring System, and the techniques employed.

As a result of the review, a research model on Energy Saving Monitoring Using Fuzzy Logic incorporating energy monitoring parameters – Central Processing Unit (CPU), Graphics Processing Unit (GPU) and Memory – as well as consumption indicators was designed and proposed in Figure 1. Explanation of the model can be found in Section 3 – Proposed Model for Energy Saving Monitoring Using Fuzzy Logic.

2.2 Energy Audit

Energy audit phase was where we collected energy consumption data from desktop computers in computer labs. The computer labs used in this research are located in the Faculty of ICT of the researcher's university. The basic purpose of energy audit is to assess and measure the level of energy consumption of computers in computer labs by capturing the intervals of energy consumption data on a daily, weekly and monthly basis. However, in this research, readings of the energy data were captured in Kilowatt-hour (KWH) from each computer on a daily basis for a period of five (5) working days. Energy audit helps us to identify where energy is being wasted and how much energy has been consumed by each computer so that we can easily identify the energy indicators of low energy consumption, medium energy consumption and high energy consumption of the computers in the computer lab [Dudovskiy,2018].

In carrying out the energy audit, two different software were installed in 30 desktop computers in two (2) teaching computer labs. These desktops were equipped with Intel Core2 duo 1.88G CPU and 2048 MB memory, running Windows 7. We have used two software's for energy audit assessment.

1. Energy audit software helped us in getting to understand that how energy is used within the computer system and process and what are the reasons behind the energy wastage by computers.
2. Through energy audit technique, we have collected interval energy data based on our energy parameters which is CPU, GPU and Memory.

2.3 Model Development

The proposed model was then implemented using Microsoft Visual Studio simulator with C++ and C# programming languages to demonstrate how the fuzzy logic approach is applied for monitoring the energy consumption following the proposed indicators. The data sets collected during the energy audit were used to evaluate the consumption indicators by observing the changes in energy performance according to each parameter. In order to create a user-friendly and visually appealing interface, and to allow access to the prototype from the internet, ASP.NET web application framework with C#, J# and VB.net programming languages were used. The result of this stage is a web-based prototype for Energy Saving Monitoring Using Fuzzy Logic.

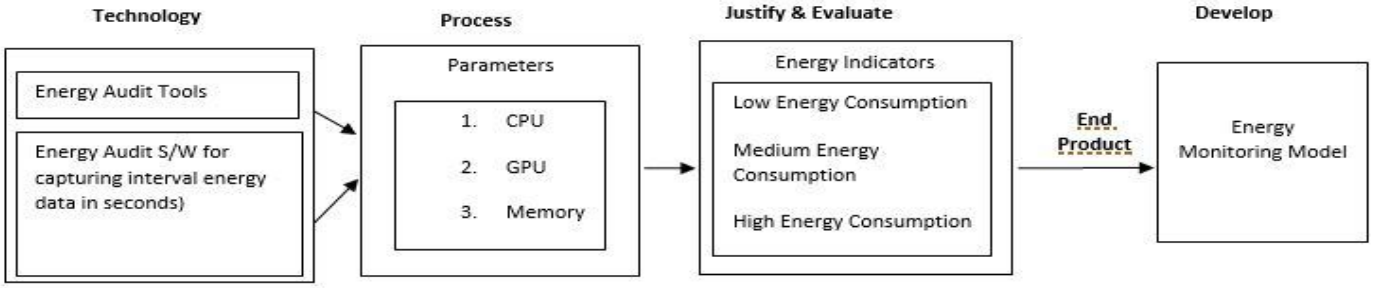

Figure 1: Proposed Energy Saving Monitoring Using Fuzzy Logic Model

3. PROPOSED MODEL FOR ENERGY SAVING MONITORING USING FUZZY LOGIC

This research proposed a research model and design for Energy Saving Monitoring, a system that monitors the energy consumption of computers according to three (3) parameters - computer Central Processing Unit (CPU), Graphics Processing Unit (GPU), and memory – employing the fuzzy logic approach to demonstrate the level of consumption. The following sub-sections briefly explains the elements in our proposed model.

3.1 Process Parameters

We have used three energy parameters which are as follows:
The three (3) energy parameters are:

1. Central Processing Unit (CPU),
2. Graphical Processing Unit (GPU)
3. Memory.

A programming software named as "Visual Studio" emulator to monitor the energy consumption by CPU, GPU, memory and desktop applications by observing the changes in energy performance based on each parameter.

3.2 Energy Consumption Indicators

We will evaluate our research findings in to three indicators which is as follows:

1. Low Energy Consumption (Minimum)
2. Normal Energy Consumption (Average)
3. High Energy Consumption (Maximum)

We will convert our collected data into useable charts and graphs. Therefore, we will use graphical representation so that we will categorize our data into minimum, average and high consumption, after that from the graphs and table we will able to identify the level of consumption based on the readings.

3.3 Fuzzy Logic

A fuzzy logic system (FLS) can be defined as the nonlinear mapping of an input data set to a scalar output data. A FLS consists of four main parts: fuzzifier, rules, inference engine, and defuzzifier. In a FLS, a rule base is constructed to control the output variable. A fuzzy rule is a simple IF-THEN rule with a condition and a conclusion [Timothy J. Ross**, 2010**]

The Fuzzy Logic is considered as the versatile method which we can used to predict electricity consumption. A review of literature highlights that the fuzzy logic approach is both sufficiently efficient and versatile to meet the energy expectation because of the non-linear relationships between the inputs (past load, past and predicted temperatures) and the output (predicted load).

The fuzzy logic method offers a new approach with a logic table composed of "If-Then" rules, such as "If temperature is low", then "electricity consumption is high". The fuzzy logic method appears to be a great way to predict electricity consumption, because human behavior can be considered as random, and at the same time, foreseeable [Timothy J. Ross**, 2010**].

The prediction system based on the fuzzy logic method is composed of the following steps:

1. The fuzzification used to convert the digital inputs into fuzzy inputs.
2. The fuzzy rules necessary to stem from a learning phase to get a better understanding of the users' habits.
3. The fuzzy inference which uses the table of rules to find the electricity consumption.
4. The defuzzification used to convert the fuzzy values into digital values.

4. ENERGY AUDIT

Energy audit defined a way to deal with energy wastage by improving overall performance of the computer by indicating the high consumption problem areas and we have get the clear view of energy consumption drawn by computer in KW values. Energy audit software provided the graphical representation into minimum, average and high consumption, after that from the graphs and table we able to identify the level of consumption based on the readings.

Table 1: Energy Audit Result

Month	Total Hours	Average (KW)	Maximum (KW)	Average (KW)	Minimum (KW)	Computer Total Energy Consumption (KW)
Jan 2018	192	231.7	523.6	523.6	161.4	44,491.4
Feb 2018	192	222.6	313.6	313.6	169.2	42,732.3
Mar 2018	216	274.2	608.6	608.6	166.8	59,216.3
Apr 2018	216	221.4	440.2	440.2	177.2	47,824.9

5. ENERGY SAVING MONITORING USING FUZZY LOGIC PROTOTYPE

We designed and developed a prototype for energy saving monitoring using Microsoft Visual Studio simulator with C++ and C# programming languages and ASP.NET web application framework. The model was based on Fuzzy Logic Inference System. The algorithm used pre-defined energy parameters which are CPU, GPU and RAM, and also calculated the overall desktop computer energy consumption. The fuzzy rule approach was applied to monitor and forecast

the real time energy consumption. The consumption was evaluated based on the following indicators:

1. Low Energy Consumption (Minimum)
2. Normal Energy Consumption (Average)
3. High Energy Consumption (Maximum)

5.1 Pseudocode

```
int
main(void)
{
   CFuzzyFunction *FuzzySet[3];

   FuzzySet[0] = new CTLowEnergy;
   FuzzySet[1] = new CTMediumEnergy;
   FuzzySet[2] = new CTHighEnergy;

   FuzzySet[0]->setInterval(-5,30);
   FuzzySet[0]->setMiddle(0,20);
   FuzzySet[0]->setType('r');
   FuzzySet[0]->setName("low_Energy_Consumption");

   FuzzySet[1]->setInterval(25,45);
   FuzzySet[1]->setMiddle(35,35);
   FuzzySet[1]->setType('t');
   FuzzySet[1]->setName("Medium_Energy_Consumption")
;
   FuzzySet[2]->setInterval(40,75);
   FuzzySet[2]->setMiddle(50,70);
   FuzzySet[2]->setType('S');
   FuzzySet[2]->setName("High_Energy_Consumption");

   double dValue;
   do
   {
    cout<<"\nImput the value->"; cin>>dValue;

    if(dValue<cdLowEnergy) continue;
    if(dValue<cdMinimumEnergy) continue;
    if(dValue>cdMaximumEnergy) continue;

    for(int i=0; i<3; i++)
    {
      cout<<"\nThe dot="<<dValue<<endl;
      if(FuzzySet[i]->isDotInInterval(dValue))
         cout<<"In the interval";
      else
         cout<<"interval";
      cout<<endl;

       cout<<"The name of function is"<<endl;
      FuzzySet[i]->getName();
      cout<<"and the membership is=";

      cout<<FuzzySet[i]->getValue(dValue);
    }
   }
   while(true);

   return EXIT_SUCCESS;
}.
```

The dataset from the energy audit were processed above the algorithm pseudocode. The prototype would indicate the consumption level and allow us to identify how much energy had been wasted at a particular time interval and the reason behind the energy wastage.

6. ENERGY MONITORING USER INTERFACE

In computing lab, when a lab user wants to see the energy consumption monitoring, first of all student should need to register and then web interface shows the password login screen page as shown in figure 1.

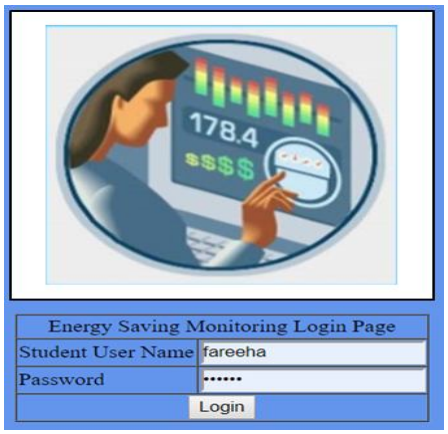

Figure 2: Login Screen

After the user enter correct username and password, the interface established the connection with the database Microsoft SQL Server 2009 that brings the live data values and energy parameters started to show on a dashboard with 100 milliseconds interval. Energy parameters which is CPU, RAM, GPU and computer total energy consumption of the energy monitoring model has been display the live power values of the model can be seen on dashboard interface. Students then monitors the energy parameters that continuously change both graphically and digitally as shown in figure 2:

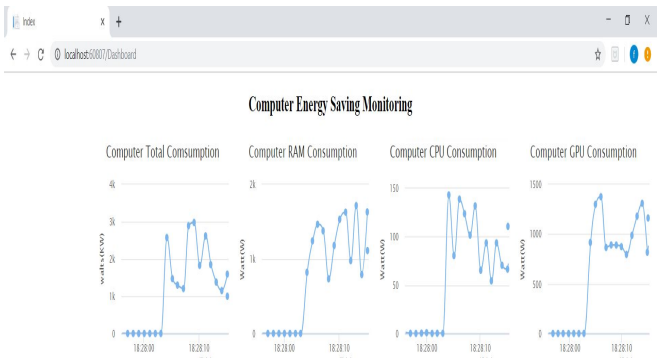

Figure 3: Real Time Energy saving Monitoring Dashboard

7. CONCLUSION

This research paper mainly focus on Green ICT and how we can improve and reduce energy consumption in Educational Institution by the help of Green ICT. The research paper has concerted on the determination of Green ICT implementation in Computing Labs of Education sector. Our research based on the monitoring and saving the energy that is consumed by large number of computer systems in computing Lab. Moreover, detailed synopsis on research model and energy assessment tool for the collection of energy dataset has been discussed. For this purpose, we have created a web interface model which is completely based on Green ICT Energy Saving Monitoring System.

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