FAULTY SENSOR DETECTION MECHANISM USING MULTI-VARIATE SENSORS IN IoT

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DEDICATION

I would like to dedicate this thesis to

“**ALMIGHTY**”

(Who gave me strength, knowledge, patience, and wisdom)

To my beloved mother and father

(Their love, devotion, cares, sacrifices, and prayers helped me to achieve this dream)

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ABSTRACT

Internet of Thing (IoT) becoming increasingly popular over the past few years because it can be implemented in many applications such as smart cities, smart agriculture, smart health, smart home and etc. IoT devices are equipped with sensors such as temperature, humidity, pulse sensor, smoke and etc., offer many types of services for these applications. IoT devices are lightweight and have limited computational capabilities often exposed to harsh environments, which can cause failure on the IoT devices. The failure on the IoT devices is caused due to limited battery life, hardware failure or human mistakes. Sensor faults can be categorized under one type of hardware failure, such as sensor burn, reduced sensor sensitivity and malfunctioned sensors. Any faulty on the IoT devices can create a problem on the overall operation of the IoT system. Thus, it is very important to manage these IoT devices efficiency. Traditional ways in the management of IoT devices, require a maintenance officer to check each device every day. Because of this, we proposed two methods for Faulty Sensor Detection and Identification mechanism based on multi-variate sensors for Smart Parking System and smart agriculture. The first proposed method is a logical mechanism uses three different types of. The second method proposed is based on a correlation method that can exploit the multi-variable sensor which existing in IoT application. The proposed methods can provide information when one sensor becomes damaged. The accuracy of the algorithm for data correlation may be changing depending on the application that wants to detect the faulty sensor in the system and according to how many data that income to the microcontroller per minute and how many data should take to calculate the correlation coefficient. Therefore, for the smart agriculture which it's used in this project, the period is adjusted to give a good diagnose for the sensor as soon as possible.

ABSTRAK

Internet Thing (IoT) menjadi semakin popular sejak beberapa tahun yang lalu kerana ia boleh digunakan dalam banyak aplikasi seperti bandar pintar, pertanian pintar, kesihatan pintar, rumah pintar dan sebagainya. Peranti IoT dilengkapi dengan sensor seperti suhu, kelembapan, sensor denyut, asap dan sebagainya, menawarkan banyak jenis perkhidmatan untuk aplikasi ini. Peranti IoT adalah ringan dan mempunyai keupayaan pengkomputeran terhad yang sering terdedah kepada persekitaran tindak menentu, yang boleh menyebabkan kegagalan pada peranti IoT. Kegagalan pada peranti IoT disebabkan oleh hayat bateri yang terhad, kegagalan perkakasan atau kesilapan manusia. Kegagalan sensor boleh dikategorikan berdasarkan jenis kegagalan perkakasan, seperti pembakaran sensor, kepekaan sensor berkurang dan sensor yang tidak berfungsi. Mana-mana peranti IoT yang rosak boleh menimbulkan masalah kepada keseluruhan sistem IoT. Oleh itu, sangat penting untuk menguruskan kecekapan peranti IoT ini. Cara tradisional pengurusan peranti IoT, memerlukan pegawai penyelenggaraan untuk memeriksa setiap peranti setiap hari. Oleh kerana itu, kami mencadangkan dua kaedah untuk Pengesanan Sensor dan Pengenalpastian Sensor yang rosak berdasarkan multi-variasi sensor untuk sistem tempat letak kereta dan pertanian pintar. Kaedah pertama yang dicadangkan adalah mekanisme logik menggunakan tiga jenis sensor. Kaedah kedua yang dicadangkan adalah berdasarkan kepada kaedah korelasi di antara sensor multi-variasi yang terdapat dalam aplikasi IoT. Kaedah yang dicadangkan boleh memberikan maklumat apabila satu sensor menjadi rosak. Ketepatan algoritma untuk korelasi data mungkin berubah bergantung kepada aplikasi bagi mengesan sensor yang rosak dalam sistem dan mengikut berapa banyak data yang diperolehi oleh mikrokontroler per minit dan berapa banyak data yang perlu diambil untuk mengira pekali korelasi. Oleh itu, untuk pertanian pintar yang digunakan dalam projek ini, tempoh diselaraskan untuk memberikan diagnosis yang baik untuk sensor secepat mungkin.

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LIST OF SYMBOLS AND ABBREVIATIONS

x_i	-	Measured data for sensor 1
y_i	-	Measured data for sensor 2
$\overline{x}$	-	Averages values
$\overline{y}$	-	Averages values
SS_{XX}	-	Sum of squares for variable *x*
SS_{YY}	-	Sum of squares for variable *y*
SS_{xy}	-	Sum of the cross Products
3G	-	Third Generation of mobile telecommunications
AMR	-	Automated Meter Reading
ANN	-	Artificial Neural Network
CCA	-	Canonical Correlation Analysis
cm	-	Centimeter
CO_2	-	Carbon Dioxide
CPU	-	Central Processing Unit
DC	-	Direct Current
DICE	-	Detect and Identify with Context Extraction
DWT	-	Discrete Wavelet Transform
EHR	-	Electronic Health Record
FCE	-	Forward Error Correction
GPRS	-	General Packet Radio Services
GPS	-	Global Positioning System
I	-	Current
ICT	-	Information and Communication Technology
IoT	-	Internet of Things
IR	-	Infrared Sensors
LED	-	Light-emitting diode
m	-	Mile

MRF	-	Markov Random Field
Ms	-	Moisture Sensor
PCA	-	Principal Component Analysis
QoS	-	Quality of service
r	-	Correlation Confections
RFID	-	Radio Frequency Identification
TPM	-	Trusted Platform Module
Ts	-	Temperature Sensor
V	-	Voltage
WiMAX	-	Worldwide Interoperability for Microwave Access
WLAN	-	Wireless a Local Area Network
Ws	-	Water Sensor
WSN	-	Wireless Sensor Network

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

As it is known before 20 years the internet started to grow and has been popular, today it becomes ubiquitous, has reached to every corner of the world and it plays an affecting part in human life. Nowadays, the internet of thing IoT is entering in our life, where an enormous and variety of devices and equipment will turn out to connect to the internet. The term of "internet of thing" has defined by many authors in a different way, the author [1] define as a reciprocal action between the physical world and the digital world by using many sensors devices and actuators. In common word, IoT is a new kind of connection between the appliances and the network which can through achieve a collaborative task that required a high grade of precision and intelligence and an example for that is the smart city [2].

The concept of a smart city is to merge information and communication technology ICT, and various physical devices connected to the IoT network. Therefore, it optimizes the efficiency of city work, services, increasing population density, mitigate the unexpected challenges and provide a better life for the citizens and visitors[3]. Thus, the word "smart" becomes a cover for ingenious technology which has a degree of artificial intelligence. The main feature of this smart application is the ability to interact with the surrounding environment and get information about the specific area and response accordingly [4]. Therefore, ICT information and communication technology applications such as actuators, sensors and any other devices are necessary means for realizing smart application in any domain [5]. The smart city consists of various smart applications or makes device smart in the city, for example, smart agriculture, smart parking, smart house, monitoring the climate environment, smart building, smart traffic and transportation systems and etc. [6].

In smart parking is an important application in modern cities, due to increase in a number of vehicles on the road, people are going to face problems of parking spaces to park their vehicle especially, in most of the big cities [7]. Drivers spend more time finding and searching for empty parking spaces which causes traffic congestion, consume more fuel, create noise, air pollution and frustration faced by the car drivers [8]. In the world, it is about 30% of vehicles in the city centre of metropolitan cities take about an average of 7.8 min searching for empty parking spaces [9]. The annual waste of resource in finding for parking spaces is 47,000 gallons of gasoline consumption, 95,000 hours of time (which about 11 years) and production of 730 tons of CO_2 [10]. In addition, it has been reported that the annual damage to the economy of Schwabing (a district in Germany) to be worth 20 million Euros because of wasting resources in searching parking space [11].

Thus researchers are recently turned to applying technologies for the management of parking area by designing and implementation of smart parking that helps and allows vehicle drivers to effectively find the free parking places. An effective solution to this service can be provided by many new technologies. Smart parking, allowing drivers to access parking information through their smartphones [12]. So that will help to maximize the utilization of spatial parking resource of a city, to reduce unnecessary energy consumption and CO2 emission of wandering cars, to improve drivers' satisfaction, and to alleviate traffic congestion due to parking guidance itself [13].

In the future, the demand for the smart parking system will increase because of the rapid growth in the automotive industries. Many cities have been launching their smart parking projects and apps, yet still very few drivers can really benefit from them. That is because this technology still has to be improved from different perspectives: the robustness of sensor devices, the anomaly of the sensor, the data of the sensor is not correct, the stability and timelines of sensor networks, and the quality and agility of urban service.

In general, The IoT devices comprise transceivers, microcontroller, sensors, and actuators. As a result, the IoT is a combination of several technologies, not a single one. Tiny networked sensors are used in various domains, such as smart parking, precision agriculture, logistics, and factory automation. Devices with sensors have identifying, sensing, networking, and processing capacities. The devices generate unprecedented vast data by giving each device a unique identifier, which leads to new possibilities for business [14]. IoT is becoming increasingly popular and has received growing attention over the past few years. Using sensors and actuators, these IoT applications offer convenient services to the User. However, IoT devices are lightweight devices exposed to harsh environments and have limited computational capabilities, which cause frequent device faults [13].

Sensors, in general, suffer from many types of faults due to hardware failure, limited battery life, or human mistakes [13]. These sensor faults in IoT environments are particularly more critical and may lead to terrible consequences. Thus, preserving the integrity of the data is an essential requirement in IoT environments [12].

Fault detection is an important process for industry monitoring IoT, but it is a difficult and complex task because there are many factors that influence data and could cause faults. And faults are application and sensor type dependent [14]. Sensors in monitoring IoT have two features. Big: thousands of sensors on different devices are working together, Multiples: many physical quantities are needed to determine the production status [15].

1.2 Problem Statement

IoT such as Smart Cities and etc. are becoming increasingly popular and have received growing attention over the past few years [12]. Using sensors, these IoT applications offer convenient services to users. However, IoT devices are lightweight devices exposed to harsh environments and have limited computational capabilities, which cause frequent device failure [13], [16]. For example in smart parking, if the sensor of one parking lot in the huge parking which consist of thousand parking lot s failed or breakdown to give the correct information about the state of the parking lot will cause a problem. Nowadays, the sensor is cheaper so can make a model consist of three sensors. Another example in agriculture if the water sensor doesn't read correctly will make the soil drier.

The previous solutions to detect faulty sensors in an IoT may be are not suitable for IoT. Existing solutions require user intervention. They require users to annotate each activity during the training period or provide additional information such as the sensor location. User intervention not only makes the system less usable but also increases the chances of error due to user mistakes [13], [17]. Other than this, the time to detect a faulty sensor is too long for some of the existing works. When the detection time takes too much time, the failure may cause serious problems to the system [18].

Because of this, we proposed a Faulty Sensor Detection and Identification mechanism based on multi-variate sensors. The proposed mechanism can provide information on which sensors are damaged. Dependent on this mechanism we have two methods. The first method is proposed because it cannot found a certain way to detect the faulty sensor in the parking lot in the previous works. The second method that proposed applied to the smart agriculture based on correlation method.

1.3 Objectives of the Study

The objective of this project.

(i) To propose a Faulty Sensor Detection Mechanism using multivariate sensors in IoT.

(ii) To design and develop the proposed faulty sensor detection mechanism using multivariate sensors in smart parking and smart agriculture.

(iii) To analyze the performance of the proposed faulty sensor detection mechanism in the constructed smart parking and smart agriculture system.

1.4 Scope of Project

The scopes of the fault detection mechanism are.

(i) Development of a prototype of smart parking system to detect the availability of parking lot, by using three type sensors IR sensor, ultrasonic sensor and Hall-Effect sensor.

(ii) Development of a prototype of smart agriculture system to monitor the soil information by using three type sensors temperature sensor, moisture sensor and water sensor.

(iii) Design and development code for a faulty sensor detection system using C++ Arduino IDE.

(iv) To evaluate the system, by implemented a smart parking and smart agriculture testbed that is built from a different type of sensors to emulation of the real world environment.

(v) Analyse results from the experiment to determine the performance of the developed faulty sensor detection mechanism according to time and accuracy.

1.5 Project Report Outline

In **chapter 1**, the background of faulty detection discussed and problem statement is identified. This is followed by the project objectives and scope of the project. In **chapter 2**, the literature view discusses the comprehensive of the published works on a topic of faulty detection in IoT by accredited scholars and researchers. It is directly related to the thesis, providing information on theories, models, materials and techniques used in the research. And hardware in the methodology is presented in **chapter 3**. This covers the project research framework and steps in carrying out the project work. The block diagram of the system design. In **chapter 4**, the results of the hardware are presented and discussed. Also in this chapter explains the data analysis techniques through written text, Figures, tables, and/or other means. Finally, **chapter 5** concludes the report are discussed.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

This chapter is briefly a review regarding a theoretical concept about the internet of thing (IoT) and fault detection in a reading of the sensor, to the understanding of every aspect of this project. Furthermore, the most part is the description of the related work previous research about management and handling fault detection. The brief explanation will be explained in the following sub-topic.

2.2 Internet of thing (IoT)

Internet of thing the abbreviation is IoT is the technology that authorizes the devices that owning the internet (smart devices) to link each device by another through the internet to send and receive the information or the data with each other [19] and also by using the appropriate remote device such as computers, mobile or etc. can be tracked these devices, monitoring and control through internet. On extends the use of the Internet provided the communication, and thus inter-network of the devices and ‘things’ or physical objects [20].

The internet defines as a huge global network of connecting many of servers, tablets, mobiles and computers by using a connecting system and global protocols. Thus, the internet enables users to exchange information between each other or communicating. The term 'thing' refers to describe the physical object, an idea or action and activity or situation, when defining it in a simple way or not precise [20].

Generally, the IoT consist of the shared network between the devices and physical objects, these objects can collect the data from remote locations and connect to the manager units, organizing the data and by using the processor can analyze the data and produce the services. This sort of data empowers the clients to get precise information and uncover the phenomena which improve the decision making the procedure a great deal. [21]. as well, it makes the thing become smart and conducts alive through computing, communication and sensing via a small device such as (home devices, wearable alarm clock watch). the smart device consists of various kinds of a sensor to sense the surrounding physical phenomena and a particular type of device known as an actuator to control with the environment [19]. The sensed data from the sensor will be transmitted with the assist of the gateway of the IoT to the cloud system to process the data, analytics it and stored it.

The IoT can be explained in simple terms in the form of the equation:

"Physical Object + Controller, Sensor and Actuators + Internet = Internet of Things" [20].

The IoT has the main advantage which is to confirm the communication between any users to anything at any time.

2.3 Internet of thing system blocks

IoT system consists of essential parts to achieve the tasks and to simplify various utilities to the IoT system such as a microcontroller, sensing actuator and communication [22]. Figure 2.1. Illustrates Architecture and fundamental blocks for IoT.

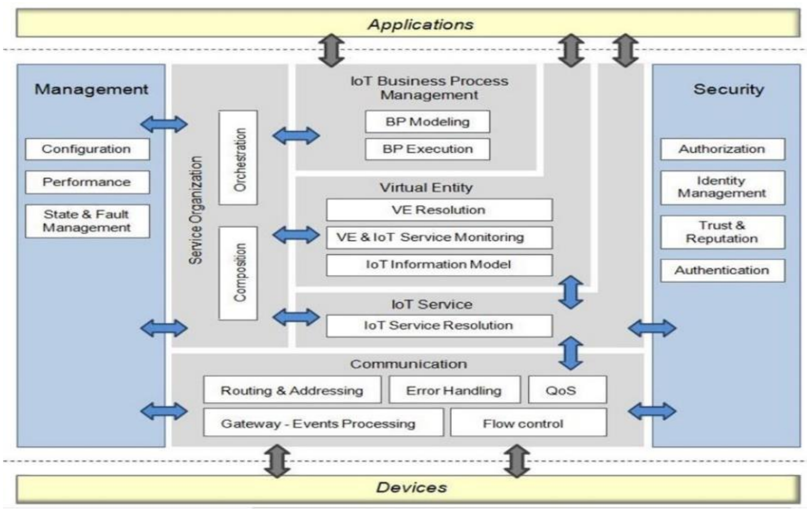

Figure 2.1: IoT- Architecture, Functional view [23]

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