SENSOR PLACEMENT OPTIMIZATION FOR MULTIPLE FAULT DETECTION USING BAYESIAN APPROACH

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This project report is especially dedicated to
my dearly beloved father
for his love, patience and support .
Thank you for everything.

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ABSTRACT

Monitoring, diagnosis and prognosis in a complex system required multiple and different type of sensors to extract data form their structures. Sensors measure physical quantity of parameters of various levels of the system for preventing faults of a system. Uncertainties inherent in sensors cause uncertainty issue in data sets. Data extraction of sensors simultaneously brings with overlapping issue in the system. Whereas, current methods are considered that there are non-overlapping in the system or uncertainties of sensors are ignored. However, reducing cost or physical and technological limitations cause to constraint the number of sensors in the systems. The right placement of sensors affects on the reliability and safety of the system. This dissertation presents an application of Bayesian approach on sensor placement optimization that covers overlapping and uncertainties issues. It also recommends the best possibility placement combination of sensors in a system. The Bayesian Network methodology is introduced with likelihood function for on-demand systems. The proposed algorithm generates evidence sets on-demand for overlapping and uncertainty data. The algorithm calculate information matrix for various possible sensor placement that the most expected information gain show the best location of sensors. This approach applies on car engine that has various faults in the performance of engine with the limited number of sensors. Finally, algorithm presents the best possible placement of sensor

ABSTRAK

Pemantauan, diagnosis dan prognosis dalam sistem yang kompleks memerlukan pelbagai jenis sensor untuk mengeluarkan data untuk membentuk struktur mereka. Sensor mengukur kuantiti fizikal bagi parameter digunakan di setiap peringkat sistem untuk mencegah kerosakan sistem. Ketidakpastian yang wujud dalam sensor menyebabkan isu percanggahan dalam set data. Pengekstrakan data sensor secara serentak dengan membawa isu bertindih dalam sistem. Namun, kaedah semasa menganggap bahawa tiada pertindihan berlaku dalam sistem atau ketidakpastian sensor diabaikan. Walaubagaimanapun, mengurangkan kos atau fizikal dan teknologi menyebabkan kekangan bilangan sensor dalam sistem. Lokasi yang tepat bagi kesan sensor pada kebolehpercayaan dan keselamatan sistem. Disertasi ini membentangkan tentang aplikasi Bayesian terhadap keadah sensor secara optimum yang meliputi bertindih dan isu-isu yang tidak menentu. Ia juga mencadangkan kombinasi terbaik bagi penempatan sensor dalam sistem. Kaedah rangkaian Bayesian diperkenalkan dengan fungsi kemungkinan untuk sistem di atas permintaan. Algoritma yang dicadangkan memberikan bukti di atas permintaan untuk data bertindih dan tidak menentu. Algoritma akan mengira maklumat matriks bagi pelbagai lokasi sensor yang mungkin mendapatkan maklumat yang memberikan lokasi terbaik sensor. Pendekatan ini digunakan pada enjin kereta yang mempunyai pelbagai kerosakan dalam prestasi enjin dengan bilangan yang terhad sensor. Akhir sekali, algoritma membenikan lokasi yang terbaik bagi sensor.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

BN	-	Bayesian network
CSV	-	Components State Vector (Input)
SIV	-	Sensor Information Vectors (Output)
BSP	-	Bayesian sensor placement
SPO	-	Sensor placement optimization
UOI	-	Unknown of interest
CPT	-.	Conditional probability table

LIST OF SYMBOLS

I	-	Number of input
J	-	Number of data
X	-	State of data
N	-	Number of state
CSV	-	Components State Vector (Input)
SIV	-	Sensor Information Vectors (Output)
S	-	Sensor
U	-	Information metric
Ui	-	Number of Information metric
p1	-	Probability of first Input
p2	-	Probability of second Input
p3	-	Probability of third Input
θ	-	Unknown of interest
σ_p^2	-	Variance of probability
Prev(i)	-	Probability of number of event evidence set

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CHAPTER 1

INTRODUCTION

1.1 Background of Study

Monitoring, diagnosis and prognosis in a complex system are required multiple and different sensors to extract reliability information of a system. While there are various possibility places of the system for multiple and various type sensors, Reliability system can be obtained through finding the best locations of sensors. For this reason, sensor placement optimization is a field of increasing scientific interest.

Review of current methods of sensor placement optimization includes Hart et al [1] and Vichers et al [2] focused on most of the previous of studies work on possible physical location of sensors. The popular method is called Bayesian approaches [3], [4] and other approaches include multi-objective optimization [1] genetic algorithm [5], statistical methods [2], [6] and neural networks.

It is almost a common practice to assume that all data sets inferred by multiple sensors in one system are independent. Likewise, in most cases, the uncertainties associated with sensors are ignored that is assumed insignificant. The presented probability functions might be difficult in most cases where the uncertainties of sensors have been ignored, due to simplify the analysis [6].

Almost methods focus on sensors placement, damage detection algorithms, structural reliability, and deterministic sensor placement optimization (SPO) algorithms [7]. From literature, Bayesian decision method utilities to formalize an optimization problem [4], [8].

Most of Bayesian methodology's application to optimize sensor placement are based on updating the state of knowledge of operation of environment by sensory data [2]. In others, Bayesian approaches are focused on smarter strategy of sensors based on decision theoretical approaches [9]. In regarding, in many systems and application due to limitation of physical or technology sensor, it may not be able to locate the sensor in needed placement.

Increase in system complexity dramatically increases the probability of failure in a system. That requires obtaining sensor placements scenario that maximizes the diagnosable performance of a given sensor set while accounting for the constraints on the number and locations of sensors, and also inaccessible areas of sensors of the system. A practical method to detect fault localization in a complex system involves synthesizing fault signature information directly, from knowledge of structure and sensors on the various levels of system [10]. Therefore, the systematic approach will be developed in this study using Bayesian network method.

1.2 Problem Statement

The level of performance in sensor placement optimization methods exhibited is insufficient for today world applications. The most of the current methods are still plagued with limitations and problems such as overlapping, computational complexity and uncertainties associated with sensors [4], [11], [12].

Uncertainties can cause impracticalities to obtain reliability information while decrease reliability of results [11].

Most of the current methods assume that the data sets are non-overlapping while a single sensor cannot make reliability information in every sample. Complex systems required to extract information simultaneously from several sensors [12].
Increase probability of failures in complex systems is deniable. In regarding, in many systems and applications in due to limitation of physical or technology of sensors, it may not be able to locate the sensor in needed placement. The approach to detect most failure with a limited number of sensors is binding [10].

1.3 Objectives

The objective of this research is to develop a methodology for sensor placement optimization in logical placement of sensors for multiple fault detection system. The Bayesian methodology developed for placing sensors throughout a system that aimed at finding the best sensor placement scenario under uncertainty and overlapping data. It occurs during extracting the most amount of expected information from the measured data. This involves three parts; first part is to develop Bayesian network approach for sensor placement optimization for multiple fault detection. Then, an algorithm will be developed for sensor placement optimization based on Bayesian network that determined best possible location of sensors. Finally, this algorithm will be applied on performance of the car engine.

1.4 Scope

This case study presents Bayesian sensor placement on performance of the car engine. Discovering of faults of the car engine effect on the performance of the car engine operates. Two of the operations of the car engine that effect on improvement of performance of engine noticeably are protection of engine and performance of fuel and ignition called performance of combustion. Figure 1.1 presents failures of the system and failure mechanism of the car engine.

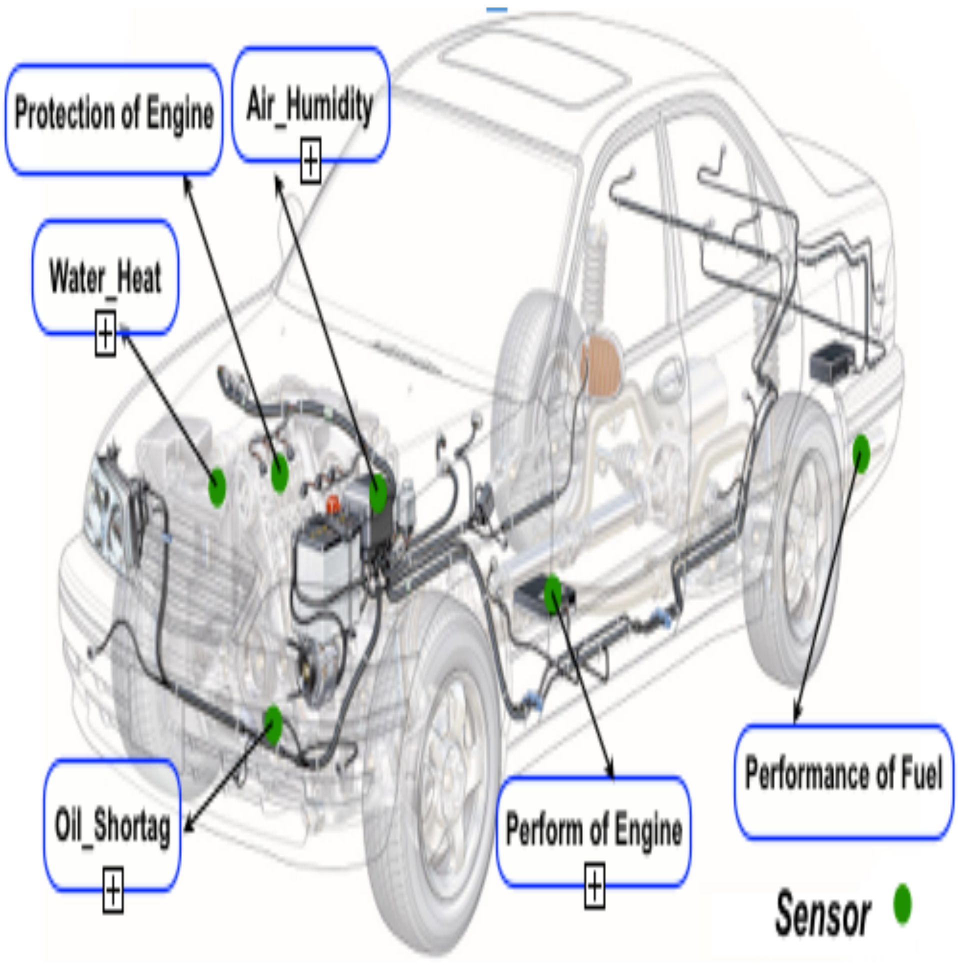

Figure 1.1: Failure of the system and mechanism of the car engine with locations of sensors.

Theses failures happen as follows:

Oil_Shortage failure: If Oil level of engine takes under desired value (I.e. under 50mm), shortage failure will happen.

Water_Heat failure: If water temperature of radiator increases more than desired value (I.e. more than 90 centigrade), water heat failure will happen.

Humidity failure: If Humidity of air increases more than determined value (I.e. more than 200), Humidity failure will happen.

Protection of Engine failure: If Oil_Shortgae and Water_Heat failures happen, protection failure will happen.

Performance of Fuel failure: If Water_Heat and Humidity failures happen, Performance failure will happen.

Performance of Engine failure: If Protection of Engine or Performance of Fuel failures happen, Performance of Engine will happen.

The purpose of this project can be divided into three main steps; First step develops a Bayesian network algorithm for sensor placement optimization. Then, design a Bayesian network for the car engine. Finally, apply the Bayesian sensor placement algorithm as follows:

(1) A set of candidate sensor placement scenarios.

(2) A measure of assessing the expected values associated with each sensor pla4cement scenario, called " information metric ".

(3) A comparison of the information metric values to determine which placement scenario yields the highest expected information metric value.

Various sets of possible location sensors based on the number of sensors will be introduced in Bayesian network of the car engine. Last, measure expected values of the most expected information, which shows the best candidate sensor placement for the car engine.

1.5 Significant of study

This research finds a general method for optimum sensor placement based on logical or functional placement. The Bayesian methodology is developed for possible location of the sensors throughout a system to obtain an optimum sensor placement. It is arisen by extracting the most amount of reliability information from the measured data. This approach will take into account all uncertainty and overlapping within the probabilistic framework and combines the different sources of information by using the rules of probability.

The developed Bayesian sensor placement (BSP) algorithm utilizes Bayesian network for modeling, updating and reasoning the causal relationship and overlapping as well as for updating the state of knowledge for unknowns of interest (inputs).

The results of this study contribute to decrease the number of sensors in due of limitation of physical and technological of sensors in the system. It also extends the using of Bayesian network based on logical or functional struggles in a relevant area.

1.6 Outline of thesis

This thesis is organized into five chapters. Their contents are outlined as follows:

Chapter 2 provides a literature review of sensor placement optimization methods and describe the limitations and gaps are in current methods. Also, discusses about two of the major problem in sensor placement optimization in section 2.4.1 and 2.4.2 about data fusion and overlapping in data sets. Finally, in section 2.5 present the briefings of current methods and limitations of sensor placement optimization.

Chapter 3 discusses the Bayesian network modeling. It also explains how applying this method to the system that contains the overview of the system and the algorithm of Bayesian network.

Chapter 4 describes the procedure of Bayesian network in the Engine of the car. The algorithm applies on the system with assumptions of three sensors network and two sensors network, and determines the best scenario of possible locations of sensors. Finally, the algorithm repeats on various numbers of sensors and gets the conclusion about location of sensors in various layers.

Chapter 5 concludes the work undertaken by summarizing of results this study. It also provides several suggestions for future work.

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