INTELLIGENT NEURAL NETWORK FOR MODELLING AND CONTROL OF AN AUTOMOTIVE AIR CONDITIONING SYSTEM

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ABSTRACT

Air Conditioning (AC) System in the automotive is to provide the thermal comfort during the driving journey. Thermalcomfort plays an essential role in nowadays sophisticated modern vehicle.Monitoring and automatic control of air conditioning systems are important to ensure drive comfort are met during the journey, therefore, this research aims to study the Modeling of AC System of Automotive by using Intelligent Neural Network to achieve the desired cooling comfort. Intelligent Neural Network by neuro controller will be introduced to the automotive for the vehicle to control the air conditioning system and the goalof this project is to improve and maintain the occupant comfort level within car cabin with introduces various disturbances and at the same time achieve as an energy efficient vehicle.The objective of the project is to design a self-tuning neuro controller for the variable speed compressor of the Automotive Air Conditioning (AAC) system within Matlab-SIMULINK environment. In this research, Recursive Least Squares (RLS) system identification techniques were used to estimate the non-linear or dynamic model of the AAC system. The input and output data used to estimate the dynamic model of AAC system were obtained experimentally in the lab. The validity of the models was investigated based on mean square error (MSE) and correlation tests. From the parameter optimization and simulation, the optimum neural network structure of AAC system was obtained. Three types of controllers, namely PID, NARMA-L2 and NARMA-L2-PID were proposed in this research. The overall comparison of three conventional and neuro controllers was presented and discussed in this research. From the simulation results, it can be seen that the proposed hybrid NARMA-L2-PID controller has performed the best amongst all in term of the time response and the effective performance of the system as compared to the heuristic tuned- PID and NARMA L2 controllers.

ABSTRAK

Sistem penyaman udara (AC) dalam automotif adalah penting untuk memberi keselesaan dalam kenderaan. Pemantauan dan kawalan automatik sistem penyaman udara adalah penting untuk memastikan keselesaan memandu, oleh itu, kajian ini bertujuan untuk mengkaji pemodelan sistem AC automotif dengan menggunakan kaedah pengenalan sistem rangkaian neural pintar untuk mencapai keselesaan penyejukan yang dikehendaki. Rangkaian neural pintar oleh pengawal neuro akan diperkenalkan untuk mengawal sistem penyaman udara automotif. Matlamat projek ini adalah untuk meningkatkan dan mengekalkan tahap keselesaan penumpang dalam kabin kereta walaupun pelbagai gangguan diperkenalkan dan pada masa yang sama mengekalkan tahap kecekapan tenaga yang baik. Objektif projek ini adalah untuk merekabentuk pengawal neuro talaan sendiri untuk pemampat kelajuan yang berubah-ubah daripada sistem penyaman udara automotif (AAC) dalam persekitaran Matlab-SIMULINK. Dalam kajian ini, teknik pengenalan Pendaraban Kuasa Dua Terendah (RLS) telah digunakan untuk menganggar model bukan linear sistem ini. Data masukan dan keluaran yang digunakan untuk menganggarkan model dinamik sistem AAC telah diperolehi secara eksperimen di dalam makmal. Kesahihan model telah dikaji berdasarkan Min Ralat Kuasa Dua (MSE) dan ujian korelasi. Dari pengoptimuman parameter dan simulasi, struktur rangkaian neural yang optimum sistem AAC telah diperolehi. Tiga jenis pengawal, iaitu PID, NARMA-L2 dan NARMA-L2-PID telah dicadangkan dalam kajian ini. Perbandingan ketiga-tiga pengawal telah dibentangkan dan dibincangkan dalam kajian ini. Dari keputusan kajian mendapati sistem pengawal hibrid NARMA-L2-PID yang dicadangkan telah menunjukkan prestasi yang baik dengan memberi respons terbaik dan sistem prestasi yang berkesan berbanding dengan penalaan heuristik pengawal PID dan pengawal NARMA-L2.

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LIST OF ABBREVIATIONS

AAC	- Automotive Air Conditioning
AC	- Air Conditioning
AI	- Artificial Intelligent
ANN	- Artificial Neural Networks
ARX	- autoregressive with exogenous
ASHRAE	- American Society of Heating, Refrigerating and Air Conditioning Engineers
COP	- Coefficient of Performance
DAU	- Data Acquisition Unit
FCC	- Fixed Capacity Compressor
LS	- Least Squares
MAE	- Mean Absolute Error
MLPNN	- Multilayer Perceptron Neural Network
MSE	- Mean Squared Error
NARMA	- Non Linear Auto Regressive Moving Average
PDP	- Parallel Distributed Processing
PG	- Percent Good
PI	- Proportional Integral
PID	- Proportional Integral Derivative
RLS	- Recursive Least Squares
RMSE	- Root Mean Squared Error
SI	- System Identification
SISO	- Single-Input-Single-Output
VAV	- Variable Air Volume
VCC	- Variable Capacity Compressor

LIST OF SYMBOLS

e	- Error
n	- Number of data
N	- Speed of the compressor
u (t)	- System input at time t
w	- Weight vector of a neuron
x	- Output vector of a neuron
y (t)	- Actual system output at time t
$\dot{W}$	- Compressor Power
$\hat{y}$	- Final output of neuron in output layer
$\hat{y}^*$	- Output of neuron in output layer
$\dot{Q}_L$	- Heat removal from the refrigerated space,
$T_{a,ievap}$	- Air temperature at the evaporator inlet
$T_{a,i,cond}$	- Air temperature at the condener inlet
$V_{a,ievap}$	- Air velocity the evaporator inlet

CHAPTER 1

INTRODUCTION

1.1 Introduction

Whilst Automotive Air Conditioning (AAC) systems improve thermal comfortableness in vehicles, they also compensate the energy consumption of vehicles. Achieving thermal comfort in an energy-efficient manner is a difficult task which requiring good coordination between engine and the air conditioning system. The purpose of controlling a compressor speed is to track that a desired temperature within the vehicle cabin to considerable achieves energy reductions. The controlled object in Heating, Ventilating and Air-Conditioning (HVAC) system has large inertia, pure lag and nonlinear characteristic. The uncertain disturbance factors affect the control performance (Spooner and Passino, 1999). The report is to presents an intelligent neuro network to modeling and control of an automotive air conditioning system to coordinated energy management to reduce the energy consumption of the vehicle air conditioning system with various disturbances while maintaining the thermal comfortableness. The controller will coordinates, synchronizes and manages the operation of compressor speed to provide the desired comfort temperature, under the various disturbances such as ambient and vehicle conditions, the energy consumption can then be optimized. Two simulations of the two different neuro controllers are performed to demonstrate its energy saving capacity.

AAC imposes an extra load onto a vehicle's engine by increasing its fuel consumption, which leads to greater exhaust emissions. There are lacks of comprehensive study to quantify the effect of vehicle air conditioning system compressor decoupled with engine where there are independent compressor powered

by battery. Therefore, this study investigates what optimum controller to control operation of AAC with independent inverter compressor to maintain desired temperature of the AC system with introduces various disturbances.

1.2 Research Background

The common AAC systems consist of a compressor powered by engine and activated by an electrical clutch. The AC system always imposes an extra load to the vehicle's engine and cause increasing the vehicle fuel consumption and emissions. Energy management control of the vehicle air conditioning is a nonlinear dynamic system, influenced by uncertain disturbances. In addition, the vehicle energy management control system interacts with different complex systems, such as engine, air conditioning system, environment, and driver, to deliver fuel consumption improvements. Therefore, energy management control of vehicle AC system decoupled with vehicle engine with battery drive through an intelligent controller is demanding for the sustainable automotive industry.

1.3 Research Objectives

(i) To develop neural model for dynamic modeling of an Automotive Air Conditioning System under various disturbances.

(ii) To design Neuro controller of an Automotive Air Conditioning System to achieve continuous comfort level of occupant

1.4 Problem Statements

Lambert et al. [1] reported that the mechanical compressor of the air conditioning system could increase the fuel consumption of the vehicle by 12 to 17% for subcompact to mid-size vehicles. Therefore, demand of intelligent control system of AAC are expected to have the ability to take into account the several disturbance that are important contributors to the energy balance in the vehicle cabin room.

1.5 Research Question

Is that neural network of automotive air conditioning System able to achieve better energy management of the vehicle?

1.6 Theoretical Frame Work

This study is to using neural network to control an automotive air conditioning system by using neuro controller.

1.7 Scopes of Research

The scopes of this project are:

(i) Literature review of dynamic modeling automotive air conditioning system, system identification and neuro controllers

(ii) Dynamic modeling of automotive air conditioning system using neural networks

(iii) Development of NARMA - L2 Neuro controller for automotive air conditioning system under various disturbances conditions

(iv) Validation, verification, analysis and compare of the controllers' performance for air conditioning system using neural network in comparison with PID controller and hybrid controller.

1.8 Research Methodology and Flowchart

The methodologies involved in this study are shown in Figure 1.1. The project starts by collecting reading materials such as books, journals and technical papers specifically on vehicle air conditioning system, artificial neural networks, applications of artificial neural networks, intelligent controller and thermal comfort.

Research has been done continuously throughout this study to get a better understanding on the concept of artificial neural networks and its advantage. Besides, consultation sessions with the project supervisor and few colleagues who are doing similar research were held periodically to discuss any arising issues and problems encountered pertaining to this study.

Based on the research conducted, semi-active with artificial neural networks and its application was crucially analyzed. The different controller typewere justified before use in simulation. The study on automotive air conditioning system has been divided into two main parts which are (1) neural network modeling and (2) simulation of the neuro controller system.

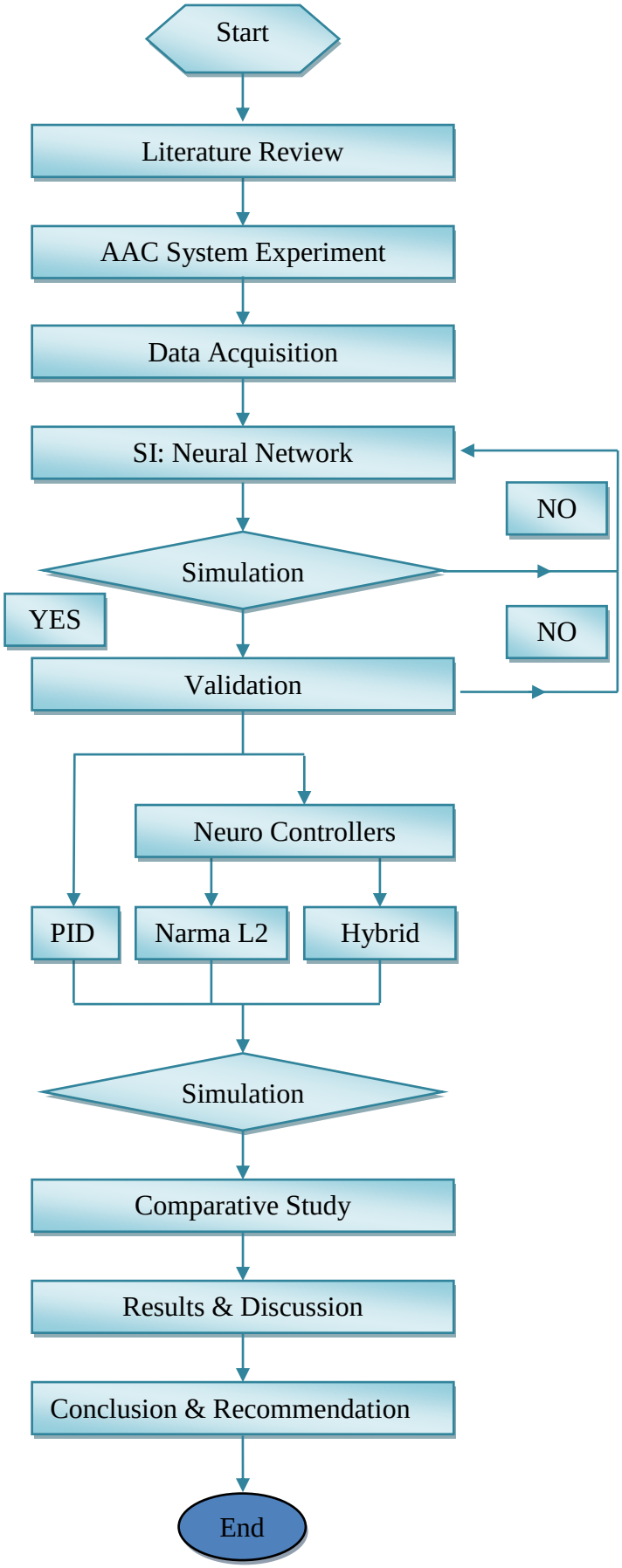

Figure 1.1: Flowchart of Methodology

1.9 Gantt Chart

NO.	ACTIVITIES	WEEKS															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Selection of project title																
2	Collecting reading materials																
3	Literature review of previous research																
4	Understanding the concept of Neural Network, System Identification and Control system of AAC																
5	Familiarization with Matlab SIMULINK																
6	Experiment Setup and data Acquisition at lab																
7	Simulation of neutral network using data acquired at the lab																
8	Comparison and Analysis of the results from the simulation of neuro controller																
9	Master Project Report writing																
10	Preparation of seminar presentation																

Figure 1.2 : Gantt Chart for Master Project 1

NO.	ACTIVITIES	WEEKS															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	Literature review																
2	Analysis of the experimental results and data acquisition from lab																
3	Design Larma 2, PID and Hybrid neuro controller																
4	Simulation of neuro controller using data acquired at the lab																
5	Comparative Study																
6	Master Project Report writing																
7	Preparation for seminar presentation and submission of draft thesis																
8	Preparation of seminar presentation 2																
9	Seminar presentation 2																
10	Submission of the thesis																

Figure 1.3 : Gantt Chart for Master Project

1.10 Thesis Outline

This thesis consists of five chapters. Chapter 1 is the introduction chapter. This chapter presents the research objective, research problem, research scopes of work, methodology of research, project grant chart and the overall outline of this thesis

Chapter 2 presents the literature review on related subjects concerning this thesis. In this chapter, the application of AAC system, the technique of the system identification and review on published articles related to current control system of AAC system.

Chapter 3 describes the project methodology. This chapter will present the details project flow and relevant methodology to obtain the experimental data and the sequences for the simulation.

Chapter 4 describes the development of the neural network and neuro controllers. The results of the proposed multiple neuro controllers of AAC system will be explained. These neuro controllers include the PID, NARMA-L2 and hybrid (PID & NARMA-L2) controller. The simulation result of neural network and neuro controllers obtained from MATLAB/SIMULINK were discussed and compared.

Chapter 5 is the conclusion of chapter of the Master Project 1. This chapter summarizes the works done in thesis study. The suggestion for future works and continues of research are also will outlined in this chapter.

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