LB/DON/77/08

NEURAL NETWORKS BASED TYRE IDENTIFICATION FOR A TYRE INFLATOR OPERATIONS

A Thesis submitted to the

Department of Electrical Engineering, University of Moratuwa

On partial fulfilment of the requirement for the

Degree of Master of Science in Industrial Automation

LIBRARY
UNIVERSITY OF MORATUWA, SRI LANKA
MORATUWA

by

KAHANDAWA APPUHAMILLAGE

GAYAN CHANAKA KAHANDAWA

621.3 "08"
621.3 (043)

Supervised by

Dr. Lanka Udawatta

University of Moratuwa
91251

Department of Electrical Engineering

University of Moratuwa

Sri Lanka

March 2008

91251

DECLARATION

The work submitted in this dissertation is the result of my own investigation, except where otherwise stated.

It has not already been accepted for any degree, and is also not being concurrently submitted for any other degree.

UOM Verified Signature

.....

Kahandawa K. A. G. C.

26.03.2008

We/I endorse the declaration by the candidate.

UOM Verified Signature

.....

Dr. Lanka Udawatta

Acknowledgement

In completion of this project, first and foremost gratitude is due to Dr. Lanka Udawatta for supervising, guiding and encouraging throughout the project giving invaluable advice. Also I thank Dr. D.C Bandara for giving valuable advice to make this project a complete success.

I would thank all the lecturers of the postgraduate study course in the Department of Electrical Engineering of the University of Moratuwa, Sri Lanka who imparted the theoretical knowledge and the encouragement in bringing up this academic work with excellent cooperation and guidance

Further I would like to thank the staff members of the Department of Electrical Engineering for spending their valuable time to provide relevant instructions and service for the progress of the research experiment.

Also I should like to thank many individuals, friends and colleagues, who have not been mentioned here personally, for making this product a success.

Finally I thank to my family members for helping and encouraging me throughout the fieldwork of the research and being patient with me. I may not be able to accomplish this task without their support.

Abstract

Tire industry has become one of the huge industries at present since the number of vehicles are rapidly increasing. Since the tire directly related to the vehicle safety, durability, running cost and comfort level of the passengers tire selection and maintenance addressed widely. Maintaining a tire is a duty of the vehicle user and he may has to check the tire rapidly for wear, cuts and other irregularities. The most important activity of tire maintenance is to maintain the pressure of the tire.

The tire pressure is an important issue since it directly relates to the safety of the vehicle, durability, running cost and comfort level of the passengers as mentioned above. A rapid check for tire pressure is essential since tire pressure may reduce

normally with the time apart from losing pressure when the tire drives over a pothole or hump. Checking the tire is done using a machine called tire inflator. This machine must be accurate and user friendly since the operator has to trust on it. Tire inflators are available mostly in tire shops and in gas stations. Tire inflators are mainly two types, Analog tire inflators and Digital tire inflators. Digital tire inflators arrived the market recently and analog tire inflators are getting replaced with digital tire inflators as the convenience of operation.

Digital tire inflators read the pressure with a pressure sensor and with this sensor the dynamic pressure readings are not possible. Hence to get the static pressure the inflation process has to be stopped. In other words, while in the inflation, the tire inflator has no idea about the tire pressure until the inflation stops. In this case, to have an idea about the rise of pressure, there must be a method to identify the type of the tire.

The tire identification mechanism must be fast, accurate and reliable. The other requirement is that the tire has to be identified online and this process must not delay the inflation process.

The main tusk of this exercise is to develop an artificial neural network based tire identification method. A developed tire inflator model was used to collect information and to test the tire identification process.

To develop the network, three inputs were considered. By expanding the number of layers in the network experiment was carried out. The results were successful and that the network with two hidden layers zero percent error achieved.

Content

Declaration	i
Acknowledgement	ii
Abstract	ii
List of Figures	vi
List of Tables	viii
Chapter 1	1
1. Introduction to the working environment	1
1.1 Background	1
1.2 Pressure inside tire	3
1.3 Goal	5
Chapter 2	6
2. Problem Identification	6
2.1 Properties of the Tire	6
2.1.1 Temperature Resistance	7
2.1.2 Tread Wear Number	8
2.1.3 Traction of Tire	8
2.1.4 Maximum load capacity and tire speed	9
2.1.5 Manufacturing date	11
2.1.6 Tire Pressure	12
2.2 Tire Inflator	15
2.2.1 Operation of Tire Inflator	16
2.2.1.1 The Analog Tire Inflator	16
2.2.1.2 The Digital Tire Inflator	17
2.2.2 Controller of the Inflator	17
2.2.3 The Tire Inflator Model	18
Chapter 3	22
3. Theoretical Background	22
3.1 Introduction to Neural Networks	22
3.2 Engineering of Brain	22
3.3 Neuron Physiology	23
3.3.1 Neuron	23
3.4 Artificial Neural Networks	25
3.4.1 Basic Model of Neuron	26
3.4.2 Learning in Artificial Neural Networks	27
3.4.3 Characteristics of ANN	28
3.4.4 Neural Network Topology	28
3.4.5 Single Layer Networks	29
3.4.6 Multilayer Neural Networks	30
3.4.7 The Backward Propagation Algorithm	31

Chapter 4 32
4. Development of Tire Inflator Model 32
4.1 Tire Inflator Model 32
4.1.1 The Microcontroller 33
4.1.2 The Pressure Sensor 33
4.1.3 Pneumatic Valve 33
4.1.4 LCD Screen 35
4.2 Working of the Tire Inflator 36
4.3 Tire Identification 38
4.4 Simple On-Off Algorithm 39
4.5 The Tire Identification System 40

Chapter 5 41
5. Neural Network Model 41
5.1 Data Analysis 41
5.2.1 Experiments With Artificial Neural Networks 43
5.2.2 Three Input MPL 43
5.3 Network with a Single Hidden Layer 44
5.4 Network with Two Hidden Layers 47

Chapter 6 52
6. Discussion, Conclusion and Future Developments 52
6.1 Discussion and Conclusion 52
6.2 Future Developments 53

7. References 54

Appendices
Appendix A A1
Appendix B B1
Appendix C C1
Appendix D D1
Appendix E E1
Appendix F F1

List of Figures

Figure 1.1	Correctly Inflated and Underinflated Tire	2
Figure 1.2	Tire Connector	3
Figure 1.3	Dynamic Pressure Rise inside a Tire with Time	4
Figure 2.1	Tire Details Available in the Tire Side Wall	6
Figure 2.2	Temperature Resistance Mentioned in Tire	7
Figure 2.3	Tread Wear Number	8
Figure 2.4	Traction of a Tire	8
Figure 2.5	Load Index and Speed Symbol of the Tire	9
Figure 2.6	Load Capacity Vs Inflation Pressure for Three Different Tires	9
Figure 2.7	Tire Manufactured Year	11
Figure 2.8	Maximum Permissible Pressure that Tire Could Withstand	12
Figure 2.9	Tire Carrying Capacity with the Tire Pressure	13
Figure 2.10	Infrared Photograph of a Tire	13
Figure 2.11	Overinflated Tire	14
Figure 2.12	Under Inflated Tire and Correctly Inflated Tire	15
Figure 2.13	Analog Tire Inflators	16
Figure 2.14	Digital Tire Inflator	17
Figure 2.15	Pressure Signal Analysis	18
Figure 2.16	Working flow chart of a Tire Inflator	20
Figure 3.1	The Biological Neuron	23
Figure 3.2	The Parts of the Neuron	23
Figure 3.3	The Synapse	24
Figure 3.4	Basic Neuron Model	26
Figure 3.5	Common Neural Network Topologies	29
Figure 4.1	The Tire Inflator Hardware	32
Figure 4.2	SX.150 Pressure Sensor	33
Figure 4.3	5/3 Valve: 5 Port, 3 Position, Center Closed	34
Figure 4.4	Port Allocation of the Valve	34
Figure 4.5	The LCD Display	35
Figure 4.6	Fiberglass Enclosure	35
Figure 4.7	Final Look of the Tier Inflator	36
Figure 4.8	Valve Positions	36
Figure 4.9	Variation of Pressure Rise of Several Tire Types	39
Figure 4.10	IR Tire Identifier	40
Figure 4.11	IR Scanning	40
Figure 5.1	Variation of Inputs	41
Figure 5.2	The Plot of Three Different Tire Types	42
Figure 5.3	The Plot of four Different Tire Types	42
Figure 5.4	Architectural Design of the System	44
Figure 5.5	Network Model with one hidden Layer	44
Figure 5.6	Variation of Percentage Misclassified error for Training Set with a Number of Iterations for Network with one hidden layer	46
Figure 5.7	Variation of Percentage Misclassified error for Validation Set with a Number of Iterations for Network with one hidden layer	46
Figure 5.8	Network Model with two hidden Layer	47

Figure 5.9 Variation of Percentage Misclassified error for Training Set with a Number of Iterations for Network with two hidden layer 49
Figure 5.10 Variation of Percentage Misclassified error for Validation Set with a Number of Iterations for Network with two hidden layer 49

List of Tables

Table 2.1	Temperature Resistance of a Tire	7
Table 2.2	Maximum Load Carrying Capacity of a Tire with Load Index	10
Table 2.3	Maximum Speed Limit of a Tire	11
Table 2.4	Tire Classification	19
Table 4.1	Pressure Rise of Several Tires for an Inflation Time of 0.25s	38
Table 5.1	Misclassified Percentage for Network with Single Hidden Layer	45
Table 5.2	The Final Network Weights	47
Table 5.3	Misclassified Percentage for Network with Single Hidden Layer	48
Table 5.4	The Weights of the Network with Two hidden layers	50
Table 5.5	Predicted Values with Actual Values	51