



UNIVERSITI PUTRA MALAYSIA

**AUTONOMOUS MOBILE ROBOT POWER MANAGEMENT
SYSTEM**

MALIK TAYSIR AL-QDAH

FK 1999 29

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**Thesis Submitted in Fulfilment of the Requirements for the Degree of
Master of Science in the Faculty of Engineering
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To my most beloved parents, brothers and sisters
and UPM



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LIST OF ABBREVIATIONS

AC	Alternating Current
ADC (A/D)	Analog to digital converter
ALU	Arithmetic Logic Unit
AMR	Autonomous mobile robot
BJT	Bipolar junction transistor
CPU	Central Processing Unit
CT	Current Transformer
DC	Direct Current
DOD	Depth of discharge (Wh/Kg)
DOF	Degree of freedom
I/O	Input output
IWBS	Inside wheel balancing system
KS	Knowledge source
LAB	Lead Acid Battery
LED	Light Emitted Diode
LVDT	Linear variable differential transformer
Na-s	Sodium-sulfur
Ni-Cd	Nickel-Cadmium
Ni-Fe	Nickel-Iron



Ni-MH	Nickel-Metal hybrid
PC	Personal Computer
PIC	Programmable Interrupt Controller
PM	Permanent magnet
PWM	Pulse width modulation
RAM	Random access memory
SCC	Signal conditional circuitry
SCI	Serial Communication Interface
USART	Universal synchronous asynchronous receiver
V.R	Variable reluctance
VRLA	Valve regulated lead acid
Zn-Br	Zinc-Bromine



Abstract of thesis submitted to the Senate of Universiti Putra
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Chairman: Md. Mahmud Hasan, Ph.D.

Faculty : Engineering

The most important part of an autonomous mobile robot is its power management in order to avoid any deadlock. A system was developed to identify the time when the autonomous mobile robot needed to return for battery recharge through an alarm of the battery error detection.

The design of this system is a car-like mobile robot with two front steering wheels and two rear driving wheels. The steering gear motor turns the entire front-wheel assembly a number of degrees to the left or right of the straight-ahead. The drive motor is mounted



to one of the rear wheels and both rear wheels are fixed to the rear axle. The gear motor can drive both of them at the same time. This mobile robot is kinematically constrained body, which can be modelled as a 2D object translating and rotating in the horizontal plane.

The discharge parameters are the battery voltage and the battery capacity. The values of these two discharge parameters are function of the battery suitability to the load. Using a microcontroller-based circuit with current and temperature sensors did achieve the battery management process. The battery temperature and voltage sensors provide information for the changed battery status. The current sensor monitors the current delivered from the battery during the discharge time. From identifying the value of the current, the applied load to the mobile robot can be known. From the sensed current the system can generate a suitable countdown time to estimate the remaining battery lifetime under load. The time is updated as the load is changed.

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SISTEM PENGURUSAN KUASA ROBOT GERAK BERAUTONOMI

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Di dalam pembinaan robot gerak berautonomi, perkara yang dititikberatkan adalah pengurus kuasanya untuk mengelak dari kebuntuan. Caranya adalah dengan melalui pemantauan lintasan secara berterusan daripada stesen pengecas. Satu sistem yang dapat mengenal pasti masa bila robot gerak berautonomi perlu pulang untuk mengecas semula melalui penggera dengan pengesanan kesilapan bateri telah dibina.

Di dalam sistem ini, satu robot gerak yang berupa kereta dengan dua kemudi depan dan dua roda memandu belakang dibincangkan. Motor gear stereng memutar seluruh roda depan dengan mengambil kira sebilangan darjah ke kiri atau ke kanan untuk menuju ke depan. Motor memandu dilengkapi pada salah



satu roda belakang, dengan kedua-dua roda belakang dipasangkan dengan gandar belakang. Gear motor boleh memandu kedua-duanya pada masa yang sama. Robot gerak ini adalah berbadan kinematik gerakan, di mana robot gerak ini dapat dimodelkan sebagai objek dua dimensi dilaksanakan dan diputar pada satah mengufuk.

Parameter menyahcas adalah voltan dan keupayaan bateri. Nilai untuk kedua-dua parameter menyahcas adalah kesesuaian dengan fungsi bateri untuk beban. Untuk mencapai proses pengurusan bateri, satu litar asas mikro-pengawal telah direkabentuk dengan sensor arus dan suhu. Suhu bateri dan garis voltan memberikan maklumat tentang status pertukaran bateri. Garis arus sensor memerhatikan penghantaran arus dari bateri, semasa penyahcas dilakukan. Dari pengecaman nilai arus ini boleh untuk mengenal pasti beban kaitan untuk robot gerak boleh diketahui. Sistem dari arus pengesanan ini boleh menghasilkan satu pengiraan detik masa yang sesuai untuk jangka masa hayat bateri yang tertinggal di bawah beban tertentu. Masa tersebut akan dikemaskinikan mengikut pertukaran beban.

CHAPTER I

INTRODUCTION

Autonomous Mobile Robot

Over the last several years, numerous prototypes of Autonomous Mobile Robot (AMR) have been developed and wide a variety of researches related to AMRs have been reported. The prototype AMRs have been built primarily as research vehicles with emphasis on aspects such as perception, control, machine reasoning, and intelligence (Boyden and Velinsky, 1994)

Overall, the interest in mobile robots is growing rapidly because of their wide potential application. The challenge is that these robots move intelligently so that they can perform various actions without human intervention. Many kinds of robots are working in various fields, especially in dangerous and hard environments; a typical example is fire fighting and working in nuclear power plants with high radioactivity's (Kobayashi and Inagaki, 1992).



Usually, the mobile robot requires locomotive function to get into a working area and back to the safety area; and also to move anywhere in a working area. In this case, the mobile robot must have a proper architecture and special constraints controllability system. The AMR system is nonholonomic system because its constraint equations are not integrable. This makes the analysis of its kinematics more complex, because by using the equation of constraint, one cannot eliminate the robot co-ordinates.

In general, based on the dimension of the movement, the most commonly used mobile robots can be classified into two categories: the first follows a fixed and constrained straight-line path such as inside pipes or channels. The second moves on a plane such as the floor of a building. In addition, there is a rarely used mobile robots in maneuvers, in space, or under water (Zhao and BeMent, 1992). The first type has specific path possibility to identify when and how the power can be supplied. The case is different in the second type, it moves in the environment randomly and needs real-time tracking to identify its position and full supervision of its power supply.

The power of the AMR can not be managed unless its battery is fully monitored and supervised. In the past, monitoring a battery was done by building a circuit with potentiometer and a comparator

with reference voltage that provided a visual or logical output about the battery level. The circuit only indicated the high or low voltage of the battery. This led to an erroneous indication about the battery real condition, because loading the battery with higher load caused a higher drop in the battery voltage. Furthermore, the battery cells may have failed at any time for reasons not understood, (e.g open or short circuit) (Stefanakos and Thexton, 1997). Therefore, battery management for mobile robot has become highly needed.

In this respect, real time battery monitoring is very essential for smart AMR operation. However, estimating the battery power is meaningless if the AMR can't return for recharge. So, tracking the AMR position should be addressed to identify the distance of the robot from the recharging point.

Objectives

To make the mobile robot know how far it is from an initial point by tracking its position then monitor the battery power so that the mobile robot will have enough time to go back to a recharge station for power recharge.

The objectives are:

- a- build and integrate mechanical and electrical aspect of the mobile robot,
- b- establish a position tracking method of the mobile robot, and
- c- monitor the three main parameter that affect the battery capacity, which are current, voltage, and temperature.

Thesis Organisation

The thesis consists of six chapters. Chapter I presents an introduction about the mobile robot. Chapter II presents a literature reviews on various aspects related to the AMR battery Management system. Chapter III describes the methods used to develop the system. Chapter IV gives the implementation of the system. The hardware circuits, Mechanical construction and the software procedure is provided. The system's performance and results are discussed in Chapter V. Finally, the thesis concluded in Chapter VI with the summary, the conclusions, and future research directions.

CHAPTER II

LITERATURE REVIEW

Introduction

There are various aspects of study related to the Mobile Robot Battery Management System; mainly battery characteristics, mobile robot navigation, stepper motor, and overall sensors and signal conditional system. The combination and the integration among these studies will produce the Mobile Robot Battery Management System.

The Battery

A battery is a chemical factory that transfers chemical energy into electrical energy. Batteries are either primary or secondary. Primary battery can be used only once because the chemical reactions that supply the current are irreversible like zinc-anode based system. Secondary batteries, sometimes called storage batteries or accumulators, can be used, recharged, and reused like sealed lead acid and sealed nickel-cadmium batteries. In these batteries, the chemical reactions that provide current from the battery are readily reversed when current is supplied to the battery.

Battery Capacity and Rating

Capacity and rating are the two principal battery-specifying factors. Capacity is the measurement of how much energy the battery can contain. Battery capacity is specified in ampere-hours. A battery with a capacity of 100 ampere-hours could deliver 1 amp for 100 hours or 100 amps for 1 hour. This doesn't help any more than drawing a straight line on a map if someone asked for a destination. So the battery needs a second co-ordinate, the second factor- rating. The second specifying factor refers to the rate at which battery can be charged or discharged.

$$R = \frac{C}{T} \quad [2.1]$$

Where R is the battery rating, C the capacity and T is the cycle time

The rating is given in amperes, the capacity in ampere-hours and cycle time in hours. In practical terms, a battery with a capacity of 100 ampere-hours that can deliver the much higher 100 amps for 1 hour (known as a C/100 rate) would not necessarily be able to deliver the much higher 100 amps for 1hour(known as a C/1 rate). Capacity depends on many factors, the most important of which are:

- 1-area or physical size of plates in contact with the electrolyte,
- 2-weight and amount of material in plates,
- 3-number of plates, and type of separators between plates,
- 4-quantity and specific gravity of electrolyte,

5-age of battery,

6-cell condition-sulfation, sediment in bottom, etc,

7-temperature,

8-low voltage limit, and

9-discharge rate.

Notice that one to four items have to do with the battery's construction plates and electrolyte; five and six items are concerned with its history; and seven to nine depend on how anyone is using the battery at any moment.

Discharge Curves

A classical method of representing a discharge curve for a secondary battery (rechargeable) is a plot of the terminal voltage against time, accounting for the discharge at stipulated battery temperatures in order to establish the effect of temperature on the voltage-time relationship.

When starting the capacity obtained for a battery during continuous discharge, it is a common practice to state the capacity available at a particular discharge rate and battery temperature; the battery is discharged to a particular end-point voltage. The 20 hours rate at 20°C is commonly used. Thus, if a battery is discharged continuously for 20 hours at 20°C, the nominal capacity is available, referred to as C_{20} capacity. If the same battery were