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Design, Development and Implementation of Educational and Entertainment Mobile Robots Utilizing Arduino Microcontroller

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Abstract

This paper provides fundamental insights on academic initiatives undertaken by Mindanao University of Science and Technology (MUST) in Cagayan de Oro City, Philippines in addressing some issues relative to the declining academic interests in science and technology (S&T) among students in the secondary schools in the country. While academic interventions were implemented both public and private efforts, career preference continue to persist in favor of the medical service programs. This notion motivated the pursuance of this study in an effort to entice students toward science and technology. The study features the design and implementation of educational and entertainment mobile robots with variety of control concept applications. The control design implemented follows pre-established parameters set forth by MUST as basis for the students in their respective robotic designs. The basic criteria sets the prototype to be light weight, "Arduino" microcontroller-based, programmable in C-Language, powered by internal battery, and a choice of DC or servo motor prime movers. The control designs are guided by the discrete truth table where input and output devices interact via programming through appropriate electronic interfacing. The outcome of the study is perceived to influence career interest and direction of students towards science and technology through high impact advocacy using the educational and entertainment mobile robots as the primary pedagogic tool and attraction. The survey results yielded positive affirmation on the performance of the educational and entertainment mobile robots as evidenced by the high to very high mean ratings on pre-established evaluation parameters.

Keywords: *mechatronics, mobile robotics, ultrasonic sensor, embedded system, servo-motor*

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1. Introduction

Higher Education Institutions (HEI) in the Philippines has been bracing academic programs in the country in conjunction to the mandate of the Commission on Higher Education (CHED) in providing quality and relevant education. CHED was established to ensure that academic enterprise of quality, excellence and relevance will provide empowerment to globally competitive human resources. By virtue of Republic Act No. 7722 otherwise known as the Higher Education Act of 1994, CHED is mandated by law to ensure the provision of undergraduate and graduate education competitive to international standards. Included in its mandate is the generation and diffusion of knowledge in the broader range of disciplines relevant and responsive to the dynamically changing domestic and international environments (CHED, 2010). The Education Commission (EDCOM) report of 1991 recommended the trifocalization of the educational system to improve governance intended to guarantee concentration on basic education effective delivery that eventually led to the creation of Department of Education (DepEd), Technical Education and Skills Development Authority (TESDA) and CHED to oversee the basic education, vocational technical school and higher education respectively. Decentralization aims to widen decision making while increasing responsibility and accountability among institutions (Valenzuela, 2010). Another supplementing initiative is the HEI's voluntary submission to some independent accreditation agencies per CHED Memorandum Order 31 series of 1995 where HEI's are evaluated in accordance to some internationally accepted assessment standards.

The latest initiative is the adoption of K-12 basic education concept in the country where students at their terminal levels will be clothed with streamlined technology-based skills needed for their occupational placement. K-12 is expected to draw so much attention on the capabilities of DepEd and TESDA as they collaborate in this undertaking. On the other hand, CHED is currently reviewing the curriculum of Philippine HEI's to meet global requirements and address the prevailing job-skills mismatch in the country in reaction to the call of local and foreign businessmen and investors to revise the curriculum, making it globally competitive (Angeles, 2008). CHED has been coordinating with the Philippines Chamber of Commerce and Industry (PCCI) and the Employers' Confederation of the Philippines to solve the mismatch and figure out what is needed by the business and the industry (Mamanglu, 2009).

The noteworthy initiatives of the Philippine educational system also receive some mixed reaction from various stakeholders as the country's economic viability is confronted by the so-called globalization and modernization phenomenon. In essence, the current technological innovations and dynamics of change in work organizations and economies will continue to fuel compelling debates on the future of the labor market and the exigency of skill upgrading requirements (Bulgarelli, 2009). These imply the need to adapt to rapid technological change and matching skills to jobs crucial to production sustainability and competitiveness. In this regard, economic sectors in the global community have been shifting to a variety of engineering concepts to stay competitive. However, as the economy continues to face job-skills mismatch, the academe struggles to provide the right human resources required by the industry due to some academic constraints coupled with the scarcity of intellectual inputs to science and technology curricular programs.

Studies revealed about the weakening interest towards science and technology (S&T) among students. There are indicators of enrollment depletion in S&T programs in favor of the medical service programs throughout the country. The present scenario posed some economic implications as the industry expects quality inputs from HEI's. With less S&T inclined human resources, the industry is expected to experience production lags due to scarcity of qualified workforce, thus job-skills mismatch continue to bother the economy. Academe-industry imbalance is blamed at the academe's failure to provide quality human resources. This notion motivated the conduct of this study in an effort to provide mitigating measure of effectively advocating science and technology to students in the basic education.

It is perceived, that the student's keen interests towards S&T may be excited through dynamic exposure to modern technology while exercising the student's human sensory to the fullest. Mobile robots in this context contribute great interests for students. In fact, students made robots as a way of learning. Application of robots for the education opens possibilities of creative learning and creative research as tool for increasing creativity (Katalinic, 2011). Robotics is considered as a flexible medium for learning, offering opportunities for design and construction against short time and small funds (Alimisis, 2009). Through mobile robotics, students generate solutions in real world problems. Mobile robots are utilized as an instructional tool for teaching and learning embedded systems design in Electronics and Computer Engineering undergraduate courses. Experts argued that developing a complete working autonomous mobile robot that integrates the concepts from analog and digital electronics, sensors and actuators, control systems and real-time programming has several advantages over working on isolated and disconnected laboratory experiments (Neto, 2009). The results shows that the challenges posed to students in this context result in a higher level of motivation and stimulate their creativity towards generating different solutions to real world problems in embedded systems design.

The design, development and implementation of educational and entertainment mobile robots with varied control applications provides exciting learning experience that will potently influence career preferences among students in the basic education. The study therefore sought to address the following questions:

1. What control design parameters to consider in the development of mobile robots utilizing an Arduino Microcontroller programmable in C-Language?

2. What are the input and output devices to use to effectively implement the mobile robotic system?

3. What evaluation parameters to apply to efficiently test the performance of the mobile robots?

The main objective of this study is to design and implement a technology-based research project that enhances science and technology advocacy in the secondary education through a collaborative research undertaking between students and faculty of Electro-mechanical Technology department in Mindanao University of Science and Technology, Cagayan de Oro City, Philippines. Specifically, the study aims to:

1. Design, develop, implement and evaluate educational and entertainment mobile robots based on “Arduino” Microcontroller platform as test bed for programming and interfacing.

2. Utilize the mobile robots as pedagogic tools in science and technology advocacy in Mindanao.

2. Methodology

The methods and materials in the study is anchored on the system framework as shown in Figure 1 where input/output devices are connected to the microprocessor modules; system programming in C-language is accomplished through an interfacing circuit.

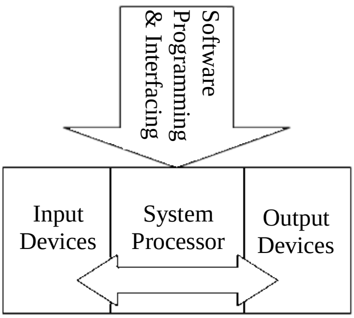

Figure 1. Basic system framework

2.1 The Fundamental Design Requirements

The fundamental design of the mobile robots follows pre-established criteria which explicitly sets the prior development requirements. The input and output devices that used in the study are shown in Table 1. The design, development, implementation and evaluation adhere to the following minimum requirements:

1. The power supply used 9-Volts battery for standalone operation by jamming the leads of a battery snap into the input Voltage (Vin) and Ground (Gnd) connections on the board. The battery snap leads were soldered to a Direct Current (DC) power jack to connect into the controller board. The mobile robot used external power supply that ranges from 6 Volts to 24 Volts (6-24V).

2. The controller used a variation of Arduino microcontroller chip and board.

3. A choice of DC and Servo motor were given preference.

4. Dual H-Bridge in a chip set L293D was recommended as motor driver.

5. Solderless breadboard was used for external circuit requirements.

6. C-Language was used in programming.

7. Discrete truth table was used to test the performance of the mobile robot.

8. The mode of operation had capabilities to: (a) follow lines; (b) avoid obstacle; (c) follow objects (object detection) and; (d) other dynamic functionality may be added.

Table 1. Choice of input and output devices

Input Devices	Assignment
Ultrasonic Sensor	Object detection and distance sensitive
Infrared Sensor	Object detection and distance sensitive
Light Dependent Resistor	Light sensitive
Reflective Sensor	Color sensitive
Output Devices	Assignment
DC Motors	Prime mover (reverse/forward)
Servo Motors	Prime mover(reverse/forward)
Stepper Motor	Prime mover(reverse/forward)
Light Emitting Diode	On/Off light indicator

The Arduino board shown in Figure 2 features an Atmel ATmega328 microcontroller which is operating at 5 V with 2 Kb of RAM, 32 Kb of flash memory for storing programs and 1 Kb of EEPROM for storing parameters. The clock speed is 16 MHz, which translates to about executing about 300,000 lines of C-language source code per second. The board has 14 digital I/O pins and 6 analog input pins. There is a USB connector for interfacing and or communicating to the host computer and a DC power jack for connecting an external 6-20 V power source, for example a 9 V battery, when running a program while not connected to the host computer. Headers are provided for interfacing to the I/O pins using 22 g solid wire or header connectors. However, other Arduino boards may be used like those with Atmel168 microcontroller.

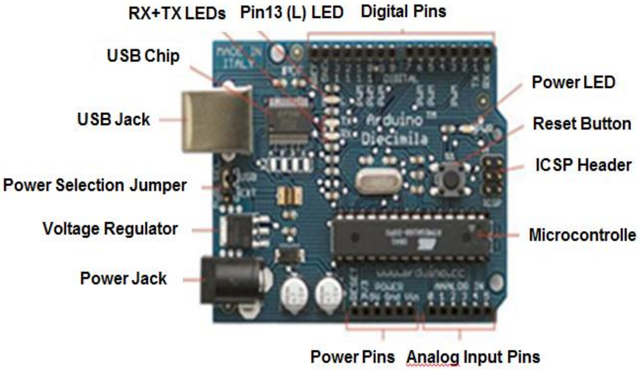

Figure 2. The arduino microcontroller board

2.2 The Development and Implementation

Anchored on the Arduino microcontroller board input/output (I/O) device module, computer programs in C-Language are encoded through the interface circuits to read switches and other sensors, and to control motors and lights. Figure 3 shows the typical I/O devices interfaced into the controller board.

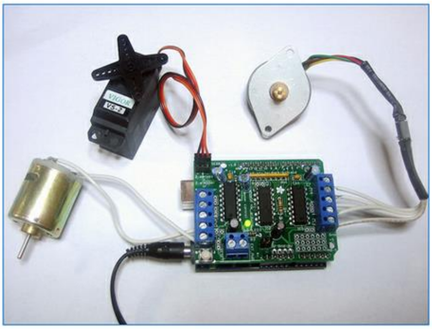

Figure 3. The typical input/output interfacing

The Arduino controller board as shown in Figure 2 features the following:

- 2 connections for 5V 'hobby' servos connected to the Arduino's high resolution dedicated timer.
- Up to 4 bi-directional DC motors with individual 8-bit speed selection (so, about 0.5% resolution)

- Up to 2 stepper motors (unipolar or bipolar) with single coil, double coil, interleaved or micro-stepping.
- 4 H-Bridges: L293D chipset provides 0.6A per bridge (1.2A peak) with thermal shutdown protection, 4.5V to 25V
- Pull down resistors keep motors disabled during power-up.
- Big terminal block connectors to easily hook up wires (10-22AWG) and power
- Arduino reset button brought up top
- 2-pin terminal block to connect external power, for seperate logic/motor supplies
- Tested compatible with Mega, Diecimila, & Duemilanove

The motors in the study were controlled through the L293D microcontroller chip embedded in the Arduino controller board. The H-Bridge chipset L293D is a monolithic integrated, high voltage, high current; 4-channel driver that provides efficient motor controls. The H-Bridge is typically an electrical circuit that enables a voltage to be applied across a load in either direction to an output, e.g. motor. The control was done by reversing the direction of current and thus reverse the direction of the motor. It works by having 4 elements in the circuit commonly known as corners: high side left, high side right, low side right, and low side left. By using combinations of these, it abled to start, stop and reverse the current. The L293D chipset is a 2 H-Bridge circuit in a single chip as shown in Figure 4.

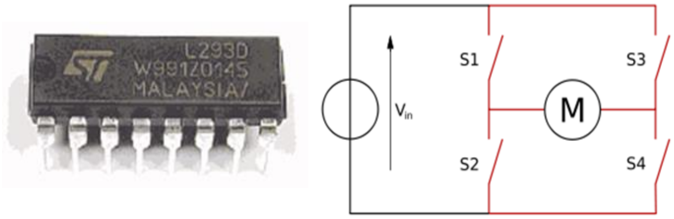

Figure 4. The L293D dual H-bridge motor driver

The H-bridge arrangement is generally used to reverse the polarity of the motor, but can also be used to 'brake' the motor, where the motor comes to a sudden stop, as the motor's terminals are shorted, or to let the motor 'free run' to a stop, as the motor is effectively disconnected from the circuit. Table 2 shows the corresponding circuit operation represented by its truth table.

Table 2. Motor action truth table

Inputs				Output Action
S1	S2	S3	S4	Motor Action
1	0	0	1	Motor rotate clockwise
0	1	1	0	Motor rotate counter clockwise
0	0	0	0	Motor free runs
0	1	0	1	Motor brakes
1	0	1	0	Motor brakes
1	1	0	0	Shoot-through
0	0	1	1	Shoot-through

Typical interfacing of DC Motor to the Dual H-Bridge L293D motor driver is shown in Figure 5. The interfacing circuit utilizes a 12 V Motor, however; it depends upon the Volt rating of the motor used. The enable in this circuit has to be set to 1 (1).

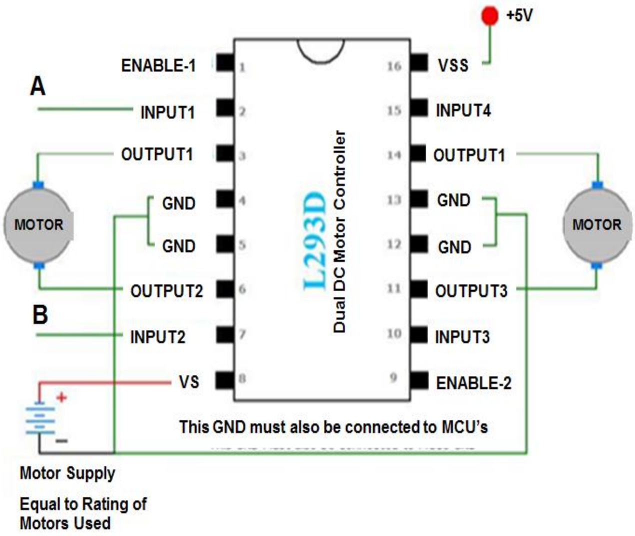

Figure 5. Motor interfacing to the L293D H-bridge driver

2.3 Evaluation Method

To test the performance of the mobile robots, the systems truth table were used to evaluate the desired action of the corresponding output devices connected into the Arduino Microcontroller board in accordance to the input devices triggering signals. The desired truth table sets the input and output status. If the performance outcome responds in accordance to the desired truth table, then the performance of the mobile robot passed the test, however; the prototypes were also tested in accordance to these parameters: (a) as to prototype functionality; (b) as to prototype aesthetics and; (c) as to efficiency.

Survey responses were measured using the Five Point Rating Scale. Adjectival rating is shown in Table 3.

Table 3. Five point rating scale measurement

Adjectival Rating	Scale Range
1 – Not Applicable	1.4 – below
2 – Poor	1.5 – 2.4
3 – Fair	2.5 – 3.4
4 – High	3.5 – 4.4
5 – Very High	4.5 – above

The assessment process involves the evaluation of the output workable prototypes which were evaluated accordingly by students and faculty of the Electro-mechanical Technology department. The efficiency of the prototype was evaluated using the truth table.

3. Results and Discussion

3.1 The Design Components

The project proponents preferred to use the Gizduino controller board with ATMega 168 microcontroller as shown in Figure 6 bearing its corresponding component description. The Gizduino is based on the open source platform of Arduino. Due to the scarcity of the Arduino board with ATmega328, the

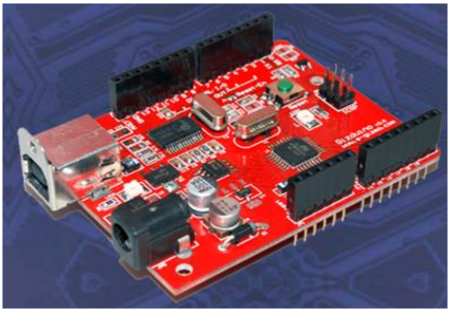

Figure 6. The arduino ATMega168 controller board

proponents resorted to the Gizduino microcontroller which is available in the local market.

3.2 The USB Interface and COM Assignments

The Gizduino microcontroller interface uses the PL-2303 chip instead of the Arduino FT-232 due to availability issues. PL-2303 is easy to source out in the Philippines. The Gizduino microcontroller has its own driver and does not worked with the Windows built-in driver and operating system (OS) installed in the personal computer. The Gizduino driver was installed first into the personal computer prior to any Gizduino controller interfacing. The COM assignment is done by launching the Arduino IDE. The serial ports record the available ports which identified COM 19 to be the dedicated port for the Gizduino. Board assignment is done by specifying the right model printed in the Gizduino board.

3.3 Project Prototypes and Concepts

3.3.1 The Experimental Modeling of an Arduino-Based Autonomous Mobile Robot

This study features a locally assembled educational mobile robot that utilized DC Motors as prime movers which draw electronic signals from the light dependent resistors and light emitting diodes in light and line tracking modes. A servo motor is also mounted to drive the infrared sensor during obstacle avoidance mode. The design and prototype is shown in Figure 7.

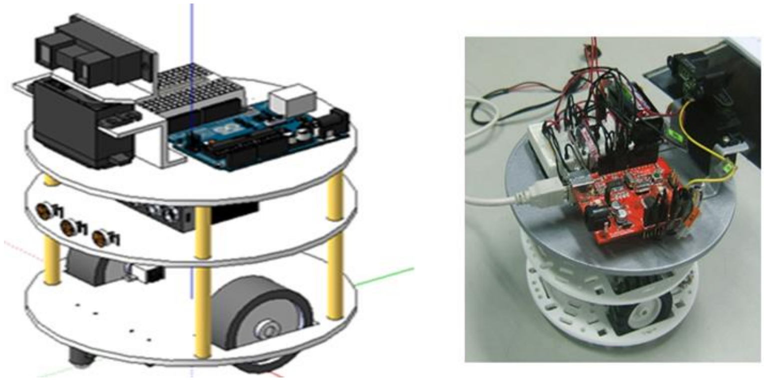

Figure 7. The concept design and prototype

The input and output devices are correspondingly interfaced into the microcontroller board I/O assignments as partially depicted in Figures 8 and 9. The dual H-bridge is externally mounted on a breadboard then through the controller board that is shown Figure 10. The program in C-Language for the obstacle avoidance for this project is shown in Figure 11 where the robot is electronically instructed to drive forward and stop when the infrared sensor detects an obstacle at a specified distance. The robot finds other route and turns to drive forward again. Figure 12 also shows the snapshots of the light and line following applications of the robot. The project prototype with the summary of mean responses is shown in Figure 13.

Figure 8. The light, line and analog IR sensors

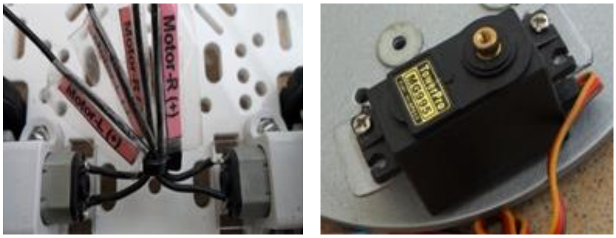

Figure 9. The DC and servo motors

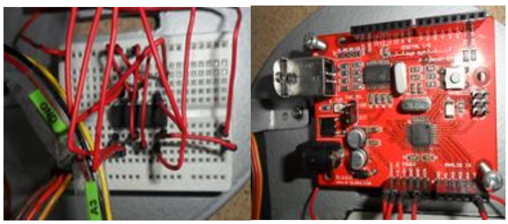

Figure 10. The dual H-Bridge and controller board

```
#include <Servo.h>

int enable1 = 6;
int enable2 = 10;
int motor_pin1 = 3;
int motor_pin2 = 12;
int motor_pin3 = 11;
int motor_pin4 = 13;
int servopin = 8;
int sensorpin = A3;
int dist = 0;
int leftdist = 0;
int rightdist = 0;
int object = 500;
Servo myservo;

void setup ()
{
 Serial.begin(9600);
 pinMode(enable1,OUTPUT);
 pinMode(enable2,OUTPUT);
 pinMode(motor_pin1,OUTPUT);
 pinMode(motor_pin2,OUTPUT);
 pinMode(motor_pin3,OUTPUT);
 pinMode(motor_pin4,OUTPUT);
 digitalWrite(enable1,HIGH);
 digitalWrite(enable2,HIGH);
 myservo.attach(servopin);
 myservo.write(90);
 delay(700);
}
void loop () {
 dist = analogRead(sensorpin);

 if(dist < object) {
  forward();
 }
 if(dist >= object) {
  findroute();
 }
}

void forward() {
  digitalWrite(motor_pin1,LOW);
  digitalWrite(motor_pin2,HIGH);
  digitalWrite(motor_pin3,LOW);
  digitalWrite(motor_pin4,HIGH);
  return;
}

void findroute() {
 halt();
 lookleft();
 lookright();

 if ( leftdist < rightdist )
 {
turnleft();
 }
 else
 {
  turnright ();
 }
}

void halt () {
 digitalWrite(motor_pin1,LOW);
 digitalWrite(motor_pin2,LOW);
 digitalWrite(motor_pin3,LOW);
 digitalWrite(motor_pin4,LOW);
 delay(500);
 return;
}
void lookleft() {
 myservo.write(150);
 delay(700);
 leftdist = analogRead(sensorpin);
 Serial.print("left -");
 Serial.println(leftdist);
 myservo.write(90);
 delay(700);
 return;
}
void lookright () {
 myservo.write(30);
 delay(700);
 rightdist = analogRead(sensorpin);
 Serial.print("right -");
 Serial.println(rightdist);
 myservo.write(90);
 delay(700);
 return;
}
void turnleft () {
 digitalWrite(motor_pin1,HIGH);
 digitalWrite(motor_pin2,LOW);
 digitalWrite(motor_pin3,LOW);
 digitalWrite(motor_pin4,HIGH);
 delay(1000);
 halt();
 return;
}
void turnright() {
 digitalWrite(motor_pin1,LOW);
 digitalWrite(motor_pin2,HIGH);
 digitalWrite(motor_pin3,HIGH);
 digitalWrite(motor_pin4,LOW);
 delay(1000);
 halt();
 return;
}
```

Figure 11. Program for obstacle avoidance

Figure 12. Snapshots for light and line following

MEAN RESPONSES		
Parameters	Mean	Adjectival Rating
Functionality	4.4	Very Good
Aesthetics	4.6	Excellent
Mobility	4.5	Excellent
Relevance to Mechatronics	4.5	Excellent
Marketability	4.4	Very Good

Figure 13. The prototype and acceptability indicator

3.3.2 The Design and Prototyping of an Object Following Mobile Robot Utilizing an Arduino Microcontroller

This mobile robot utilizes two servo motors as prime movers that draw corresponding electronic signals from four ultra- sonic sensors to detect objects. With appropriate C-language programming, the ultra-sonic sensors were programmed in such a way that when the object is far in accordance to the desired detection range, rolls the robot forward however, when it detects the object near in accordance to the programmed detection range, the robot rolls backwards. The design model with its project outcome prototype is shown in Figure 14 following the fundamental control framework shown in Figure 15.

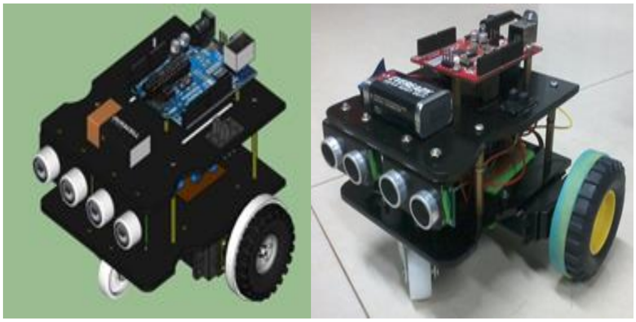

Figure 14. The sketch model and prototype

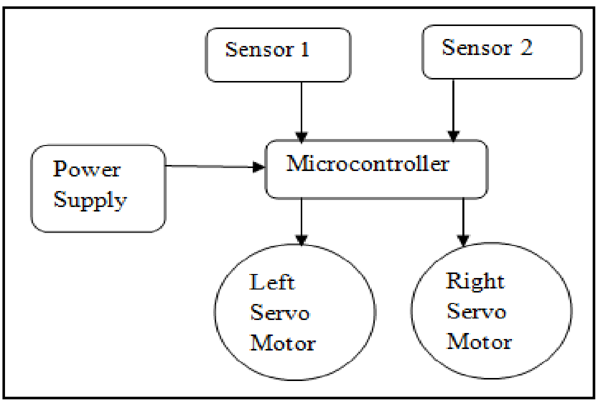

Figure 15. The control framework

Figure 16 shows the schematic diagram of the ATmega 168 used in this project. This is the brain of the robot where the program is stored. The microcontroller shows the I/O ports which connect the peripherals to the microcontroller. These ports send and receive signals from the microcontroller and the devices connected to it.

The Gizduino microcontroller interface uses the PL-2303 chip instead of the Arduino FT-232 as shown in Figure 17. The IC Component which is PL2303 converts USB to Serial so that the microcontroller can be connected to any laptop and provides its power needed by the microcontroller if no external power supply is available.

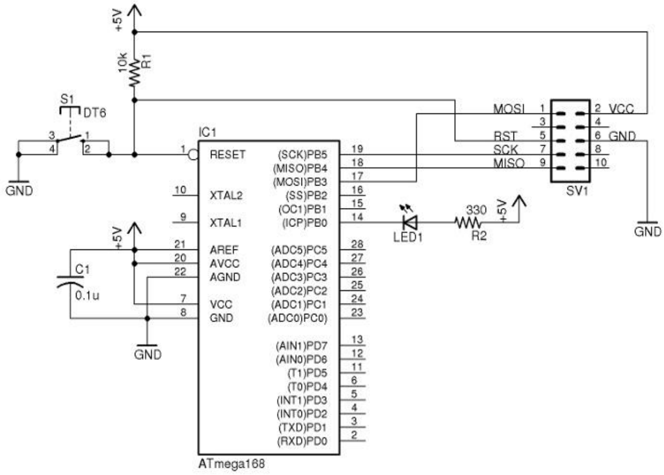

Figure 16. The ATmega 168 controller

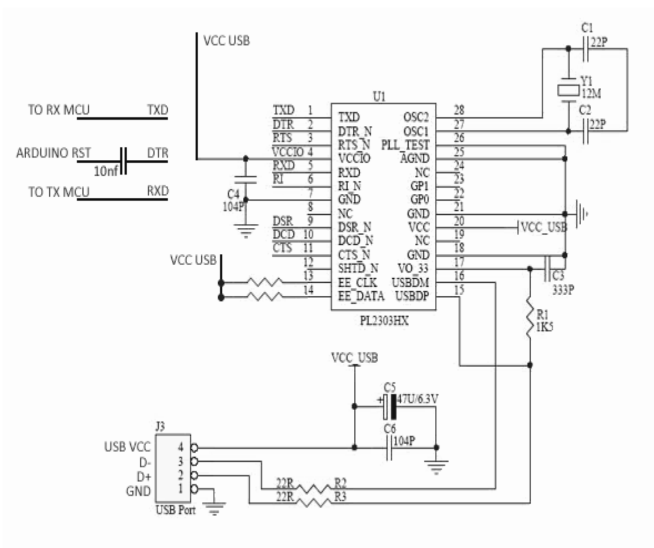

Figure 17. The PL2303 USB interface

Figure 18 shows the sketch design of the mobile robot and its corresponding final project output bearing the ultra-sonic sensing device used to detect objects. The ultra-sonic sensors were programmed in such a way that when

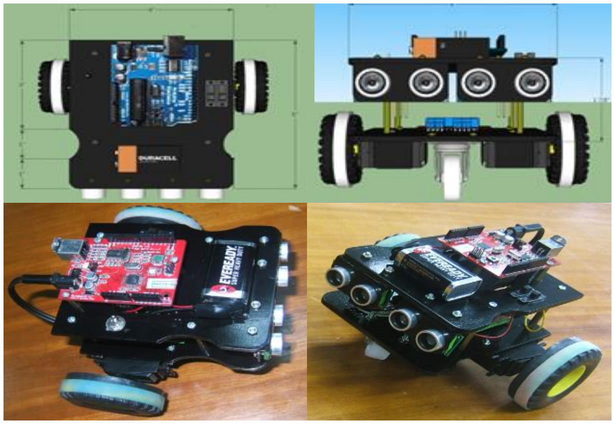

Figure 18. The design and final prototype

an object is at a distant, the robot follows the object in accordance with the distance range programmed. If the object is closer to the robot according to the programmed range, the robot back tracks until it stops moving when the object is not within the programming range. The input and output response with respect to the ultra-sonic sensor and the servo motors used is shown in Table 4.

Table 4. The input and output response table

	Input Sensors	Output Motor Rotation	
	Left Sensor (S1) & Right Sensor (S2)	Servo 1 (Left Wheel)	Servo 2 (Right Wheel)
1	S1<=5 & S2,=5	Clockwise	Counter Clockwise
2	8 <S1<=25 8<S2<=25	Counter Clockwise	Clockwise
3	S1>25 & S2> 25 6<S1<=8 6<S2<=8	Stop	Stop
4	S1<=10 S2>=10	Counter Clockwise	Counter Clockwise
5	S1>=10 S2<=10	Clockwise	Clockwise

3.3.3 Design and Development of Sumo Mobile Robots Utilizing a Gizduino Microcontroller

This mobile robots feature servomotor driven prime movers with mounted ultrasonic sensors for object detection. Ultrasonic sensors are programmed to detect target objects and provide triggering signal to the servo motors to bump competitor and eject out of the arena. Figure 19 shows the two Sumobot portraying as wrestling competitors. Line sensors (reflective sensors) are also mounted to keep track of the line and operate within the arena as depicted in Figure 20 with their corresponding down sensors attached beneath the Sumobots.

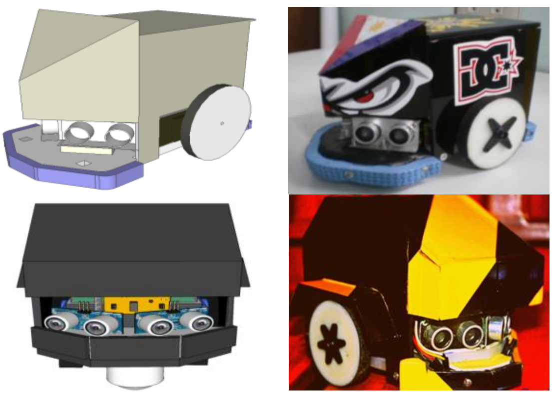

Figure 19. Two sumobot designs and prototypes with a pair of ultrasonic front object sensors

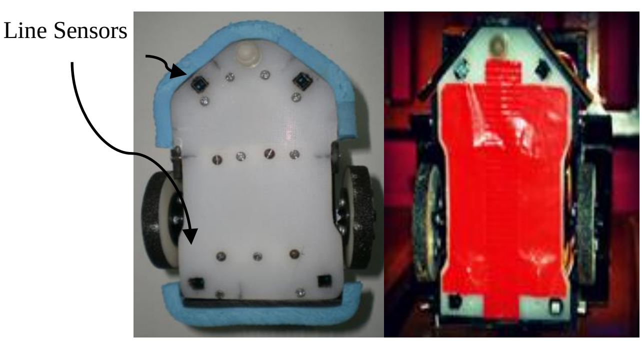

Figure 20. The line sensors attached beneath

The logic of the program is addressed hierarchically in logical modules in Figure 21 and Figure 22 showing the structured programming of line sensors (L) and object sensors respectively with respect to the mobile robot direction. L1, L2, L3, and L4 are Line Sensors while M1 and M2 represent the left and right wheels.

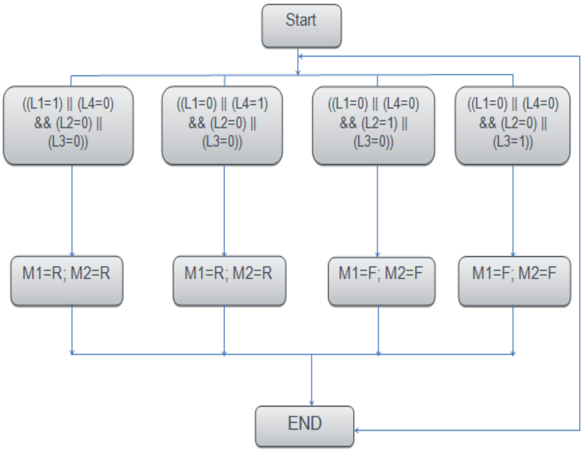

Figure 21. The line following program structure

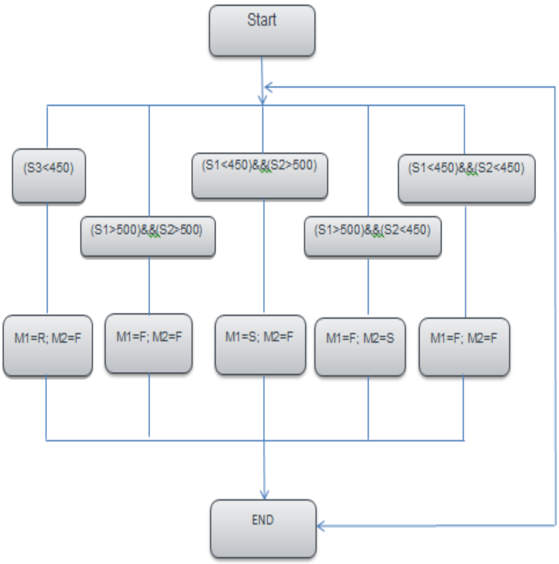

Figure 22. The object following program structure

In Figure 22, the forward motion of the robot is dictated by the sensing of the ultrasonic sensors (S1, S2, S3, and S4) which plays within the range < 200 cm - < 20 cm distances while the reverse motion is directed by the object detection within the range of < 800cm - < 80 cm distance. The robot is in the stop motion when the range of object detection is >2000 cm - < 2 mtrs. Motors are represented by M1 and M2 that serve as the left and right wheels.

3.4 The Overall Performance Efficiency Test

The overall performance efficiency of the mobile robots were tested using the corresponding truth tables for line following and object detection as shown in Tables 5 and 6.

Table 5. The truth for line following

Line Sensors				Servo Motors			
				A (Left Wheel)		B (Right Wheel)	
LFS1	RFS2	LRS3	RRS4	CW	CCW	CW	CCW
1	0	0	0	0	0	0	1
0	1	0	0	1	0	0	0
0	0	1	0	0	0	0	1
0	0	0	1	1	0	0	0
1	1	0	0	0	1	1	0
0	1	0	1	0	1	1	0
0	0	1	1	0	1	1	0
1	0	1	0	0	1	1	0

Legend: LFS1-Left Front Sensor; RFS2-Right Front Sensor; LRS3-Left Rear Sensor; RRS4-Right Rear Sensor; CW-Clockwise; CCW-Counter Clockwise

Table 6. The truth table for object following and evasion

Object Sensors	(Ultrasonic Sensors)		Servo Motors			
			A (Left Wheel)		B (Right Wheel)	
FLOS1	FROS2	ROS3	CW	CCW	CW	CCW
1	0	0	0	0	1	0
0	1	0	0	1	0	0
0	0	1	0	1	1	0
1	1	0	0	1	1	0

Legend: FLOS1-Front Left Object Sensor; FROS2-Front Right Object Sensor; ROS3-Rear Object Sensor; CW-Clockwise; CCW-Counter Clockwise

In line following routine, the mobile robot has to be at the center of a black line and has to be detected by reflective sensors that include an infrared emitter and phototransistor in a leaded package which blocks visible light ideal for line tracking applications. The logical representation means, one (1) means ON and zero (0) means OFF. Table 6 shows the input and output interaction where in order for the mobile robot to move forward, the following has to be satisfied:

1. Left and right front sensors detect the line,
2. Right front and right rear sensors detect the line,
3. Left and right rear sensors detect the line, and
4. Left front and left rear sensors detect the line

In object following routine shown in Table 6, the mobile robot has to detect the object within the programmed distance range for it to follow and or collision mode. In order for the sensor to be in collision mode, either of the two ultrasonic sensors must be at least at logic 1. However, when the back object sensor detects (logic 1) an object at the rear, the robot is on the evasion mode. The mobile robot is on tracking mode during initial system operation even if all ultrasonic sensors have logic zero (0) or no detection mode, thus the robot continue to roll forward however, the line sensors beneath have to do its role also to be always on track of the black color line.
The mean responses in terms of overall functionality as shown in Table 7 indicated that the input and output devices' functionality are highly acceptable with the Mean ratings of 3.8 and 4.00 respectively, which means that the input signals received by the output devices are efficient to effect appropriate reaction. The functionality of the software, program algorithm and the microcontroller also indicated high acceptability with mean ratings of 4.20 and 4.40 respectively during commissioning period.

Table 7. Summary of mean responses in functionality

Parameter	Mean
Functionality of Input Devices	3.80
Functionality of Output Devices	4.00
Functionality of the Microcontroller	4.20
Functionality of the Software	4.40

Table 8 also shows the mean responses in terms of the Sumobots aesthetics which indicated High cceptability ratings from respondents. The physical

Table 8. Summary of mean responses on aesthetics

Parameter	Mean
Physical Design	4.00
Component Arrangement	4.20
Cable Harnessing	3.60
Overall Presentation	4.50

design, component arrangement, cable harnessing and overall presentation showed high mean ratings of 4.00, 4.20, 3.60 and 4.50 respectively.

Table 9 depicts the positive response of the survey participants to the projects' relevance to S&T, mechatronics, and its impact towards career decision in S&T. The respondents also acknowledged the potency of the mobile robots as advocacy tools that influence career decisions of the students with very high mean ratings. The respondents also agreed that the mobile robots are potent laboratory tool in computer interfacing and programming.

Table 9. Summary of mean responses on advocacy potency

Parameter	Mean
Relevant to science and technology	4.70
Relevant to mechatronics	4.80
Impacts decision towards career in S&T	4.60
Potent S&T advocacy instrument	4.60
Potent Laboratory tool	4.50

4. Conclusion

The arduino-based mobile robots were responsive to the control design truth table specified in varied prototype featured bearing the input and output components installed.

The line sensors which are generally made of reflective sensors responded efficiently to the logical algorithm and effectively influence the motor rotation and physical motion of the mobile robots. Object sensors which are made of ultrasonic sensors also responded efficiency in accordance to the programmed distance detection range. The ultrasonic signals provide appropriate rotational direction of the prime movers.

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5. References

Alimisis, D. (2009). Robotics & Constructivism in Education: The TERECoP project (2009) Retrieved from www.terecop.eu/downloads/p-alimisis.pdf, [Accessed 11/20/2011]

Angeles, E., (2008), Jobs-Skills Mismatch, Commission on Higher Education, Retrieved from http://www.gmanews.tv.print, [Accessed 10/31/2008].

Bulgarelli, A. (2009), Skills Mismatch, Identifying Priorities for Future Research, Cedefop Research Arena, Cedefop Working Paper No. 3.

Commission on Higher Education (2010), About CHED, Retrieved from http://www.ched.gov.ph/index, [Accessed 7/14/2011]

Katalinic, B. (2011). Robots for creative learning and creative research as education and research tools in knowledge based society Vienna University of Technology

Mamanglu, Shianee (2009), CHED Pushes Curriculum Review to Address Global Needs and Job-skills Mismatch, Manila Bulletin Publishing Corporation. Retrieved from www.mb.com.ph, [Accessed 10/25/2009]

Neto, H.V. (2009). Mobile Robotics as a Tool for Teaching and Learning Embedded Systems Design, Federal University of Technology – Parana´ Brazil, Avenida Sete de Setembro, 3165, Curitiba-PR, CEP 80.230-910

Valenzuela, EA (2010), "Decentralization of Education in the Philippines: Status, Trends and Challenges", SEAMEO INNOTECH