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Selection And Implementation Of Electric Drives And Its Control For Mobile Humanoid Robot

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Abstract: A robot has many components which includes a base (fixed or mobile), a manipulator arm with several degrees of freedom, an end effector or gripper holding a part or a tool, drives or actuators, controller with hardware and software support for giving commands to the drives, sensors and interfaces connecting the robotic subsystems to the external world. This paper describes the selection of the motors and the drives for the Mobile Humanoid Robot Prototype-I (MHRP-I). The robot has totally 28 degrees of freedom (DOF) in that head has 2 DOF (pitch and roll), arm has 7 DOF, torso has 4 DOF and base platform has 8 DOF. The detailed selection procedure of the motors is presented. The ATmega 8 microcontroller is used for the motor control and the Modbus is used for the communication between the motors.

Keywords- Mobile Humanoid Robot, Degrees of freedom (DOF), ATmega 8, Modbus

1. INTRODUCTION

A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialized devices through various programmed motions for the performance of a variety of tasks. In practice, it is usually an electro-mechanical machine which is guided by computer and electronic programming. Robots can be of autonomous or semi-autonomous. Normally robot is employed to do three main functions of safety, unpleasantness, repetition and precision. Humanoid Robots (HR) offer great potential for assisting human with a variety of tasks. By definition, HR will work autonomously or in cooperation with humans in a dynamic, relatively unstructured environment as assistance or guidance and they will need a high degree of robustness, adaptability and advanced communication abilities in order to deal with unexpected situations.

In recent years, the MHRs [1] have been widely applied as service robots although they cannot climb stairs, jump or step over obstacles where humans can walk around without consuming too much energy; they can access most of the in-door environment. MHRs will be indeed a much better choice not only because wheels would suffice but also because batteries and computers, as well as additional hardware could be easily built into the base without limiting its usability but enormously increasing autonomy.

Mobile robots have the capability to move around in their environment and are not fixed to one physical location.

To drive the joints, the motors are used. Humanoid robots have many motors and sensors and many control methods are used to carry out complicated tasks of the robots. Robots often need to transport themselves from one place to another to perform a task, or they might need to move an arm to grab a tool. To do this, robots require actuators, which are generally various types of electric motors.

Actuators, also known as drives, are mechanisms for getting robots to move. Actuators are the muscles of the robots. In a robotic application, an actuator should have the following characteristics,

1. Low inertia
2. High power to weight ratio
3. Possibility of overload and delivery of impulse torques
4. Capacity to develop high accelerations
5. High positioning accuracy
6. Good trajectory tracking and positioning accuracy

A variety of electric motors provide power to robots, making them move with various programmed motions. The most commonly used motors in robots are DC motor, stepper motor and servomotor.

A servo motor [2] is a small device that has an output shaft. This shaft can be positioned to specific angular positions by sending the servo a coded signal. As long as the coded signal exists on the input line, the servo will maintain the angular position of the shaft. As the coded signal changes, the angular position of the shaft changes. Servos are extremely useful in robotics. The motors are small, have built in control circuitry, and are extremely powerful for their size.

The servo motor is used in this mobile humanoid robot because it has high holding torque, small in size, light in weight; speed-torque curve is linear and offers smoothest control. The proper sizing of servomotor will reduce the energy and power consumption and increase the working hours of the robot.

SPECIFICATION OF HUMANOID ROBOT

The robot was to be human like in appearance, 1.65m tall and approximately 100kg in weight. It can move inclined surface of 15° slope. The specification of the MHRP-I is shown in Table I.

TABLE I
SPECIFICATION OF HUMANOID ROBOT

S. No	**General details**	**Units**
1	Height	1650 mm
2	Width	679.4mm
3	Moving speed	10 km/h
4	Maximum load handled	20 kg
5	Weight of the robot	100 kg

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DEGREES OF FREEDOM

DOF of MHRP-1 is shown in Table II. Degree of freedom is the number of independent relative motion that a robot joint can perform. It has totally 28 degrees of freedom (DOF) in that head has 2 DOF (pitch and roll), arm has 7 DOF, torso has 4 DOF and base platform has 8 DOF.

TABLE II
DEGREES OF FREEDOM

Head	**Torso**	**Arms**		**Base**	**Total**
		Left arm	Right arm		
2/head 1pitch 1yaw	4/torso	2/shoulder 2/elbow 3/wrist	2/shoulder 2/elbow 3/wrist	4/roll 4/steer	
2	4	7	7	8	28

SELECTION OF MOTORS

The type of motor chosen for an application depends on the characteristics needed in that application. These include the weight and size of the object, the cost and size of the motor and the accuracy of position or speed control needed. The motors are selected from Maxon and Parker depends upon the below torque calculations, voltage and weight.

A. Selection of Motors for Base:

In mobile base eight motors are present. Four motors are used for rolling and four motors are used for steering. The motors are selected based on the torque, voltage, speed, size and weight.

The torque equation for the roll motor is as follows,

$$\text{Roll Motor, } T_{roll} = \frac{Wg\,\sin(\alpha)\frac{d}{2}}{n} \quad (1)$$

$$\text{Torque at motor level} = \frac{T_{roll}}{(R_1 \cdot R_2 \cdot R_3 \cdot eff)} \quad (2)$$

The torque equation for the steering motor is as follows,

$$\text{Steering motor, } T_{st} = T_{roll} \cdot \left(\frac{L_{off} \cdot 2}{d}\right) \quad (3)$$

$$\text{Torque at motor level} = \frac{T_{st}}{(R_4 \cdot R_5 \cdot eff)} \quad (4)$$

where,

W - Weight of the robot and payload,
A - Inclination of ramps,
V - Desired velocity,

L_{off} - Lateral offset of the wheel,
n - Number of driving wheels,
d - Diameter of the wheel,
R_1 - Timing belt 1st stage reduction for wheel rotation
R_2 - Bevel gear 2st stage reduction for wheel rotation,
R_3 - Timing belt 3st stage reduction for wheel rotation,
R_4 - Planetary gear reduction for wheel steering

R_5 - Timing belt reduction for wheel steering

Depends upon these torque calculations, the motors are selected from Maxon, for the base rolling and steering. The power for the steering motor is 25 Watts [4] and for the rolling motor is 200 Watts.

B. Selection of Motors for Arm:

The arm has totally seven degrees of freedom. The shoulder and elbow has 2 DOF (pitch and roll) and the wrist has 3 DOF (yaw, pitch and roll).

The torque equation [6] for the shoulder joint is as follows,

Shoulder joint torque =

$$\left(\left(M_p + M_e + M_f + M_u 0.5\right)L_u . g\right) + T_e \qquad (5)$$

To calculate the shoulder motor torque, the 100% reduction ratio has to be considered with the shoulder joint torque.

The torque equation for the elbow joint is as follows,

Elbow joint torque =

$$\left(\left(M_p + M_e + M_f 0.5\right)L_f . g\right) + T_w \qquad (6)$$

The torque equation [6] for the wrist joint is as follows,

Wrist joint torque, = $(M_p + M_e)\, L_g . g$ (7)

As like the shoulder motor torque, the elbow motor torque and wrist motor torque is calculated by considering the 100% reduction ratio with the elbow joint torque and the wrist joint torque.

where,

M_p - Mass of payload,
M_e - Mass of end effector,
L_u - Length of upper arm,
L_f - Length of fore arm,
L_g - Centre distance of the gripper,
M_u - Mass of upper arm,
M_f - Mass of fore arm,
L_{total} - Total length of the arm,

$$L_{total} = L_u + L_f + L_g \qquad (8)$$

From the above calculation, for the shoulder and elbow the motors are selected from Parker and for the wrist the motors are selected from Maxon. The Parker Frameless Kit Motors allow for direct integration with a mechanical transmission device, eliminating parts that add size and complexity The power ratings for the shoulder motor and the elbow motor are 322 Watts and 168 Watts and the power rating for the wrist (pitch& yaw) motor is 20 W and the wrist (roll) motor is 60 W.

C. Selection of Motors for Head:

Head is able to change the viewing directions vertically and horizontally. It has two DOF. One for pitch and the other for yaw.

The torque equation for the head is as follows,

T= Weight of the head*Distance between camera & joint.

The amount of torque that is needed out for the motor can be determined by the ratio of the required torque to the Reduction ratio and efficiency (without the percentage) of the reducer.

Head motor torque, $T_m = \frac{T}{R_1 \cdot R_2 \cdot eff}$ (9)

From this calculated torque, the motors are selected from Maxon. The power rating of the head motor is 12 Watts.

D. Selection of Motors for Torso

The torso has 4 joints as shown in the Fig.1. It has four DOF (yaw, pitch and roll).

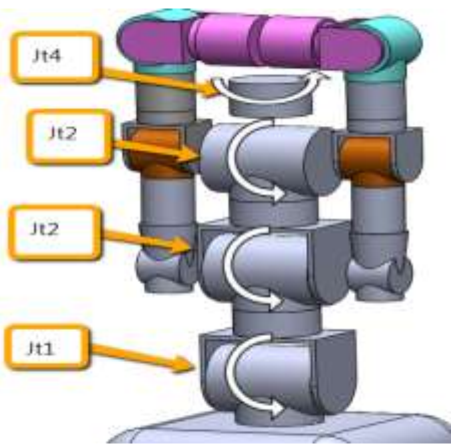

Fig. 1 Joints of the torso

The torque equation for the torso is as follows,

$$T_3 = g\left(d_3\left(P_{arm} \cdot 2 + P_{load} + \frac{P_{chest}}{2}\right)\right) \quad (10)$$

$$T_2 = T_3 + \left(g \cdot d_2\left(P_{arm} \cdot 2 + P_{load} + \frac{P_{chest}}{2} + P_{jt}\right)\right) \quad (11)$$

where,

d_1 - distance between Jt1 – Jt2
d_2 - distance between Jt2 – Jt3
d_3 - distance between Jt3 – Jt4
P_{arm} - weight of the arm and gripper
P_{load} - weight of the payload
P_{chest} - weight of the chest
P_{jt} - weight of the joints Jt1 – Jt2 – Jt3

To calculate the torso motor torque, the 100% reduction ratio has to be considered with the torso joint torque.

From the calculated torque, the motors are selected from the Parker Bayside. These motors are frameless kit motors and have reduced weight.

The power ratings and the quantity of the motors are tabulated in the Table III.

TABLE III
POWER RATINGS AND QUANTITY OF MOTORS

S. No	Position (Joint)		Power (Watts)	Quantity
1	Shoulder	Pitch	322	2
		Roll	322	2
2	Elbow	Pitch	168	2
		Roll	168	2
3	Wrist	Yaw	20	2
		Pitch	20	2
		Roll	60	2
4	Head	Pitch	12	1
		Yaw	12	1
5	Base	Roll	200	4
		Steer	25	4
6	Torso	Yaw	322	1
		Pitch	322	1
		Pitch	322	1
		Pitch	322	1
7	Total			28

SELECTION OF DRIVES

The drive provides a current boost to actually drive the motors based on the commands from the controller. The motor drives the transportation system either directly or through a gear system or chain system. The drive is selected from Advanced Motion Controls (AMC). Depends upon the dimensions and the weight, the AMC drive is selected.

E. AMC Drive

The selected digital servo drive from AMC is designed to drive brushed and brushless servomotors from a compact form factor ideal for embedded applications. This drive features a single RS232 interface used for drive configuration and setup. Drive commissioning is accomplished using DriveWare.

F. Mounting Card

Mounting cards are designed to hold plug-in Z-Drives for prototyping. Z-Drives are intended to be mounted directly to the PCB however in the prototype stage an off-the-shelf mounting card can greatly facilitate the system design process.

The selected mounting card is designed to host a digital servo drive. The drive plugs into the bottom side of the mounting card, providing a compact assembly with connectors and switches readily accessible. This drive utilizes side-entry right angle fixed screw terminals for the Motor and Power connectors.

CONTROLLING OF MOTORS

For the mobile base control and testing, the 10 rpm and 100 rpm geared DC motors were taken. The 10 rpm motor is used for steering and the 100 rpm motor is used for rolling.

Processor selection is depending on the optimal cost, system performance, memory space requires and testability.

Considering all these parameters, following are the list of hardware components which are used.

1. Microcontroller AVR ATmega 8
2. IC L293 Driver for Motor
3. MAX 485
4. IC 7805 regulator
5. 12 V battery
6. RS 232 to RS 485 Converter

The ATmega 8 microcontroller is used to control the motors. As the microcontroller ports are not powerful enough to drive DC motors directly, the drivers are needed. The L293D driver is used to drive the motor. This drive can control two motors. The communication is accomplished by Modbus.

G. ATmega 8

The Atmel AVR ATmega8 [7] is a low-power CMOS 8-bit microcontroller based on the AVR RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega8 achieves throughputs approaching 1MIPS per MHz, allowing the system designed to optimize power consumption versus processing speed. The ATmega 8 controller board is shown in the Fig. 2.

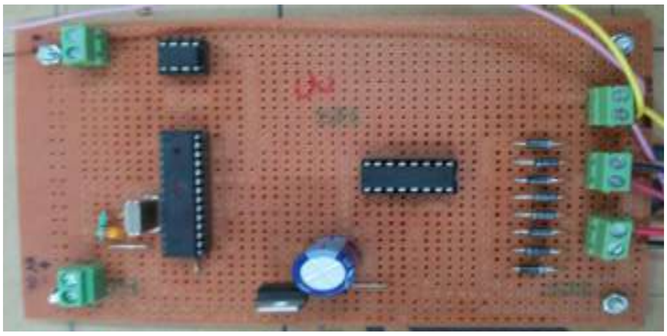

Fig. 2 ATmega 8 controller board

The schematic diagram of the ATmega 8 controller board is shown in the Fig. 3.

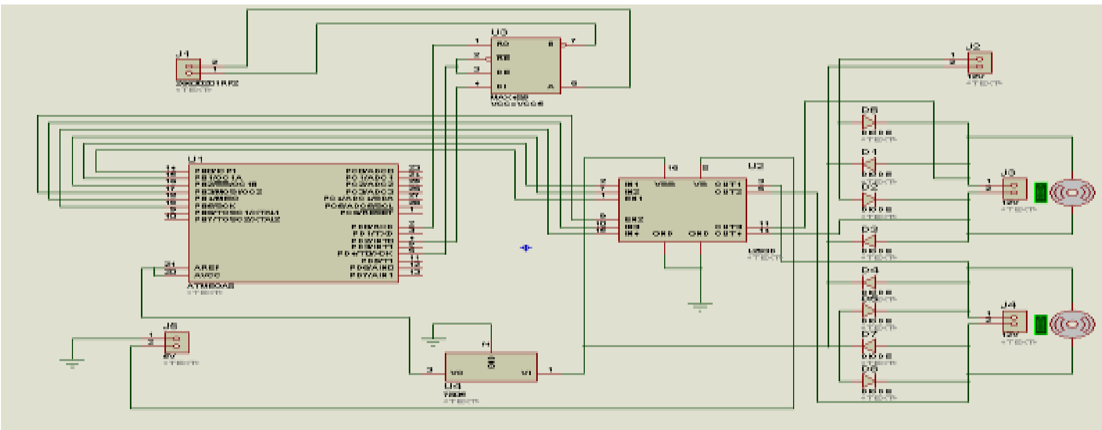

Fig. 3 Schematic diagram of ATmega 8 controller board

H. Modbus

The Modbus standard defines an application layer messaging protocol, positioned at level 7 of the OSI model that provides "client/server" communications between devices connected on different types of buses or networks. It standardizes also a specific protocol on serial line to exchange Modbus request between a master and one or several slaves.

RS-485 is the hardware specification for the physical wiring and connections. Modbus is the protocol specification that each device uses to communicate over the RS-485 serial line. It is a serial hardware specification over which most Modbus devices communicate. The terminating resistor on each end of the RS-485 loop is designed to match electrical impedance characteristics of the twisted pair loop, to prevent signal echoes from corrupting data on the line. A 120 Ohm termination resistor should be installed on BOTH ends of the RS-485 loop. Short and medium length Modbus/RS-485 loops can operate without the resistor. Longer runs may require it.

The data is sent as series of ones and zeros called bits. Each bit is sent as a voltage. Zeros are sent as positive voltages and a ones as negative. The bits are sent very quickly. A typical transmission speed is 9600 bauds (bits per second).

I. Modbus Poll

Modbus Poll is a powerful, easy to use, master simulating tool. Modbus Poll is a Modbus master simulator designed primarily to help developers of Modbus slave devices or others that want to test and simulate the Modbus protocol. With the multiple document interfaces we can monitor several Modbus slaves and/or data areas at the same time. For each window we simply specify the Modbus slave ID, function, address, size and poll rate. We can read and write registers and coils from any window. Multiple data formats such as float, double and long with word order swapping are available. Fig. 4 shows the Modbus poll simulator screenshot, while setting the function and address.

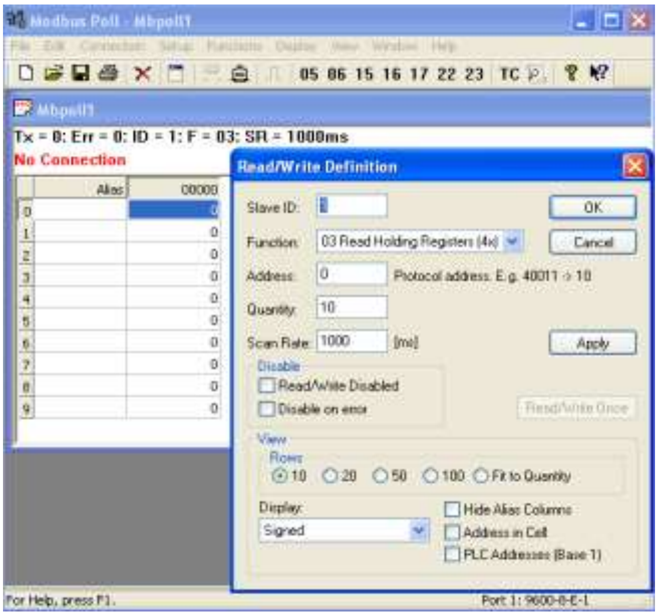

Fig. 4 Modbus Poll

EXPERIMENTS

The mobile base has experimented with the available components. It has 4 roll motors and 4 steering motors. The ATmega 8 controller is used to control the roll and steering motors. The roll motor is 100 rpm the steering motor is about 10 rpm. The 12 V battery is used to give the supply. Modbus RS 485 is used for the communication. Fig. 5 shows the controller communication network block diagram.

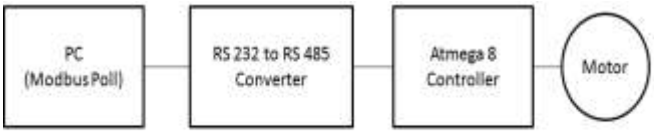

Fig. 5 Controller communication network block diagram

The specific address is given in the Modbus poll from the PC. The RS 232 TO RS 485 is a Converter, which converts the RS 232 Serial Port Signals from PC to RS 485 or RS 422 signals for long distance driving and for interfacing devices supporting RS 485 or RS 422 Ports.

This converter allows interfacing any device using an RS232 serial link to an RS485 link. The RS485 link was conceived for long haul data acquisition and control applications. The original specifications allowed to network up to 32 stations on the same lines, at speeds up to 10 Mbits/s to distances of 4,000 feet. RS485 links are much used in industrial process control where reliability is important. The converter is connected to the controller and the motor. The pictorial view of the mobile base is shown in the Fig. 6.

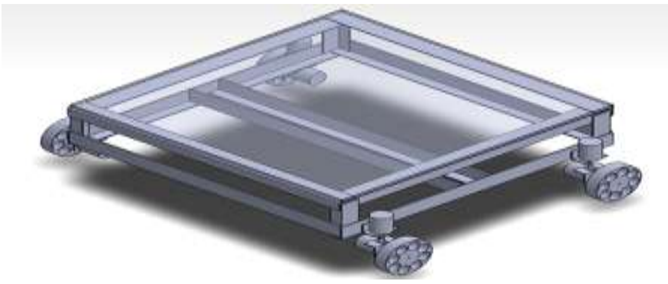

Fig. 6 Mobile base

The mobile base with roll and steering motor is shown in the Fig.7

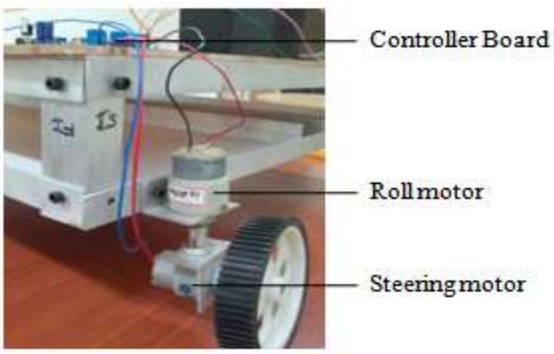

Fig. 7 Mobile base roll and steering motor

By giving specific addresses to the controller from the Modbus poll the motors are controlled and the communication is done by Modbus RS 485.

2. CONCLUSION

This paper discussed the selection of motors and drives for the Mobile Humanoid Robot. A variety of electric motors provide power to robots, making them move with various programmed motions. The motors are selected depends upon their torque calculation, weight and the size. The drive is selected mainly based on their dimensions. The communication is done by Modbus RS 485 and the motor is controlled using ATmega 8 microcontroller.

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