Low-cost MultiTerrainRescuing 4-Legged Bot Prototype

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***Abstract*—in modern day disaster recovery mission has become one of the top priorities in any natural disaster management regime. Smart autonomous robots may play a significant role in such missions, including search for life under earth quake hit rubbles, Tsunami hit islands, de-mining in war affected areas and many other such situations. This paper presents a way to build a low cost rescuing 4-legged bot prototype based on Arduino with multiple features like obstacle avoidance , wireless communication as well as sending the pictures of the area using on board wireless camera. The bot can also fly using heli rotors and can be controlled wirelessly by 4 channel transmitter. In others words we can say that it can walk, it can climb on sloppy surface and it can fly also when needed. This 4-legged-bot is built on an ATmega8 microcontroller which has been programmed using Arduino. This paper also describes the method of terrain negotiation navigation in a hazardous field.**

Keywords- arduino, robot, rescue systems, quad bot, wireless

I.INTRODUCTION

The catastrophic cyclone Sidr that wrecked havoc Bangladesh in 2007, tsunami hit most of the countries of Asia around Indian ocean in 2004, Katrina hit Arkansas in 2005, and the terrorist attacks on the World Trade Centers in 2001 are clear indication that we are not prepared for disaster recovery at all. In all cases the infrastructure could not withstand the fury of nature, even in the case of WTC the NYPD was not prepared for such gigantic task of rescue mission. The conventional reaction to such disaster is not adequate; a new paradigm shift is needed to address such calamities utilizing all resources at hand. Disaster recovery is defined to be the emergency response function which deals with the collapse of manmade structures. In any disaster either man made or due to Mother nature, the elementary tasks at hand are: (i) to reach the affected hazardous field (ii) find and get information about victims, and (iii) rescue as many of them as possible.

Quad pod robots can play significant role in disaster recover mission. It is possible for robot to reach any hazardous field unlike who have limited mobility in such missions. Nowadays many legged and wheeled robots are involved in this mission . In terms of hazardous field navigation for disaster recovery mission, Quad pod robots have advantages over wheeled robots. Given sufficient intelligence Quad pod robots may discover and negotiate any kind of terrain over wheeled robot.

In order to traverse a given terrain the robot needs to be equipped with some sort of locomotion system whether it is wheels, legs or articulated bodies (snakes). Different types of fields require different types of locomotion, wheels and tracks are preferred on even terrain but on uneven terrain the advantages of wheels became minimal or obsolete. Instead the advantages of legs make walking more useful in an uneven terrain because of the positioning the leg with high precision.

Well everyone finds it easy to build a Quad-bot and helicopter from the scratch, which can walk and can fly but separately using 8051 and other shields. But can one take this concept one step beyond and build a Quad-bot with helicopter feature inbuilt in it, specifically a bot that can walk, climb and fly.

Well it's very difficult tasks because of several reasons, popular among them are:

1. The microcontroller board used should be of a very compact size.
2. Configuring many sensors and devices in compact design. The sensors used should be quick and highly sensitive so that it can trace conditions with ease or detect obstacles with ease.
3. The Quad-bot must be in a position to withstand minor crashes caused during flying due to human error.
4. If at all the Quad-bot can't detect an obstacle it crashes, resulting in the loss of components especially the microcontroller and its board.
5. Finding out the centre of gravity of the design for proper flying.

This paper presents a way in which all these problems can be overcome. Firstly the usage of an Arduino board solves the problem of compactness of the microcontroller board. The sensors used should be Arduino compatible with the shield. The usage o f ultrasonic sensors provides accuracy i n detecting obstacles. Wireless camera installed on the board gives the live feed of the surrounding area. Brushless motor and the blades make it to fly and it is controlled by the 2.4 GHz transmitter. To withstand crashes if one can load the landing gears with thick rubber padding then the probability of damage of components due to crash gets reduced. It also solves the crucial problem of frame damage which renders the Quadbot useless for further use.

II.RELATED WORK

Wheeled robots are the simplest and cheapest and tracked robots are very good for moving, but not over almost all kinds of terrain. Many manned wheeled vehicles or robotic systems have already been tested. Navigate over obstacles and ditches and even on stairs is one of the foremost advantages legged robots hold over their wheeled or tracked counterparts. It shows that legged robots can operate in both even and rough terrain.

The Quad pod provides additional degrees-of-freedom for the robot's sensors and onboard equipment. Some general-purpose robots were tested for this application at the first but nowadays specific prototypes developing special features are being built and tested. The TITAN VIII walking robot, a four-legged robot developed as a general-purpose walking robot at the Tokyo Institute of Technology, Japan. COMET-I is maybe the first legged robot purposefully developed for rescue missions. It is a six-legged robot developed at Chiba University, Japan, and incorporates different sensors and location systems. This robot weights about 120 kg and results very heavy for real search and rescue missions. The Chiba University group has developed the fourth version of this robot, COMET-IV, which weighs about one ton. ARIEL is another hexapod robot, developed by the robots Company, for mine-recovery operations. The Defense Advanced Research Projects Agency (DARPA) and the US Office of Naval Research (ONR) are exploring methods for using this robot for underwater missions. This robot uses six 2-DOFlegs with limited mobility to perform omni directional motions. The legged robots working group at the Industrial Automation Institute (IAI-CSIC) has long experience in the development of walking robots since 1999 it has been working on the application of the RIMHO-2 walking robot for detecting and locating unexploded ordnance. The Quad pod robot could be used in agricultural field also, though wheel robots already are being existed in this field. But the wheel robot can move only directed even terrain. In this case Quad pod robot can navigate even and uneven terrain. Quad pod robots appropriate for disaster recovery mission. Disaster recovery mission refer to be the crisis rejoinder task, in this case workers feel an uncomfortable to work in this hazardous work environment .Often, there are substantial risks involved in field work due to the hazardous environment. The main application of robots in the mission has been concerned with the substitution of manual human labor by robots or mechanized systems to make the work more time efficient, accurate, uniform and less costly. A legged locomotion robot has more advantageous than the wheel locomotion at the moving on such rough ground .The legged locomotion has some features: It is hardly influenced by the condition of ground; It is able to walk stably; It can dynamically tune with high-speed. In the comparison with 2-legged locomotion, 4-legged one always keeps the balance of body at walking. That is, it is easy to control the system of leg mechanism for walking without over-consideration against the control of posture. On the other hand, insects have 6 or 8 legs, but it is easily supposed to be unsuitable for the locomotion mechanism of bigger system than insects because multi-legged system with more than 4 legs requires the complex mechanism so that its weight becomes heavy although the stability of its posture is superior to other locomotion with less than 4 legs.

Most professionals and researchers use 8051 & PIC microcontrollers since it have an on-board driver circuit for the motors for building obstacle avoiders. It is also more compact than an Arduino board. But the two features cannot be so easily integrated into a single system. Since it suffers from several setbacks like having insufficient analog input pins to aid usage of multiple sensors, cost, software for programming the microcontroller is not available free of cost etc. So an ATmega8 based Arduino board which has several features apart from several different kinds of pins on it compared to PIC& 8051 is preferred in this particular application. The shields for interfacing are easily available and make the design highly compact.

Some naïve designs of Quadbot are just with 4-legged movement, using 8 servo motors, out of which each leg consists of 2 servos for proper 180^0 leg movement. However this is very basic design and can be constructed using any scratch and blueprint.

One can mount sensors like ultrasonic or ping sensor for obstacle avoidance, temperature sensor (LM35 Ic) for sensing the temperature inside any area on board so that the bot can take its own decisions of moving according to the physical factors present around any area. One can also make the Quadbot to fly by applying the helicopter concept.

Some naïve designs of helicopters are with just two DC motors. One dedicated to the main propeller and other for the rear to control the direction. However the disadvantage of this method is that the helicopter frequently goes out of control because of the torque and non torque turns of the tail rotor. It takes longer to turn left than right because of the speed in which the rotor has to rotate to make the helicopter turn right. So one can use 3 DC motors to solve this problem. One dedicated to making the helicopter turn left, other to make it turn right and the other to control the forward and backward moves of the helicopter. This methodology was really helpful in making the bot to fly with compact design.

Some researchers even use quad-rotor helicopters, wherein there are four rotors operating simultaneously on the same plane separated by 90 degrees. These further increases the cost and it will be very difficult for the bot to sense an obstacle directly in front of it in some cases.

Some people do not give much preference to the design of the bot , but only the design of the bot is most important as finding out the centre of gravity of the is most difficult task, because the implementation of the brushless motor depends upon the centre of gravity of the design. Several researchers and students from reputed universities use very costly designs and ,materials for the bot but we can make the bot using acrylic sheet also which lowers the cost and the Arduino board is also helping in cutting the cost of the project. UV sensors, cameras and other expensive sensors to aid helicopters to detect obstacles in the air. The main focus of this research is to develop an efficient terrain negotiation & locomotion for a 4-legged robot. The focus is to negotiate hazardous field of even and uneven terrain, the big aim is that the bot should fly also. In Section III, we will discuss methodology, details of the algorithm developed followed by control system design in section IV. Finally we present conclusion and future direction in section V.

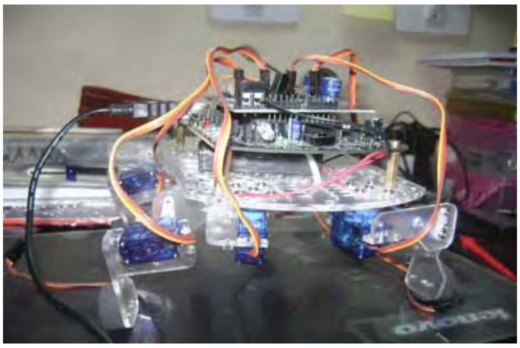
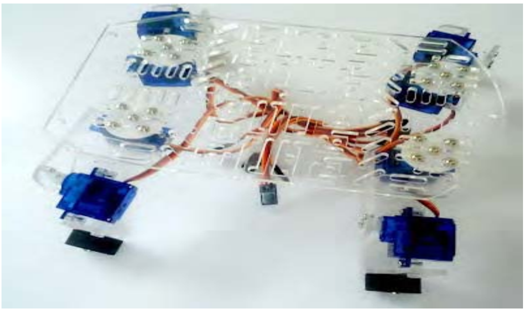


Fig.1 Simple Quad pod robot

III. METHODOLOGY

A. *Body Configuration*

A Quad pod robot is a perfunctory medium that walks on four legs. Since a robot can be statically secure on three or more legs, a Quad pod robot has a great deal of suppleness in how it can move. If legs become disabled, the robot may still be able to walk. Furthermore, not all of the robot's legs are needed for stability; other legs are free to reach new foot placements or manipulate a payload. A Quad pod, can achieve higher speed than other designs. However, the robot’s static stability margin is not optimum, for instance, five-leg support patterns present better stability. Nevertheless, a Quad pod configuration using alternating tripods has been chosen just to try to increase the machine’s speed, albeit at the cost of slightly jeopardizing stability. To navigate in the hazardous field, it will rotate in any direction; light legs with powerful servo motors are chosen over other types as they can withstand heavy loads. It contains the required subsystems, such as an onboard computer, electronics, drivers, an Atmega8 Microcontroller LC and batteries. Walking robots body shape can determine key features such as static stability. Fig. 2a and Fig.2b depicts the configuration.



(a)

Fig. 2a

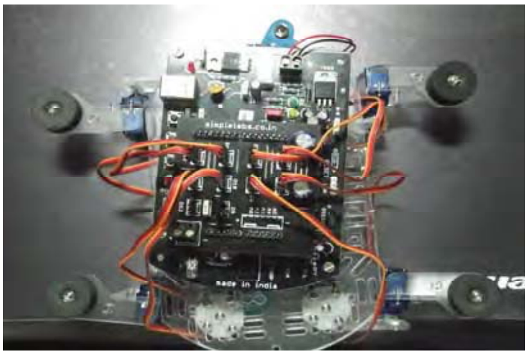


Fig. 2b
Fig. 2a and Fig.2b Robot body configuration

B. ***Leg Configuration***

Quad pod robots require legs that touch the ground only at certain contact points. Legs have been designed keeping in mind weight consideration mechanisms because their weight is part of the robot's total weight, which must be supported by the legs themselves. Spider-like leg configurations are typical for walking robots. It is known that a spider configuration is the most efficient leg configuration from the energy point of view because it requires lower torques. However, it is not very efficient in terms of stability. Insect-like legs seem to be more efficient stability-wise, but power consumption increases extraordinarily in an insect-like configuration. The idea is to provide a leg configuration that can accomplish its job with both stability and energy efficiency (a very important factor for outdoor mobile robots). So, we used a leg system that can be used in the spider configuration. By reducing servo motors size we can allow motions in two joints simultaneously. This configuration gives the benefit of using small servo motors if we impose some constraints on the possible trajectories. Two servo motors are used one horizontal and one vertical for joints 1 and 2. Joint 1 is configured around a typical rotary joint with horizontally constructed servo motor. With each leg configuration we have all two servo motors confined within a very small volume near the body. This gives additional advantages because the expensive leg components are away from the foot, the most dangerous point in the leg. This decreases the cost of replacing parts in the case of an accident. Fig. 3a and Fig.3b shows a leg indicating the main parts and components.

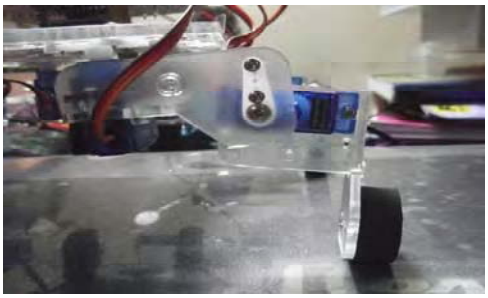


Fig. 3a

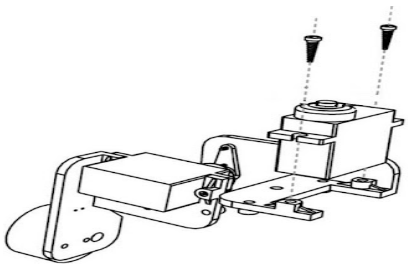


Fig.3b
Fig.3a and Fig.3b Robot leg configuration

C. *Locomotion*.

For the Quad pod locomotion, we would like to configure it by using two types of movement system. As this robot is able to navigate all kind of terrain in the hazard field, so it can move faster when it will get into even terrain, and in the event of uneven terrain, it will navigate very leisurely and it will also fly in case of highly rough terrain. Ultrasonic sensor helps it to detect any obstacle which it may encounter in the hazardous field. This obstacle refers to uneven terrain.

D. Algorithm for Movement

TABLE II
SET OF ELEMENTARY REACTIONS

Behavior 1	Go forward
Behavior 2	Rotate right
Behavior 3	Rotate left
Behavior 4	Go backward
Behavior 5	Continuous forward (high speed)

From the Table II, the steps of Quad pod movement control system with elementary behaviors are summed up as follows- Steps of progress:

1. The Quad pod stands for forward movement until grasps some obstacle.

2. If perceive obstacles then

a) timer on for t seconds

b) terrain consider as uneven

c) Go backward in the terms of behavior4, and then it uses its behavior 3 & 2 to rotate left or right (90 angle) according to the opposite direction of the obstacle.

d) use behavior1 until grasp obstacle

3. Else behavior 1.

4. If obstacle is unavoidable or more distance is to be covered it should fly.

E. *Sensors and Edifice*

The Quad pod contains 1 ultrasonic sensor, at the front with the necessary sensor’s construction. It also consists of onboard wireless camera which sends the live feed to the monitor present with the controller. Xbee with wireless SD shield is also present on the board for wireless communication.

Fig.4 Robot sensors edifice (ultrasonic sensor)

F. *Obstacle and Collision Avoidance*

We have designed the Quad pod robot will detect these obstacles during the navigation period. Ultrasonic ranging module HC - SR04 provides 2cm - 400cm non-contact measurement function, the ranging accuracy can reach to 3mm.

The basic principle of work:

(1) Using IO trigger for at least 10us high level signal.

(2) The Module automatically sends eight 40 kHz and detect whether there is a pulse signal back.

(3) IF the signal back, through high level , time of high output IO duration is the time from sending ultrasonic to returning.

Test distance = (high level time × velocity of sound (340M/S) /2.

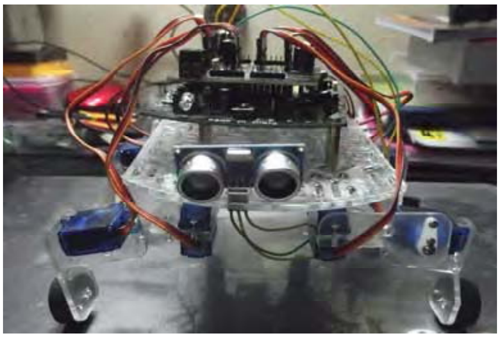
The modules includes ultrasonic transmitters, receiver and control circuit. Table III shows the method of different types of action during obstacle detection.

TABLE III
DIFFERENT OPERATION

Behavior 1	No obstacle
Behavior 2	Left obstacle
Behavior 3	Right obstacle
Behavior 4	Front obstacle
Behavior 5	Unavoidable obstacle

The Quad pod will negotiate two different types of terrain: even terrain & uneven terrain. Terrain negotiation always comprises safety aspects on the motion execution in order to protect living creatures as well as the robot's hardware. Especially rough terrain capabilities require the robot to distinguish traversable from hostile locations. Obstacles make sense to the Quad pod robot about the types of the terrain.

5(a)



5(b)
Fig.5 (a, b) Obstacle avoidance configuration

G. *Xbee Transmission and Wireless Camera*

This is the Xbee XB24-Z7WIT-004 module from Digi. Series 2 improves on the power output and data protocol. Series 2 modules allow you to create complex mesh networks based on the Xbee ZB ZigBee mesh firmware. These modules allow a very reliable and simple communication between microcontrollers, computers, systems, really anything with a serial port! Point to point and multi-point networks are supported. These are essentially the same hardware as the older Series 2.5, but have updated firmware. They will work with Series 2.5 modules if you update the firmware through X-CTU. Xbee sends wireless signals and also receives it as it is a transreceiver protocol, we can send the signals for controlling the bot movement and Xbee will also send the temperature and other physical factor info to the main computer.

Wireless A/V camera is also installed on the board which sends the live feed to the receiver present at users end and that receiver is again connected to the monitor which shows the live picture of the surroundings where the bot is present the camera can be moved up-down using two servos.

Fig. 6 Xbee module for wireless communication

H. *Making Quad Pot Bot to Fly*

The brushless motors are built from the best materials available and feature high quality bearings, powerful magnets, superior electromagnetic design, and rigorous engineering control. They are designed to provide both quality and performance at an affordable price. These definitely are not the cheap quality motors that are available in the market.

7(a)

7(b)

7(c)
Fig. 7(a, b, c) Brushless motor, Propeller & its assembly

Specification of motor & propeller used for flying the quad pod bot is given below

RPM / V - 1350 rpm
Cell - 3 cell / 11.1V
Prop - 8 x 6
ESC - 30 amp
Weight (approx) - 58 gms
Thrust - 1010 gms

The motor and propeller are applied by keeping in mind that motor should be installed over the centre of gravity of the design this is done by trial and error method. One receiver with li-poly battery is also attached to the design for fulfilling the higher needs of power to the motor.

As the robot a start flying it is controlled by 2.4 GHz transmitter externally for forward and backward movement.

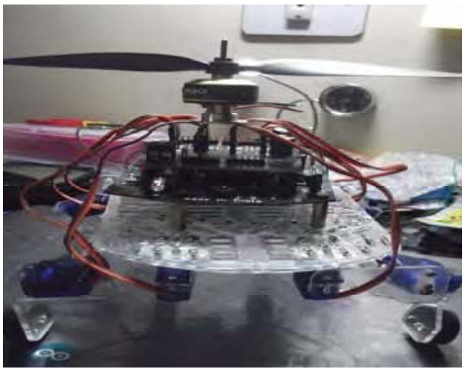


Fig.8 Configuration with motor and propeller

I. *Terrain Negotiation*

The Quad pod will negotiate two different types of terrain: even terrain & uneven terrain. Terrain negotiation always comprises safety aspects on the motion execution in order to protect living creatures as well as the robot’s hardware. Especially rough terrain capabilities require the robot to distinguish traversable from hostile locations. Obstacles make sense to the Quad pod robot about the types of the terrain.

J. *Scenarios of Quad Pod Bot*

We have a state table in Appendix, and we have constructed the state diagram from this state table. We need to examine it further and construct a stable state table. In all the states, the actions to get to the robot and the action performed by it. For example, when Quad pod turns on, it puts itself in the turned on state. From here, it is allowed to conduct various movements.

i) Steps of Algorithm:

1. Idle mode

2. Call turn-on procedure. (Initially stand alone)

3. Active state: able to do all operation sequentially

(a). move forward

(b). move backward

(c). turn left

(d).turn right

(e). ultrasonic sensor (on)

(f).wireless camera (on)

(g).Xbee transmission protocol (on)

4. Un even terrain state: if presence of any obstacle

(a). move forward

(b). move backward

(c). turn left

(d).turn right

(e) Unavoidable obstacle

-stand alone

- start flying

5. Even terrain state: else

(a). move forward

K. *Control System*

The user interfaces have control over the running of the microcontroller and are fed back information about the status of the robot. The onboard controller is an Arduino Microcontroller system. In test phase, communication between operator station and onboard computer is performed by a data cable. The microcontroller reads the information and controls the movements of the robot. The drive system consists of servo motors. The motor is driven by a high powered PWM (Pulse Width Modulation) controller board; it gets the signal from the microcontroller. The servo motor controller has its own self start and stop facilities allowing smooth stopping and starting with no processing time required for the microcontroller. The 0-5v analogue signal input also allows the microcontroller to control the speed, acceleration and declaration. Computer module shows the user relevant information on the robots status and allows the user to control the robot directly with ease.

APPENDIX

STATE TABLE FOR RANDOM SCENARIOS

State	Event	Actions	Comment	Caused By	Will Effect
A. Active	1.turnOn	Boot Up	Quadpod is turning on		2-10
	2.bootUp	Activity	Allow various activities	1	3-8
	3.forward movement	Walk Forward	Quadpod will begin to walk forward	2	11,12
	4. backward movement	Walk Backward	If obstacle is in front, Quadpod will begin to walk backward		12
	5. right rotation	Rotating in right side	If obstacle is left side, Quadpod will turn by 90* angle in right direction		12
	6. left rotation	Rotating in left side	If obstacle is right side, Quadpod will turn by 90* angle in left direction		12
	7. ultrasonic sensor	Button on	Obstacle detection		11
	8. Wireless camera	Button on	Live Feed		12
	9. Xbee transmission	Button on	Wireless protocol		12
	10. Flying	Gets on	In case of unavoidab le		11
B. Even terrain		Fast movement	Quadpod will walk or rotate very fast until it gets an obstacle	7, 10	3,8,9,10
C. Uneven terrain		Slow movement	Quadpod will walk or rotate at a snail's pace for t seconds.	8, 9	3,4,5,6,11

Fig.9 Full Quad pod Robot assembly

IV. CENTRAL OPERATOR

The central operator station is situated at a distance from the walking robot and is in charge of human–machine interface, database management and system communication to take the corrective action in the hazardous field. The human–machine interface is a component anticipated to fulfill main requirements of assignment designation for taking corrective action against disaster our environment. The user has the ability to control robot motion remotely, with real-time visual information on what the robot is doing. Communication between the operator computer and the onboard computer is conducted by means of a data cable.

L. *Platform Description*

Arduino is an open source physical computing platform based on a simple microcontroller and development environment for writing software for the board. Tiny computer one can program completely standalone and talks to other devices. It's intended for artists, designers, hobbyists and anyone interested in creating interactive objects or environments. We use Arduino because its inexpensive, cross-platform, open source and extensible software and hardware.

The microcontroller used is a high performance AVR ATmega8 microcontroller as shown in Fig.10 an Arduino board is as shown in Fig. and Fig. shows the component mapping.

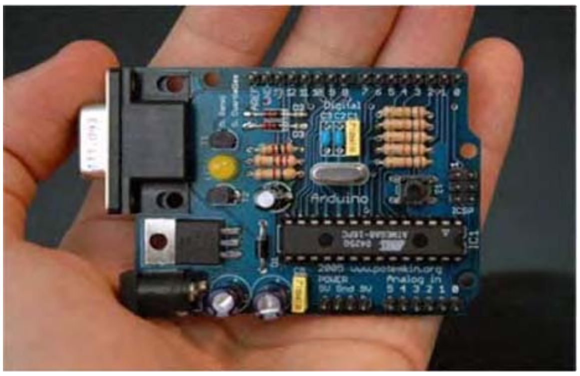


Fig.11 Arduino Board

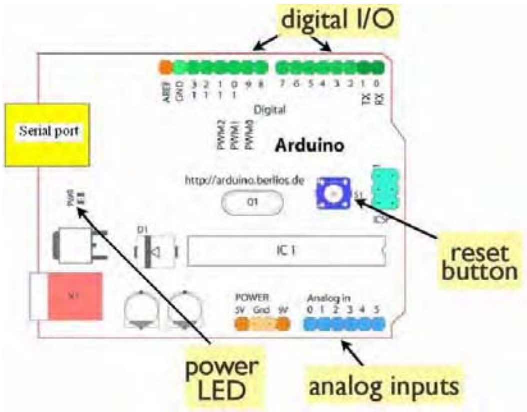


Fig.12 the component mappings of an Arduino board

So finally with the usage of ATmega8 based Arduino board a cost-effective, simple, durable multiple-colored line following and obstacle detecting helicopter has been built.

V. CONCLUSION

In this paper we demonstrated the development of low cost quadbot prototype using arduino with various features. We have also developed a method to perform obstacle avoidance terrain negotiation in a dynamic uncertain environment by using different locomotion. The novelty of the method we have developed consists of the explicit consideration of uncertainty in the perception system, to negotiate the terrain of the environment from sensors bumping. The developed method can be able to take the decision of the locomotion in accordance with the terrain. The case of Quad pod robot's different navigation system in the hazardous field has been analyzed in this paper. The algorithm we have developed for Quad pod robots that may overcome many of the shortcomings of previous legged robots developed for hazardous field.

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