Monitoring and Management of Unstable Network through Solar Powered Robotic Vehicle

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●要約

本論文では、不安定ネットワークの管理に利用可能なロボット車両の設計・開発を紹介する。特に、我々は赤外線反射センサを用いた車両ロボットのソフトウェアとハードウェアの設計や開発研究を行っている。さらに、TCP/IP ネットワークにおいて、不安定ネットワークに安定的に電源を提供するため、ロボット車両の応用を考える。ネットワークを安定的に運用するために、物理層での解決策としてネットワーク機器の電源供給を試みる。そのようなネットワークで利用するロボット車両の具体的な開発コンポーネントとして、方向制御に利用する DC モータ、組み込み制御プログラムの８ビットマイクロコントローラやギヤーなどを利用する。ロボット車両がサーバルームまで移動するメカニズムとして、パストレースメカニズムを利用することにした。パストレース情報を受け取る光電センサを開発し、リアルタイムでマイクロコントローラに提供され、方向情報をゲットしている仕組みになっている。本論文では、センサーユニットのメカニズム、マイクロコントローラおよびネットワーク管理の面でロボット車両とその応用について議論する。

●キーワード

Robotic Vehicle

Unstable Network Management

Path Tracing Sensors

1. Introduction

Computer network technology consists of electronic computer and communication technology. The history of computer network is not so old; however, it has passed number of phases to achieve the stage of today's Internet. ARPANET (Advanced Research Projects Agency Networks) had contributed to advance this technology as it had brought most of the concept of packet switching technology in 1969 [1],[2]. Network of that time was just a mini-step from a circuit switching to packet switching. However, this mini-step can be taken as a major milestone step in the history of computer networks. The closed and small ARPANET networks has later on enhanced by ALOHAnet in 1970 and by the principle of Ethernet in 1973 and further enhanced by DARPA project. The latest architecture of TCP/IP has first been deployed in January 1, 1983, as the new standard host protocol for ARPAnet [3].

In this paper, we introduce the concept of robotic vehicle which is applied to monitor the unstable power supply of the computer networks. Our robotic vehicle is an electro-mechanical machine which is guided by an electronic circuit. It can be deployed in the field of networks either by autonomous or by semi-autonomous or remotely controlled.

1.1 Unstable Network

The history of networks began from ARPAnet and attained to today's Internet with numbers of advancements. For example, the network media has been changed from copper wire to fiber optics that can carry millions bits of data in a second today. However, this kind of advancement of technology does not cover all parts of the world. There are still the regions where it is very difficult to install and cost millions of dollars to deploy the wired network. Many rural regions such as in Nepal, India, Bangladesh of South-Eastern Asian countries and most of the African countries, especially in developing regions of those countries, do not have good connectivity solutions which are economically viable. In order to provide internet access in these countries, government and INGO are working to provide wireless service in these areas. In our previous studies [4], [5] we have built partial-mesh networks in Himalayan regions and this network is still working thereby providing community networking service in the remote village of Nepal. However, these networks are not stable as compared to the networks built in urban areas. Lack of proper electricity and network infrastructure in rural areas and high installation costs as compared to urban areas are the two major hindrances in building stable wireless network. Wireless Network in rural areas is not stable due to the power outage and link failures due to signal loss.

1.2 Fundamental Idea

Our fundamental idea of keeping network stable relies in two methods. One of which is to monitor the network by using network management protocol such as SNMP. However, SNMP requires that each device understand SNMP protocol and it works above network layer. SNMP is very useful to monitor and notify about the status of network to the network administrator. However, we found that most of the devices used in unstable networks in the developing regions are not utilizing the features of SNMP due to less literacy of network knowledge. There are also various kinds of network management and monitoring tools such as nagios, MRTG, PRTG, Dude and many others by which network administrator can monitor their networks and keep their network under control. These tools are very useful to monitor and manage the networks however in order to properly utilized these tools; network administrator must have knowledge of these tools. This is possible in general scenario, however, this situation is not applicable in the remote areas of developing countries at which this research has been carried out. Most of the available tools are usable while the networks are alive. We still think that it is necessary to create some kind of tools or application so that network can be maintained more stable. Therefore, we realized that in this research, our focus should be on robotic vehicle at which the robot can sensed the down state of the network and proceed to the server to provide the electric power to the node without using SNMP.

2. Flow Diagram

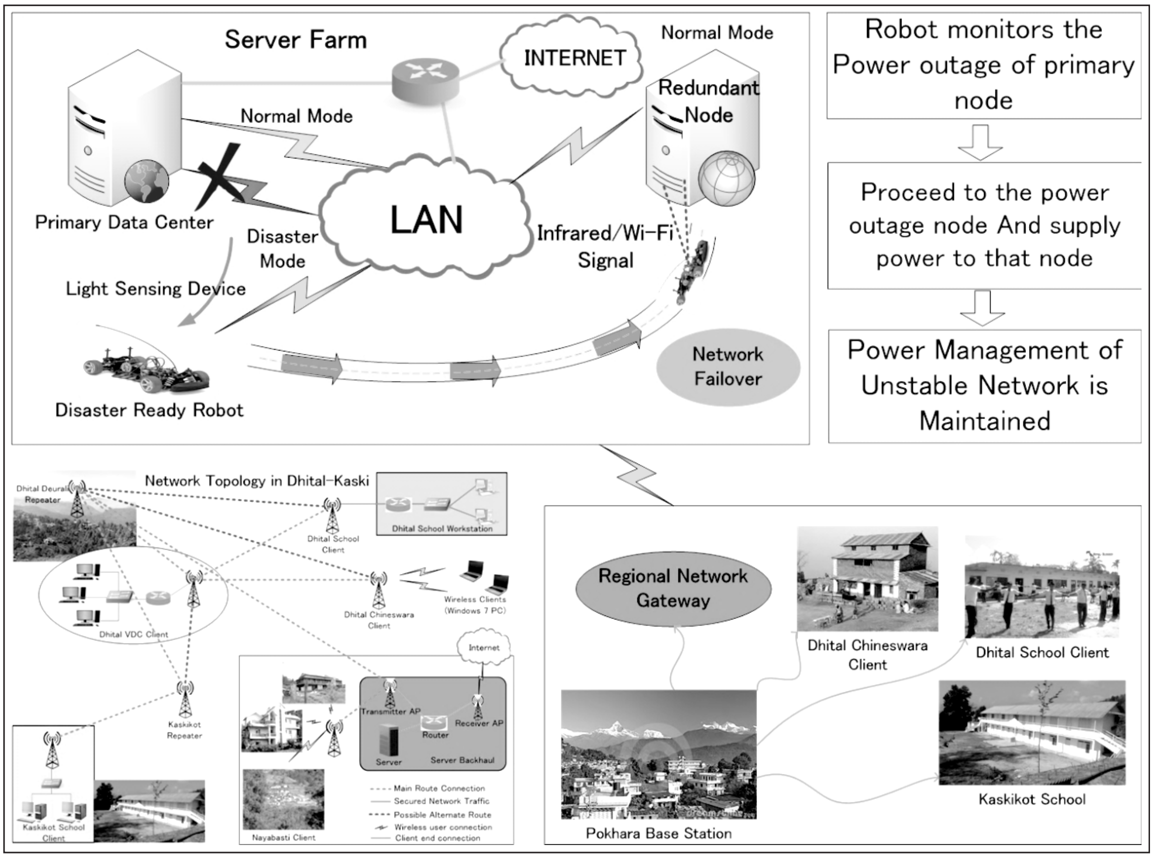


Figure 1: Conceptual Flow Diagram

As shown in the figure 1 above, let us explain about how our robotic vehicle application can contribute to manage the unstable network in WAN, LAN or PAN area networks. Our robotic vehicle is equipped with sensor application attached on its body. While network goes down, this sensor automatically can sense about it and proceed to server room in order to supply the power of the redundant node. The detailed steps are described in the figure 1 above. This figure is our test-bed network built in Nepal during our previous researches [4], [5]. The departure of our research as the first step would start from a development of power monitoring module between the servers. We are focusing to this problem that can be occurred due to an unstable power source. We recognized that unstable network trouble can arise due to other related networks problem such as signal loss, routing problems and many others. In this paper, we limit our research scope only in power monitoring module.

3. System Requirements and Architecture

3.1 Microcontroller and it's Functionalities

A microcontroller is an electronic device that can either be programmed in already prepared device or can be embed the program into it. This device is a compactly designed to govern the operation of embedded systems such as motor vehicles, robots, computer systems and many other appliances. A typical microcontroller includes a CPU, RAM, ROM, I/O ports, and timers like a standard computer, but because they are designed to execute only a single or a few specific tasks to control a single system, they are much smaller and simplified so that they can include all the functions required on a single chip.

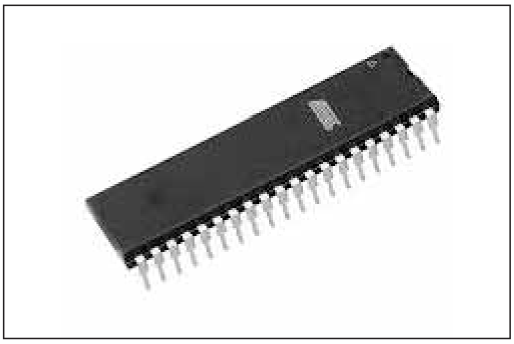


Figure 2: AT89S51 Microcontroller

The microcontroller used in this research is the AT89S51 microcontroller, the figure of which is shown in figure 2 above. This device is used to control the motors of our robotic vehicle. This controlling device has two different kinds of functionalities. One of which is to regulate the motor as per the signal received by sensor units that is attached in it. The other of which is to pursue the vehicle motion either in forward direction or in backward direction. Depending upon the synchronize signals between these two units; the signal received from the path the program embedded in the controller will be executed by which the robotic vehicle has to move accordingly. The whole program is written and burnt into the microcontroller itself as per design decision.

3.2 Electronic Circuit and it's Analysis

Electronic circuit used in our robotic vehicle is shown in the figure no 3, 4 and 5 below.

This circuit is built on the basis of path tracing and motor control objective. Path tracing is responsible for tracking the black and white colored path. Since infrared signals are absorbed by the black surface these signals could not reach the microcontroller via sensors. However, when the sensor steps into white surface then microcontroller gets the signal and it gives control signal for motor to change the current direction that its following and vice versa. This feature is designed in IR sensing unit.

Similarly, voltage control unit VCU is responsible for providing a controlled and uninterrupted voltage to devices used for smooth operation of the circuit. Accordingly, DC motor control is responsible for direction and forward-backward movement. We have installed 2 DC motors in our vehicle. One of which is used for forward-backward motion and the other is for direction control. In order to regulate these motions, we have also designed it in our circuit. These circuit sections responses according to the signal changes in input IR sensors. For example, if left sensor on around left wheel transmits signal to microcontroller then microcontroller understands that left wheel has tracked into white portion of the path then it immediately sent motor the corresponding command to change the direction to right. This results that left wheel goes to black track and follow the path. Similarly if right sensor gets signal then microcontroller understands that vehicle is required to turn into left direction and it immediately sends command for motor to change its direction to the left. In this way, our circuit with the help of sensors keeps the right path and move to the target. Forward-backward motor is responsible for forward-backward movement of vehicle. As soon as microcontroller senses that server in our network is off then microcontroller will immediately sent control command to this motor and vehicle moves forward to the server room to supply the power. Both of the forward-backward control and direction control units are designed as shown in the figure 3 below.

Track is designed in such a way that width of path is slightly greater than the width of wheel of vehicle and only one sensor (either left or right) has a chance of falling on white track at a certain time. Initially both will be on black track and when they change the path then they will reach to white track and microcontroller immediately response this and again sends signal so that both wheel always lies in black track.

Switching commands are responsible to control forward-backward motor and also responsible for switching on the server by sending the command to IR based remote control system attached on vehicle that sends command to the offline server and thus offline network is healed.

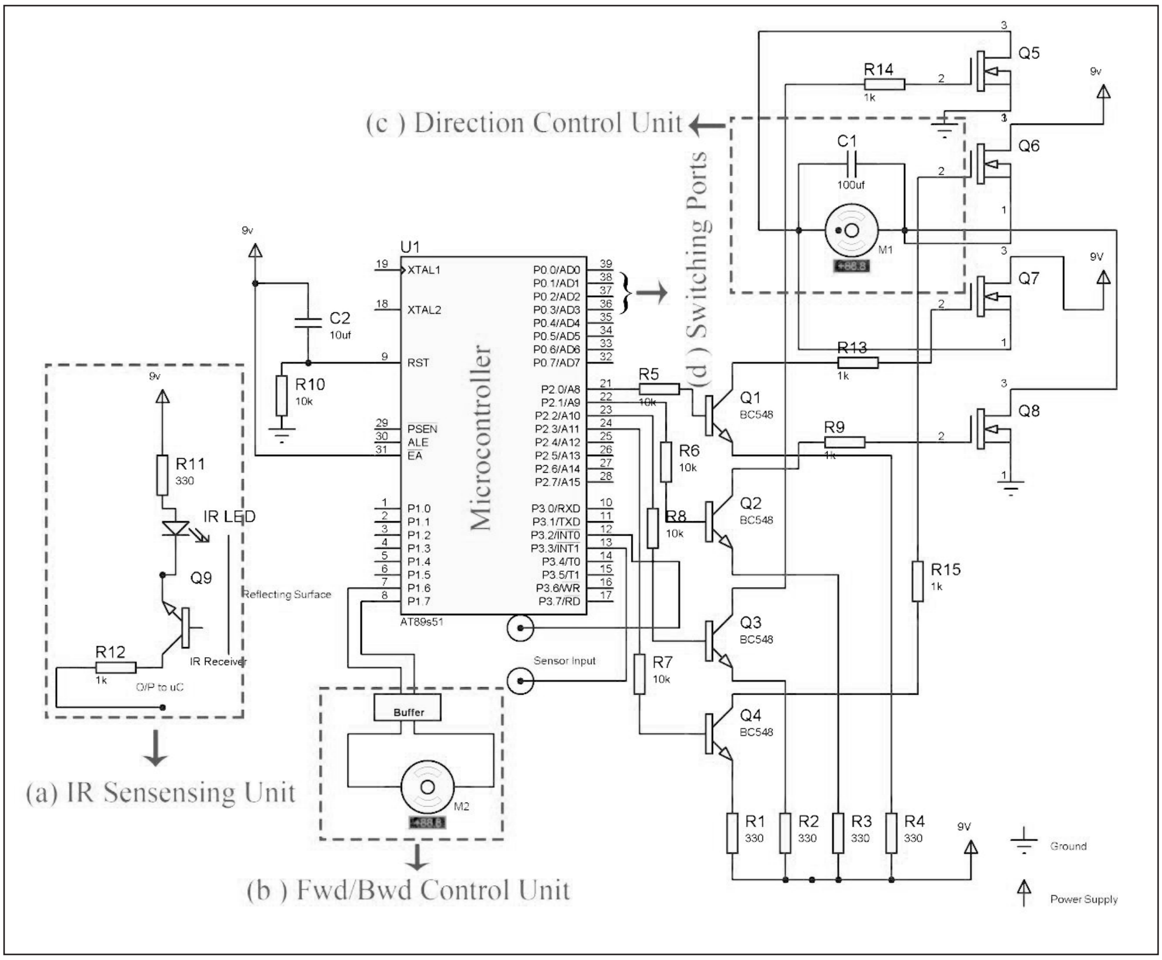


Figure 3: Electronic Circuit for Path Tracing and Motor Control

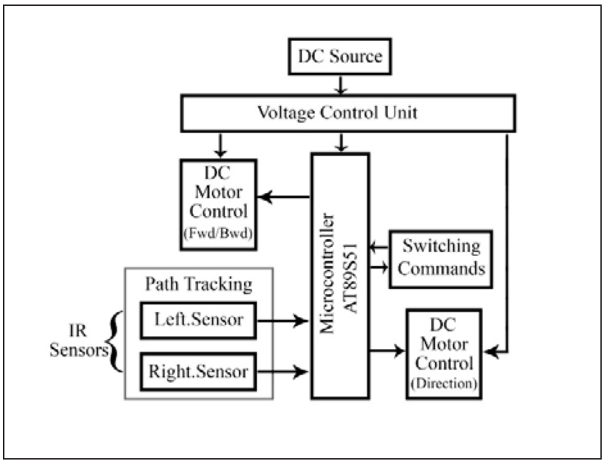


Figure 4: Over all flow diagram

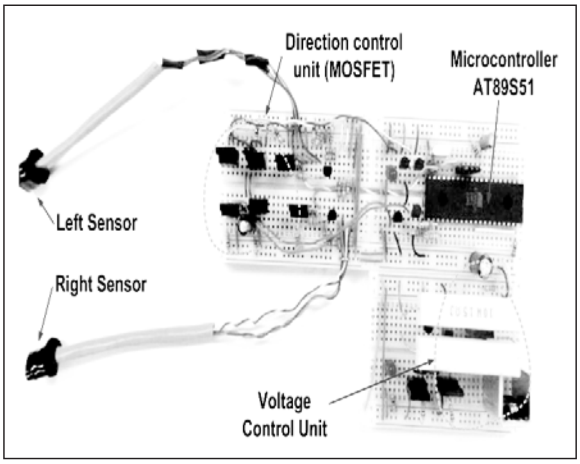


Figure 5: Snapshot of Bread-Board

3.2.1 Path Trace

To experiment robotic vehicle, we designed a 6.5 m oval shaped track-line in our lab. In order to move along the track line, the IR sensor detects the track line and signals from the sensor will execute corresponding command lines in the program embedded in the microcontroller. Accordingly, it regulates DC motor in order to control the motors' direction and speed. Presently developed track tracing system is able to control the vehicle in order to retain in the track and prevent from run out of the track-line.

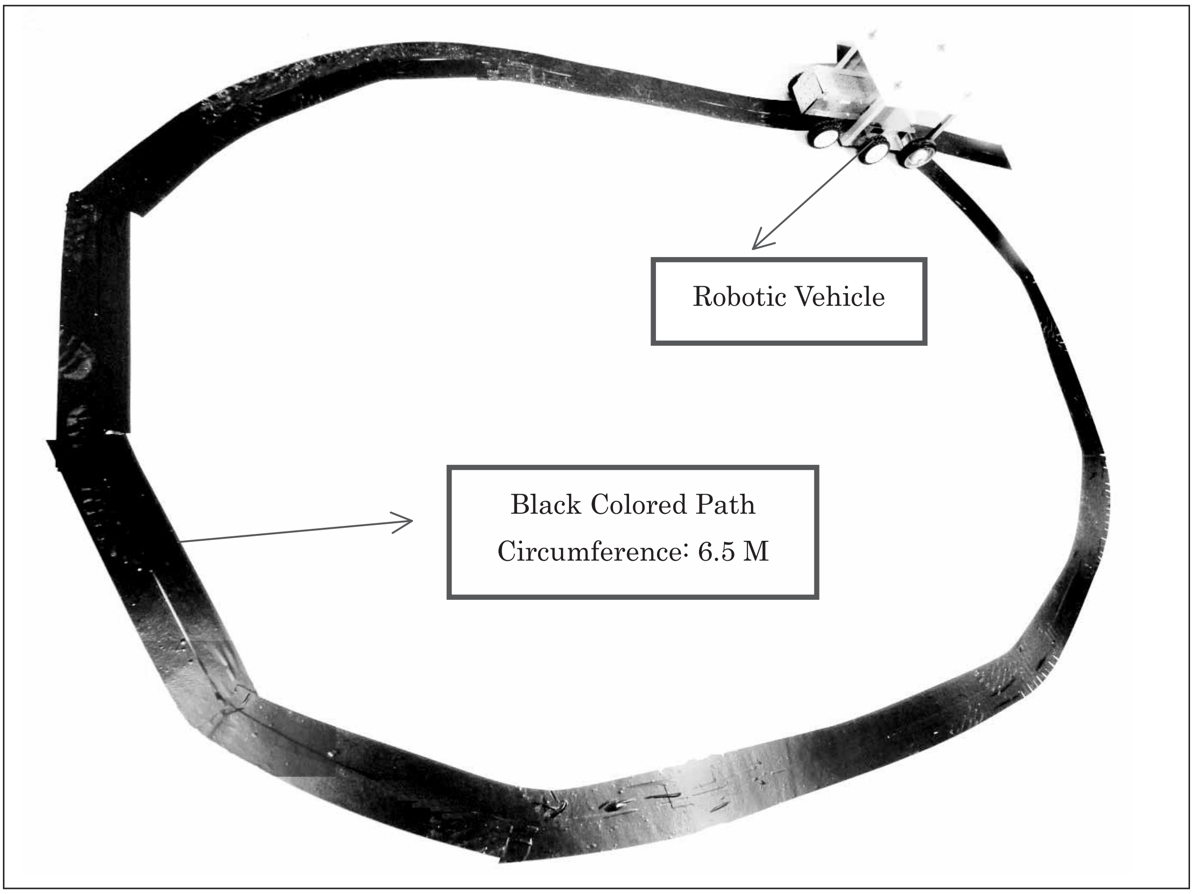
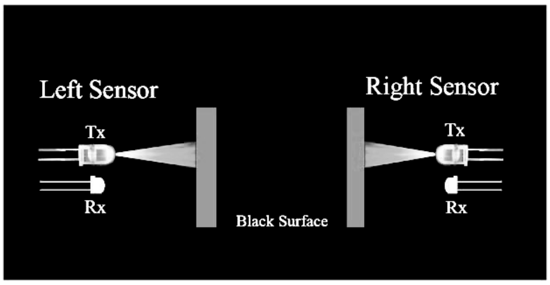


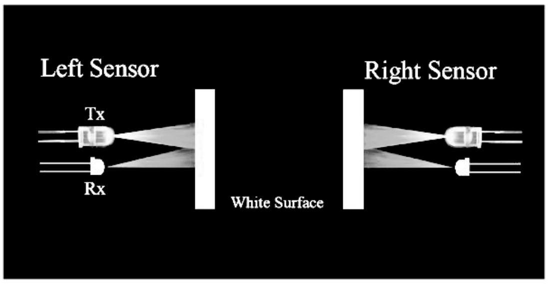
Figure 6: Experimented Path

3.2.2 IR Sensor

IR Sensors [6],[7] work by using a specific light sensor that detects the certain light wavelength in the Infra-Red spectrum. In our robotic vehicle, we are using 2 units of IR sensor as shown in figure no 7. These IR sensor units are made of LED and photo transistor (IR Receiver). Led produces light at the same wavelength and strike it in the frontal object. Our frontal object is a black labeled path. In our case, we are using the feature of IR sensor in order to sense the white object. For example when our vehicle get off the black labeled track and the light hits other surface, the sensor start to sense the reflected light as the light emitted from LED reflects into the light sensor. This mechanism is shown in the figure 7 more clearly.



a) IR receiver is not getting reflected light



b) IR receiver is getting reflected light

Figure 7: IR Sensor

3.3 Power System

Our power system used in this robotic vehicle is solar energy. Solar energy is regarded one of the comprehensive renewable resource by which the solar cell made up of semiconducting materials such as silicon that allows the electron energy to flow freely while sun light struck its surface. In our robotic vehicle, our battery is charged by solar panel.

The solar powered robotic vehicle aims to operate and manage the networks is a totally new concept. By this concept, network administrator can save his/her time by reducing the number of field visits while there is power outage. The robotic vehicle has a capability to sense the power outage and also the capability to be operated through solar energy which is consumed by the robot itself. The main advantage of this method is that there is time savings for network administrator and also it can be operated without producing CO_2

4. Other Parts and Vehicle Anatomy

4.1 DC Motors

We have used dirt tuned motor manufactured by Tamiya Pvt Ltd. This motor is equipped with worn out brushes which can be replaced too. Heat sink type end bell allows effective heat dissipation.

Figure 8: Dirt Tuned Motor

This motor is 27 turn type motor that can works in the range of 6-12 V though the correct usable voltage is 7.2. The efficiency of RPM at no load produces 17,000 rotations per minute. Torque at best efficiency is 37.24mN.m. Both of the torque and rpm works at the usable voltage of 7.2 V as described in Tamiya official website. The main function of this motor is to run as per the digital signals received from the microcontroller and produce the rotation and transfer this rotating energy into the gearbox.

4.2 Gears Mechanism

Gears are special kinds of wheels with teeth. Robotic vehicle cannot properly move without gears.

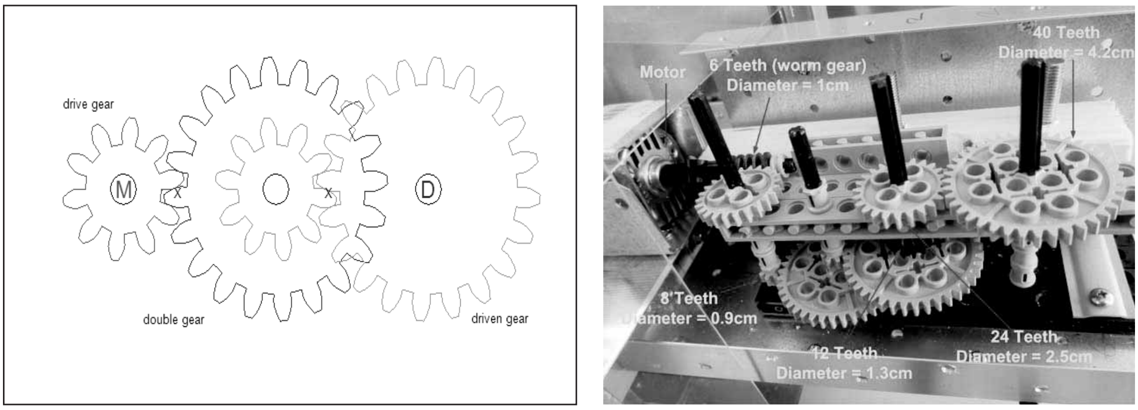


Figure 9: Gear Principle and Snap Shot of Gears (Lego) Used in Robotic Vehicle

Gears in robotic vehicle are used to transfer motion or power from one moving part to another more efficiently.

Let's describe the gear principle of our robotic vehicle by using the figure 9 above. Our robotic vehicle has numbers of gears which are used in order to increase the efficiency of torque received from motor indicated M in above. The total numbers of gears used for forward and backward motion is 9. Similarly we are also using gears in our direction control section too. The complete specification of the gears is mentions in table 1 and table 2 below. When our motor receives the signal from microcontroller, it starts to rotate and the speed of which will increased. First of all, it transfer the torque to driving gear and transmit to double gear and finally to the driven gear.

We are using 3:1 ratio in order to build a mesh gear as shown in the figure 9. We started to receive the torque from small gears and transfer this spin to larger gears. As the circumference of driven gear is larger than drive gear, the speed at the end decreased. This sort of mesh design is intentional as we want more torque in our drive gear so that it can pull more loads. Most of the parts of our vehicle are steel made and thus making it heavier. In order to pull this vehicle, we require more torque rather than speed in our drive gear. In order to understand relation between force and torque, let see the equation below.

$$\tau = r \times F$$

Where, torque is denoted by τ, moment arm by r and force by F. As the distance of r (Moment arm) is larger in drive gear, the amount of torque is increased. In this way, we are amplifying the torque at the output gear.

Table 1: Gear Specification for Direction Change

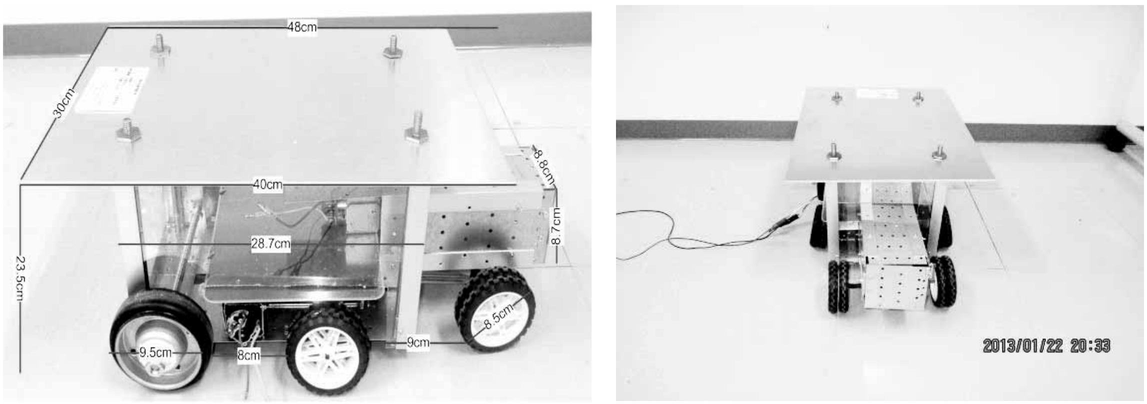
Numbers of Teeth	Diameter (in cm)	Quantity Used	Remarks
6	1	1	Worm Gear
8	0.9	2	
12	1.3	1	
24	2.5	2	
40	4.2	3	

Table 2: Gear Specification for Forward-Backward Movement

Numbers of Teeth	Diameter (in cm)	Quantity Used	Remarks
8	0.9	3	
12	1.3	2	
24	2.5	2	
40	4.2	3	

4.3 Conceptual Prototype of Robotic Vehicle

The complete conceptual prototype of robotic vehicle is shown in figure 10. The total length of robotic vehicle is 48 cm and the height is 24 cm.



a) Side View B) Front View

Figure 10: Body of Robotic Vehicle

5. Future Works

We are implementing a prototype of the robotic vehicle that can be used in order to manage the networks. Our departure of research starts from stabilizing the power networks by providing and monitoring the redundant power supply. In our future work, we want to collaborate our robots with other monitoring tools such as Nagios, SNMP, PRTG so that our robots can be notified by those tools in order to rescue the networks from being offline for a longtime. The key component of this research includes microcontroller based control system, path tracing IR sensor devices and solar powered DC motors. Currently, we have not implemented the obstacle detections unit in its path, however, in our future work we will implement the IR sensor device that can detect the obstacle in its path and reflect back to the microcontroller so that it can regulate the motor to avoid the obstacle. Theoretically, it is possible to avoid the obstacle as infrared waves get reflected back to the robot and can be programmed accordingly.

6. Conclusion

In this paper, a new concept of utilization of robotics vehicle in order to manage networks is proposed, and the construction of a solar powered path tracing robotic vehicle that employs such mechanism is described. The power system of the robotic vehicle is equipped with solar unit. Moreover, DC motor supported with gear mechanism is constructed as a means to attain faster movement.

To conclude, the main purpose of this research lies in the usage of robotic vehicle system in the management of network, based on renewable energy. On this basis, our research presents the concrete methods of a path tracing mechanism and solar powered mechanism in order to achieve the reliability of networks. On the other hand, it also proposes the new concept and un-experimented usage of robots in this field. We believe that this research has contributed a major milestone in the field of robotics thereby combining multi-discipline of network engineering, robotics and electronic vehicle in the common research platform.

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● Abstract

This paper introduces the design and development of the autonomous tracing robotic vehicle that can be utilized in unstable network. Particularly, we have done the research to develop the path tracing module in terms of the software and hardware design which realizes the autonomous tracing vehicle using the infrared reflective sensors. Furthermore, the concept of robotic vehicle in order to provide stable power system in TCP/IP network is presented. In order to accomplish such situation, this system utilize 8 bit microcontroller in order to regulate the DC motor for motion and direction control and reach to the server and supply the power. Path tracing

mechanism is developed by using photoelectric sensors that receive the path tracing information and provides to the microcontroller in a real time. The mechanism of sensors units, role of microcontroller and the anatomy of our robotic vehicle and its utilization in terms of network management is discussed.