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Design & Development of Electric Cable Inspection

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Design & Development of Electric Cable Inspection

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Abstract- Previously, electric cable inspection are being done by human. With the advancement of nowadays technology, robot are now being implemented in this situation in order to replace the old-fashioned inspection methods. In this report, the aim of this project is to develop a functional electric cable inspection robot that are able to navigate along electric cables. This robotic device will be able to avoid the electric poles and obstacles as well as to capture and record the defects of the electric cable by using the camera attached to it. This robot need to be in stable condition in order for it not to toppled down or tilt down when doing the inspection. In this project, a new design of the robot are being developed in order for it to achieve its objectives. The user operating system consists of four DC servo motors, two micro DC motor, a remote controller, two cameras, two balancing bar and a screen to display the video feed. This report includes brief discussion on previous methods and robots, theory of operation, design summary, stability analysis and the expected budget for this electric cable inspection robot.

Chapter 1

I. Introduction

a) Background

In today's world, there are many innovation and development that have been produced by the engineers and scientists around the world. One of them is the electric cable inspection robot which is able to help human to do their works. This type of robot can move along a cbale as well as to overcome obstacles along its way.

Previously, the maintenance of the electric cables have being done by using humans. A person requires to move along the electric cable in order for them to check the condition of the cable. This type of jobs are very dangerous to human even though all the safety procedure are being taken into consideration. Due to tis reason, the researches abroad have developed few robots that can move along the electric cable in order to help human in his dangerous job. This type of robot are remotely controlled by the specialist worker from the ground without moving along the power lines. One o f the robot that has been developed is the Expliner. Expliner was developed primarily as a robot to inspect live lines, perform detailed inspections and also have enough mobility in order to overcome the obstacles along the electric cable (Paulo Debenest & Michele Guarnieri, 2010).

In this report, I will present a study on the development of the electric cable inspection robot which can move along a suspended electric cable as well as to overcome the obstacle. Moreover, this robot will also capture the image and record the video of the cable while moving along the electric cable and able to balance itself while overcoming the obstacles. This report will introduce the modified robot design from the previous design and the working principle on overcoming the obstacle and capturing the image of the cable.

b) Problem Statement

Human safety will be the top priority when it is related to engineering –technical areas as well as any other job or task related to human. There are many reported case where a technician of an electric cable maintenance team died while working on this power line. This occur in different ways such as electrical shock and falling to the ground while inspecting or repairing the electric cable. One of the solution for this problem is developing a robot which can help human as well as replace human force by a robotic system. There are many robot that can move along the suspended cable and overcome obstacle, but not much of it can capture the image of the defective cable. Thus, a robotic system with an ability to move along the cable, overcome the obstacle as well as capture the image of the cable need to be developed with the simplest structural design in order to help human in this related task of cable repairing and inspection.

c) Research Objectives

The aim of this research is to design and develop an electric cable inspection robot that can move along a cable, overcome the obstacles and capturing the image of the cables.

The objectives set is justified the aim are as follows:-

i. To develop an autonomous robot that will be able to navigate along electric cables avoiding obstacles.
ii. To equip the robot with camera to capture defects of wire.
iii. To evaluate performance of the robot

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d) Research Methodolgoy

In order to achieve the objectives and the target of the research, some steps and procedure are need to be taken into consideration. First and foremost, the topics of the research was studied through the previous research papers, journals, websites and other different type of books that related to this research. This is to make sure that the basic concepts about the design is adapted and the new design can be develop based on the previous and current design that available nowadays. Then, some important facts and concepts from the previous research have been rephrased in the literature review of this report. After that, the brainstorming of the idea and design are drafted based on the previous design that have been developed by the previous student and researchers. During the drafting stages, several design have been purposed for this robot. Some of it are rejected due to the unbalanced condition of the design. The design are constructed by sketching manually on the paper and then constructed by using Computer Aided Design (CAD) software. The designs are then divided into several subsystems. Here, it is divided into three subsystems which is mechanical part, electrical part and software part. The crucial part of the design is to choose the suitable components and devices that required in order for this robot to functions well at the end of this research. This system must be modeled in order for it to achieve its research objectives. Finally, the systems are being analyzed by using several calculation especially for the stability of the robot while moving along the cable as well as while overcoming the obstacles. Then, the documentation of the whole research are being done for the reference in future developments.

e) Project Outline

This report consists of six chapters. In chapter 1, there are the overview of the study, problem statements, research objectives and methodology as well as the project outline. In chapter 2, other researchers design and research have been discussed and compiled in the literature review part. Then, in chapter 3, the design of the system are drafted and it is divided into three major subsystems which is mechanical part, electrical part and software part. At the end of this chapter, the bills of materials has been tabulated for the budget reviewing and design implementation. The selection of component that required for this robot also being discussed and selected in this chapter. Chapter 4 will show the analysis of the design and some working principle flowcharts on how the system works and being controlled. The last chapter which is chapter 5 will be the conclusions of the research and the references used for this report.

Chapter 2

II. Literature Review

a) Introduction

In this part, some of the literature studies from the previous and current researchers are being presented. These include some types of publications such as articls, journals, conferences and other related resources that available which is related to this thesis. The discussion will be started with the comparison of different types of electric cable inspection robot that has been developed by the previous researchers. After that, the discussion will be summarize the advantages and disadvantages of the design that being implemented on the current robots. Then, this chapter will end up with a conclusion made based on the literature studies.

b) Electric Cable Inspection Robot And Cable Climbing Robot

Nowadays, there are several kind of electric cable inspection robot that has been developed by the engineers. This type f robot are able to help human in doing the various king of inspections and maintenances of the electric transmission power lines. With the emergence of this robot, the maintenance of the power lines can be easily to maintain and observe. This robot are programmed to do the same task that the power lines maintenance workers did. By using this robotic system, the precision and evaluations of the faulty of the cable can be increased as compared by using human power. Moreover, the electric cable inspection robot is one of the cable climbing robot. Most of the electric cable inspection robot can climb and move along an electric cable. This robot also can overcomes several obstacles that found along the cable. Therefore, several type of electric cable inspection robot and cable climbing robot such as Expliner, LineScout, SkySweeper and Robonwire are being discussed in the next section of this subsection.

i. *Expliner (A Cable Inspection Robot)*

Expliner is one of the sophisticated design that has beaten most of the previous machines that has been developd before it. Expliner was developed primarily as a robot to inspect live line and able to perform detailed inspection in up to four cables as well as the enouch mobility to overcome any obstacles that it faced. Expliner was manufactured and developed by HiBot Corporation in Tokyo, Japan. Expliner can performs visual inspections of cables, conductors, spacers and any other components on the electric cables with the equipped camera on board.

The concept of this design employs pulley to move on the transmission lines and has a carbon-fiber structure with a T-shaped based and a 2-DOF manipulator. Expliner can be actively controls its posture and overcomes the obstacles by moving its center of

mass. This is performed by moving it counter-weight to front or rear side based on where it want to moves. The counter-weight must be placed as far as possible from the base of the manipulator in order to maximize its influence over the position of the center mass of the robot. This robot also can acquired image from the entire surface of the cable with two CCD mini-camera and mirror assembly attached on it. Besides acquired an image, it can also determine and calculate the diameter of the cable by using the laser emitter and receiver located with the robot.

Furthermore, Expliner also have consist a sensing units that connected on its compliant arms to allow the robot to balance itself and to make sure that the robot are not swinging when doing its preferred tasks. One of the safety aspect that is performed in this robot is the safety hook system. This safety hooks are installed under the pulleys of Expliner. The hooks will lock the pulley and the cable together without touching the cable. If there are the disturbances from the winds for example. Expliner will still safe with the safety hook locked. Moreover, the safety of the attitude of Expliner also constantly monitored. When the robots swing at a certain angle, a warning message will displayed and informing the operator that it is unsafe to continue the operation. The failure of the control system also being overcome by using a parallel microcontrollers which will be automatically activated when the main microcontroller fails.

ii. *Linescout (Electric Cable Inspection And Maintenance Robot)*

A LineScout robot are quite similar to the Expliner but differ in their theory of operations. A LineScout was developed by Hydro-Quebec's research institute which is the one of the leading technologies in the area of applied robotics, as it has been successfully deployed in the field for the live-line teleoperated inspection and maintenance. This type of robot can various kind of inspections such as visual inspections of the power line as well as doing the maintenance of the power line. Similar like the Expliner, LineScout also equipped with camera but it has extra two cameas that the Expliner. Two of the camera are mounted on the gripper arms while the other one is mounted between the wheels of the robot with the pan and tilt functions which provide the adjustable point of view. The images that the camera transmitted are most important as they used it as a feedback on the ground to drive different axes of movement.

Besides that, in order for the Lines Scout robot to move efficiently and fairly quickly along parts of spans with no obstacles, two-wheel design was chosen for this robot. Furthermore, it also have its own obstacles avoidance scheme as show in Figure 2.6. This avoidance scheme involves several clamps, a slide and some actuators to remove the drive pulleys from the conductor. By sliding its clamps and grabbing the power line, the robot is able to release its pulleys from the power line and slide over to the other side of the obstacles.

Apart from that , LineScout equipped with an onboard video card which enable it to receive a signal from up to four cameras and then transmits a combination of any two images either in "pictures on picture mode" or "split screen mode". This are very useful by combining the two wide-angle camera images since it allows viewing the grippers on both side of the obstacle simultaneously. The Line Scout also have a god telecommunications design. This robot can be controlled within a 5km wireless control range. The video feed, controls and sensor data are mainly communicated by using the radio connection. The Line Scout also have many tools that can be used for the maintenance of the power line cable. The camera and the robot can be controlled with the joysticks from the ground. Even though the Line Scout is fairly complex, but its control system are simple, intuitive and also ergonomic in design.

iii. *Skyseeper (A Low Dof, Dynamic High Wire Robot)*

SkySweeper is one type of a mobile robot designed to operate in the environment same as the Expliner and LineScout robot. This robot comprised of two links that is pivotally connected at one end. At this joint, a series of elastic actuator can actuate a relative rotation between two links of the robot. Actuated three-position clamp is located at the opposite end of each link. The clamp of the robot can be either open partially closed or fully closed. This robot can locomote on the cable in various ways by actuating the elbow joint and cleverly choosing the positions of the clamp.

This robot symmetrically comprised of two links of equal length which are pivotally connected with a rotary series elastic actuator (SEA) at the end. This SEA contains of a motor and a torsion spring connected in series. Motor housing is connected to the first link meanwhile the motor shaft is connected to one end of the spring. The other end of the spring is connected to the second link. This robots may have different kind of clamp positions which is open clamp, rolling clamp and pivoting clam position. By appropriately combining the actuation of the elbow SEA and the clamps, several modes of locomotion are possible to be achieved such as inchworm locomotion, swing and roll locomotion, swing –up locomotion and back flip locomotion.

Sky Sweeper have the disability to overcome the obstacles. This robot can only locomote along the cable. Then, this robot alos cannot have a camera that can be place on it. If there is the camera, it will not give a clear viw of the image that it captured due to the vibrations occurs while it's moving along the cable. Due to this disadvantages, this robot still need to be developed by the researchers and engineers in future.

iv. *Robonwire (Low-Cost, Lightweight Powerline Inspection Robot*)

Robonwire (Robot on wire) is a robot that designed to perform a tasks while moving on a cable. This robot can operate autonomously or being controlled by the remote which makes this robot is attractive for the inspection and maintenance of the powerline. This robot is lightweight and developed by using a low-cost budget. The Robonwire is equipped with wheels and arm mechanisms for locomotion and obstacles avoidance. The robot avoid the obstacle by retracting and engaging its arms sequentially. Robonwire consists of a base frame on which three arms are mounted.

The arm of the Robonwire is designed as a modular unit. The arm are designed to mount the wheels on the line without any coupling or claw mechanisms. Each of the arm are divided into three parts which is the base bracket, arm body and the wheel mount. The base bracket is mounted onto the base frame and connected to the arm body through a joint (Lower joint). Meanwhile the arm body is the main part of the arm and carries a wheel mount at its top through a joint (Upper joint).

This Robonwire come with some safety features. It has a safety clamp in each arms. The clamps is responsible for securing the robot to the line. Two powition of the servo determines the strength of the clamping. For example, the position of the servo may be heightened when gripping the line during obstacles avoidance. This clamp is essential to prevent the robot from tilting from the line or losing the grip. The obstacles avoidance methodology is quite similar to the LineScout robot. This robot is designed to detach the arm closest to the obstacles. Then the arm will fold underneath the robot to maintain the center of gravity of the robot. Two wheel will move the robot until the first arm crossed the obstacles. This steps will be rotated by the robot for the next arm until all arms have crossed the obstacles.

c) *Conclusion*

From the literature review, it can be conclude that many research has been done by researchers around the world in order to helps human in doing the electric cable inspection and maintenance jobs. Several prototype have been developed and some of it are now commercialize for this maintenance and inspection jobs. However, all of this research are develop by using a big amount of budget due to the demand from the power line inspection and maintenance company. So, in this report the approach taken are to build and develop a simple system with the implementation of mechatronics system with low –cost budget but reliable in doing the same operation as the previous researchers had done. Therefore, the prototype that will build must be able to overcome the obstacles as well as to capture the images and able to move along a cable without toppled down or tilt down from the cable.

Chapter 3

III. System Design

a) *Basic Overview Of The Project*

The main objective of this project is to develop a robotic system that can move along suspended cables like electric power lines. This robot must be able to overcome the obstacle such as electric poles, cable suspender, cable spacer and other obstacles that available along the cable. This robot will only use one cable to travel along it. Then the camera attach to this robot will capture the image and video feed of the cable and transmit it to the monitor. The design is recommended to use the simplest structure. The conceptual design of the robot is shown in Figure 3.1.

b) *Purposed Designs*

In this section, the design of the robot is being discussed and drafted properly. The design are divided into several mechanisms such as the branch arm, the robot body and the locking mechanism to attach the left and right part together.

i. *Branch Arm Mechanisms*

♦ Overview of the mechanisms

This mechanisms is the main part of the robot because this part will determine the ability of the robot to move along the cable as well as to overcome the obstacles along the cable either in stable condition or it will be toppled sown. Without this mechanism, the robot cannot overcome the obstacles.

♦ Proposed design of the body arm:

- Linear/ Rectangular branch arm:

This type of arm is the easiest type of arm that can be done. This is because it just only one item to make this arm. This branch arm will be attach together with the robot body and the RC servo motor that will lift – up the arm when avoiding the obstacles. This type of arm need to have additional counterweight for it to balance on left and right side of the robot.

- 45° slanted branch arm:

This type of arm is 45° slanted from the linear arm. This reason why it is slanted at 45°to make the body of the robot balanced on the left and right side. Thus ,the center of the gravity will be focused on one point of action. As liner branch arm, this arm will be place on the same location as the linear one.

♦ Selected design:

From the design discussed above, I choose the 45° slanted branch arm to be developed and put together on my prototype. This is because of the ability for the arm to locate the center of gravity on one point of action. Thus, four of this branch need to be on the prototype to achieve the desired objective.

ii. *Robot Body Shape*

♦ Overview of the shape

In the planned design for the prototype that will be constructed, the shape of the robot body need to be balanced on both side of the wings. Due to that, a minimized design of the robot body are required in order for it to achieve the objective. This body need to be light and have only few part that need to be attached together by screw or glue or other fastener. Therefore, this robot can balanced itself on the left on the left and right wings.

♦ Proposed design of the body arm:

- Rectangular-Shaped Body

This shaped is the commonly used on most robot. This type of shape need to be screw and fastens together in order for it to achieve the desired shape. Like the previous design of this robot, the robot body is made by using this type of shape. Due to that, it is not able to balance well while moving along the cable due to the screw used to attach the wall of the robot body together.

- Cylindrical-Shaped Body

This shaped is easy to be constructed for the body of the robot. This is because, this shape can be done using a pipe. we can find the bigger diameter of the pipe in order to balance both side of the robot. With this implementation, there are no screw or glue that are being used together to make the robot body. From that, the weight of the robot can be reduced and it can make the robot to be stable on both sides.

♦ Selected design

From the design discussed above, the prototype of the robot will used the cylindrical-shaped robot body. This is to ensure that the robot balanced on the left and right side and to make sure that the robot body are light enough. Due to that, the error of the joint and attachment of the rectangular-shape of the robot body design can be reduced.

iii. *Lock Mechanisms Of The Branch Arm*

♦ Overview of the lock mechanisms

The need of the lock mechanisms on the branch arm is crucial because the robot is developed using two wings which is left and right side. This two side of the robot will attach together by using the branch arm of the robot. At the end of this branch, there will be a lock mechanisms that attach the left and right side of the robot together. This lock mechanisms is important for the robot. If the lock mechanisms is not located at that point, the robot will swing to the left and right side while moving along the cable.

♦ Proposed design of the lock mechanism:

- Using electromagnet

This type of design was being done on the previous robot. At the end of the branch arm, an electromagnet mechanism is placed in order to be lock the left and right side of the robot. By using this type of mechanism, it will required more power to the robot due to the electromagnetic field that need to be created for this lock. Due to that, this lock become hot and might damage the robot.

- "Door-like" lock mechanism

This type of design look alike the door lock mechanism. This mechanism only allow one direction of movement due to the shaped of the lock itself. As we can see on the door lock mechanism, when we closed the door, the door handle need to be pulled or pushed in order to unlock the door. Thus, this type of mechanism can be applied on this robot to attach the left and right side of the robot together. This mechanisms will be used with the micro servo motor in order to unlock this locking system.

♦ Selected design:

From the design discussed above, the prototype of the robot will used the "door-like" lock mechanisms. This type of lock is easier to be constructed and will consume less power from the power source. Thus, both side of the robot can easily being lock and unlock using this type of mechanisms.

c) *Finalized Approved Design*

After discover the purposed design for this robot, the design of this robot is finally being done. All of the mechanism that discussed at the previous chapter has been implemented in designing the robot.

i. Cad Design (Picture)

ii. Dimension Of The Design (Picture)

iii. Part Names (Icture)

iv. Front, Top, Side & Isometric View (Picture)

d) *Components Selection*

i. *Basic Overview Of Component Use*

From the design that has been created as the previous chapter, this prototype required several components to make this prototype functions as desired. In this chapter, the selection of the components that will be used for this prototype will be discussed. This discussion will start from the controller selection of this robot, motor selection, sensors and other related components.

a. *Arduino Mega*

♦ Description:

- This board features additional SDA and SCL pins that are near to the AREF pin and two other new pins placed near to the RESET pin, the IOREF that alow the shields to adapt to the voltage provided from the board.
- The Arduino Mega2560 has a resettable polyfuse that protects your computer's USB ports from shorts and over current. Although most computers provide their own internal protection, the fuse provides an extra layer of protection. If more than 500 mA is applied to the USB port, the

fuse will automatically break the connection until the short or overload is removed.

- The Arduino Mega is a microcontroller board based on the ATmega1280/2560. It has 54 digital input/output pins (of which 14 can be used as PWM outputs), 16 analog inputs, 4 UARTs (hardware serial ports), a 16 MHz crystal OScillator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started. The Mega is compatible with most shields designed for the Arduino Duemilanove, Diecimila or Uno.

♦ Specifications:

• Microcontroller	ATmega2560
• Operating Voltage	5V
• Input Voltage (recommended)	7-12V
• Digital I/O pins	54 (of which 14 provide PWM output)
• Analog Input Pins	16
• DC Current per I/O Pin	40 mA
• DC Current for 3.3V Pin	50 mA
• Flash Memory	256 KB of which 8 KB used by bootloader
• SRAM	8KB
• EEPROM	4 KB
• Clock Speed	16 MHz

♦ Use in this project:

Arduino mega will be used as controller for left and right part of the robot. The reason why Arduino mega is used to this robot because each part of the robot need at least 6 PWM output pin to control two servo motor (for branch open and close). One micro metal gearmotor (for robot movement on the cable), one servo motor (for actuator as a balancer) and two micro servo motor (for the branch arm lock and unclock). Therefore, Arduino Mega which has 14 PWM output are more than enough as this robot only need 12 PWM output.

b. *Rc Servo Motor*

♦ Description:

Servomotor is a rotary actuator that allows for precise control of angular position. It consists of a motor coupled to a sensor for position feedback, through a reduction gearbox. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. Servomotors are used in applications such as robotics, CNC machinery or automated manufacturing. Inside a typical RC servo contains a small motor and gearbox to do the work, a potentiometer to measure the position of the output gear and an electronic circuit that controls the motor to make the output gear move to the desired position. Because all of these components are packaged into a compact, low –cost unit, RC servos are great actuators for robots.

♦ Specifications:

• Dimension	40.2mmx19.8mmx36.0mm
• Weight	38.0g
• Torque	6kg/cm(4.8V),7kg/cm(6.0V)
• Speed	0.19sec/60degree(4.8V) 0.16sec/60degree (6.0V)
• Operating Voltage	4.8V-6.0V
• OperatingFrequency	50.0Hz
• Moving Range	0° - 180°
• Pulse Width Range	0.5ms-2.5ms
• Gear Material	Plastic

♦ Calculation of maximum load torque:

The mass of micro metal gearmotor or electromagnetic system which placed at the end of the branch arm and the weight of the branch itself cannot be more than this maximum allowable mass which is 0.4667kg

c. *Rc Micro Servo Motor*

♦ Description:

Servomotor is a rotary actuator that allows for precise control of angular position. It consists of a motor coupled to a sensor for osition feedback, through a reduction gearbox. This RC micro servo motor is tiny

and lightweight with high output power. Inside a typical RC micro servo motor contains a small motor and gearbox to do the work, a potentiometer to measure the position of the output gear and an electronic circuit that controls the motor to make the output gear move to the desired position. Because all of these components are packaged into a compact, low-cost unit, RC servos are great actuators for robots.

♦ Specifications:

• Dimension	22.2mm x 11.8mm x 31.0mm
• Weight	9.0g
• Torque	1.8kg/cm (4.8V)
• Speed	0.1sec/60degree (4.8V)
• Operating Voltage	4.8V
• Operating Frequency	50.0Hz
• Moving Range	0° - 180°
• Dead Band Width	10μs
• Gear Material	Plastic

d. *Micro Metal Gearmotor*

♦ Description:

Micro metal gearmotor provides enough torque with combination of gears. It is suitable for small size robot.

♦ Specifications:

• DC	6V
• Gear ratio	298:1
• Stall Current	360mA
• Stall Torgue	1.8kgcm
• Weight	10g
• Free-run (rpm)	45
• Freerun(current)	30mA

♦ Calculation

♦ Use in this project

Micro metal gearmotor will be used as driver for robot to move along the cable. Lowest angular speed (rpm) of micro DC motor has been chosen to provide greater torque during movement along the cable.

e. *Tilt Sensor Module*

♦ Description:

Tilt sensor module is a sensor that will detect the movement of the object either it is tilted or not. This sensor is a ball rolling type sensor. The module will output logic LOW when the module is not tilted until the threshold angle and it will output logic HICH when it is tilted over the threshold angle. The tilt angle for this sensor is from 45 degree to 130 degree.

♦ Specifications:

• Operatingvoltage	:	3.3 to 5VDC
• PIN	:	VCC=5V,GND=0V,DO=digital output from module

♦ Use in this project:

Tilt sensor module is used in this robot to detect the orientation of the robot. When the robot is tilt, this sensor will activate the balancer located at the bottom of the robot body to stabilize the robot.

f. *Ultrasonic Ranging Module*

♦ Description:

The Ultrasonic module detects the distance of the closest object in front of the sensor (from 2 cm up to 400cm). It works by sending out a burst of ultrasound and listening for the echo when it bounces off of an object.

♦ Specifications:

• Operating voltage	+5V
• Static current	less than 2mA
• Detectionangle	Not greater than 15°
• Range	2cm~400cm
• Precision	0.3cm

♦ Use in this project:

Ultrasonic sensor is use in this prototype to detect the obstacle which this robot need to overcome it. When the obstacle is detected within specific range, this sensor will trigger the roller driver to stop and the branch arm lock to unlock. Then the servo motor located at the branch arm will activated and lift-up the branch arm.

g. *Camera Module*

♦ Description:

The webcam is the easy to used camera which we can only plug-and-play the camera as we desired.

This camera will provide enough resolution for image and video that will be recorded.

- Specifications:
  - Video capture: Up to1024x768pixels
  - Logitech Fluid Crystal™ Technology3*
  - Photos:Up to 5 megapixels (software enhanced)
  - Built –in mic with noise reduction
  - Hi-speed USB 2.0certified (recommended)
  - Universal clip fits laptops, LCD or CRT monitors
- Use in this project:

This webcam is used for the image capture and video recording of the cable during the inspection of the cable is done. This camera must be able to capture enough resolution of the cable to inspect the aulty that may occurs on the cable. Note that, this type of camera are subject to change with respect to the size of the robot and cost of the camera module.

e) Estimated Budget

No	Component	Quantity	Unit Price (RM)	Total Price
1.	Arduino Mega 2560 R3	1	77.50	77.50
2.	298:1 Micro Metal Gearmotor	2	35.00	70.00
3.	RC Servo Motor (C40R)	4	49.00	196.00
4.	RC Micro Servo Motor (SG90)	4	10.80	43.20
5.	Ultrasonic Ranging Module	4	10.90	43.60
6.	Tilt Sensor Module	2	13.00	26.00
7.	Camera Module	2	50.00	100.00
8.	Bread board 85mm x 55mm x10mm	2	7.90	15.80
9.	Male to Female Jumper Wires, 40pcs	2	6.80	13.60
10.	Male to Male jumper Wires, 60pcs	2	6.80	13.60
11.	IR Transmitter & Receiver	1	3.00	3.00

Chapter 4

IV. Design Analysis

a) Introduction

In this chapter, the design proposed in chapter 3 will be analyzed. The analysis will consist of the design dimension, component placement on the robot, communication between the components, the microcontroller scheme and the working principle of the robot.

b) Design Dimension

The dimension of the robot is already described in chapter 3. This dimension is subject to change depending on the size of the component that will be used when constructing the robot.

c) Component Placement

From the design, it can clearly see that the component will be placed mostly on the body and the arm of the branch of the robot. After all the component is placed on its position, one counterweight will be place on top of the body to make the robot stable. If the robot is stable enough after putting all the component at its desired location, no counterweight will be used for this robot.

d) Attachment Of The Robot

As we can see in figure, the body of the robot is actually separated into two parts which is left and right part. This two part of the robot will be attached together by using the door-lock mechanisms that located on top of the body. The mechanisms is attach with the branch arm of the robot. The branch of the robot will be lifted-up one by one when avoiding the obstacles. The working principle of this mechanisms can be seen with the working principle flowchart provided in next section of this chapter.

e) Communication Between The Components

In this robot, only one microcontroller will be used and place on the robot. As we can see in figure, all the component are placed in its desired location. Each of the component is related to each other. In other words, each component need to communicate between another components. In this robot, servo motor of the branch arm will communicate with the ultrasonic sensor as well as the micro metal gearmotor and micro servo motor while overcoming the obstacles. While moving on the cable, the micro metal gearmotor will communicate with the ultrasonic sensor as well as the tilt sensor. Therefore, to communicate between all the components, the used of microcontroller which is Arduino Mega is required. With this microcontroller, all the component, all the component can know the sequence of their movement and their time when the component is required and when the component are not required in each of the movement. This can be clearly seen on the working principle flowchart and the microcontroller unit scheme in next section of this chapter.

f) Working Principle Flowchart

Working principle flowchart of the robot has been constructed as shown in the next section of this chapter. This flowchart shows how the microprocessor will be programmed in order for the robot to functions as desired.

i. *Overview Of The Working Principle*

The robot will move along the cable by using its roller. This roller will be driven by a micro metal gearmotor attached together with it. This motor can move forward and backward. When the ultrasonic sensor detect certain range of distance, the MCU will transmit the command to the RC servo motor and the micro and the micro servo motor. The micro servo motor will unlock the lock and the RC servo motor will lifted-up the branch arm. Then, the driven roller will move forward to overcome the obstacle. After the first branch arm crossed the obstacle, the RC servo motor will then lifted-down. The roller of the first branch arm will stay on the cable and the lock of the arm is activated. Then, the second branch arm will follow the same step as the first branch arm. It will continue until all the branch arm crossed the obstacles. During the movement of the robot along the cable and during the obstacle avoidance, the tilt sensor will be activated . This sensor will triggered the RC servo motor of the balancer at the bottom of the robot body to move forward or backward in order to stabilize the robot. If the robot is not tilt, the RC servo motor of the balancer will remain at its current position.

ii. *Working Principle Flowchart For Obstacles Avoidance*

As shown in Figure 4.4

iii. *Working Principle Flowchart For Robot Balancing*

As shown in Figure 4.5

iv. Working Principle Flowchart For Camera

As shown in Figure 4.6

g) Graphical View For Obstacls Avoidance Scheme

Chapter 5

V. Conclusion and Recommendations

a) Conclusion

After all the research done, finally I manage to construct one design of the electric cable inspection robot. In designing this prototype, all the knowledge that related to this type of robot are applied. This robot is able to overcome the obstacles that found along the cable as well as to capture the image of the cable during the movement along the cable. Therefore, this design of the robot will be implemented in the next progress of this project which is to build the prototype of this design. This implementation will be done in the next semester together with the performance evaluation of the robot. Hopefully this project will achieved its objectives successfully and become the beneficial references for other in future.

b) Recommendations

- Use a lightweight item to ensure the motor can perform the actions required perfectly.
- This robot can be protected from the electrical shock by using suitable insulator around the body of the robot.
- Make sure the microcontroller are using a parallel network in order for it to functions well if there are unexpected disturbance of electricity or power sources and other electrical components.
- To balance the robot, we can used other type of actuator as well as other type of sensor that suitable with the size and budget of the robot.

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