2019 IEEE International Conference on Robotics, Automation, Artificial-intelligence and Internet-of-Things (RAAICON)
29 November - 1 December 2019, Dhaka, Bangladesh

Multitasking Spider Hexapod Robot

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Abstract— A hexapod robot is a type of spider robot which uses six mechanical limbs for movements. It is more versatile than wheel robots and it can traverse many critical terrains areas. This robot has been designed to solve some critical problems which are manually very hard and risky for human beings. This robot can pass through any risky slope and terrain areas. It can climb any obstacle or object and balance on rough surfaces as well. By using suction cups, it can climb any buildings.

This model has been improved for climbing techniques, camera system (360º view), walking angles and payload. SOC [System on Chip] has been used to control the camera for monitoring the affected earthquake area and give the information by video capturing footage. For instance, when the hexapod robot will climbing and walk through the affected earthquake areas, the camera will be capturing the affecting moment and broadcast by live streaming on YouTube with the help of the MQTT broker. This hexapod can carry the 20 lb load on its top of the body frame. Climbing over an obstacle has been improved for this hexapod model compared to other hexapods. Critical angle climbing is one of the most important improvements for this robot and it can walk smoothly near about 60º angles of the surfaces with a good balance. In risky areas, it can detect dark and light surfaces with the help of infrared sensors, as well as it can detect sound by using the sound sensor module and reach there for human safety purposes where an earthquake, fire incidents will occur. The robot was pragmatically assessed and above 85% efficiency for application, mechanism, and the system has been observed compared with other researches.

Keywords— Spider Robot, Hexapod Robot, Washing Robot, Climbing Robot Using Suction Cup

I. INTRODUCTION

Multitasking spider hexapod robot is developed for multiple working purposes such as an information provider of the earthquake destroyed areas, illegal areas, and also will work in cleaning the building glass with help of climbing, etc. Walking robot is one of the most discussed topics in the modern era. Nowadays there are have various types of walking robots. Hexapod is one of them. Hexapod robots are a kind of spider robot that has six legs for their locomotion. Because of its traversability abilities, it is used as dispersed ground vehicles in complex and rough terrains and some critical circumstances where human beings can't involve because of riskiness. [1] The idea of moving the hexapod robot has existed since the early 18th century. A mathematician named Augustin Louis Cauchy researched on a topic which was known as "stiffness of an articulated octahedron" at that time. This topic is the progenitor of the hexapod. [4] April 2014 in P.R. china a group of engineers from Harbin Institute of Technology developed a bionic hexapod robot for walking on unstructured terrain. They have formed the entire sensor to construct the robot with the observation of the external environment and its internal situation. [5] Multitasking spider hexapod robot can be used as spy information purposes for crime areas, earthquakes destroyed areas as a piece of provider information about injured people and give information about their status. Besides, the robot can be used in many other cases. As hexapod uses sex legs for its movements, it is much more stable and the movements become flexible unlike a two-legged humanoid robot or four-legged quadruped robot. Even if one or two-legged becomes failed to work, then it is no problem to complete its locomotion.

Many pieces of research/projects were accomplished on the hexapod robot. Malmros and Eriksson tried to improve the hexapod in [Figure 1]. Force sensors were installed in this robot to balance the hexapod. The Beagle Bone Black (BBB) is the motherboard on the hexapod. However, this hexapod cannot balance on rough terrain at the last moment. [3] It was taken by Thilderkvist and Svensson. It is the main medium contacting all the hexapods sensors and systems. The Inertial Measurement Unit (IMU) that is implemented on the hexapod is a Spark Fun Degrees of Freedom MPU-9150 including an accelerometer, a gyroscope, and a magnetometer. [3].

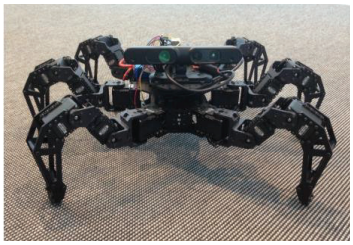

Figure.1. Hexapod Robot made by Malmros and Eriksson, 2016 [3]

[Figure 2] This intelligent robot was designed for tracking a missing person or give support to an endangered person in a remote area where humans will struggle to reach there to support. It can hide, detect or sense. In this robot, eight servo motors were used for moving the robot. NI Lab VIEW interfacing with the smart controller and corporation of the GH-311 ultrasonic sensor, smoke sensor, and LM35 temperature sensor were used for this robotic design.[2] For a

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non-contact distance and exact measurement GH-311, ultrasonic sensors were also used. It can climb any rough terrain and can detect any unusual movement. In Figure2 the model has shown. [2].

Figure.2. Aluminium structure of the intelligent Hexapod Robot [2]

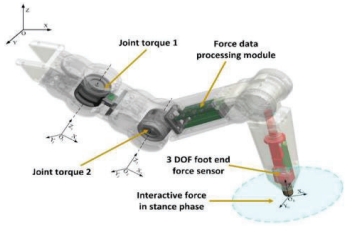
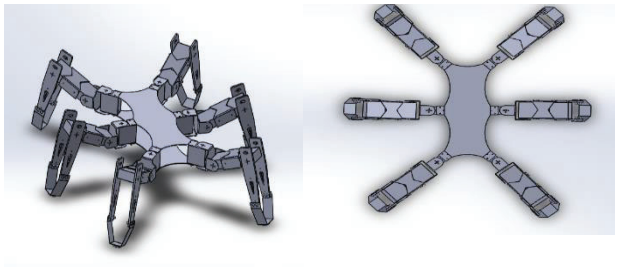


Figure.3. Joints using U- Brackets [2]

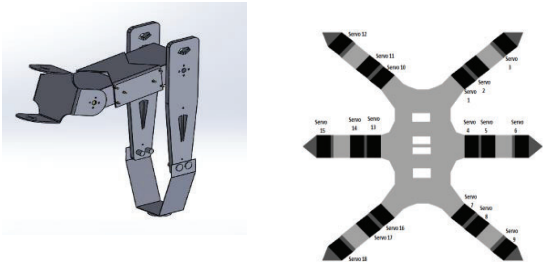
[Figure 3] Shows the robot limbs connected with the 3 joints. The servo bracket was used to connect. [2] Shape-based coordination in locomotion control robots can drift in the terror area easily. Microcontroller model Raspberry Pi 3 Model B was used in this model. Here the camera also used so that the owner can get the information status about the area. [6] In cities, the walls of those upgraded buildings such as constructed by glasses, oval-shaped buildings, etc. After a certain time, those glasses are needed to be washed by people. In that situation can be risky and took a lot of time for the human being. At the same time, it will cost a lot of money. So, hexapod is a smart solution to do it easily. There are a few pieces of research and improvement has done with the Hexapod Robot. This robot can play a vital role in society if it's improved and the importance of it can be expressed properly.

II. METHODOLOGY

A CAD model of this hexapod has been built for 3D printing of all body parts, joint frame, elbow frame, etc. After 3D printing, all parts of the hexapod have been assembled then, the robot is stabilized. The hexapod control system is executed after assembled. For controlling the overall process, a servo model is constructed from system recognition methods.



(a) (b)



(c) (d)

Figure.4. (a) Hexapod CAD model using SolidWorks software. (b) Top view of Hexapod CAD model. (c) 3 DOF Arms view of hexapod and, (d) Servo motor position setup using Code::Blocks software in OpenGL mode design.

[Figure 4] is a CAD model of this Hexapod Robot has designed with SolidWorks version 2017. The servo motors are the most important and a major part of this hexapod. Three servo motors on one leg and a total of 18 servomotors on 6 legs were used. Mainly, this hexapod can walk with the help of 18 servo motors. These servo motors are controlled by a microcontroller, single-board computer and a servo motor controller. MATLAB and SIMULINK software version 2017 has been used to get the switching system of 6 limbs of the hexapod and check the error of every angle joint of the 6 limbs.

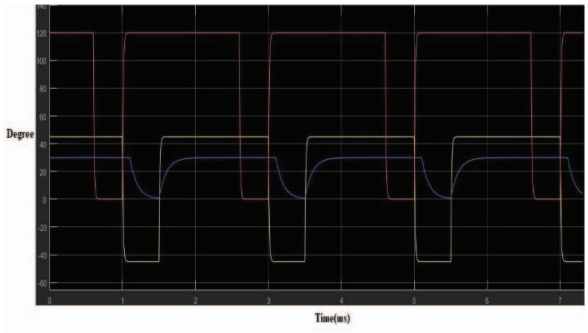


Figure.5. Leg 1, 3 and 5 Angle vs. time wave shapes in MATLAB.

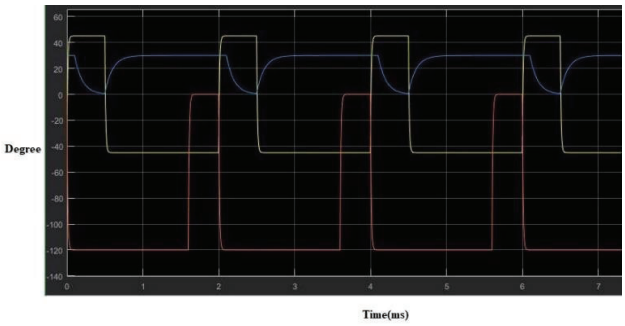


Figure.6. Leg 2, 4 and 6 Angle vs. time wave shapes in MATLAB.

SolidWorks 3D CAD model is tested in Simulink for any walking movement and elbow joint error. [Figure 5] wave shapes are the 1, 3, and 5 number limbs of the hexapod walking movement. In the same case of [Figure 6] for the hexapod limbs of 2, 4, and 6 wave shapes. And 95% successful ratio between this wave shape values and practical values.

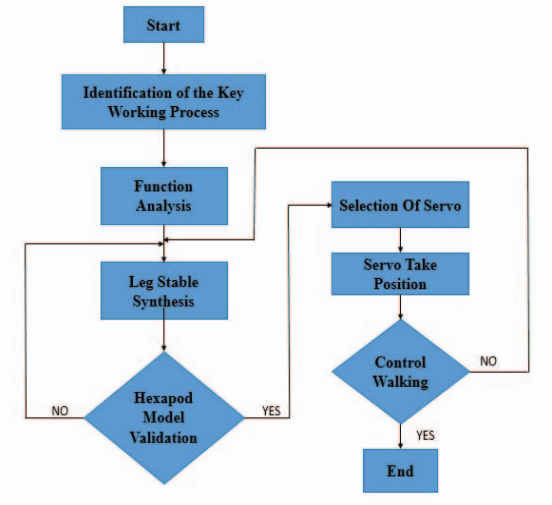


Figure.7. Flowchart of Hexapod Robots key working process Algorithm.

[Figure 7] flowchart is the walking procedure of hexapod robot. Initially, the all logical condition and the programs were inputted in the microcontroller and single-board computer for the walking process. It will be verified by the microcontroller and passed it to the servo motor controller to verify it. Then the servo controller controls all servo motor from logical user commands. Leg Synthesis steps have to stable all the limbs to move and every leg has 3 DOF (Degree of freedom) for using 3 servo motors. Later on, Hexapod will validate the total process. When the servo will take a position to walk to the surfaces, then the main task will start. If it can't walk or move then it will follow the Leg Stable Synthesis process will be followed. The movement algorithms of leg 1, 2, and 3 are almost the same. And leg 2, 4, and 5 movement algorithms are the same. After completing all the steps it will end its tasks.

Figure.8. Six Suction Cups (Black parts) and two motors (left side) for climbing technique.

By using suction cups it can climb any buildings or metal, alloy, steel structure easily. Push-pull techniques have been applied for these suction cups using air pumping by the 20-volt DC motor. And, it will climb and hold the upper step of the structure buildings. In [Figure 8] six suction cups for six limbs and two motors for pumping and help the building climbing of the hexapod robot. Although sometimes this robot was failed in a slope and critical path by using suction cups, but this hexapod had special rubber mounted on its legs, allowing it to climb on the slope area on critical feet [Figure 14].

In the mechanical process, all the servos were attached with the servo shield and the servo shield was powered up by microcontroller. A 7.4V lithium polymer battery was attached to the Arduino Mega and the process was executed by the logical condition program.

[Figure 9] is the all servo motor of this hexapod. [Figure 10] is the electrical throng diagram, which means the total hexapod mechanical process is executed.

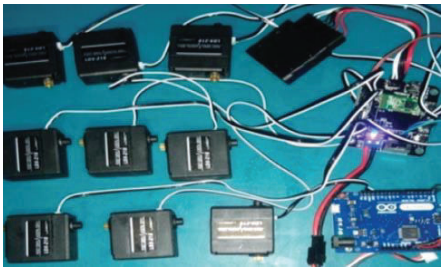


Figure.9. The mechaniocal throng of servo with the servo shield and microcontroller.

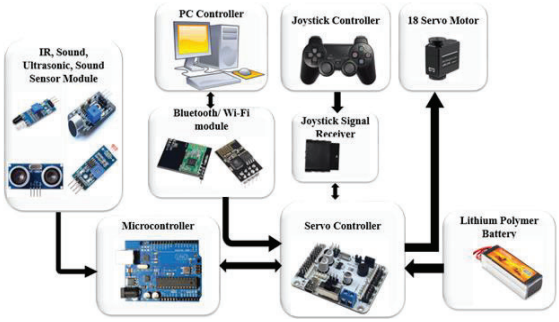


Fig.10. Electrical throng of total project.

III. EXPERIMENTAL RESULT

Six limbs of hexapod can move at the same time and the total degree of freedom is 18 for six legs. Each servo motor has different position values. The payload of the hexapod robot depends on its torque of servo motors.

A. Theoritical Data

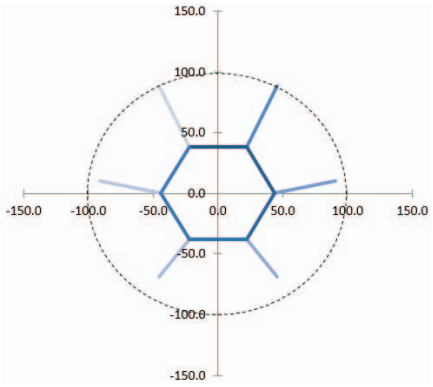


Figure.11. Shape of Forward movement of Hexapod.

[Figure 11], When the robot moves forward, the values of the 3DOF angles are shown in [Table 1] for each leg, and the position graphs of each leg are shown in the [figure 13].

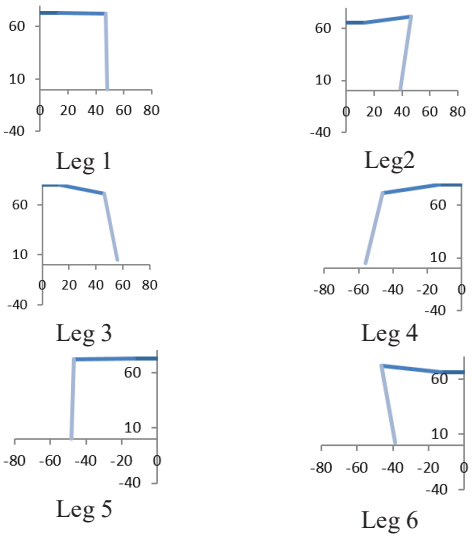


Figure.12. Angle graph of forward movement.

TABLE I. THE TABLE OF ANGLE VALUE OF FORWARD MOVEMENT.

Leg Number	1	2	3	4	5	6
New Position X	23.40	47.10	23.40	-23.40	-47.10	-23.40
New Position Y	72.10	72.10	72.10	72.10	72.10	72.10
New Position Z	50.75	10.00	-30.75	-30.75	10.00	50.40
Coxa Feet Distance	55.90	48.10	38.70	38.70	48.10	55.90
KSW	83.85	80.10	76.45	76.45	80.10	83.85
KA1	0.55	0.46	0.35	0.35	0.46	0.55
KA2	1.05	1.15	1.25	1.25	1.15	1.05
Tibia Angle	1.75	1.60	1.50	1.50	1.60	1.75
IK Tibia Angle	-8.05	-0.86	5.85	5.86	-0.86	-8.05
IK Femur Angle	-0.95	-0.02	-0.85	-0.85	-0.02	-0.95
IK Coxa Angle	65.15	12.05	-52.60	232.60	167.99	114.90

B. Practical Data

The forward direction of 18 servo motors position values shown in [Table 2]. In the same perspective backward right, and left direction of servo motors is a quite similar format. Here in the above table, the servo position of a total of 18 servos practical measures has been taken and based on this position in the graph [Figure 13] for the constant time. Forward direction (Table 2- A, B), when time is 150ms then the servo 1 position is 1700, servo 2 is 1000, servo18 is 2500. So by changing the time period forward, backward, left and right direction movement of the servos has been changing gradually and stable the hexapod as well. Servo angle can be found by using the servo position. Servo position values are different for the different movements of the servo. The hexapod stable position depends on its servo motor and servo bracket.

TABLE II. (A, B) FORWARD DIRECTION OF SERVO POSITION WITH THE CHANGE OF TIME (MS) (ID: SERVO NUMBER)

(A)

Index	Time (ms)	ID:1	ID:2	ID: 3	ID: 4	ID: 5	ID: 6	ID: 7	ID: 8	ID: 9
1	150	1700	1000	500	1300	800	500	1700	1000	500
2	100	1700	1000	500	1300	1000	500	1700	1000	500
3	150	1300	800	500	1700	1000	500	1300	800	500
4	100	1300	1000	500	1700	1000	500	1300	1000	500

(B)

Index	Time (ms)	ID:10	ID:11	ID: 12	ID: 13	ID: 14	ID: 15	ID: 16	ID: 17	ID: 18
1	150	1700	1700	2500	1300	2000	2500	1700	1700	2500
2	100	1700	1700	2500	1300	2000	2500	1700	1700	2500
3	150	1300	1300	2500	1700	2200	2500	1300	1300	2500
4	100	1300	1300	2500	1700	2000	2500	1300	1300	2500

C. Servo power calculation

For calculating the Servo Motor Power (Ps) the following calculation has been followed:
We know,

$$\omega = \frac{\theta}{t}$$

$$\Rightarrow \omega = \frac{31.81^\circ}{30\ sec}$$

$$\therefore \omega = 1.063 \text{ Degree/sec}$$

Now,

$$\text{Power, P} = \frac{Force * LinearDistance}{Time}$$

$$\Rightarrow \text{P} = \frac{\left(\frac{Torque}{r}\right) * (r * AngularSpeed * T)}{Time}$$

⇨ Power= Torque*Angular speed

⇨ Power, P= 15 kg. cm* 1.063 Degree/sec
∴Power, P= 15.945W
So, P = 16 W (Approx.)

D. Battery Run Time Calculation

7.4V battery has been used which capacity is 2200mAh.

Here,
Battery Capacity = 2200mAH
= 2.2 AH

$$\text{Run Time} = \frac{2.2AH}{0.5A}$$

= 4.4 Hour.
But, practically found 80 min.

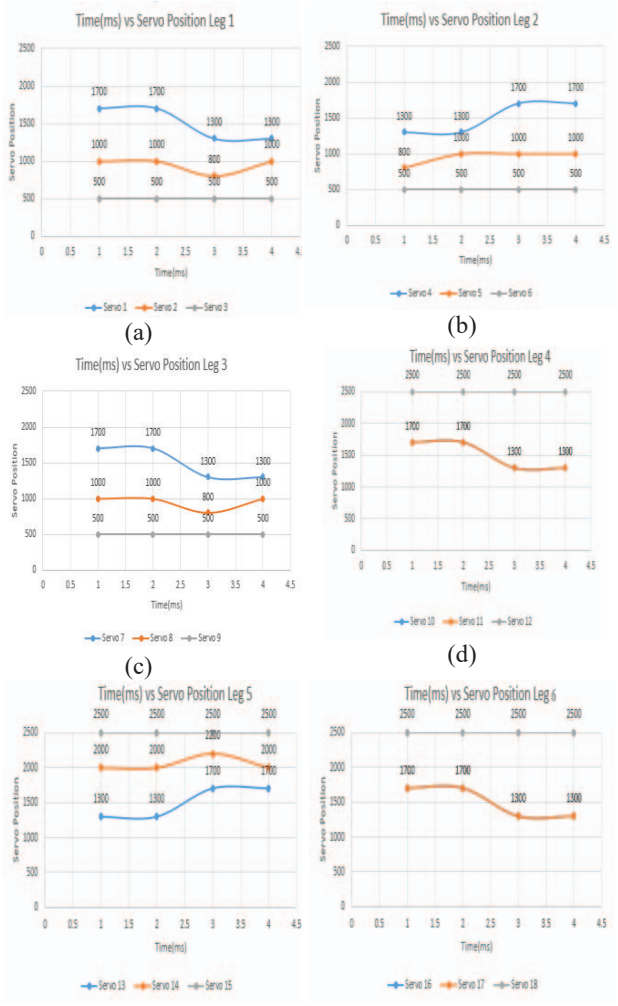


Figure.13. Forward direction of Servo Motors Position vs. Time (ms)

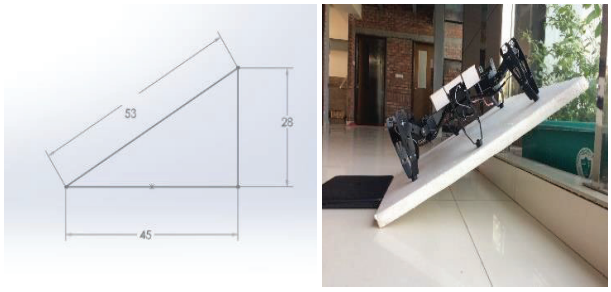


Figure.14. 45º angle climbing position slope, angle

[Figure 14], Hexapod can walk within 45º angle and so it can climb up any oval or curve buildings.

Here, the slop angle between 2 lines has been calculated. The calculation process has shown below.

$$Cos\theta = \frac{45\ cm}{53\ cm}$$

$$=> Cos\theta = 0.849$$

$$=> \theta = \cos^{-1}(0.849)$$

$$=> \theta = 31.89°$$

So, the angle of 2 lines of the slope is 31.89^0.

As, tan θ = (perpendicular / Base)

So, tan θ= 90^o.

E. Hexapod's Weight Carrying Calculation

For this calculation the torque and mass has been used. Mainly depending on the servo motor the total calculation depends on it. So, there are 18 servo motor has been used and the weight will depend on it.

From the hexapod:

Number of Servo motor, n_1= 18

Number of limb, n_2= 6

Per Servo Torque, $\tau = 15$ Kg. cm (7.4V)

$$\therefore \text{Hexapod carrying weight} = \frac{n1 * \tau}{n2}$$

$$= \frac{18 * 15}{6}$$

$$= 45 \text{ Kg}$$

But, practically the carrying weight is 7Kg.

Figure.15. Rough Terrain Critical climbing position

[Figure 15] hexapod robot can walk through rough terrain as can climb over an object as well. So, walking and climb over an object has improved in this project.

Figure.16. Side view of Hexapod Robot.

Figure.17. Top view of Hexapod Robot

Here in [Figure 16] and [Figure 18] finalize version of hexapod robot's side view and top view has shown respectively.

Results were taken after the practical implementation. Hexapod robots movement's parameters have classified into two sections. First one is time (ms) and second one is servo positions. The results has found in both by theoretically and practically.

IV. COMPARISON WITH OTHER MODELS

Multitasking spider hexapod robot has little bit similarities with Artificial Intelligence and Terrain Handling of a Hexapod Robot [3], but the motive and functionalities are very different. They used one of the most expensive servo motors in the world for hexapod development in Artificial Intelligence purposes, but multitasking spider hexapod robot has been used normal servo motor and metal aluminium frame body, which is very cost-effective for people. And this robot develops for human safety purposes and information providers in earthquake destroyed areas and a camera that is placed on the head of the multitasking spider hexapod robot acts as a server-based MQTT protocol through which live broadcasting can be done. "Robotics," Design Issues for Hexapod Walking Robots [3], the first-time hexapod designs are shown, and the multitasking spider hexapod robot has been designed in SolidWorks software [Figure 4] in a modern dynamic way and tests with MATLAB. Hexapod robot is developed for walking on unstructured terrain. [5] Multitasking spider hexapod robot also developed for terrain areas and slope areas in a modern way [Figure 15], [Figure 16], [Figure 17], [Figure 14].

V. CONCLUSION AND FUTURE WORK

Multitasking spider hexapod robot is the best solution of multiple riskiness works which is very risky for human beings. An earthquake destroyed areas this hexapod can walk and give all the information of injured people, destroy objects and more with the help of a 360-degree camera. And streaming the whole situation on YouTube with the help of MQTT broker. On the other hand, this robot can be used for building washing purposes with the help of suction cups. This robot can be the best solution for many different riskiness works for human beings. A survey was done to find out how much this project would benefit people, often with over 250 people answer being 95 percent satisfied.

In the future, this hexapod robot camera will be specially worked based on machine learning algorithms. For example, Tensorflow, Yolo, Deep learning neural network, Viola-Jones algorithms, Haar cascading, etc machine learning algorithms will be used for detection and identify the objects, humans in earthquake destroyed areas. The suction cups part of Hexapod will be developed in future in a dynamic way.

VI. ACKNOWLEDGEMENT

First, of all, we would thank Almighty Allah to successfully complete this project. Gratitude and sincere thanks to our supervisor Md. Arif Abdulla Samy, Assistant professor, department of EEE in AIUB, who have supported us. This hexapod robot won the reward in the biggest many robotics competition in Bangladesh.

REFERENCES

[1] Tedeschi, Franco and Carbone, Giuseppe, "Robotics," *Design Issues for Hexapod Walking Robots,* vol. 3, pp. 181-206, 2014.

[2] Beer, Randall D. and Chiel, Hillel J. and Quinn, Roger D. and Espenschied, Kenneth S. and Larsson, Patrik, "A Distributed Neural Network Architecture for Hexapod Robot Locomotion," *Neural Computation,* vol. 4, pp. 356-365, 1992.

[3] M. a. E. A. Malmros, "Artificial Intelligence and Terrain Handling of a Hexapod Robot," 2016.

[4] "symetrie," [Online]. Available: http://www.symetrie.fr/en/technology/hexapod-history/. [Accessed 23 06 2018].

[5] He Zhang, Yubin Liu, Jie Zhao, Jie Chen, Jihong Yan, Development of a Bionic Hexapod Robot for Walking on Unstructured Terrain, vol. 11, no. 2, p. 176–187, 01 06 2014.

[6] Matthew Travers, Julian Whitman and Howie Choset, Shape-based coordination in locomotion, pp. 1-14, 2018.