DESIGN AND CONTROL OF BIOMIMETIC WALKING ROBOT: SMART WALKER

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Abstract

In this project, it is aimed to design and control biomimetic smart walker robot. Basics of algorithm are created with data sets which are provided from many sensors and these data will be used to train the artificial intelligence. So, it is aimed to create an artificial intelligence that can build different motion configurations according to ground which are able to walk on rough grounds and avoid from obstacles. The most proper design that "Hexapod" as spider design is selected for our project. Conceptual design, trajectory and inverse kinematic calculations are carried out by using SolidWorks environment.

Introduction

The definition of robots and their designs have evolved over time. Nowadays, robots come in a variety of shapes and sizes. There are four types of robots in different areas. These are humanoids, unmanned vehicles, tele operated devices, bionics and biomimetics. They are categorized due to their shapes, structures, workload, workspace or ability.

Biomimetics is a generic description for building a process or system that mimics biology. A smart robot is an artificial intelligence (AI) system that can learn from its environment and its experience and build on its capabilities depending on that knowledge. Smart robots can collaborate with people, working along-side them and learning from their behavior.

In terms of biomimetics, it is needed to inspired from a biological model. Main purposes of the project is smart walking. Therefore, walking styles is taken into consideration while making the selection. When we look at the scorpion, spider and other living creatures that has at least six legs, the spider was the one that catch our attention. Also, there are tons of literature research about biomimetic spider robot that may inspire our project.

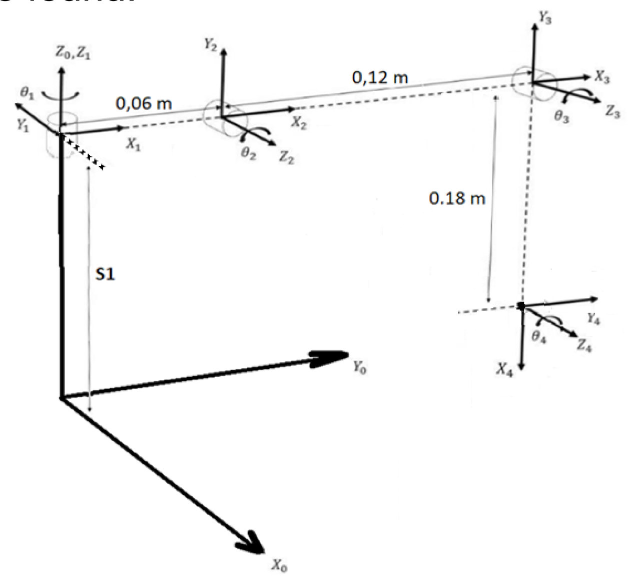
Theoretical Review

Kinematic Analysis

In the kinematic analysis, the relation between joint states and end effector should be described for legs. This relation contains forward and inverse kinematics. In the leg walking gait analysis, the end effector location and orientation may be determined by forward kinematics, the joint states can be retrieved by inverse kinematics.

1. Forward Kinematics

The Denavit-Hartenberg technique is used to find end effector location and orientation. In this way, homogeneous transformation matrices of three revolute joints and end effector are found.



Axis Number (i)	Link Length ($a_{i-1,i}$)	Twist Angle ($\alpha_{i-1,i}$)	Link Offset (S_i)	Joint Angle (θ_i)
1	0	0	S_1	θ_1
2	0.06	$\pi/2$	0	θ_2
3	0.12	0	0	θ_3
4	0.18	0	0	0

$$ {}^0_4T = {}^0_1T \times {}^1_2T \times {}^2_3T \times {}^3_4T \Longrightarrow {}^0_4T = \begin{bmatrix} C_1C_{23} & -C_1S_{23} & S_1 & 0.3S_1 + 0.104 \\ S_1C_{23} & -S_1S_{23} & -C_1 & -0.3C_1 \\ S_{23} & C_{23} & 0 & 0.06 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

2. Inverse Kinematics

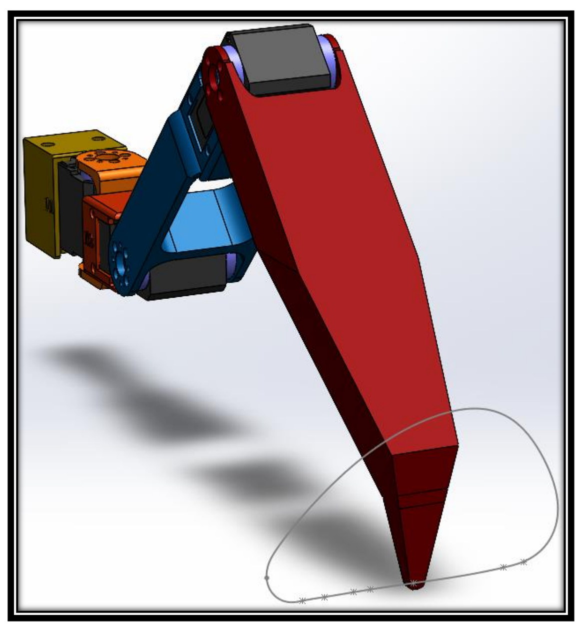
In this step, the parametric transformation matrix is given as follows, and it is used to calculate joint states by comparing the transformation matrices acquired from the Forward Kinematic Analysis and defined as parametric in the Inverse Kinematic Analysis.

$$ {}^2_3T^{-1} . {}^0_4T = {}^0_1T . {}^1_2T . {}^2_3T . {}^2_3T^{-1} . {}^3_4T = \begin{bmatrix} 0.354 & -0.612 & 0.707 & 0.231 \\ 0.354 & -0.612 & 0.707 & -0.127 \\ 0.866 & 0.5 & 0 & 0.06 \\ 0 & 0 & 0 & 1 \end{bmatrix} $$

$$ = \begin{bmatrix} C_1C_2 & -C_1S_2 & S_1 & 0.18S_1 + 0.104 \\ S_1C_2 & -S_1S_2 & -C_1 & -0.18C_1 \\ S_2 & C_2 & 0 & 0.06 \\ 0 & 0 & 0 & 1 \end{bmatrix} \quad \left. \right\} \quad \begin{aligned} \theta 1 &= Atan2(\sin(\theta 1), \cos(\theta 1)) \\ \theta 2 &= Atan2(\sin(\theta 2), \cos(\theta 2)) \\ cos(\theta 2+\theta 3) &= acos\theta 1 \end{aligned} $$

Trajectory

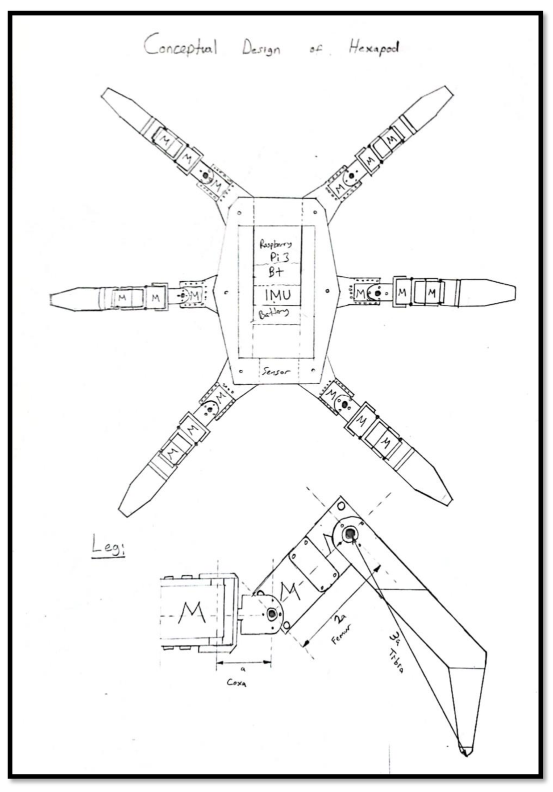
In this step, trajectory calculations are provided by using inverse kinematic data. However, SolidWorks calculation algorithm is used for faster and more practical methodology. Trajectories are fixed to leg tip as shown in Figure. Then, it is mated by using Path Mate tool. So, leg's motion is constrained by drawn trajectory.



Design

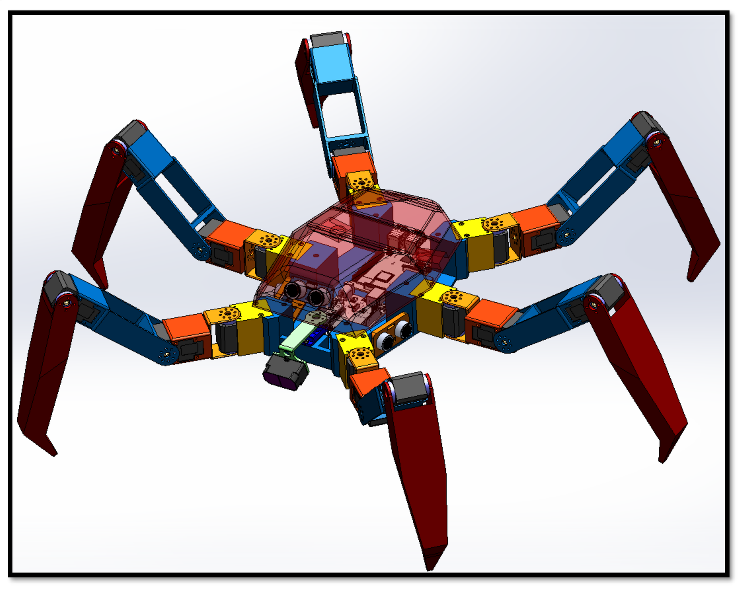
Conceptual Design

In the concept design, body structure and leg structure are the main headlines according to biomimetic walking task. Each leg consisting of three links denoted coxa, femur, and tibia (6 cm, 12 cm, 18 cm) that are connected by three joints (θ1, θ2, and θ3) indexed according to the next respective link. A certain equation is used when determining body measurements. At the right equation, the body width and height ratios are proportional to the height of the coxa.



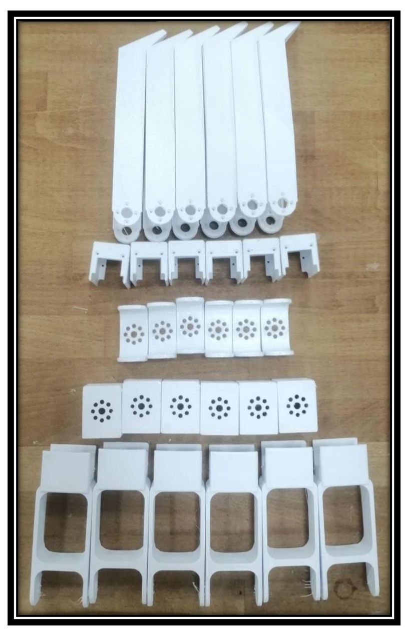
$$ b=2c+a $$

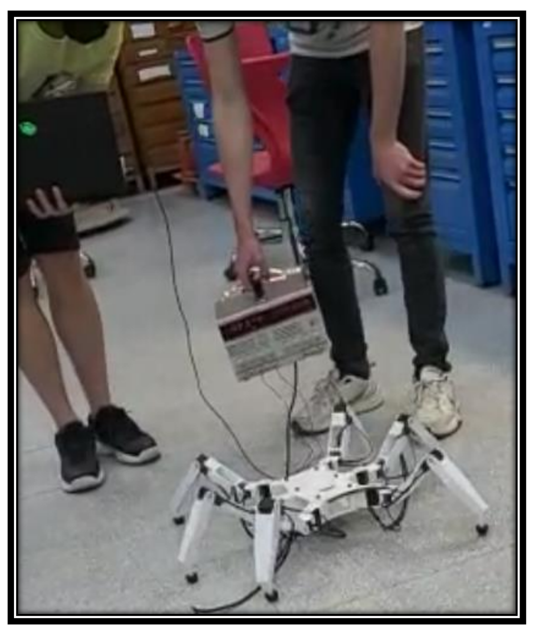
$$ 20 \text{ cm} = (2 \text{ cm} \times 5 \text{ cm}) + 10 \text{ cm} $$

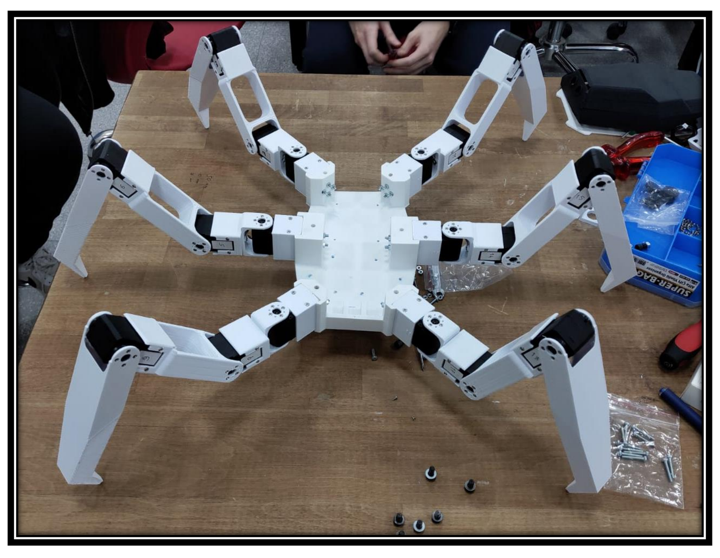


Experimental Setup

The detailed mechanical designs of Biomimetic Walking Robot parts are designed in the SolidWorks by considering the first concept design of robot. Afterwards installation of the parts is assembled via using SolidWorks. Finally, parts of hexapod robot are printed with 3D printer.







Results and Discussion

The necessary calculations are taken from SolidWorks algorithm such as Angular Displacement and Torque values in the below. Excel tables can be acquired from SolidWorks motion study as spreadsheets. After that, these excel data can be imported by Python code that drives the 18 LX-16A Bus Servo motors. Each motor can handle the torque value about 19 kg*cm=1.9 Nm. So, it is enough for walking gaits.