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Kinematic Design Analysis and Optimization of Mobility System Using MATLAB

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In this research work, several sophisticated types of equipment and automation have been studied, points taken and considered to realise the locomotion of modern territory of all uneven environments. One of the most main mission and structure of this study is the preferred simplicity of the bipedal walking locomotion system. The study included from simple to complicated legs as like single-legged, like humanoid and up to sixteen legs like a caterpillar. Most of the bipedal walking robots are with research study and we concentrated to emphasizes the significance of robotic legged motion stability in the compact. These bipedal walking robots can walk on rough surfaces, turn efficiently and climb staircase if needed. In particular, a suitable bipedal walking model having an upper link and a lower link will make the system to the desired motions, which has been experimentally exposed to provide a stable walking system. The MATLAB software tool is used to optimize the mechanical constraints and to compare, analyse and investigate the influence of motion stability. The simulation results show a possible performance of projected leg bipedal walking mechanism.

Keywords: Bipedal, Degree of Freedom, Design, Four-Bar Mechanism, Lower Linkage, Mobility, Simulation, Upper Linkage, Walking Mechanism

Introduction

Bipedal walking robots[1, 2]have been implementing ever from the past four decades and certain major developments have been accomplished. Most of the bipedal walking mechanism robots are still offering to lag in its robustness and stability[3]on even and uneven terrains in single degree of freedom 1. A simple bipedal walking robot is built with light-weight material which acts as the structural members under open-loop controlled servo motors are being utilized for lateral balancing[1.] The hybrid bipedal walking motion provides certain stability and agility as of a human being driven by unilateral constraints at ground contact and impulse-like forces that occur at foot level[4.]The mobility system tilting is minimized, which is always the limitation for a conventional walking robot, using an algorithm that uses body ergonomic posture to perform the corrective actions[5, 6.]

Design Procedure

Bipedalkinematic walking mechanism theory

Bipedal walking mechanism submits to the type of locomotion in which two legs are used and only one leg at a time is off the ground. A basic step includes two distinct phases of the stand phase and the return phase. A step refers to the period of motion between foot lift-off event and foot touch-down event of one leg point.

Desired Walking Motion

The major attempt should be made to investigate that the mechanism should respond and then to fabricate for the desired movement as shown in given Table 1. In a walking mechanism movement, the key parameters to refer are how the angle of the upper and lower links behaves and also how the mechanism linkage modifications affect the new linkage configuration. In this work, we propose a conceptual design linkage mechanism that can repeat a given set of walking movement to perform stable walking. The discussed bipedal walking robot linkage mechanism consisting of two legs and a hip with totally of twelve degrees of freedom on its legs advantages and drawbacks as shown in Table 1.

In Figure 1(a), the X-axis from 0 to 2π radian denotes one-step phase. The movements of the upper linkage and lower linkage conceptual design are plotted here and the cycle is repeated. The zero radian represents a foot lift-off phase. The next 0 to π radian

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represents the rest phase. From the next π radians to 2π radians represent the posture phase. In the Y-axis, Figure 1(b) depicts the leg angle measured relative to a fixed reference frame. In this case, the reference was chosen as the horizontal. A discontinuity in the slope of the upper link and lower link movement is visible at π radian. Slope discontinuities also exist at 0 radian, although they are less apparent. These slope discontinuities are results of the foot impacting and leaving the ground respectively. Now the desired movements have been determined, so the process steps of designing a leg walking mechanism to match these movements may begin. In the end, the walking movement motions that were chosen to serve as the desired motions come from the robot mechanism. It is noted that the outer two legs have slaved together so that they produce the precise identical movement as shown in Figure 1(b). The effect of having two legs slaved together is stability in the side-to-side plane. The main focus of the given robot mechanism and the research presented in this paper is on stability and the anatomical boundary that exists between the left and right sides of the body and also this plane that extends in the direction of walking. The input angle of upper and lower linkage movements carried out by walking robots graph plotted below as shown in Figure 2(a).

Table 1 — Advantages and drawbacks of a single DOF mechanism Compared to a high DOF Robot

Single DOF Mechanism	High DOF Mechanism
A single motor is required	Range of motions is restricted
smaller number sensors are desirable	Motions may not be most favourable
A Control strategy is easy	The Structural integrity of robot may difficult
inexpensive	High cost
Light load	More load

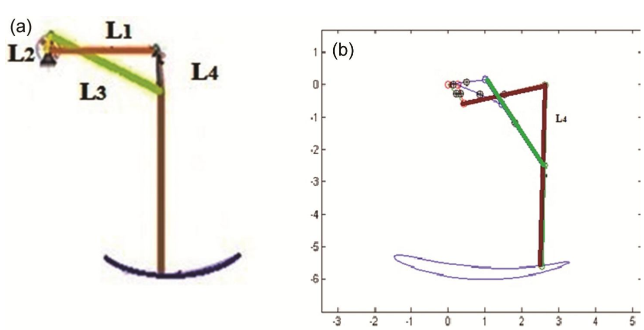

Fig. 1 — Upper and Lower four-bar linkages mechanism (a) Conceptual design mechanism, (b) After optimized mechanism

Upper linkage and Lower linkage using Four-Bar mechanism

Numbers of possible mechanisms are being developed for obtaining the movement of upper link and lower link in a walking motion. A conceptual Solid works CAD model as shown in Figure1 has been drawn to the preferred possible mechanism configuration similar to an actual upper and lower linkage motion during walking. The four-bar linkage is the simplest mechanism, which reasonably gives the upper and lower linkage movements. The first step in forming the equations of motion for the mechanism is to express each link as a vector. After these vectors are formed, a vector loop equation is to be written. For the modelled mechanism linkage configuration, vector loop equation is formed. They arrived by Chebyshev mechanism equation vectors are then described in X and Y coordinates as two equations. The output angle is calculated from the above formed equation and then optimized the link lengths.

Data Analysis

Optimization of Upper linkage and Lower linkage Mechanism

There is an equation which describes the upper link motion as a function of each link length and the input link rotation. The desired motions of the upper link will be supplied by a set of equation of motions performed by the bipedal mechanism. The MATLAB tool box function named *fmincon* is used to optimize the configuration. For the *fmincon* function, we must first give an objective function as script file and it should be of a value or values that are being optimized. The objective function of the upper link length optimization was defined as *f=S((?f – femurangledesired)2)*, where *?f* is the function of angle of upper link. The variable upper link angle desired as vector of the same length *?f* and that describes the desired angle of the upper link for single full step cycle. Several iterations are necessary and it may be necessary to optimize only one parameter at a time during the initial state. By adjusting the upper and lower limits of the parameters, we can make sure that the resulting mechanism is suitable. The values of the upper link angle formed as well as link length and lower link angle are considered necessary for the desired motions and plotted as shown in Figure 1(a).

Discussion

The bipedal design mechanism basically inspired from the human body functional mobility. Due to the complex skeletal structure and human muscular system, the essential internal mobility is limited and

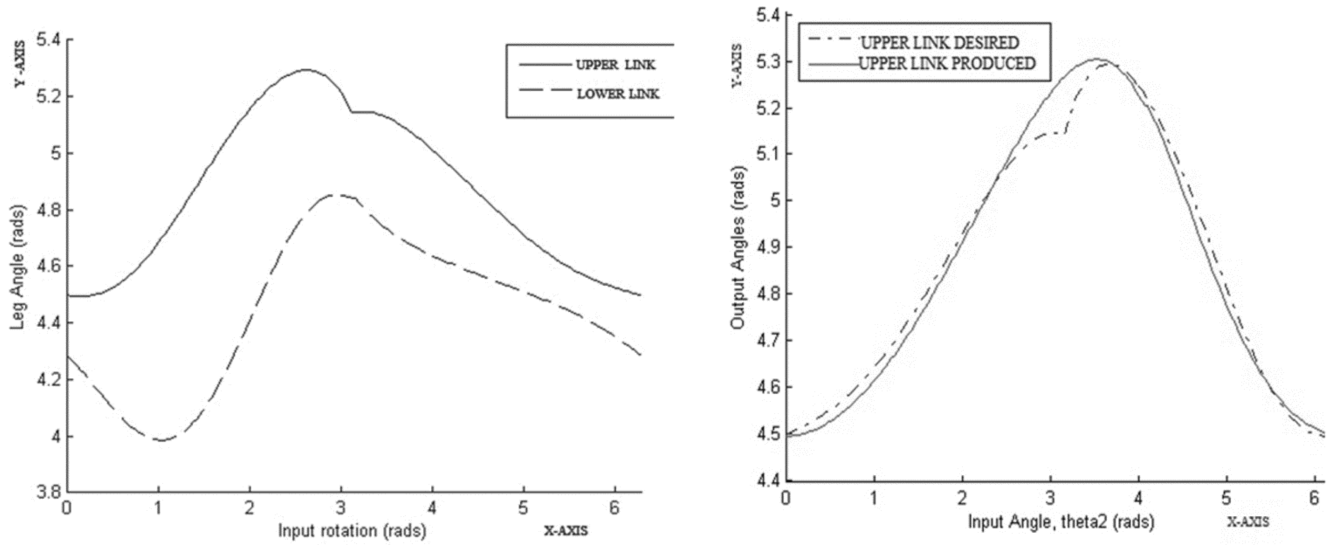

Fig. 2 — (a) Upper and lower link desired motion, (b) Desired and produced upper linkages motion

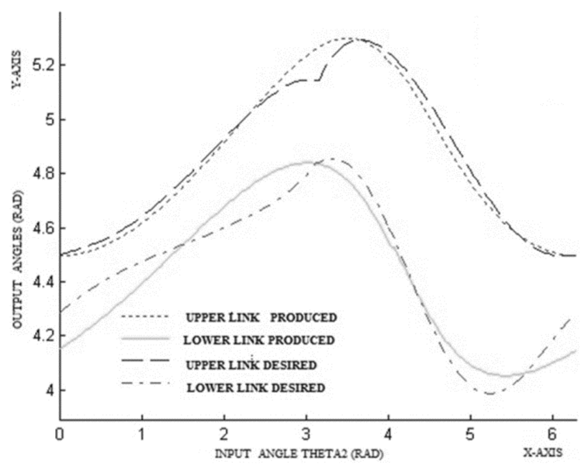

Fig. 3 — Combined desired and produced upper and lower link Motion

Table 2 — Upper linkage mechanism parameters

LinksParameters	Link position	Link length Values(mm)
L_1	fixed	100
L_2	crank	25
L_3	coupler	80
L_4	follower	50

should have simple actuation system. When comparing to human body, a bipedal mechanism has fewer degrees of freedom as shown in given Table 2. The Figure 2 and Figure 3 show the desired and produced motion path curves of upper and lower links. The Figure 2 plot shows the desired path and Figure 3 plot shows the produced and optimized path which is reasonably good. There is being one portion of the movement which is not strongly harmonized and that plots at π radian only. When observing this plot, where the foot comes to rest and which is happening in a gait. It is important to note that there is error at this location and which will affect the stability of the gait. By considering this error, a suitable link length of four-bar linkage which controls the upper linkage and lower has been determined. By changing the footstep length and swinging step height will not affect the main design factors of a bipedal walking mechanism, but improves the performance. The size of the joint linkages formulates the overall mechanism model more efficient than the anthropomorphic design. We found an optimized and satisfied walking mechanism model for upper and lower links with an efficient walking step towards the reduced effort on crank torque.

Conclusion

In this research paper presented, the main upper and lower four-bar linkage bipedal walker mechanism, which favoured the simplicity and flexibility of bipedal walking mobility linkage mechanism and its different terrain applications. The optimized analysis of this mechanism demonstrates its design configuration and reduces the linkage length function to achieve more stability and the step towards reduced effort on crank torque in the single degree of freedom.

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