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# Cable-Driven Constrained Traversal Mechanism for Planar Motion

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**ABSTRACT**

In this paper a simple model of mobile traversal mechanism suspended by cables and actuated by motors is presented. A detailed description of the workspace on which the payload is traversed is discussed. The mechanism is actuated by cables which are driven by motors. The rate of change of length of cables and the angular velocities of motors are determined such that the payload traverses along the shortest path in the desired duration of time. The motors are programmed to operate separately as per the derived formulas. The mechanism thus designed is portable and can be applied in the field of agriculture, farming, manufacturing, surveillance etc.

**Keywords:** Parallel robots, traversal mechanism, portable, payload, cables, motors

## I. INTRODUCTION

Cable-Driven Parallel Robots (CDPRs) are a special category of parallel robots where a moving platform is positioned by changing cable lengths. Using this type of robots, it is possible to attain completely constrained six degrees-of-freedom (DOF) despite of the fact that the cables can be subjected to only tension.

Key properties of CDPRs, which varies a great deal from conventional robots [1,2] enable the automation of completely new tasks, which were not quite possible to be automated previously. For example, cost addition in case of increasing cable length is minimal, and hence, CDPRs can be used to span very large workspaces, that are orders of magnitude larger than those covered by the biggest serial robot today. In addition, CDPR designs usually have stationary actuators. This results in a marked decrease in actuated mass, which allows the employment of greater speeds and accelerations[7] (Kawamura, Choe et al. 1995). Tasks with high payloads and large workspaces are thus ideal for automating using CDPRs.

A cable-driven parallel robot (CDPR) is composed of four basic components. A platform or payload, which is positioned within a workspace to perform a specific task, cables to control and move the payload, actuator system which change the cable length, and a frame upon which this actuator system is mounted.

The high load conveying ability, modular construction and energy-efficiency of CDPRs make them better than traditional parallel robots [8] and great prospect for an assortment of testing substantial workspace errands, for example, multidimensional cranes [3,4], very high speed robots [5], camera frameworks for stadiums [6], *etc*.

Planar motion of a rigid body is said to be accomplished when all the points move parallel to some fixed plane. The proposed traversal mechanism, which is constrained by cables, can be called as Cable Suspended Parallel Robot (CSPR) with 2-DOF (both translational) rather than CDPR because payload is suspended by 4 cables. Though the mechanism is predominantly planar in nature, due to mobility of the framework of the workspace and the design considerations of the cables and also the considerations regarding the payload, it can be realised to be of three degrees of freedom (all three translational) as shown in figure 1.

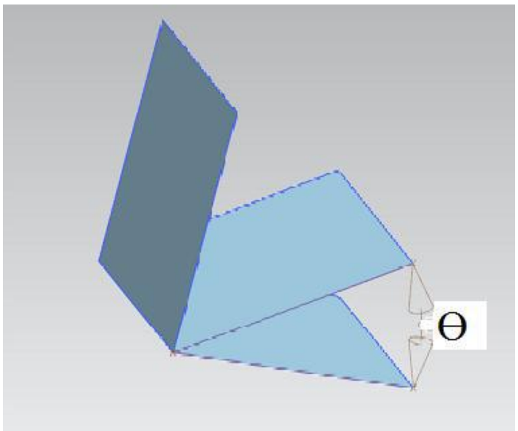


**Figure 1.** Base of the framework realised in three dimensions

## II. THE MECHANISM

Recalling the basic components of a CSPR, it comprises of a framework, actuator system, cables and the payload. The shape of the working arena over which the payload has to traverse can be a square or a rectangle. The framework consists of four fixed columns, one each erected at four corners of the base outside the workspace. Motors, eye hooks, spools etc. constitute the actuator system. A bipolar stepper motor is stationed at each corner of the base with a spool fitted on its shaft. The columns are fitted with eye hooks in order to support the position and movement of cables. A flexible cable – more than 1.5 times the length of the diagonals of the workspace – is wound around each motor (spool) and their free ends are connected to the platform of the payload. These cables form the connecting links of the mechanism. The end-effector is thus constrained to achieve only translational motion in the workspace making it a planar mechanism as shown in Figure 2.

The position of the payload is determined by the length of each cable. In order to achieve the required motion of the payload, the length of the cables should vary in tandem such that it guides the payload to cover the shortest path – straight line – between the two desired points in the desired duration of time.

Figure 3 depicts the workspace with the four motors and their corresponding cables. Let **a** and**b** be the length and breadth of workspace and L1, L2, L3 and L4 be the lengths of the cables between the vertical support and the payload as shown in figure 3.

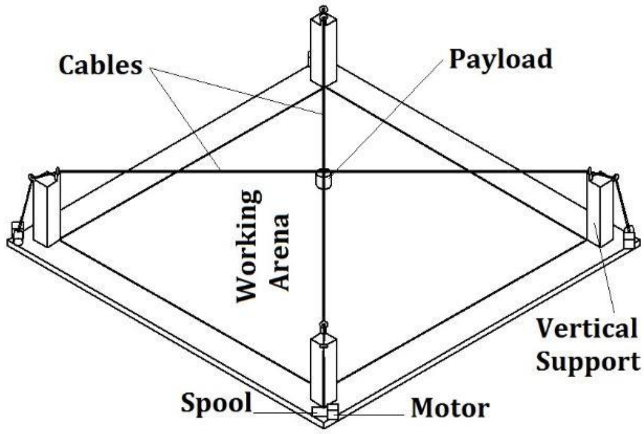


**Figure 2.** Schematic sketch of the construction of the mechanism

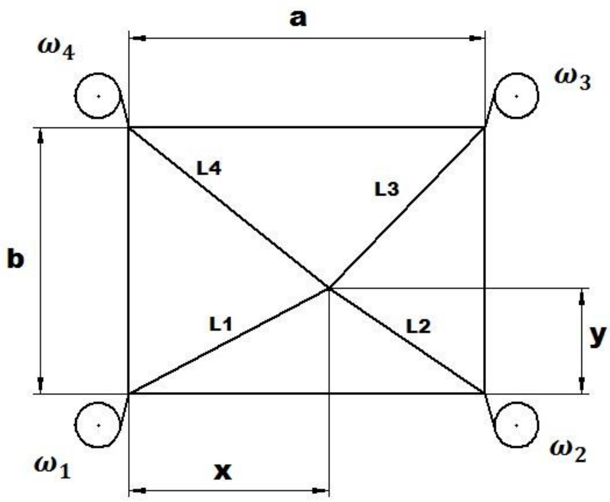


**Figure 3.** Schematic sketch depicting the notations used

The rate of change of length of the cable 1 is given by

$$v_1 = \frac{x\,\dot{x} + y\,\dot{y}}{\sqrt{x^2 + y^2}}$$

Likewise, the rate of change of length of the cables 2, 3 and 4 are given by

$$v_2 = \frac{-(a-x)\dot{x} + y\,\dot{y}}{\sqrt{(a-x)^2 + y^2}}$$

$$v_3 = \frac{x\,\dot{x} - (b-y)\dot{y}}{\sqrt{x^2 + (b-y)^2}}$$

$$v_4 = \frac{-(a-x)\dot{x} - (b-y)\dot{y}}{\sqrt{(a-x)^2 + (b-y)^2}}$$

These changes in lengths of cables are effected by 5 V bipolar stepper motors. The voltage supply to each of the motors is varied separately using a microcontroller kit (Arduino Uno) and A3967 stepper motor drivers as shown in figure 4 in order to vary their speed of revolution which in turn varies the rate of change of length of the cables. Considering the workspace to be x-y plane, the angular velocity of motor 1 is given by

$$\omega_1 = \frac{v_1}{r}\hat{k}$$

Similarly, the angular velocity of motors 2, 3 and 4 A are given by

$$\omega_2 = \frac{v_2}{r}\hat{k}$$

$$\omega_3 = \frac{v_3}{r}\hat{k}$$

$$\omega_4 = \frac{v_4}{r}\hat{k}$$

where 'r' denotes the radius of the spool.

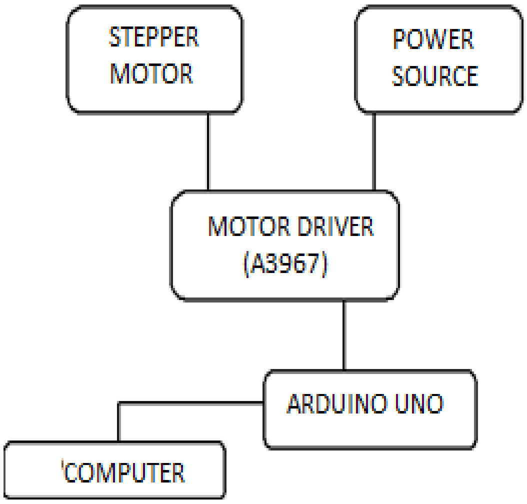


**Figure 4.** Block diagram of the circuit to vary the speed of revolutions of the stepper motor

## III. RESULTS AND DISCUSSION

Assuming the dimensions of the workspace to be 100 cm x 100 cm, simulation of the mechanism was carried out and the results were obtained as discussed below.

Consider the initial position of the payload to be (50, 10), as shown in figure 5. By virtue of the changes in the length of the cables, the payload has to reach its destination at (90, 90) along the shortest path in the stipulated duration of time.

The trends followed by the motors and the cables are discussed below:

1. Motor 1 undergoes constant anticlockwise rotation which unwinds the cable 1.
2. Motor 2 undergoes small clockwise rotation initially, which winds the cable 2, and then changes to anticlockwise rotation with gradually increasing speed such that the cable unwinds accordingly.
3. Motor 3 undergoes constant clockwise rotation which winds the cable 3.
4. Motor 4 undergoes clockwise rotation initially with gradually decreasing speed, which winds the cable 4, and later changes to gradually increasing anticlockwise rotation, thus unwinding the cable.

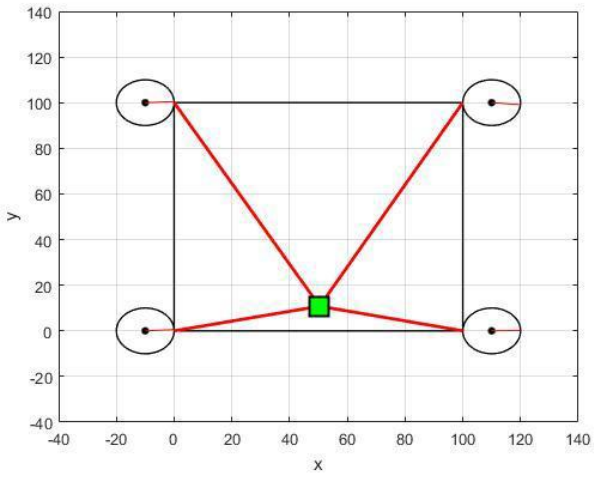


**Figure 5.** Initial position of the payload

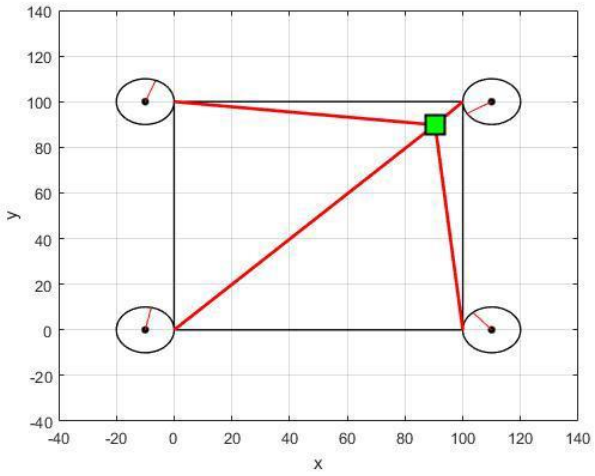


**Figure 6.** Final position of the payload

The variation of length of each cable with respect to abscissa of the position of the payload is shown in figure 6.

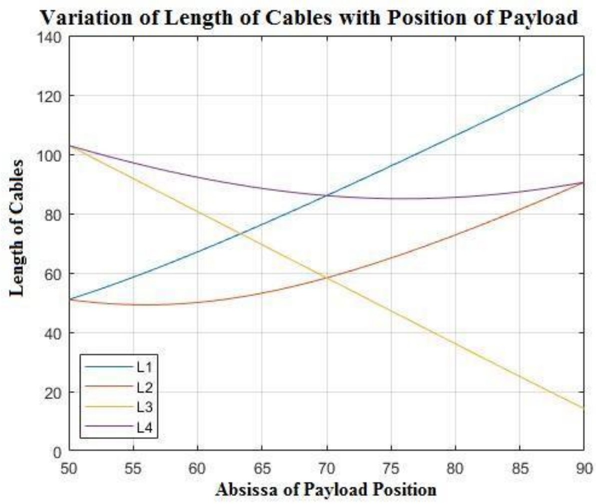


**Figure 7.** Plot to show the variations of length of cables with respect to positions of payload

As a result of these variations in lengths of cables, the payload is traversed from its initial point (50, 10) to its final point (90, 90). It is to be observed that the time of travel or the speed of travel is specified initially, along with the initial and final positions, as the requirement may be but the path followed remains a straight line. It is worth to be mentioned that the path to be traversed can also be programmed as per the requirement, which has its own applications such as 3-D printing *etc.*

## IV. CONCLUSION

A thorough study of CSPRs and CDPRs is done and a simple constrained traversal mechanism for planar motion is formulated. The mechanism is made mobile and portable, which aids in extending the mechanism from being purely a 2-dimensional fixed mechanism to a portable, table-top, 3-dimensional mechanism. Depending upon the payload employed, this mechanism can be applied in various areas as in understanding the surface roughness along a particular line, sowing of seeds at particular intervals, spraying of fertilizers and pesticides on plants, handling of toxic chemicals in a laboratory, 3-D printing, monitoring the conditions in a closed environment, and so on and so forth.

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