ISSN: 0974-2115
www.jchps.com Journal of Chemical and Pharmaceutical Sciences

Design and fabrication of mini flexible trunk like manipulator

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ABSTRACT

Robotic manipulators play a vital role in the field of manufacturing industries. There are several types of manipulators such as Industrial manipulator, Pneumatic manipulators, Material handling manipulator and so on. These manipulators are employed for lifting objects, welding purpose, paint spraying etc., depends on the end effector fixed on the robot its application varies. Although there are lots of manipulators they are not so flexible and are very expensive. This paper construes about “design and fabrication of mini trunk like manipulator” which was inspired from trunk of an elephant. This manipulator is mainly designed to be very flexible and at the same time to reach maximum points in its work volume so as to reduce singularity errors. The central rod which is a flexible spine structure forms the backbone of this manipulator. A basic prototype was fabricated as a proof of this paper. Due to its high manoeuvrability, the manipulator may find niche applications in areas like human –robot interaction, multi-arm manipulation and unknown environment exploration.

KEY WORDS: Elephant Flexible spine, Manoeuvrability, multi-arm manipulation, workspace, singularity error.

1. INTRODUCTION

Anyone who has observed an elephant for any length of time cannot help but watch in amazement at the creature’s ability to manipulate its environment through an appendage that contains no rigid parts whatsoever. It seems almost counterintuitive that an elephant’s trunk, despite its flexibility, can lift huge weights (e.g. tree trunks) with apparent effortlessness, and at the same time it has necessary delicacy and precision to pick up a peanut. As with arms, legs, and hands, artificially constructed trunk like manipulators will likely never reach the zenith of complexity represented by the real thing. Nevertheless, some of the reproducible aspects and capabilities of trunks and tentacles could enrich the field of robotic manipulation in certain applications, like material transport from (or exploration of) unknown environments, and whole arm manipulation. Continuum manipulators’ inherent passive compliance could also prove beneficial in human–robot interaction and multi arm-cooperating manipulation by reducing reliance on complex force-feedback schemes that prevent the arms from fighting one another.

Trunk and tentacle like devices belong to a category of manipulators termed continuum, for the lack of joints or rigid links. The alternate category, high-degree-of-freedom (HDOF) devices, might best be imagined as snake backbones, consisting of many joints connected by relatively short links. In fact, the two classes, broadly categorized as hyper-redundant, share many similarities, and a significant body of work exists attempting to describe the kinematics of HDOF devices with continuum models. It should be noted, however, that the dividing classifications mentioned above are somewhat imprecise, and the capabilities of a hyper-redundant manipulator may be better characterized by noting the relation of its structure to its actuation scheme.

Figure.1. Structure of elephant trunk manipulator

2. METHODOLOGY

The approach towards the making of the robot has been split into different steps which go like designing, fabrication and controlling of the robot. Figure 3.1 depicts the steps of the methodology of work.

First step is identifying the problem. The second step is developing the concept to overcome the problem which has been identified in the first step. Once the concept is developed for the identified problem, the different possibilities of the concept is sketched out and studied. The optimum solution for the concept is achieved after the studies.

The next step is to develop the conceptual idea into a 3 dimensional model using a modelling software. Next stage is to fabricate the robot. Then an algorithm is to be developed for the trunk like manipulator robot for the purpose of its operation. Finally, the robot is interfaced with the controller for verifying the algorithm in multiple trials.

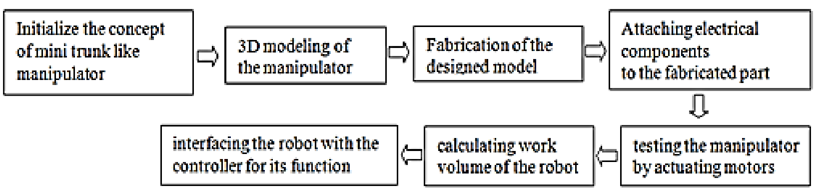

Figure.2. Flow chart for trunk like manipulator

Design of Trunk like Manipulator: First step of design process is to develop circular discs of various diameters followed by a design of a base plate. Next step is to design central rod. Then it is continued by assembly work of mating process of central rod with circular discs which is accompanied by drilling of holes on the circular discs.

Fabrication: Circular discs are arranged in a manner of descending diameter at each section from the base. These arranged discs are attached to a flexible spine (Central rod).

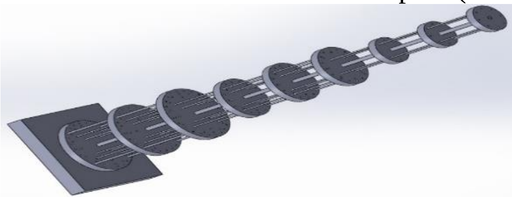

Figure.3. Design of Trunk like Manipulator

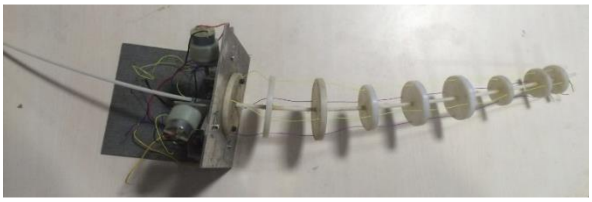

Figure.4. Fabricated Model of Trunk like manipulator

Diameter ratio: The discs are fabricated in a proportionate diametric ratio. The ratio is 2: 3: 4. The ratio is for outer diameter of disc.

Base diameter to length ratio: The base diameter and length of elephant trunk manipulator are designed in the ratio of 1:5, in order to make the manipulator flexible and to meet maximum reachability.

Distance between each disc: The distance between each disc are calculated by the ratio of distance between first disc and last disc to the total number of disc 1.

$$D = (Dn-D_1)/ (x-1)$$

Where x is the total no. of disc, $Dn-D_1$ = distance from first disc to last disc.

Holes drilling ratio: Holes are drilled along the circumference of the outer diameter of the disc. They are concentrically drilled with 10mm less than previous diameter.

Dc Motors: Four DC motors are attached to the base of the trunk. Each motor will actuate one tendon. The tendons are connected to the shaft of the motors. The specification of DC motor is given below. All the motors are of same rating.

The trunk like manipulator has infinite DOF as its links are continuously attached. It can give only continuous motion. The actuation of one link affects the motion of other link. It cannot be actuated individually. These links are actuated by using tendons which are directly attached to shaft of the motor. The tendons used for actuation is made up of nylon material.

Table.1. Physical properties of Nylon

Tenacity	4-9 gm/den (dry), in wet 90% of dry
Elasticity	Breaking extension is 20-40%
Stiffness	20-40 gm/den
Dimensional stability	Good
Resiliency	Excellent
Hand feel	Soft and smooth

Table.2. DC Motor specification

DC Supply	4 to 12V
RPM	60 @ 12V
Total length	46mm
Motor diameter	36mm
Motor length	25mm
Brush type	Carbon brush
Gear head diameter	37mm
Gear Head length	21mm
Output shaft	Centred
Shaft diameter	6mm
Shaft length	22mm
Gear assembly	Spur
Motor weight	100gms

Table.3. Disc dimension table

Section	Outer Diameter (mm)	Inner diameter 1 (mm)	Inner diameter 2 (mm)	Inner diameter 3 (mm)	Number of holes
I	50	40	-	-	8
II	75	65	55	-	16 , 8
III	100	90	80	70	24 , 16 , 8

Motion Study: This manipulator consists of Trunk shaped body made up of circular discs, Base, DC motors. Tendon mechanism is used to actuate the trunk. This mechanism is used to reduce mechanical complexity (or) to reduce biometric of motion. The tendons used in robotic mechanism are categorized into 2 classes: one is passive tendon and other is active tendon. A passive tendon is not connected to an actuator, whereas active tendon is attached to driver directly. The categories are picturized below in figure.5.

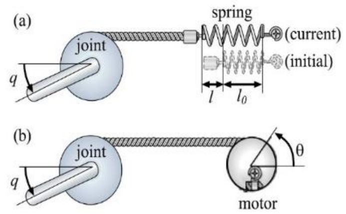

Fig.5. Tendons (a) Passive tendon connected with springs (b) Active tendon driven by actuator

The trunk can be actuated to four directions by actuating its respective directional DC motor. It can attain left, right, downwards and upwards motion direction. The schematic diagram to explain the motion of trunk is given below.

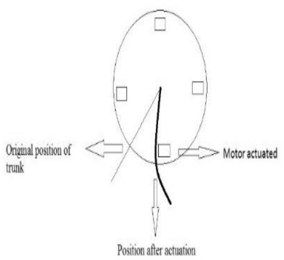

Figure.6. Down motor actuated and its position after actuation

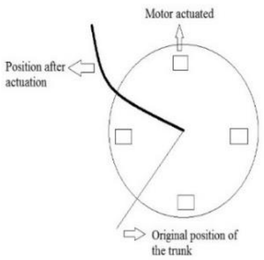

Figure.7. Up motor actuated and its position after actuation

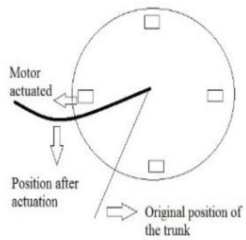

Figure.8. Left motor actuated and its position after actuation

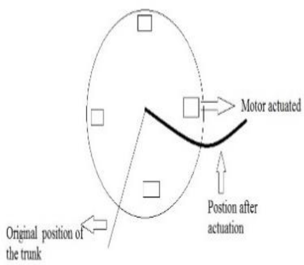

Figure. 9. Right motor actuated and its position after actuation

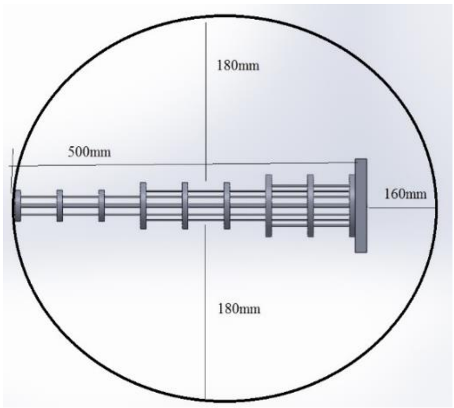

Figure.10. Working range of robot with direction up and down

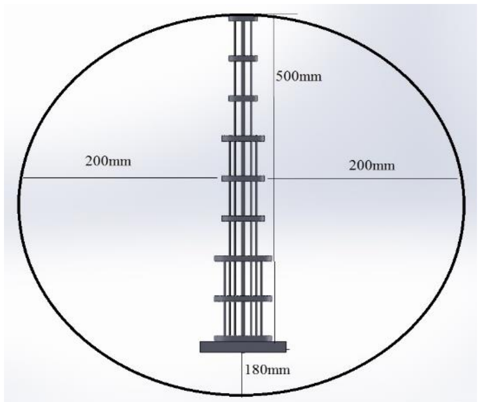

Figure.11. Working range of robot with direction left and right

Work volume of the robot is defined as the maximum number of points robot will be able to reach. The work volume of the trunk like manipulator is shown in above figures. This robot can reach all the points within this work volume without any singularity error. Singularity error is defined as when a point in a work volume is not able to reach for the robot by means of linear motion but it can be attained by circular motion. The trunk like manipulator will overcome this error since its work volume is spherical in shape and its body is flexible enough to reach all the points.

3. CONCLUSION AND FUTURE WORK

A detailed study of Trunk like manipulators has been done. The trunk like manipulator is capable of reaching maximum number of points inside the work volume. Design trails were made and rectified using SOLID WORKS® software. Experiments will be done in future by adding load to its end effector and programming it for desired angle of motion. Spray gun is attached as the end effector so as to do spray painting to narrow down the applications of trunk like manipulator.

4. ACKNOWLEDGEMENT

I feel greatly indebted to my project guide Mr.Balamurugan S, and I thank him for the deep interest he has shown in this project and for motivating me to do my best.

REFERENCES

Annisa, Jamali Bt, Raisuddin, Khan Md., and Mozasser Rahman, Design and Control of Variable Length Hyper Redundant Robot, International journal on Robotics and Intelligent Sensors, Procedia Engineering, 29 (10), 2012, 400-415.

Coralie Escande, Pushparaj, Mani Pathak, Rochdi Merzouki, Taha Chettibi, and Vincent Coelen, Kinematic Calibration of a Multi section Bionic Manipulator, IEEE/ASME transactions on mechatronics, 20 (2), 2015, 90-102.

Gregory, Chirikjian S, and Joel, Burdick W, Kinematically optimal hyper redundant manipulator configurations, IEEE transactions on robotics and automation, 11 (6), 1995, 75-90.

Hannan M. W, and Walker I.D, The 'Elephant Trunk' Manipulator, Design and Implementation, IEEE International transactions on robotics, 18 (5), 2009, 365-378.

Ian Gravagne A, and Ian Alker D, Manipulability, Force, and Compliance Analysis for Planar Continuum Manipulators, IEEE transactions on robotics and automation, 18 (3), 2002, 180-193.

Ian Gravagne A, Christopher, Rahn D, and Ian Walker D, Large Deflection Dynamics and Control for Planar Continuum Robots, IEEE/ASME transactions on mechatronics, 8 (2), 2003, 52-65.

Ian, Grangne A, and Ian, Walker D, Kinematic Transformations for Remotely-Actuated Planar Continuum Robots, ASME International transactions on Robotics & Automation, 5 (1), 2000, 500-520.

Ian, Walker D, and Michael, Hannan W, A Novel 'Elephant's Trunk Robot', IEEFJASME International transaction on Advanced Intelligent Mechatronics, 10 (5), 1999, 421-435.

Jessie, Lee, Santiago C, Ian, Walker D, and Isuru, Godage S, Continuum Robots for Space Applications Based on Layer-Jamming Scales with Stiffening Capability, IEEE/ASME International transactions on robotics and automation, 10 (12), 2013, 352-365.

Matthias Rolf, and Jochen Steil J, Efficient Exploratory Learning of Inverse Kinematics on a Bionic Elephant Trunk, IEEE transactions on neural networks and learning systems, 25 (6), 2014, 25-46.

Pasquale Chiacchio, Bruno Siciliano, Lorenzo Sciavicco, and Stefano Chiaverini, Global Task Space Manipulability Ellipsoids for Multiple-Arm Systems, IEEE transactions on robotics and automation, 7 (5), 1991, 65-79.

Robert, Webster J, Joseph, Romano M, and Noah, Cowan J, Mechanics of Pre curved Tube Continuum Robots, IEEE transactions on robotics, 25 (1), 2009, 89-105.

Ryuta Ozawa, Hiroaki Kobayashi, and Kazunori Hashirii, Analysis, Classification, and Design of Tendon-Driven Mechanisms, IEEE transactions on robotics, 30 (2), 2014, 105-118.

Tobias Mahl, Alexander Hildebrandt, and Oliver Sawodny, A Variable Curvature Continuum Kinematics for Kinematic Control of the Bionic Handling Assistant, IEEE transactions on robotics, 30 (4), 2014, 150-169.

Yong Jae Kim, Karl Iagnemma, Sangbae Kim, and Shanbao Cheng, A Stiffness-Adjustable Hyper redundant Manipulator Using a Variable Neutral-Line Mechanism for Minimally Invasive Surgery, IEEE transactions on robotics, 30 (2), 2014, 41-63.