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3d Prototype of a Low-Cost Spherical Parallel Manipulator

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ABSTRACT

Aerial/shipboard video surveillance systems, mobile robots for emergency scenarios, defense modules, and many other applications all require motion (orientation) control systems. The majority of motion systems for mobile applications use 2 axis pan-tilt platforms in their architecture.

Many contemporary systems use dynamical object tracking algorithms in addition to gathering general video image data for a variety of security and surveillance objectives. Mobile pan-tilt based systems frequently use platform stabilization to reduce platform vibration while moving in order to achieve desired performance. Most often, platform stabilization control systems that use inertial measurement units to modify the positions of the pan-tilt actuators as necessary are used to do this because there are only two degrees of freedom (pan and tilt rotations) available for altering the positions of the attached sensor systems, using pan-tilt platforms in mobile applications for precision pointing and target tracking has major disadvantages. To solve this issue, a number of SPM configurations have been suggested for creating three degrees-of-freedom pure rotation systems for the best camera orientations. The fact that the end-effectors are coupled to the base via various kinematic chains is a defining characteristic of parallel manipulators.

The air of this paper is to provide a novel concept for a 3-axis internally stabilized motion control system that may be used in mobile applications. This will be accomplished in various stages like designing, assembly, and intervention of electronics. Finally testing the prototype and the cycle repeats in case of tuning. The parts are modeled in Solid works, the designed parts are 3D printed using the FDM technique, and intervention is carried out using a Microcontroller for tuning.

Keywords: Video Surveillance Systems, Pan-Tilt Platforms, Parallel Manipulators, SPM.

List of Abbreviations

CAD -Computer-Aided Design
CCT - Conservative Congruence Transformation
DOF- Degree-Of-Freedom
EE -End-Effectors
FEA -Finite Element Analysis
GA -Genetic Algorithm
GCI- Global Conditioning Index
MOEA -Multi Objective Evolutionary Algorithm
MP -Mobile (Moving) Platform
NSGA- Non-dominated Sorting Genetic Algorithm
PKM- Parallel Kinematic Machine
PM- Parallel Manipulator (Mechanism)
PPM -Planar Parallel Manipulator
SPM- Spherical Parallel Manipulator
VJM -Virtual Joint Method

INTRODUCTION

When we talk about the term robotics, we associate it with the robot concept. A robot is a set of multifunctional reprogrammable digital manipulators, sensors, and devices, designed to move specific materials, objects, tools, or devices through various movements programmed to perform certain tasks. Robots can help people in a variety of ways in a home, for example, multiple tasks can be performed such as cleaning the house, being your pet, looking for lost objects, and warning about health hazards when monitoring children and the elderly. The automation of tasks that robots execute motivates the creation of a whole new field for people to build robots, provide maintenance, or simply share daily tasks with robots. In industry and in business, tiresome and repetitive activities can be performed by machines. In the past it was thought that robots would replace humans in almost every task. Nowadays, it has been recognized that there has been a cost reduction in production with the automation and inclusion of robots, while at the same time the labor dispensed has discovered that even though the need a for the workforce has decreased in these environments, there are still several options available. Typically, the industry applies static robotics solutions, i.e., machines that have well-defined, finite functionalities that operate within a small area of space. However, the attention of the paradigm of robots required by the industry, based on fixed robots with robotic mechanical arms, nowadays attention has turned to mobile robots, able to move in the environment they are and especially in Autonomous Mobile Robots (RMAs) and Intelligent Autonomous Vehicles.

The RMAs have, as fundamental characteristics, the locomotion and operation capacities in semi or completely autonomous mode. It should also be considered that higher levels of autonomy will be achieved only as the robot begins to integrate other aspects considered of major importance, such as: the ability to perceive (sensors that can ”read” the environment where it acts), ability to act actuators and motors capable of producing actions, such as the displacement of the robot in the environment), robustness and intelligence (ability to handle the most diverse situations, in order to solve and perform tasks as complex as they are).

The use of robust planning and control techniques for the navigation and autonomous operation of robots is known by the term” Intelligent Robotic Control”, in which this intelligent control allows the RMAs to be able to perform the most diverse and complex tasks. With all this, the field of robotics has been developing activities in the last few years, and the research in Human Computer Interaction (IHR) comes to take the development of robots to a whole new level.

1.1 Background

Of the different types of PMs, three degrees-of-freedom (DOF) parallel mechanisms- based manipulators have high potential and a good prospect in the practical implementation in the industry, such as ABB Triceps and Flex Picker. 3-DOF parallel manipulators include translation, orientation, planar and spatial mixed-DOF manipulators, which can be used as robotic manipulators, double parallel robotic arms, shoulder or wrist joints and micro-positioning devices. The translation (ABB Triceps and Flex PickerOrth glide robot) and spatial mixed-DOF (Cap Aman robot, Micro robot MIPS, Hunt’s mechanism in the Dock welder project) manipulators have achieved success in many applications, while for the planar and orientation (spherical) ones, their research and development were received relatively less attention. The research work in this thesis will focus on these two types of manipulators. The planar and spherical manipulators have fewer mobility degrees than the Stewart platform, thus, one advantage is that they are easy to be built. Moreover, they are able to alleviate the shortcoming of the limited workspace by changing the structure or layout of their kinematic chains without largely increasing mechanism space. However, with the increasing requirements of robotic technology such as lightweight, high accuracy and rigidity, and low energy consumption, their design.

1.2 Kinematics

kinematics, also known as direct kinematic problem or forward kinematics, consists in finding the generalized coordinates (the variables that describe the pose of the mobile platform) from the auricular coordinates (the variables that describe the actuated joints), or, in other words, in determining the position and orientation (the pose) of the mobile platform for a given set of the auricular coordinates. For the parallel robots, usually, the direct kinematics is much more complex than the inverse kinematics, but it is necessary for motion planning, control purposes and calibration of the robot. Inverse kinematics, also called inverse kinematic problem, or reverse kinematics, consists in finding the auricular coordinates from the generalized coordinates, or, in other words, in determining the vector of leg lengths for a given pose of the mobile platform, defined by the position vector and the rotation matrix. For the parallel robots, the inverse kinematics is usually uncomplicated and easy to do or understand. A comparative study on the optimum kinematic designs of the parallel, serial and hybrid machine tools and robotics structures is presented in [13] and few strategies for kinematic designs of some parallel and hybrid mechanism are developed, discussed and analyzed. For an experimental prototype of a new type of a 2RPU-2SPR parallel manipulator, presented in [14], the direct kinematics solution is calculated by applying an artificial intelligence method, namely the back propagation neural network (where the notation used for the kinematic pairs means:

P - prismatic; R - revolute; U - universal or Hooke's or Cardan joint; S – spherical). To solve the inverse kinematics for any kind of parallel robot used, generally, for drilling or milling, that require three translational and two rotational degrees of freedom, 3T2R, a general kinematics model is introduced

1.3 Planar Parallel Manipulator

Planar parallel manipulators (PPMs) are parallel manipulators that have two translations in the plane and one rotation whose revolute axis is perpendicular to the plane. In the design and application of parallel manipulators, the accuracy is one of the most important performance criteria, which can be evaluated by conducting error analysis. Sources of errors for parallel mechanisms are diverse. The most significant ones are related to manufacturing/assembly errors and compliance in the mechanical architecture, actuation errors/backlash in the control loop, and clearances in the joints. The influence of most sources of errors is predictable and can be compensated through calibration and model-based control except joint clearance due to its poor repeatability

Despite the fact that joint clearance can ease assembly/manufacturing and is sometimes inevitable, the existence of the joint clearance will lead to poor performances of the mechanism as it introduces extra DOF of displacements between the pairing elements of a joint. The existing joint clearances may lead to an uncertain location of the manipulator end-effectors that is unexpected. Besides, it results in impact of the pairing elements and thus quicker wears of the mechanism elements. Thus, the error modeling and analysis with respect to joint clearances are of importance for both design and control in order to utilize the PMs Potential of high Accuracy.

1.4 Spherical Parallel Manipulator

Spherical Parallel Manipulators (SPMs) are a class of parallel mechanisms for which all points on the mobile bodies are located on concentric spheres, which is a relatively new research area in robotics, with a history of around two decades. A representative example for this type of mechanism is the Agile Eye. The motivation of the research on SPMs is to meet the increasing demands of actuating technology providing 3-DOF rotations.

The traditional approach to achieve pure rotations is through serial-chains based wrist mechanism. Such kinds of mechanisms normally have a relatively low payload ratio and complicated structure. Moreover, it increases the energy consumption with unevenly distributed power requirements among the actuators. To overcome these drawbacks, wrists based-on SPMs can be utilized. With advantages inherent from the parallel structure, wrists made of SPMs are able to rotate accurately with high transmission torque. In order to improve the performance of such kind of spherical actuated joints, the wrist mechanisms have to be compact, lightweight, stiff and energy efficient. This can be accomplished with an optimization method which is able to take multiple design criteria into account simultaneously.

The subject of this study in particular is to develop a modeling method and formulation of design guidelines used for parallel manipulators, focusing on error and stiffness analysis and design optimization. It is envisaged that the error model should be simple, readily identifiable from principal error sources and valid for its application of the error compensation. Besides, the magneto static model can be used or the optimum design to formulate systematic design guidelines. Eventually, the developed models are expected to improve characterization of the PMs

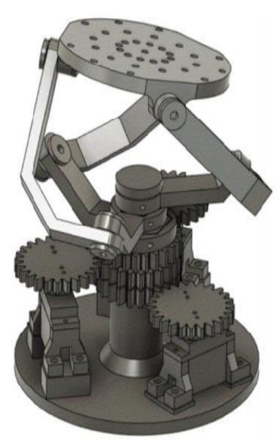

Figure: 1 Spherical Parallel Manipulator

1.5 Manipulator under Study

Figure 1.1 presents the prototype of the 3-PPR PPM with different mobile platforms (MPs), i.e., disk- and triangle-shaped.

In each leg, one prismatic joint can be chosen as an active joint while the other one is a passive joint. The parameterization of the manipulator is illustrated in Figure 1.1. The x-axis of the reference coordinate system Fb is parallel to segment A1A2, where Ai, i = 1; 2; 3, are fixed points on the base. The origin P of the coordinate system Fp is located at the geometric center of the mobile platform. The X-axis is parallel to segment D1D2, where Di is the center of the revolute joints. The location and orientation of the MP are denoted by p and, where p = [x; y] is the position vector of point P in Fb

1.6 Significance of the SPM

The SPMs are mostly used in applications involving high-speed motion; therefore, the dynamics has a very important effect on the required actuator torques. With the consideration of the kinematics and dynamics, such an SPM is a multibody dynamic system. In order to determine the motion of the entire system, it is necessary to establish the dynamic equilibrium condition that leads to a system of second-order differential equations generally called the equations of motion. Due to the highly nonlinear behaviors and the complicated kinematic problem, the equations of motion for the SPM can be formulated in dependent coordinates, where the method of the Lagrange Multipliers can achieve this aim.

LITERATURE REVIEW

Hay et al. [1] determined a manipulator design so that its workspace corresponds to a prescribed workspace is considered. Two different strategies, resulting in two different types of optimization problem are considered. The first strategy attempts to obtain a good overall approximation to the prescribed workspace and results in an unconstrained optimization problem. The second strategy entails designing a manipulator so that its workspace fully encloses the prescribed workspace and results in a constrained optimization problem.

Chaker et al. [2] did design and the analysis of a spherical parallel manipulator (SPM) for a haptic minimally invasive surgery application. First the medical task was characterized with the help of a surgeon who performed a suture technique called anastomosis. The optimized SPM was then analyzed to determine the error on the orientation of the end effector as a function of the manufacturing errors of the different links of the mechanism.

A. Verma and **V.A. Deshpande** [3] analyzed SCORBOT-ER Vplus robot arm which is used for doing successful robotic manipulation task in its workspace. The SCORBOT-ER Vplus is a 5-dof vertical articulated robot and all the joints are revolute.The kinematics problem is defined as the transformation from the Cartesian space to the joint space and vice versa. The Denavit-Harbenterg (D-H) model of representation is used to model robot links and joints in this study along with 4x4 homogeneous matrixes. SCORBOT-ER Vplus is a dependable and safe robotic system designed for laboratory and training applications.

M.T. Rana and **A. Roy** [4] worked to make a cost efficient autonomous robotic arm in terms of industrial automation. It is a type of mechanical arm, usually programmable, with similar functions to a human arm; the arm may be a unit mechanism or may be a part of a more complex robotic process. The end effectors or robotic hand can be designed to perform any desired task such as welding, gripping, spinning etc., depending on the application. For detective investigations and bomb disposal it can be used as an essential machine.

H. Choi et al. [5] performed robotic manipulators which are actively interacting with humans should be able to emulate the characteristics and performance of human body systems. Among various approaches to this end, this paper introduces a novel coordination system to control a two link manipulator in a more intuitive and human-friendly way: the polar coordinate system to describe the motions of a two-link manipulator and a particular actuation mechanism.

V. Deshpande and **P.M. George** [6] analyzed control of a robotic arm has been a challenge since earlier days of robots. The kinematics problem is defined as the transformation from m the Cartesian space to the joint space and vice versa. A general D-H representation of forward and inverse matrix is obtained. An analytical solution for the forward and inverse kinematics of 5 DOF robotic arm presented, to analyze the movement of arm form one point in space to another point. The 5 DOF robotic arm is a vertical art iculated robot, with five revolute joints.

T.P. Singh et al. [7] explained about Robotic manipulators. They are simpler than mobile robots in that they perform tasks in a fixed and known environment. They are more complex than mobile robots because they move in the three spatial dimensions and in the three dimensions of rotation. Using a simplified planar model of a robotic arm, the two central problems of manipulators are presented.

METHODOLOGY

3.1 Components of the 3D Model

- ESP 8266 Wi-Fi module
- Booster module 5volts
- 5000 Amah power bank
- MG 90 servo motors
- Jumper Wires

3.1.1 ESP8266 Wi-Fi Module

- The ESP8266 Wi-Fi Module is a self-contained SOC with integrated TCP/IP protocol stack that can give any microcontroller access to your Wi-Fi network. The ESP8266 is capable of either hosting an application or offloading all Wi-Fi networking functions from another application processor.
- An ESP8266 Wi-Fi module is mainly used for the development of end- point IoT (Internet of things) applications. It is referred to as a standalone wireless transceiver, available at a very low price. It is used to enable the internet connection to various applications of embedded systems.
- ESP8266 Wi-Fi Module
- Espresso systems designed the ESP8266 Wi-Fi module to support both the TCP/IP capability and the microcontroller access to any Wi-Fi network. It provides the solutions to meet the requirements of industries of IoT such as cost, power, performance, and design.
- It can work as either a slave or a standalone application. If the ESP8266 Wi-Fi runs as a slave to a microcontroller host, then it can be used as a Wi-Fi adaptor to any type of microcontroller using UART or SPI. If the module is used as a standalone application, then it provides the functions of the microcontroller and Wi-Fi network.
- The ESP8266 Wi-Fi module is highly integrated with RF balun, power modules, RF transmitter and receiver, analog transmitter and receiver, amplifiers, filters, digital baseband, power modules, external circuitry, and other necessary components.

Figure 2: Esp 8266 Wi-Fi Module

3.1.2 5000 Amah Power Bank

- 5000mAh Li-Polymer Battery: SYSKA Power Bank comes with high-density advanced Li-polymer batteries that makes it more durable and optimizes Zoom charging efficiency. 10W Zoom Charging: The Sy ska Power Bank series comes with 10W Charging Facility. It charges your devices with quick fast time without harm of device strength. Classic Dual Port: Two USB output port, Power ON/OFF on Top of device, Port Features: Micro USB Input, C-Type USB Input (5V/2A), USB Output ((DC 5V/2.1A), USB 2 Output: DC 5V/2.1A
- Layers Protection Feature: Output Overvoltage Protection, Output Overcurrent Protection, Input Overvoltage Protection, Input Undervoltage Protection, Input Surge Protection, Battery Temperature Protection, Battery overcharge and over discharge Protection, Output Short circuit Protection, Electrostatic Protection, Electro Magnetic field Protection, Chip Thermal Shutdown Protection, Reset Protection.

Figure3:5000 Amah Power Bank

3.1.3 MG 90 servo motors
Specification:

- Weight: 13.4g
- Dimension: 22.8×12.2×28.5mm
- Stall torque: 1.8kg/cm (4.8V); 2.2kg/cm (6.6V)
- Operating speed: 0.10sec/60degree (4.8V); 0.08sec/60degree (6.0V)
- Operating voltage: 4.8V
- Temperature range: 0℃_ 55℃
- Dead band width: 1us
- Power Supply: Through External Adapter
- servo wire length: 25 cm
- Servo Plug: JR (Fits JR and Futaba)
- servo arms &screws included
- It's universal "S" type connector that fits most receivers, including Futaba, JR, Hitech, GWS, Cirrus, Blue Bird, Blue Arrow, Corona, Berg, Spektrum

Figure 4: Mg90 Servo Motor

3.1.4 Booster module 5volts
The 5V Fixed Output Boost Module is a DIY mobile power supply. It only needs one battery, using which can output 5V voltage for your phone, MP3, MP4, and a PSP charger. In order to power your electronic devices when your device needs a 5V power supply, when you only have a lithium battery, this module can directly supply the voltage to 5V.

Figure5: Booster Module 5volts

3.1.5 Jumper Wires

A jumper wire is an electrical wire, or group of them in a cable, with a connector or pin at each end (or sometimes without them – simply "tinned"), which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering. Stranded 22AWG jump wires with solid tips. Individual jump wires are fitted by inserting their "end connectors" into the slots provided in a breadboard, the header connector of a circuit board, or a piece of test equipment.

Figure 6: Jumper Wires

DESIGN MODELS

4.1 Items to Print on a 3D Printer

- **Base**
- Drive Gear - 3no’s
- 90 Deg Link - 3no’s
- Motor bracket - 6no’s
- Link Pin - 3no’s
- Stack Pin
- Stage Pin - 3no’s
- Top Stage
- Washer - 6no’s

4.1.1 Base

- Where the all components were placed.
- The servo motors were fixed on this base.
- The pin stage is supported by this base.

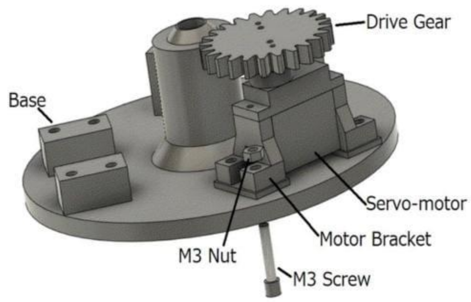

Figure 7: Base

4.1.2 Drive Gear

- The gear that transmits the rotational motion of a motor or other device through the drive shaft is called the driving gear.
- The gear transmitting force is referred to as a drive gear, and the receiving gear called the driven gear.

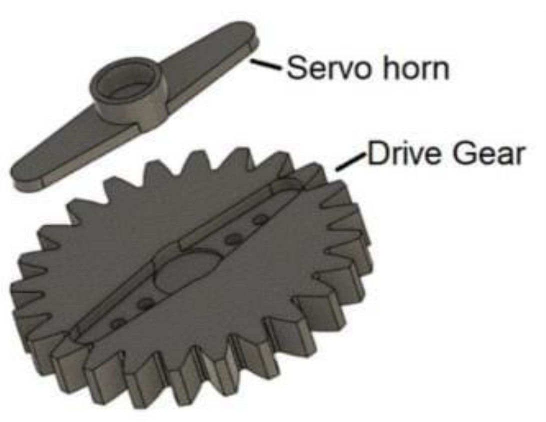

Figure 8: Drive Gear

4.1.3 90 Deg Link

- 90 Deg Links are screwed to Gear stack assembly these are attached by screws M2.
- The links are end connected to Top stage.
- Every link having 90 deg angle to the respective axis

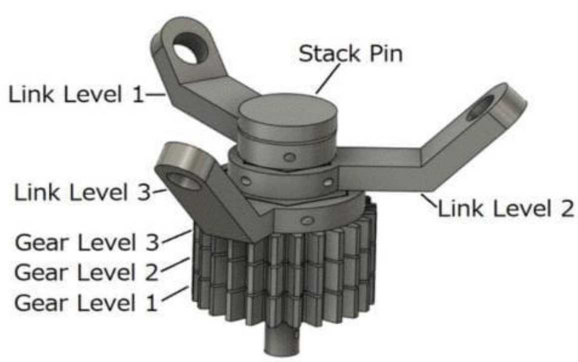

Figure 9:90 Deg link

4.1.4 Motor bracket

It is a structural or decorative member. This motor mounting bracket provides easy and secure mounting for motors.

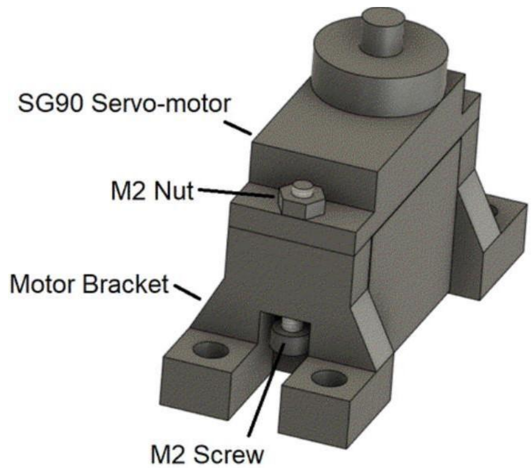

Figure 10: Motor Bracket

4.1.5 Link Pin

This is used to attaching the two revolute joints, avoiding from detaching.

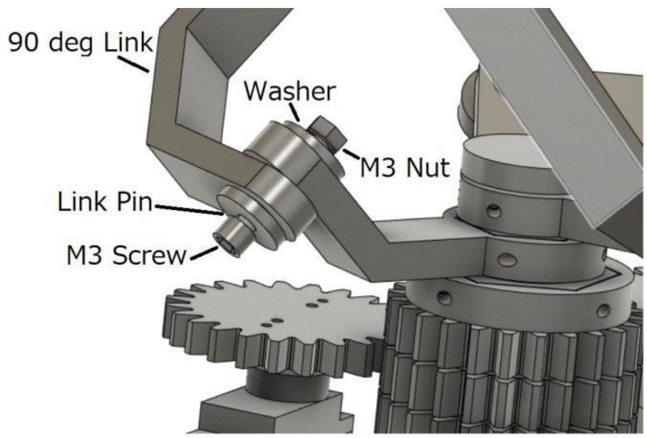

Figure 11: Link Pin

4.1.6 Stage Pin

- Pin stage is attached to base.
- Pin stage carries the all-level gears in it.

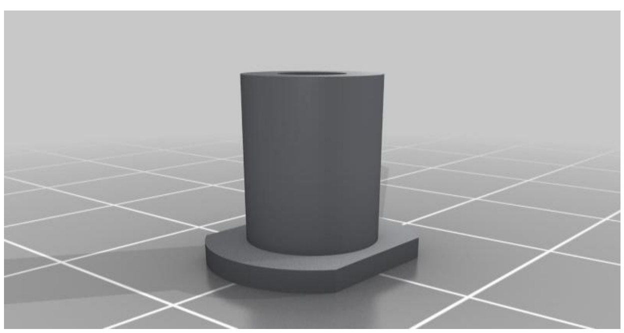

Figure 12: Stage Pin

4.1.7 Top Stage

- Top stage is upper portion of the body were place things.
- The 3 links (90 deg links) where attached by M2 screws

- Top stage is upper portion of the body were place things.

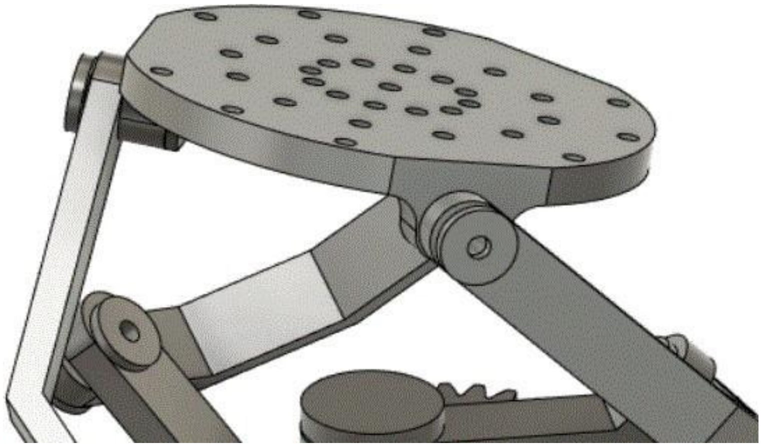

Figure 13: Top Stage

4.1.8 Washer

- Washers are used to grip purpose.
- All revolute joints have washer to get goof tightness of the joints

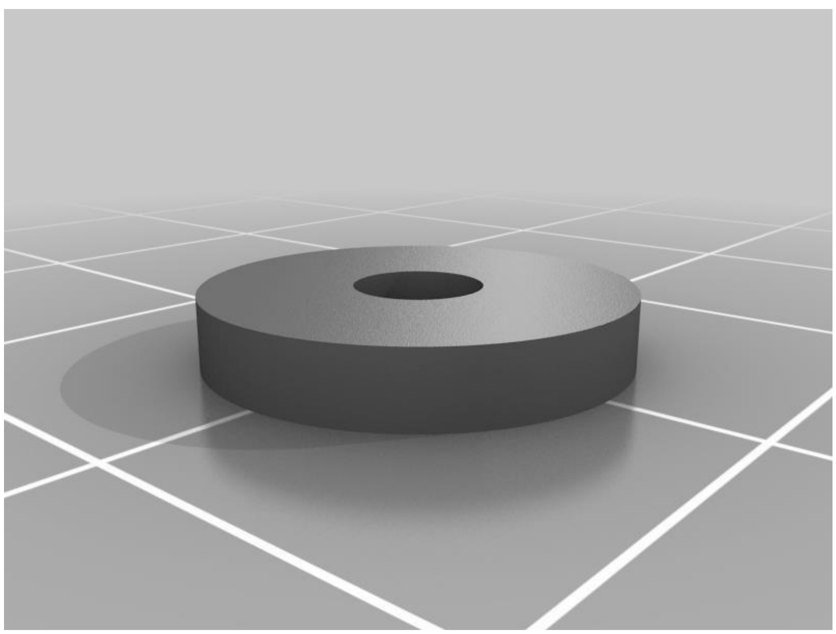

Figure 14: Washer

Fabrication

3d Printing Method

3D printing or additive manufacturing is the construction of a three-dimensional object from a CAD model or a digital 3D model. It can be done in a variety of processes in which material is deposited, joined or solidified under computer control, with material being added together (such as plastics, liquids or powder grains being fused), typically layer by layer. It is a Modern Additive manufacturing process that has many advantages as compared to other manufacturing processes

- As we already designed the 3D model of parts to be generated, the next step is generating the STL (STANDARD TRIANGULAR LANGUAGE) Files
- The STL Files are then sliced

- The real part building starts with transfer of slice format data to 3D printing machine by system computer. The 3D printing machine consists of powder feed bed by which powder is fed.
- A multi jet print head deposits (prints) a liquid adhesive to the targeted regions of part build bed corresponding to slice data, to a depth equal to one layer thickness.
- For multi colored parts, different jets deposits different color binder for different combination of colors
- These regions of powder are bounded together by the adhesive, at locations where it is printed to form one layer of the part
- After forming one layer, the part build platform is lowered and the powder is deposited for the next layer
- The process is repeated until the complete part is built layer by layer
- Then the parts are subjected to finishing process for better Accuracy
- All the parts are built in the same manner
- The parts are then assembled.

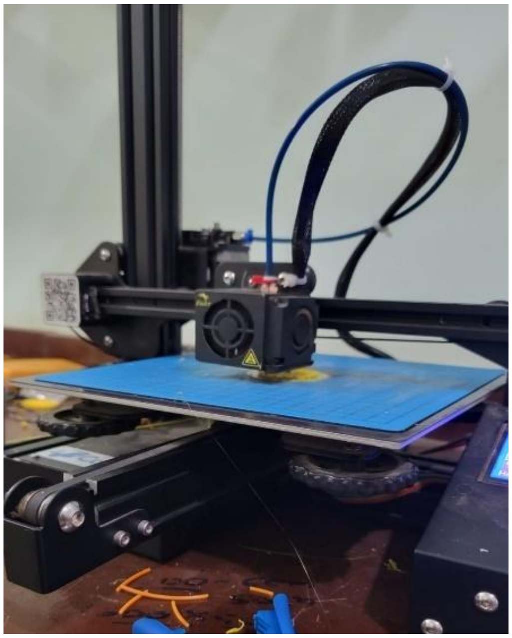

Figure 15:3d Printing

Filament-based 3DPrinting

Standard home printers usually work with plastic filament. The technology behind this is usually known as a Fused Filament Fabrication FFF. Instead, this new form of 3Dprinting shall cover is a new technology called Fused Deposition Modeling (FDM)In an FDM printer, a long plastic filament is fed by a spool to a nozzle where the material is liquefied and sketched on the platform, where it immediately cools and hardens again. The nozzle moves to place the item in the right location to build your model or item up layer by layer by layer. When a layer is drawn, the platform lowers by one layer so the nozzle can start to draw the next layer. Unlike most standard home printers, the FDM printing machine actually uses another Filament that is used for building support material. Because the material used to build Unlike most standard home printers, the FDM printing machine actually uses another filament that is used for building support material. Because the material used to build the model cannot fully support its own structure at this time, the support material prevents it from falling down. After the printing process has finished, the model is then put in to a bath with special chemicals and soap. The support material because of its make-up and reaction to the chemicals inside the bath dissolves automatically. Due to this process designs can be really intricate, complex and contain interlocking, interlinking, and movable parts. An example of the kind of item you can make using this technology is the fully functional, continuously adjustable spanner all printed in one piece. The printing material these type of printer’s use is called ABS. ABS is very useful for functional applications because it has an 80%match of the properties of real injected production material. However, the surface of the models produced by this form of printing is rougher compared with other materials.

Figure 16: Filament Based 3d Printing

Powder-Based 3D Printing
The type of printers that I will concentrate on is not based on filament but on powder. Laser Sintering is used to create 3D prints in Polyamide, Titanium, Alumite and Rubber The inside of the printer is heated up slightly below the melting point of the powder. The printer then spreads out an incredibly thin fine layer of this powder. A laser then heats up the areas that need to be sintered together just above melting point. This process then reveals the parts that were touched by the laser arenow fused together while the rest continues to remain loose powder. The models are printed layer by layer with the assistance of this laser beam. After a layer is printed, a new layer of powder is spread overthe surface. After the printing is finished, the result is a large block of powder that contains the printed/sintered models inside the block. In order to get the prints out of the large powder block, the block has to be mechanically slammed against the box of un-sintered powder and the excess brushed away. Other materials such as Stainless Steel and High Detail Stainless Steel also use powder, but are not laser sintered. Instead, a binder is used to glue parts together. This technology is referred to as Powder-& Binder-based 3DPrinting.

Ardunio Process
In this project we are going to control Processing sketches with the Arduino via serial communication. Processing is free, open-source software based on Java. It was designed for the visual arts community for creating drawings, animations, and interactive programs. Download the latest version of Processing from Processing.org. Select the right file according to your operating system. Processing is available for Linux, Mac OS X, and Windows. Extract all the files and click the Processing icon inside the folder to open it. The Processing IDE interface is very simple In the bottom of the IDE there is a message area that, when you compile your program, gives you information about errors if any. Upload the different examples found below and play around with them.

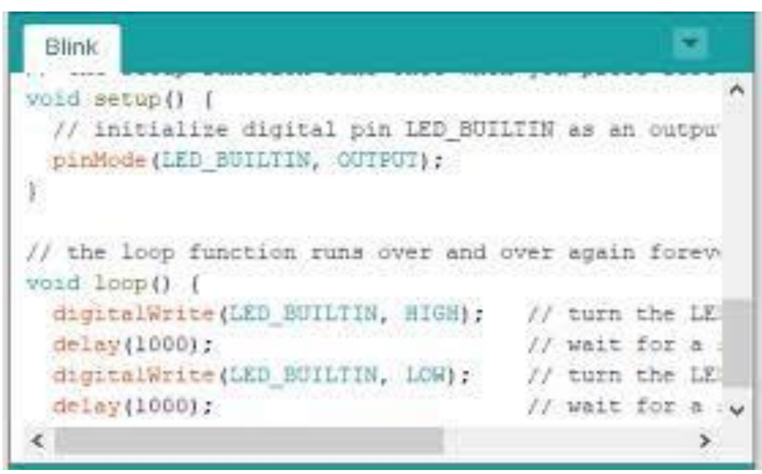

Figure17: Arduino Programmed

Esp 8266 Wi-Fi Module Programming
The ESP32 WIFI module has 32 pins and unique programming for turning on servomotors. After connecting the ESP module to the Arduino with a data wire and uploading the program by restoring the credentials of the Wi-Fi ESP module, we reprogrammed the module to connect to the internet utilizing the libraries of the Arduino board, and it has a range of up to 800 meters. According to the servomotors adjust the angle to 90 deg to minimize the error.

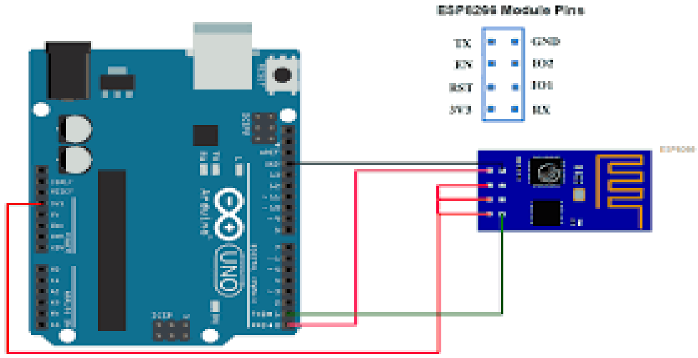

Figure 18: Esp Wi-Fi Module Pinout

Blynk 2.0 Cloud

Blynk 2.0 is an IOT application that can be used anywhere thanks to cloud computing. This application, which includes data streams, Meta data, and automations as well as the addition of three servo motors as a data type of degrees, is being used in this project to run a manipulator. In this application, the minimum value is 0 degrees and the maximum value is 90 degrees. Additionally, there are three degrees of freedom for adding and customizing all the data; the next step is to calibrate the ESP Wi-Fi module. To activate servo motors, different toggles can be added.

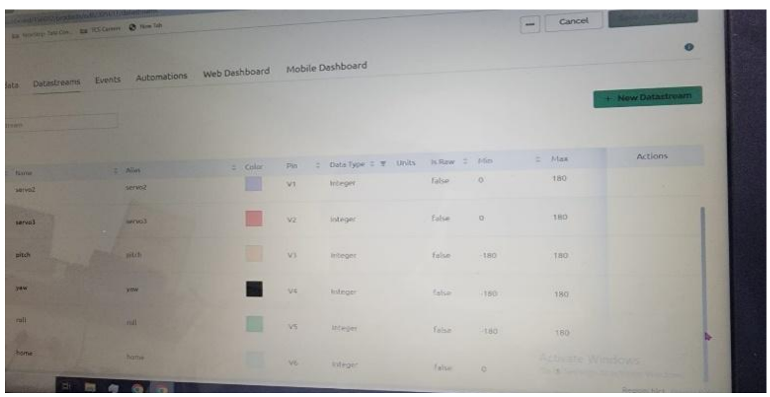

Figure 19: Blynk 2.0 Interface

Figure 20: 3d Printed Parts Assembled

CONCLUSION

This project proposes a simple structure and working prototype of a spherical parallel manipulator it can be extended to microelectronics manufacturing, laser engineering, and other fields. By considering the literature reviews we found that the efficiency of the spherical parallel manipulator is more than other parallel and serial manipulators taking sample design parameters and developing a 3d model prototype and assembling.

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