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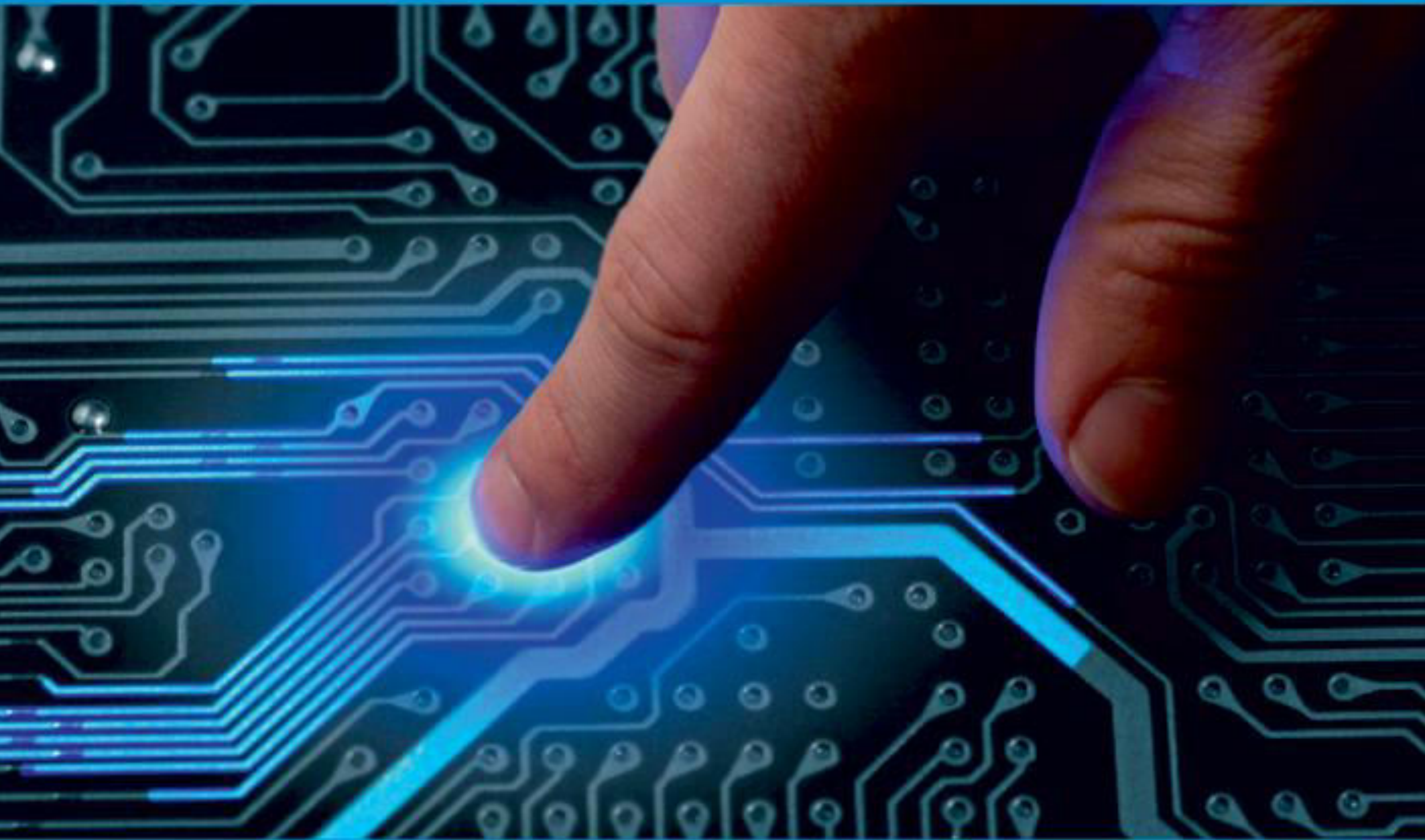

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Virtual Robot Simulator

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ABSTRACT: Delta robot is a kind of parallel robot that is increasingly being used in the industry. The robot has quick and fluid control over how it approaches different applications. Moving into different positions is therefore easy. They are capable of working quickly; some can pick up to 300 items per minute.

Since it is frequently used in industries, the student must be given the right information about the robot in order to learn about it. The curriculum in schools, however, does not promote genuine development. Typically, when teaching robotics in a classroom, only the fundamentals are presented. This project created a virtual simulation of a delta robot to help people comprehend and perceive delta type robotics.

This project's major goal is to assist users and students in visualizing delta robot operation and comprehending the kinematics of delta type robots. Simple computations for delta's forward and inverse kinematics.
Additionally, this project's goal is to avoid any mistakes that might be made in the design of a delta robot.

KEYWORDS: simulation, virtual lab, kinematics and dynamics, 3D object, delta parallel robot

I. INTRODUCTION

1.1 Overview

Over the past 20 years, theoretical and practical advancement in the field of parallel manipulators has accelerated significantly. The fundamental causes are that these systems are more powerful, quick, and accurate.A delta robot is a parallel robot variety comprising three arms joined at the base through universal joints. The essential design feature involves incorporating parallelograms in the arms to maintain the alignment of the end effector. Delta robots are commonly used in industries for picking, placing and packaging tasks because they can work quickly—some may complete up to 300 picks per minute. Delta robot is a kind of parallel joints based robot which is increasingly being used in the industry. The robot can control its approach to various applications quickly and smoothly. As a result, moving into various positions is simple. It may travel in different directions and is appropriate for moving workpieces. Up to 500 grams can be used as the payload. It is applicable to the current state of the food manufacturing industry. Consequently, the aim of this research is to demonstrate the process of developing a fully operational rotating delta robot. To accomplish this, it is necessary to construct a simulation model for the delta robot by establishing a comprehensive kinematic model specific to the delta robot type

It includes :

- Fixed Frame (Base)
- Proximal Link (Active Link)
- Distal Link(Passive Link)
- Joints
- Moving Platform (End Effector)

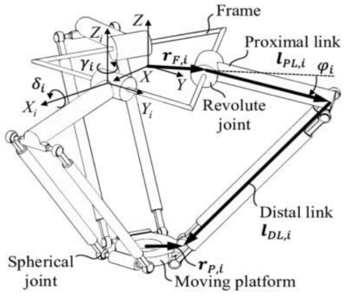

fig: Delta Robot schematic diagram

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Over the past few decades, several researchers have concluded the motion control of Delta robots. Castan et al. developed an adaptive controller that enables reference in tracking for a Delta robot even in the presence of uncertainty.

Due to the limited availability of joint velocity measurements for the Delta robot, the adaptive controller incorporates an observer. Ramírez-Neria and colleagues explored a robust trajectory tracking technique that utilizes linear feedback control and effectively handles disturbances through a linear disturbance observer. In a separate study, "Guglielmetti and Longchamp" developed a Delta robot model that the joint angle and end-effector coordinates serve as the state variables.

1.2 Objective

A recently popular topic is designing delta robots. However, school curriculum does not foster actual development. Typically, basic theory is all that is covered when teaching robotics in a classroom. In order to better understand and visualize delta type robotics, this research produced a virtual simulation of a delta robot.

The main objective of this project is to help users and students, to visualize the working of delta robots, and understand the kinematics of delta type robots. Handy calculations for forward and inverse kinematics of delta. The objective of this project is also to prevent the failures that may occur while designing a Delta Robot.

1.3 Problem Statement

A hot topic in industry and innovation is the Delta Robot. It operates quickly and has a very small structure. Due to their rapid speed and excellent precision, Delta robots are now used by numerous food industries. This is just one of the reasons behind the project. Although it's a hot topic, one robotics enthusiast finds it challenging to comprehend and picture how the Delta robot functions. These are a few of the issues:

- Lack of proper visualization of delta robot structure.
- No specific tool for delta's workspace and movement visualization
- No handy calculation of delta's forward and inverse kinematics
- Lack of easy tool for academic experiments and learning
- Lack of knowledge on functionality of Delta Robot
- Growing significance of Delta Robot

Some of the main issues that discourage robotics enthusiasts from learning more about Delta Robot include those just mentioned. In this project, we develop a straightforward website (virtual delta robot lab) that offers details about the Delta robot's operation, among other things. Additionally, it includes a simulation that aids the deep and precise visualization and understanding of robotics enthusiasts. Additionally, they can view the necessary parts together with their proportions, which will be useful when they are making their own models. Additionally, the website offers transformation matrices as well as forward and inverse kinematics. As a result, the website gives accurate information about Delta robots, enabling many robotics students to learn more effectively and without confusion.

II. Literature Review

The development of a free body diagram was the first step in the concept design of the Delta robot, which was followed by the measurement of forward and inverse kinematics. The delta robot's designing mechanism has now been put into practise. Even if the design processes of all linked activities are the same, the end products vary. Particularly, the fundamentals of mechanical design are the same, but for purposes like food production, small workpieces, and cycle duration, the length of the arms and some mechanism specifics change. As a result, numerous studies have concentrated on improving the Delta robot. Improvements have been made to controller and programming in addition to speed and accuracy.

2.1. Existing system

Method 1: Experimental and simulation studies of motion control of a Delta robot using a model-based approach.

In this article, a direct and uncomplicated model-based control strategy is presented for a Delta robot equipped with three degrees of freedom for translation and three rotational motors. The position-based control system, commonly employed in robot positioning tasks, is adopted for this approach. By employing this control technique, the robot's control problem is segmented into individual motor control problems. However, a significant limitation of this control

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system is its failure to account for the robot's dynamics within the control loop, which may result in restricted accuracy in positioning.

Among the model-based control techniques explored in the literature, computed torque control stands out. This method calculates the torques to be applied by considering the inverse dynamics of the robot and taking into account errors in joint angles and angular velocities. The proposed model-based control approach leverages these calculated torques to identify deviations between the applied torques and the desired torques, which are subsequently used to implement feedback control. It is worth noting that this technique, known as indirect torque control, offers the advantage of eliminating the requirement for torque and current sensors, resulting in a notably streamlined configuration.

The article carries out a thorough comparison between the simulation and experimental results derived from both the model-based control system and the position-based control method. The analysis results that the model-based control system demonstrates enhanced precision in positioning distinguished from the position-based control method.

Method 2: Development of Pick and Place Delta Robot

This project demonstrated how the delta robot was created, and it can be used as the basis for future projects that teach about delta robot basics.Numerous robot applications, including packing, pick, and place, are used in industrial automation. Humans are capable of performing jobs that demand good location and accuracy, but doing so takes expertise and experience. The primary objectives are to minimize errors in the manufacturing process and enhance the performance of yield rates. To address these challenges and reduce working hours, robots have emerged as a replacement for humans in high-speed pick-and-place operations, offering new opportunities for educational purposes. Consequently, the study of the Delta robot is an intriguing field due to its distinctive design, calculation workspace, and operational mechanism. Consequently, researchers aim to develop experimental platforms for robots with complex designs, enabling them to operate more efficiently within automated production lines. Students can gain hands-on experience by examining and testing the Delta robot using a prototype training set. By creating mechanisms and controllers, project-based learning utilizing the Delta Robot can be integrated into coursework. During learning exercises, students can explore the forward/inverse kinematic models and conduct experiments with real-world tasks, allowing them to observe the outcomes of altering the model's parameters. This collection of literature provides valuable insights for researchers and students interested in the field of robotics.
This project can be used to improve student understanding of the mathematics behind robot models. Additionally, it can be applied to or modified for usage with different robot types. It can also research how to create a robot product for an industrial use. The robot prototype still exhibits significant erroneous results, though. It is not suitable for industrial uses that call for errors of less than 0.1 mm. To increase the efficiency, the robot's accuracy and efficiency must be increased.

Method 3: The Design and Simulation of Training Delta Robot

Due to their higher rigidity and higher positioning precision as compared to serial robots, parallel kinematic structures are intriguing. Although there are various applications for this type of mechanism, robots and numerically controlled machine tools account for the majority of them. The delta robot design has generated a lot of interest in academia as well as in industry. This study provides information on the mechanical subsystem development, kinematic analysis, and modeling of the Caertec rk 2010 training Delta robot at the University of Zilina. Three parallelogram mechanisms form the foundation of the robot's parallel kinematics. Inverse kinematics was used to count the kinematic loops in the Delta robot. Software was created for delta robot control and trajectory programming that enables simulation, workspace analysis, position programming, and communication management.

Method 4: Delta Robots pick and place coloured objects

This section aims to compile several related studies on Delta Robots that make use of pick-and-place and item detection techniques. The results of these studies can be compared to those from the current project or even used as a foundation for the methodology.The initial development of the "Design and Implementation of a New DELTA Parallel Robot in Competitions" project took place in 2015.. A 3D printer was used to produce some of the parts for this project. The primary goal of this research was to create a low-cost delta robot that could pick and arrange objects using image recognition.
There were also 3 case scenarios that the robot needed to be able to handle. In the beginning, several domino pieces had to be picked up and placed. Second, the robot must meet certain requirements for writing and drawing. The third scenario, which involves choosing and placing an object based on its color.

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III. PROPOSED SYSTEM

Delta robot is a one of the parallel robots which is commonly being used in the industry. The robot has quick and fluid control over how it approaches different applications. Moving into different positions is therefore easy. They are capable of working quickly; some can pick up to 300 items per minute.

Since it is frequently used in industries, the student must be given the right information about the robot in order to learn about it. The website assists in providing the necessary robot information and also enables students to envision the robot and observe its operation in a virtual setting. Additionally, the website offers crucial details like dimensions and parts used to assist those who want to construct their own robot. The website also offers the crucial details that aid in a deeper comprehension of the Delta robot, such as joint angles, transformation matrices, end-effector position, etc.The main objective of this project is to help users and students, to visualize the working of delta robots, and understand the kinematics of delta type robots. Handy calculations for forward and inverse kinematics of delta. The objective of this project is also to prevent the failures that may occur while designing a Delta Robot.

Fig: Web view of Delta robot simulator

IV. METHODOLOGY AND WORKING

The Delta robot's dimensions are first calculated. In order for the dimension to do the designated task, it must be calculated correctly. After determining the robot's dimensions, we must determine its forward and inverse kinematics. These kinematics make it possible to precisely move the robot to the specified location. After that, we design every part needed to assemble the robot. The Delta Robot's 3D design is completed by assembling all the parts together after they have been designed, including all the screws needed to join all the components together

Once the 3D model is complete, it is exported in a suitable format so that it can be used in web pages. After that, we create the website and insert the 3D model into it. After that, we create a calculator that computes robot data such as joint angles, kinematics, transformation matrices, etc

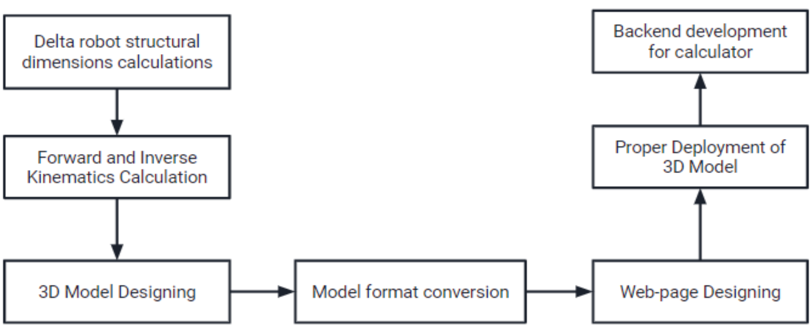

fig : block diagram of project methodology

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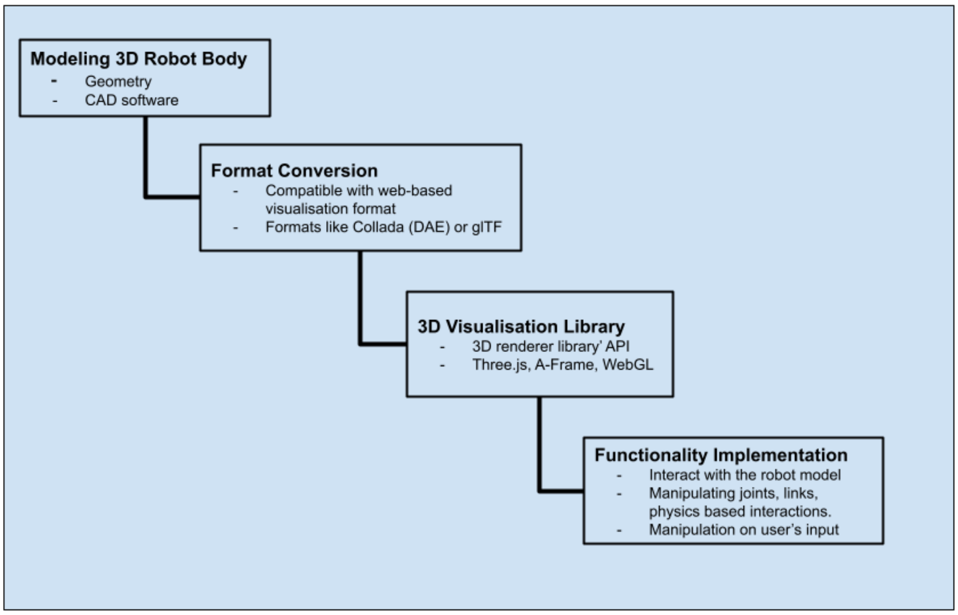
In order to provide a 3D drawing environment for web-based graphics visualization, WebGL employs OpenGL as a shading language. WebGL is an application programming interface (API) for 3D graphics that functions seamlessly across multiple platforms. It enables programmers to utilize their computer's 3D rendering hardware from within a web browser by using conventional JavaScript and Hypertext Markup Language (HTML).The non-profit Khronos Group oversees the WebGL standard, which debuted its specification 1.0 on March 3, 2011. The selection of 3D visualization libraries such as Three.js, A-Frame, or Babylon,js that provides the necessary APIs for rendering and interacting with 3D models in the browser. After proper selection of the library, the conversion of the robot 3D model being rendered in CAD software into a compatible format like OBJ, FBX, or glTF. After that, the HTML structure to define a container element, where the 3D model will be displayed is set up.



To enable specific joint or link movement of a robot model on a webpage based on user input, we need to implement additional logic to handle the manipulation of joints and links. We can add the updateRobotKinematics function, which retrieves the rotation values of specific joints/links (e.g., joint1 and joint2) and updates the robot's kinematics accordingly. This function can perform calculations or operations based on the joint angles, such as calculating the end effector position or orientation. We need to implement the calculateEndEffectorPosition and calculateEndEffectorOrientation functions according to our specific robot's kinematics.

Several high-level JavaScript programming libraries have been released to simplify the modeling and development process with WebGL. Among the well-known WebGL libraries are Three.js, GLGE, SceneJS, and PhiloGL. These libraries are designed to make it simpler to create intricate 3D computer animations that run entirely within a web browser. We mostly used Three.js as an authoring library to create the suggested virtual lab in this study. The Three.JS is a single JavaScript file that may be added to a webpage by making the following link to a local or remote copy:

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```
import * as THREE from 'three';
import { GLTFLoader } from 'three/examples/jsm/loaders/GLTFLoader';

// Get the container element
const container = document.getElementById('model-container');

// Create a scene
const scene = new THREE.Scene();

// Create a camera
const camera = new THREE.PerspectiveCamera(75, container.clientWidth / container.clientHeight, 0.1, 1000);
camera.position.z = 5;

// Create a renderer
const renderer = new THREE.WebGLRenderer();
renderer.setSize(container.clientWidth, container.clientHeight);
container.appendChild(renderer.domElement);

// Load and display the 3D model
const loader = new GLTFLoader();
loader.load('path/to/robot-model.glb', function (gltf) {
  scene.add(gltf.scene);
});

// Render the scene
function animate() {
  requestAnimationFrame(animate);
  renderer.render(scene, camera);
}
animate();
```

V. HARDWARE AND SOFTWARE USED

In this project we did not build any physical model of the Robot. But to build this Robot we need a microcontroller, servo motors and other components :

- We suggest using aluminum or carbon fiber tubes for Links because they are light, rigid, and won't generate a lot of torque load or oscillate when stopped and started.
- We suggest using either servo or stepper motors with speed control that have strong torque and resolution. Due to their low resolution and inability to perform speed control, pre-designed closed loop PID conventional servo motors are not advised.

The end effector's components might vary depending on the application. Here are some examples:

- Pneumatic suction for picking and placing applications with light objects.
- For magnetic objects like metal boxes, tools, or nuts, use an electromagnet.
- Additional 3 degrees of freedom on the drill mechanism for CNC applications.
- Plastic Heater nozzle for 3D printers..

For Software we used Fusion 360 where the robot's 3D model is made. Fusion 360 is a 3D modeling programme that may be used for many different things, including manufacturing, engineering, and product design. Fusion 360 has so many uses. It can be applied to both individual and business endeavors. All the parts are put together to make a complete 3D model of the Delta Robot after being designed for the robot (including the biceps, forearm, links, joints, screws, etc.).

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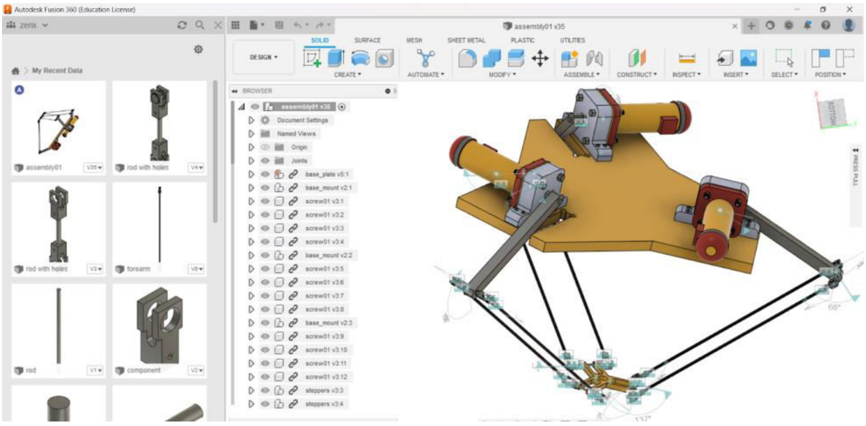

Fig: Delta Robot assembly in Fusion 360

The finished 3D design is exported in the appropriate format (.stl, .obj, or .step) so that it may be used in websites utilizing APIs like openGL, webGL, and three.js .

- OpenGL is a versatile application programming interface (API) that supports the rendering of 2D and 3D vector graphics across different programming languages and platforms.
- WebGL, also known as Web Graphics Library, has emerged as the current standard for delivering 3D graphics on the web. It has been specifically designed to facilitate the rendering of both 2D graphics and interactive 3D graphics.
- Three.js is a JavaScript library that is open source and widely utilized for rendering and presenting graphics, including 3D and 2D objects, within web browsers.

VI. ADVANTAGES OF PROPOSED SYSTEM:

Parallel kinematic structures are interesting because, compared to serial robots, they are more stiff and have higher positional accuracy. Although this kind of mechanism has several uses, robots and numerically controlled machine tools are the most common ones. Both academia and business are quite interested in the delta robot concept. This project aids in understanding the parts of the delta robot, how it functions, and its various uses.
Some of the advantages are listed below:

- Building a physical robotics lab can be expensive, requiring significant investments in equipment, tools, and maintenance.It allows students and researchers to gain hands-on experience without the need for expensive hardware.
- It provides the visualization of the Delta robot.
- It helps in visualization of Delta workspace and movement.
- It helps in the calculation of forward and inverse kinematics.
- It can be used by students to conduct various experiments on the robot and its movements.
- It provides the capability to modify robot parameters, test different control algorithms, simulate various environmental conditions, and analyze the results.
- It helps to provide the knowledge on the functionality of the Delta robot.
- It allows users to share simulation setups, experiments, and results with others, fostering knowledge exchange and teamwork. Collaborative features enable users to work together on complex projects, share insights, and collectively solve problems.

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VII. CONCLUSION AND FUTURE WORK

Due to their higher rigidity and higher positioning precision as compared to serial robots, parallel kinematic structures are intriguing. Although there are various applications for this type of mechanism, robots and numerically controlled machine tools account for the majority of them. The delta robot design has generated a lot of interest in academia as well as in industry.

A simple website was built with the necessary information to study about the delta robot. the website consists of introduction to the delta robot,its application , objective, components , etc. it also shows the 3d model of the robot,

The robot's physical realization is what will need to be done in the future. The job will involve integrating the mechanical and electrical systems and creating an intuitive user interface for the end user once extensive material procurement is completed in order to materialize the robot in its physical form. The electrical components must be carefully picked and acquired, whereas the mechanical components are likely to be manufactured by the industry. Except for a few components, such as carbon fiber tubes for the arms, which will be purchased from other manufacturers, the majority of the mechanical parts will be manufactured within the industry itself. Servo motors, drives, and the control system needed to run them precisely and in sync are all included in the robot's electrical system.

The robot system needs to be tested in real-world settings when system integration is finished, and the system needs to be tweaked accordingly. A proper and user-friendly interface must be offered to the end user in addition to a functioning system. The user's hand holds a teach pendant or a small HMI that provides real-time information about the robot as the interface, or sometimes both.

Throughout the development process, We need to consider factors such as performance optimization, user experience, and the specific requirements of the proposed system.Performance Optimization: As the simulator involves rendering 3D graphics and potentially handling complex calculations, optimizing the performance is essential. This includes optimizing rendering techniques, utilizing efficient algorithms, and minimizing unnecessary computations to ensure smooth and responsive interactions. Monitoring and optimizing the simulator's performance will enhance the user experience and prevent any lag or delays. User Experience: The user experience plays a vital role in the simulator's usability and effectiveness. It is essential to design an intuitive and user-friendly interface that allows users to easily interact with the virtual robot. Clear instructions, tooltips, and visual cues can guide users on how to manipulate the robot's joints or perform specific actions. Paying attention to usability, aesthetics, and overall user satisfaction will enhance the overall experience.

Specific Requirements: Consider the specific requirements of the proposed system. This includes identifying the objectives and goals of the simulator and aligning the development process to meet those requirements. Understanding the intended use of the simulator, such as educational purposes, research, or training, will guide the design decisions and functionalities to be implemented. Adapting the simulator to address the specific needs of the target audience will increase its value and relevance. Testing and Iteration: Testing the simulator thoroughly is crucial to ensure that it meets the objectives and provides an engaging and accurate virtual representation of the robot.

Performing different tests, including functional testing, usability testing, and performance testing, assists in identifying and resolving any issues, bugs, or areas that require improvement. Gathering feedback from users or stakeholders and incorporating it into iterative development cycles will result in a more refined and robust simulator.

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