Project Description: Remote Eye

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Introduction

The problem definition included designing a remote orientation camera using parallel robotics. Remote Eye has found wide applications in security surveillances, improved photography, satellites surveyors etc. This project also focused around global design solutions and intercultural teamwork. The project was completed in Shanghai Jiao Tong University as a partnership project with Purdue University, USA. Students from both universities came together to come up with solutions and design structures to obtain the final product.

Functional description of the mechanism

For this remote eye project, the given design constraints were:

- Must have 3 degrees of freedom: Translation along one axis and rotation along the other 2 axis
- Must include a Revolute-Prismatic-Spherical system of joints for the resulting range of motion
- Must be cable driven for remote operation
- Must include a passive constrained frame
- Must be ease to fabricate and manufacture

Clear statement of the novel features of the mechanism

The mechanism is different from other passive mechanisms because it is a hybrid configuration that uses 3RPS (Revolute-Prismatic-Spherical) concept as the passive constraint frame and is actively actuated using the 3-cable motor driven system. The final product can then be implied in disaster activities and industrial equipment detection. Taking the demand of flexibility and miniaturization into consideration, we choose cable driven robot as our main choice for driving type. The 3 cables constitutes a 3SPS mechanism which allows for 7 degrees of freedom. These are constrained using the passive frame 3RPS to get the resultant range of motion as translation in one axis and rotation along the other two axis. The three cables allow for remote operation, which is one of the functional requirements.

Procedures used to design the mechanism

The procedure of design can be broadly classified in two: Type Design and Dimensional Design. Type design included the decision making process. The team brainstormed ideas and final concept selected was passive constraint and active actuation. Dimensional design included a lot of optimization techniques using simulation to achieve efficient results.

To start off, the project goal was loosely defined to replace a Pan-Tilt-Zoom camera head with a 3RPS structure. For remote access, cables were decided as the main driving system. The team built a 3D model for kinematic and dynamic analysis. The
modeled mechanism showed some shortcomings. For practical applications, a wide range of rotating angle is needed which a spherical joint could not provide. After thorough analysis of degree of freedom of different joints, replacements for the spherical joint were found. It was seen that a combination of roller bearing with cross-pin type joint replaces the spherical joint without changing the degree of motion. Post this analysis; each spherical joint was replaced with a universal cross pin and a revolute roller bearing.

A prototype was then built to realize the optimized range of motion. The combination of cross pin with revolute showed a definite increase in angle of rotation. The prototype had a significant expansion of the working space and the motion was smoother and did not lock at any angle.

The joints used were off the shelf products and the prismatic joint was an air cylinder with air stored under pressure. For our purposes, the team decided to use smaller gas springs since the provided gas springs were too hard for the PTZ model, we decided to let out the gas in the springs and used the wire springs to support it. The big wooden disc that marks the supporting plane is 30cm in diameter, and the small movable wooden disc is 20cm in diameter. These were just the dimensions for the prototype. The final product will be scaled smaller than the prototype.

Functional relationships between angular displacement curves, force on cables, resultant motion of passive frame were then calculated using different forms of simulation. This process was highly qualitative due to the limited resources available and complex mathematical relations between the different physical parameters. Large scale of data was analyzed on the functional relationship between the input forces on the cables to the motion of the platform.

To find the relationship between the angle and the length of every spring, the stroke of spring was divided into 7 segments, and marked 0 to 7. As the mechanism is symmetrical about the translational axis, we only tested the PTZ model 288 times (8x8+7x8+6x8+5x8+4x8+3x8+2x8+1x8).

Controls were then added to the prototype using an MCU to control the motor. The broad algorithm to work the controls is:
1. Through joystick, the controller can send angular displacement information to computer.
2. Labview is used to manipulate data and identify the length of each spring, which is sent to the MCU
3. The MCU then rotates the motor accordingly to perform the required motion.

Error analysis was a major part of the procedure. Errors related to hand fabricating the model, high complexity of mathematical and kinematic relations and limited availability of the required simulation and analysis tools led to a lot of unexpected results from our model. These were reduced by persistent analysis and alternative solutions. The prototype was then matured into a final product that follows the industry standards and can be used in practical applications. Controls were then added to allow for motor actuated remote controlled device.

**Benefits and possible applications of the mechanism**

Remote Eye can be used in a wide variety of applications. The most important application stems out of its cable driven and remote controlled features. It allows for image capture in fairly remote and inaccessible locations, which can drastically help in disaster analysis, industrial and construction sites, oil-mining sites. PTZ cameras have seen wide applications in security surveillance. With the use of cables and remote access, depths of oil mining zone can be surveyed by use of a joystick and computer program.

Additional scope of the remote eye feature is Wi-Fi enability. Being able to watch over the interiors, exterior of your home and watch over pets while on vacation can enhance home security options. The remote eye is a basic mechanism that can find variety of applications for use. Its biggest advantage is the simplicity of the mechanism, which allows flexibility of add-on features.
All appropriate figures, tables, photographs, etc, incorporated into the document

Figure 1: Simulation and analysis in ADAMS.

Figure 2,3: Graphs of the Angle Variation Range of the upper table
Figure 4: Modeling the prototype

Figure 5: Labview Front Panel

The picture above is Front Panel of the program. There are five inputs (r, R, a, b, h) and 3 outputs (L1, L2, L3). With the program and the given inputs, three outputs will be determined. Then, these three data will be immediately transformed into MCU address.
Figure 6: Calculation process in Lab-view

Figure 7: Co-ordinate sent to MCU using VISA function
Figure 8: Prototype
Figure 9: Rough Calculations

\[ R_a \cdot y = \begin{pmatrix} \cos \alpha & 0 & \sin \alpha & 0 \\ 0 & 1 & 0 & 0 \\ -\sin \alpha & 0 & \cos \alpha & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \]

\[ R_b \cdot x = \begin{pmatrix} 1 & \cos \beta & \sin \beta & 0 \\ 0 & \cos \beta & -\sin \beta & 0 \\ 0 & \sin \beta & \cos \beta & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \]

\[ P = \begin{pmatrix} 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \]

new \( b_i = \) initial \( b_i \) \( P \cdot R_b \cdot R_a \cdot \) initial \( b_i \)

\[ L_i = (P_i - \text{new } b_i)^T (B_i - \text{new } b_i) \]

(I had left the radical sign before)
Figure 10: Concept of the final model