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Robotic Arm Challenge Report

Introduction:

Having limb paralysis, otherwise known as quadriplegia (paralysis of all four limbs) makes it almost impossible for people to perform simple tasks that allow them to live a normal, stress-free life. However, many scientists have devoted their time to researching "robotic arms" and their ability to function automatically (by means of a computer program controlling its movements), giving people with such conditions the ability to complete these tasks. Along with Anny Zhou, and Gwen Kirschke, I have taken part in a project that has given me the opportunity to join the community of researchers who are working towards the development of such robotic arms by using my prior mathematical knowledge to explore the subject. In this project, my partners and I set out to use mathematics (trigonometry in specific), to better understand the usage and development of the robotic arm. As eating independently is one of the most predominant struggles of people with quadriplegia, and one which is of high importance, this project revolves around using mathematics to figure out a way to get the robotic arm to pick things up (in this case, a small plastic apple). There are two major parts to this experiment. While the first is designed to help the team become more comfortable and familiar with the robotic arm, the second part is more mathematically centered and requires the team to use trigonometric concepts to solve the robotic arm challenge of moving the "gripper" of the robotic arm over the apple to pick it up. Our goal then, is to use these concepts to successfully program the gadget (that is, give it instructions having obtained its angles of rotation) to pick up the apple without having to input random values and obtain a more accurate result.

Approach:

For this experiment, the robotic arm is placed on a coordinate grid (each unit measuring exactly 1 inch) with a starting position of (0,0). This arm has 3 total parts (shoulder, elbow, and wrist), and 2 significant lengths (shoulder-elbow, measuring 4.5in., and elbow-wrist, measuring 4in.) which at the start of the experiment are perfectly aligned. A small plastic apple is placed on the coordinates (6, 2.5) which is set to be picked up by the robotic arm. Due to the fact that the arm is approximately 8.5in. in length, the apple cannot be picked up by simply rotating the shoulder. Both the shoulder and the elbow need to be rotated (one in the positive y-direction and the other in the negative y-direction), in order to be able to complete the task. Throughout this project, an online program linked to the robotic arm is used to give it rotational instructions (in +/- degrees) of it's shoulder and elbow based on the input (+/- degrees) manually inserted.

To begin this project, the team used this software to observe the function of the robotic arm, and then attempt to pick up the apple using the trial and error method. After inserting various quantities for both shoulder and elbow rotations, the team came up with 2 combinations which satisfy the positions required to pick up the apple. These combinations consist of a 60° shoulder rotation with a -80° elbow rotation, and a -10° shoulder rotation with a 75° elbow rotation (- sign entails direction). Both combinations yield different positions, but still manage to attain the same goal.

Subsequently, the group set out to find a way to obtain these same angles of rotation using trigonometric concepts. To begin, they generated a list of "givens", or information they already knew which would help them solve for the missing angles. These givens include the following: the position of the apple (6, 2.5), the starting point of the shoulder/arm (0,0), the length from the shoulder to the elbow (4.5in.), and the length from the elbow to the wrist (4in.). Then they made a diagram which included the position of the apple and new position of the arm (using 60°, and 80° for the sake of having positive numbers, allowing for simpler computation). Not knowing the exact angles of rotation (as this is what they are seeking to find), the group estimated the position of the arm on the diagram. After doing so, they established their ultimate goal, or what they were trying to find (the rotation of the shoulder, B+D, and the rotation of the elbow, E), and included their givens on the diagram.

Figure 1:

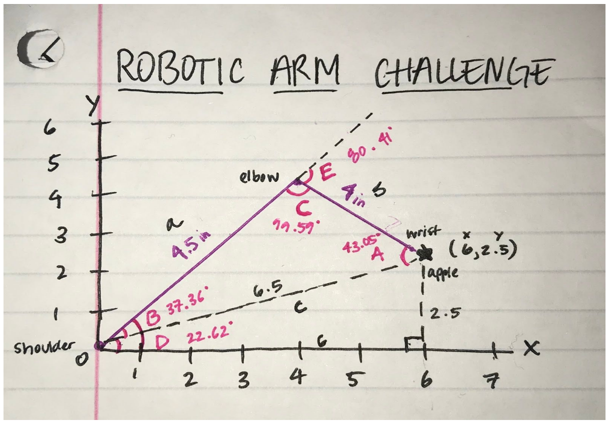
* units = inches
= robotic arm
= angles
→ mathematical concepts used

Givens:

- position of apple $(\overset{x}{6}, \overset{y}{2.5})$
- starting point of shoulder (arm) $(\overset{x}{0}, \overset{y}{0})$
- length of shoulder-elbow (4.5 in) → a
- length of elbow-wrist (4 in) → b

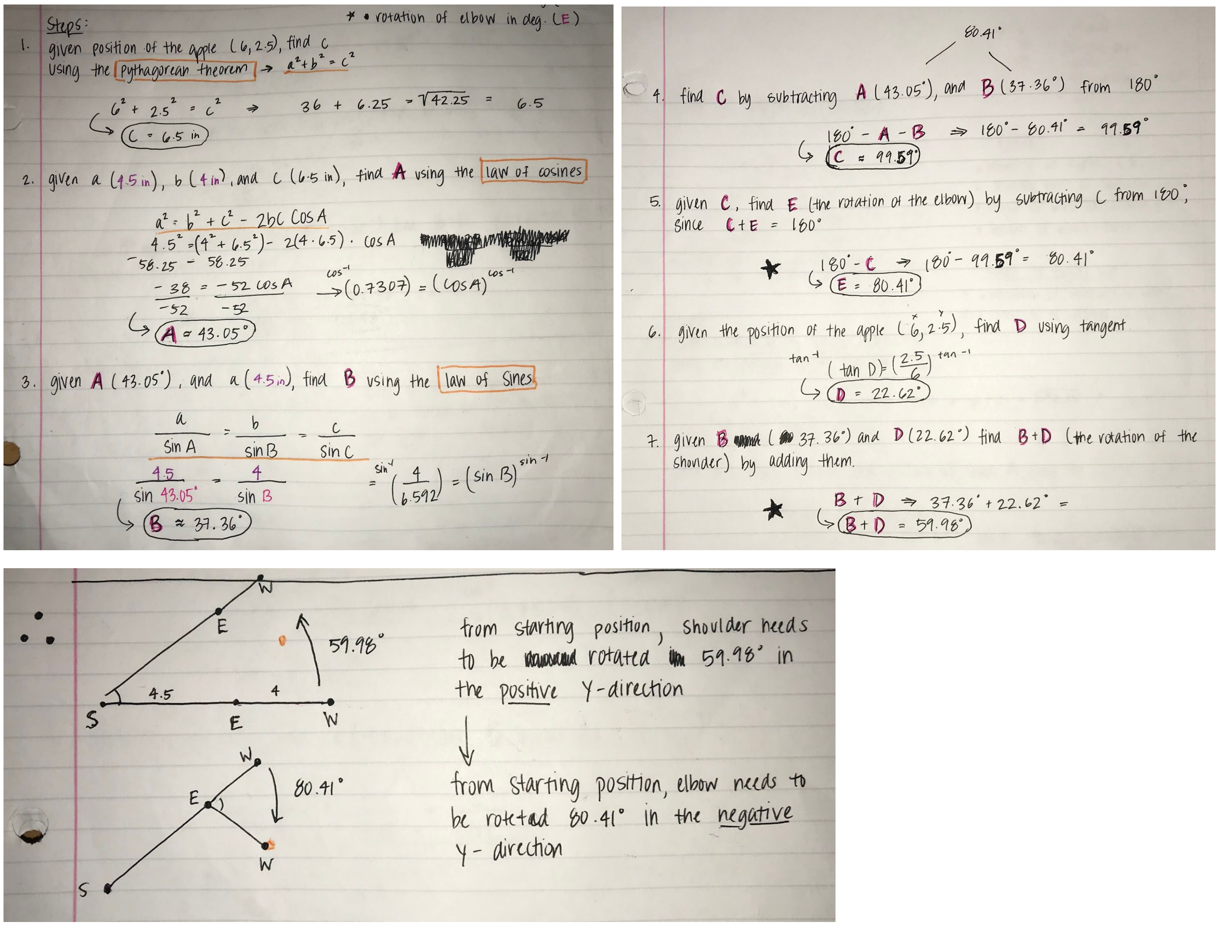
Want to figure out:

* • rotation of shoulder in deg. (B+D)
* • rotation of elbow in deg. (E)



To begin their computation, the group first found the length of the hypotenuse (c) of the right triangle created by the position of the apple (6, 2.5), which also happens to be the last side of the triangle created by the robotic arm (Figure 1). Using the Pythagorean Theorem ($a^2 + b^2 = c^2$), a technique used to find the missing length of a right triangle given 2 of its sides, the group solved for c, 6.5in. Having this length, and the 2 other lengths of the adjacent triangle (robotic arm), the group then went on to find one angle measurement in this triangle using the Law of Cosines ($a^2 = b^2 + c^2 - 2bcCosA$), used to obtain "the third side of a triangle when two sides and their enclosed angle are known, and in computing the angles of a triangle if all three sides are known." With this new angle, A (43.05°), the group was able to find the second angle in this triangle using the Law of Sines (a/SinA = b/SinB = c/SinC)), used to "compute the remaining sides of a triangle when two angles and a side are known, and when two sides and one of the non-enclosed angles are known." Now having angles A (43.05°) and B (37.36°), the group easily solved for the last angle, C, by subtracting A and B from 180°. The group then solved for the wanted angle E (angle of rotation of the elbow - 80.41°), by subtracting angle C from 180°, having the knowledge that a straight edge has that equivalent. To find the last angle, a combination of B and D, which amounts to the angle of rotation of the shoulder, the group used the tangent of D (2.5/6) to solve for D (22.6°) and added it to B (37.36°). This final computation resulted in the last missing piece of desired information, the shoulder's rotational angle (B + D = 59.98°).

Figure 2:



Results & Discussion:

Before the computations were done to obtain the angles of rotation in Figure 2, the group hypothesized that these values would be very close to the ones predicted. As seen in Figure 2, one of the 2 possible positions for the robotic arm include the rotational angles of 59.98° in the positive y-direction for the shoulder and 80.41° in the negative y-direction for the elbow. Noticeably, these angles are almost exact to the estimated angles from the beginning of the experiment. This was expected as the angles obtained from the trial and error method were able to successfully pick up the apple. The fact that the original estimated angles did not allow the arm to pick up the apple exactly in the center however, can be used to prove the accuracy of the mathematical tactic and give validity to the new results. Once the angles derived from the series of trigonometric computations were inserted into the program, the apple was more accurately picked up by the robotic arm. This proves the importance of mathematics in a project as delicate as this which has the potential to improve a person's life. If mathematics were to not be used in this development, the project would lose credibility and accuracy, resulting in devastating problems.

Conclusion:

Based on the information presented throughout the text, the group successfully met the objectives and reached their ultimate goal of mathematically programming a robotic arm to pick up an apple. Using a simplistic trigonometric approach, the team was able to obtain a more precise solution than the one previously approximated. Such findings thus show that the robotic arm can properly function automatically in a real world setting and hence, give people with conditions such as quadriplegia the ability to complete simple tasks. The experiment as a whole demonstrates the effectiveness of the robotic arm, meanwhile educating students about the importance of mathematics. Moreover, this project speaks to the power and relevance of technology, which in tandem with mathematics, contributes to improving the lives of people and solving a wide range of pressing problems.

References:

1. "Law of Cosines." *Wikipedia*, Wikimedia Foundation, 5 Oct. 2017, en.wikipedia.org/wiki/Law_of_cosines.

2. "Law of Sines." *Wikipedia*, Wikimedia Foundation, 13 Oct. 2017, en.wikipedia.org/wiki/Law_of_sines.