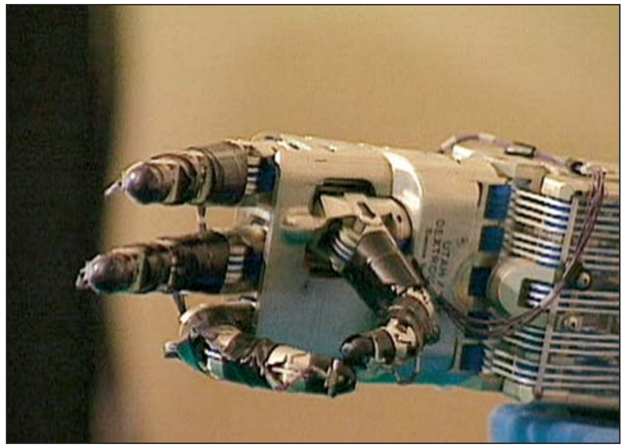
Testing the Robotic Hand

The Movie:



NASA engineer Larry Li has built a robot's hand that can catch a baseball—or recover an essential tool in the vacuum of space. Featured: Larry Li, robotics system engineer, NASA. *(Movie length: 2:46.)*

Background:

One of the more marvelous features of a human body is the remarkable flexibility of arms, hands and fingers for performing a variety of tasks. The fact that we can use the same "tool" to lift 100-pound sacks of cement, play classical guitar, throw a touchdown pass or build a ship in a bottle is an engineering feat of some magnitude.

Designing a robotic hand that can match even some of the capabilities of the human hand is also an engineering feat. Replacing nerves with wires and muscles with motors is the easy part. Building and programming a sensory-motor feedback system that enables the hand to grasp and let go of objects is another story entirely. But even that challenge can be met through an application of the basic problem-solving strategies that every engineer learns.

Curriculum Connections:

Ratios

1

Imagine that you want to build a robotic hand with three fingers which are very similar in shape to the three middle fingers of a person's hand, but 150% as big. Make measurements on your own hand to determine the lengths of the phalanges of your middle three fingers. Then make an accurate full-size sketch of the three fingers of the robot hand, noting all dimensions.

Algebra (patterns and functions)

2

This table shows how the intensity of an infrared beam reflected from an object is related to the distance of the object from the source of the beam.

Distance (mm)	3	5	10	15	20	30
Intensity (compared to intensity at 10 mm)	8.5	3.9	1.0	.42	.21	.09

a) Plot these points in a Cartesian coordinate system, with distance as the independent variable and intensity as the dependent variable. Join the points with a smooth curve.

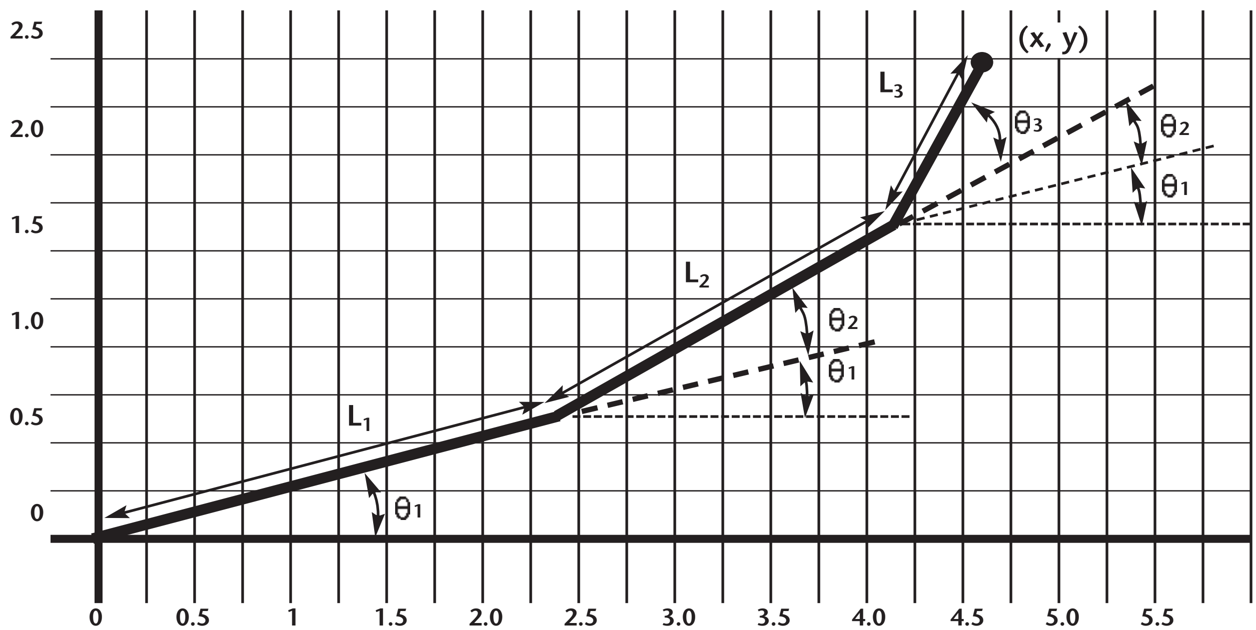
b) What intensity would you expect at a distance of 8 mm? 12 mm? 25 mm?

c) What would the distance be for an intensity of 0.8? 0.3? 2.5?

Regarding: Finger Motors
From: Senior Robotics Systems Engineer
To: Engineering Team #2

We are re-designing the motors that cause rotation in the finger joints of the robotic hand, and we need some calculations done.

As you know, the exact location of a fingertip depends on the angle of rotation of each of the joints in that finger. This diagram illustrates how that works:



$$x = L_1 \cos(\theta_1) + L_2 \cos(\theta_1 + \theta_2) + L_3 \cos(\theta_1 + \theta_2 + \theta_3)$$

$$y = L_1 \sin(\theta_1) + L_2 \sin(\theta_1 + \theta_2) + L_3 \sin(\theta_1 + \theta_2 + \theta_3)$$

For the position illustrated above,

L_1 = length of phalange 1 = **2.5 in.**
L_2 = length of phalange 2 = **2.0 in.**
L_3 = length of phalange 1 = **1.0 in.**
θ_1 = angle between phalange 1 and x axis = **15°**
θ_2 = angle between phalange 2 and phalange 1 = **15°**
θ_3 = angle between phalange 3 and phalange 2 = **30°**

x = 2.5cos(15°) + 2.0cos(15°+15°) + 1.0cos(15°+15°+30°) = **4.65**

y = 2.5sin(15°) + 2.0sin (15°+15°) + 1.0sin(15°+15°+30°) = **2.5**

Your task is as follows:

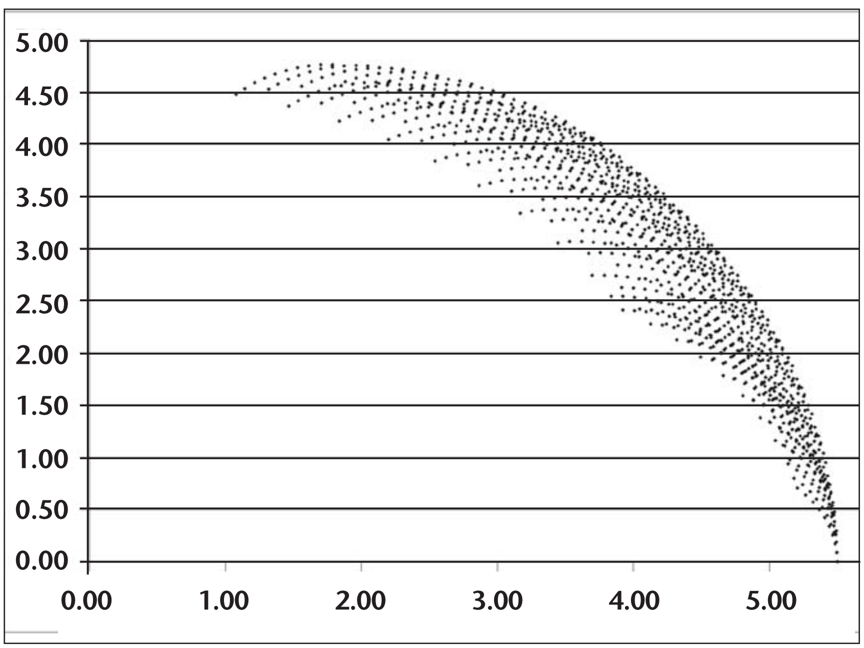
A. Using the same values of L_1, L_2, and L_3, determine x and y for these angles of rotation:

θ_1	θ_2	θ_3	x	y
10°	15°	18°		
30°	20°	5°		
25°	5°	10°		
10°	25°	90°		
45°	45°	45°		

B. Find two sets of angles of rotation that give these values of x and y, to the nearest tenth of an inch (you will probably have to do this by trial and error):

x	y	θ_1	θ_2	θ_3	θ_1	θ_2	θ_3
4.2	3.4						
4.6	2.3						

C. The diagram below indicates the range of possible fingertip positions that can be reached with the present motors, which allow angles of rotation of 0° to 45°.



We are considering using motors that restrict the values of θ_1, θ_2, and θ_3 to no more than 30° (and, of course, no less than 0°). On the above diagram, indicate what effects that will have on the range of possible fingertip positions.

Teaching Guidelines: Regarding Finger Motors
Math Topic: Trigonometric ratios

To understand the formula, it is best to start with the first phalange. The x and y coordinates for the location of its end are simply $L_1 cos\theta_1$ and $L_1 sin\theta_1$, according to the definitions of the trigonometric ratios.

For the second phalange, the angle of the phalange from the x axis is the sum of θ_1 and θ_2, which gives the change in x coordinate from the left end to the right end of that phalange as $L_2 cos(\theta_1 + \theta_2)$. This must be added to the x coordinate of the left end, which was determined above as $L_1 cos\theta_1$. Thus the x coordinate at the end of the second phalange is $L_1 cos\theta_1 + L_2 cos(\theta_1 + \theta_2)$. Similar reasoning gives the y coordinate of that point, and that same reasoning for phalange 3 gives the x and y coordinates of its end point, which is the finger tip.

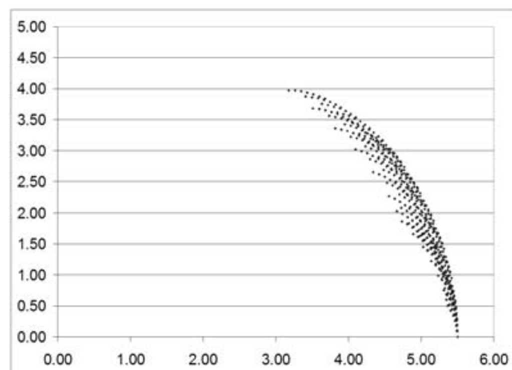
A.

10°	15°	18°	5.01	1.96
30°	20°	5°	4.03	3.59
25°	5°	10°	4.77	2.69
10°	25°	90°	3.53	2.40
45°	45°	45°	1.08	4.48

B. Answers vary. Once students determine one matching set of angles by trial and error, a second set can be found by slightly reducing the angle of one phalange and increasing the angle of another. Here is one set of possible values:

x	y	θ^1	θ^2	θ^3	θ^1	θ^2	θ^3
4.2	3.4	30°	10°	20°	30°	15°	5°
4.6	2.3	5°	35°	15°	5°	40°	0°

C. Students should realize that the limit of the motion can be computed by using the formulas with all angles equal to 30°, which eliminates one area of the graph. They may also explore further to try to find other boundaries of motion. The actual range is shown in this diagram:



Note: This is an excellent project for spreadsheet-based investigation.

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