ROBONAUT 2: FIRST HUMANOID ROBOT IN SPACE

Background

NASA uses robots in many ways to help with space exploration. When it's possible for robots to perform tasks, rather than people, there are some obvious advantages. Robots do not have to eat, drink, breathe, or sleep. They can perform tasks over and over in exactly the same way without getting bored. And they can also perform tasks that are too dangerous or physically impossible for humans.

A previous example of NASA's robotics was the space shuttle's robotic arm—which held astronauts during spacewalks and helped move objects in and out of the shuttle. Mars rovers are also NASA robots and are being used to take photos and collect and analyze samples from the surface of Mars.

In 1996, NASA began developing and using robots that looked and functioned more like humans. Robonaut 1 (R1) was a human-like robot prototype that could perform maintenance tasks or be mounted on a set of wheels to explore the surface of the moon or Mars. Through 2006, R1 performed in numerous experiments in a variety of laboratory and field test environments, proving that the concept of a robotic assistant was valid.

Currently, NASA is collaborating with General Motors (GM) on the development of a next-generation Robonaut. Robonaut 2 (R2), a dexterous humanoid robot, was launched to the International Space Station (ISS) in February of 2011. Initially, R2's primary role on the ISS is experimental; performing tasks and operations similar to those that it has already performed on Earth. This will allow engineers to observe how a dexterous robot will behave in space and make any needed adjustments.

Figure 1: R2 in the Destiny Laboratory of the ISS

Figure 2: R2 holds an instrument to measure air velocity during a system check-out on the ISS

The dexterity of R2's arm joints and fingers was developed to be similar to that of human movement. One advantage of this design is to allow R2 to assist astronauts with (or even take over) simple, repetitive, or dangerous tasks. R2 does not require specialized tools because its dexterous capabilities allow it to grip and maneuver the same tools used by astronauts.

R2 continues to demonstrate capabilities of performing routine maintenance tasks, such as monitoring air velocity and cleaning handrails. Planned upgrades to R2 will allow it to function in the vacuum of space, where it can perform repairs on the exterior of the ISS or simply help astronauts as they perform spacewalks. Engineers observe how the dexterous robot behaves in space, and make adjustments as needed, so R2 can one day take over tasks and responsibilities.

The next step for NASA robots (like R2) could be the exploration of near-Earth objects, such as asteroids and comets, and eventually Mars and its moons. The robots could serve as scouts, providing advanced maps and soil samples, and beginning work on the infrastructure of a base for future missions. The astronaut crew to follow would then be better prepared for the exploration ahead. Humans and robots working together to explore space will provide greater results than either could achieve alone, enabling an exciting future of new discoveries.

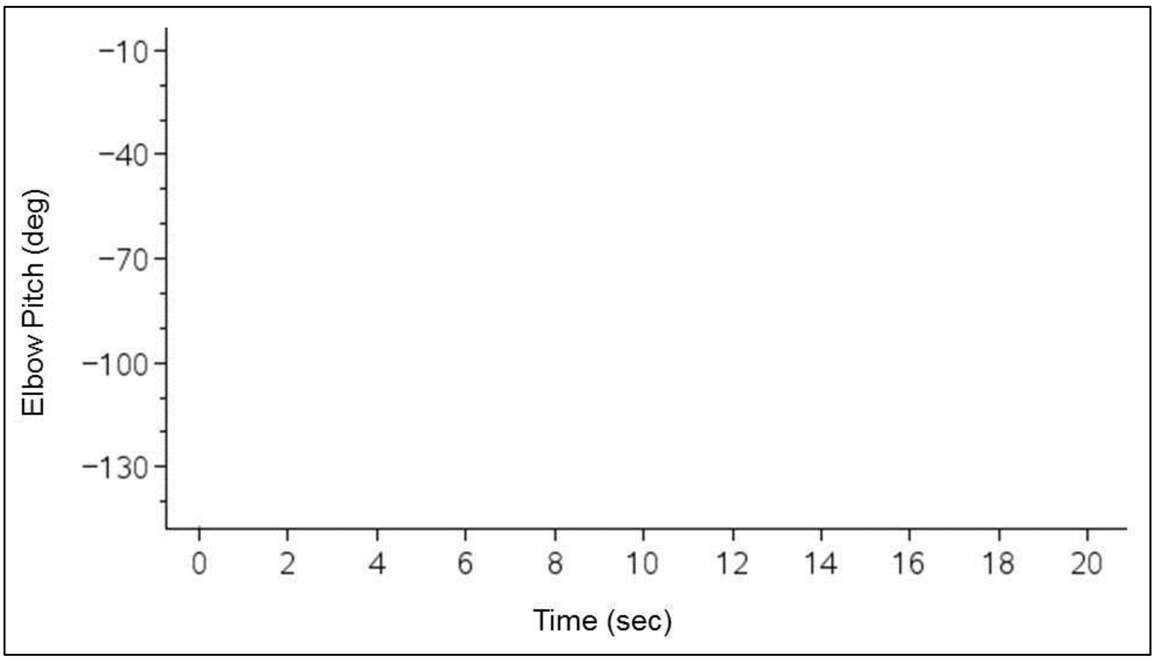
For an introduction to Robonaut 2, watch the video, Robonaut 2: Introduction, accessible at the following link: http://youtu.be/Wf8E1Iyelu4.

Problem

On the TI-Nspire™ handheld, open the document, *Robonaut2*. Read through the problem set-up and complete the instructions and questions embedded within the document. The video, *Robonaut 2: Force Control for Working Around People*, can be found at http://youtu.be/MoDHhq0FiuU.

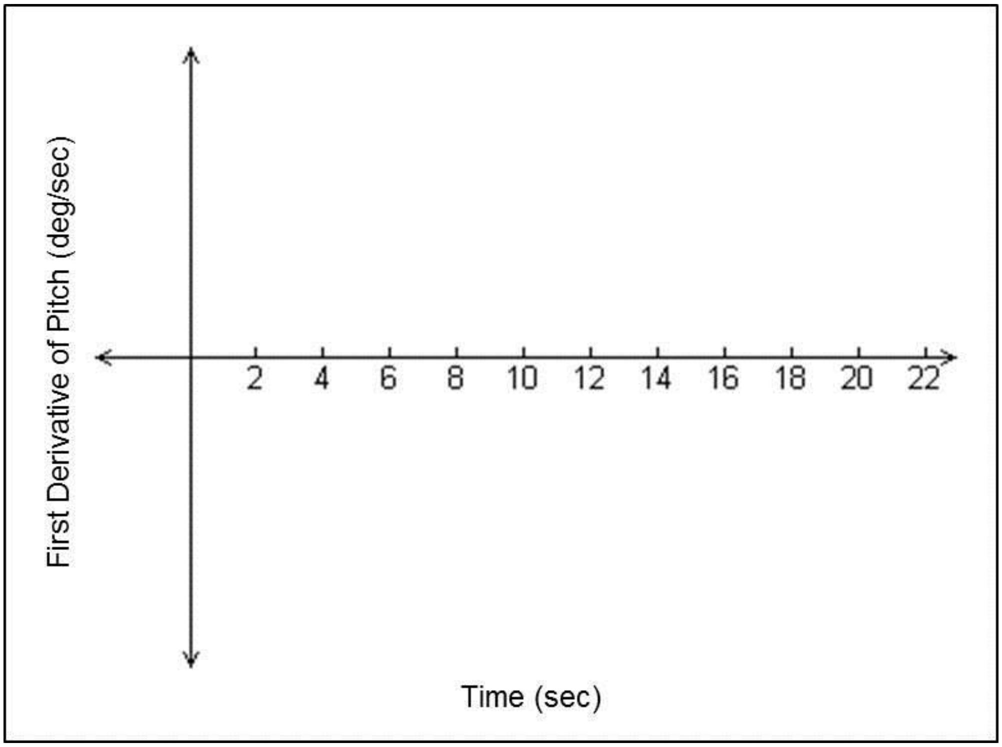
A. Analyze the data.

   I. On page 1.6, make a scatter plot of elbow pitch vs. time and sketch it in the window below.



II. On page 1.7, estimate the angular velocity (or rate of change of the pitch) of R2's elbow at 6 seconds. Show all calculations. Copy and paste values from cells in the data table by using **Ctrl C** to copy and **Ctrl V** to paste.

III. Predict the graph of the derivative of pitch with respect to time. Sketch your prediction in the window provided below.



B. Use numerical methods to approximate a derivative.

I. Go back to page 1.5 and enter the following command in the formula cell for the column labeled deltatime: **deltatime:=deltalist(time_sec)**. What does this command do?

II. Now go back to page 1.5 and enter the following command in the formula cell for the column labeled deltapitch: **deltapitch:=deltalist(pitch_deg)**. What does this command do?

III. Return to page 1.5 and enter the following command in the formula cell for the column labeled der_pitch: **der_pitch:= ((deltapitch)/(deltatime))**. What does the resulting list approximate?

C. Estimate a rate of change.

I. On page 1.12, make a scatter plot of the derivative of pitch vs. time.

II. Based on the graph in part I, estimate the maximum angular speed of R2's elbow. Explain how you arrived at your answer.

III. Estimate the angular acceleration of R2’s elbow at 6 seconds.

IV. Based on the estimated values of angular velocity and angular acceleration of R2’s elbow at 6 seconds, explain how R2’s arm is moving at that time.