Robotic practicals 5 - Haptics

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1 Introduction

A haptic device is a mechanic interface that makes interaction with the human body. There are two types of interactions: tactile feedback and force feedback. We only focused on the force feedback for this lab, in which the purpose was to understand the main hardware and software components of haptics.

2 Method

First of all we had to connect correctly the motor encoders to the Data Acquisition Card and the motor had to be connected to an amplifier because they are controlled by current which need to be sufficiently high and thus amplified by a driver. After setting up the pantograph, the next task was to investigate the data sheets to implement the code written in C to read the data from the encoders. Then we had to derive the forward kinematic of the system to define the position of the end point of the device given by x and y coordinates from the values received by the incremental encoders. We then found an inverse kinematic command model to define the torque to apply to the haptic arms as a function of the x, y position of the endpoint.

3 Results

Exercise 1:
The first task was to derive the forward kinematic model. For that we used the dimension of the pantograph model (see figure 1). The following equations describe accurately the Cartesian position of the end point P with respect to M1. We defined P1 and P2 as the points at the elbows.

$$p1x = a * sin(\Phi 1)$$

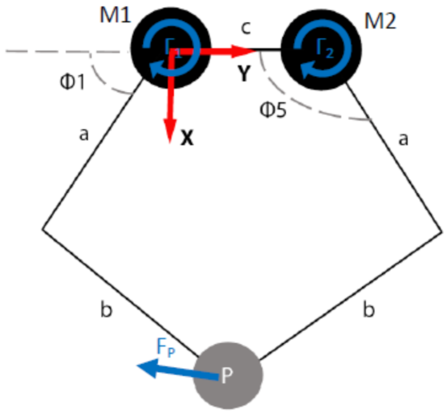

Figure 1: kinematic model of the pantograph haptic device

$$p1y = -a * cos(\Phi 1)$$
$$p5x = a * sin(\Phi 5)$$
$$p5y = c - a * cos(\Phi 5)$$

$$norm = \sqrt{((p5x - p1x)^2 + (p5y - p1y)^2)}$$

$$x = \frac{p1x + p5x}{2} + \frac{p5y + p1y}{norm} * \sqrt{(b^2 - norm^2/4)}$$

$$y = \frac{p1y + p5y}{2} - \frac{p5x + p1x}{norm} * \sqrt{(b^2 - norm^2/4)}$$

Exercise 2:

For the second task, we implemented the code in C to read the encoder values, we then wrote the equations above in the code to get the x, y values of the end point of the device.

Exercise 3:

The last task was to program a feedback command. A convenient way to control the motors is to command the torque to apply (t1 and t2) as a function of the x, y coordinates. In fact, the torque can be proportional to the current applied, which allows linearity for the control. This is inverse kinematics. We modeled the endpoint to simulate a 2D spring by putting the following equations. To do this, we used a simplified model which pretends that the endpoint is attached with only one arm to M1 with norm n1 and with only one arm to M2 with norm n2. This allows simplification for the algebra but restrict the plane area for which the device is correctly controlled

$$n1 = x^2 + y^2$$
$$n2 = x^2 + (y + c)^2$$

from

$$Fx = \frac{x * t1}{n1} + \frac{x * t2}{n2}$$

and from

$$Fy = \frac{y * t1}{n1} + \frac{(y+c) * t2}{n2}$$

, we found the inverse kinematics for torque as a function of the position.

$$t1 = \frac{n1 * (\frac{Fx*(y+c)}{x*y} - \frac{Fy}{y})}{1 - \frac{y+c}{y}}$$

$$t2 = \frac{n2 * (\frac{Fx}{x} - \frac{Fy}{y})}{1 - \frac{y+c}{y}}$$

with the forces given in our case by:

$$Fx = -x * k$$

and

$$Fy = -y * k$$

with k the rigidity parameter of the simulated spring.

Answers to the questions:

1. The unique property of a haptic interface is that it gives a force or tactile feedback which a human-computer interfaces does not necessarily do.

2. When designing a haptic device, it must be really safe as undesired interaction with a human could lead to severe injuries because of the important forces that can be involves. The command muss also be robust to vibrations so that the motion becomes smooth as a human motion. To overcome the vibration, the command rate needs to be faster then 600 hz.

3. A haptic device can be used to train surgeons to do complex operations. It allows the surgeons to train the operation while receiving in feedback a simulation of the feeling of touching and getting inside the patient. This is an important application and can prevent many failed operations.

4. It is not possible to drive the motors directly from the NI card because they require to be controlled with a current which needs to be high and thus we need to use amplifiers.

5. On the pantograph device, the encoders are not absolute, thus it is necessary to use counters to read the encoders after initialization.

6. The encoders are relativ and thus can not work with no reference to an initial position.

7. The advantage of the PWM compare to a linear output encoder is that less energy will be dissipated. The PWM allow to make a proper signal that correspond to the weighted average of a high and a low signal. The weight is defined by the time of the low and the high signals.

8. Impedance control is a way of controlling by applying a force in function of the position. We used impedance control for the small program that we implemented which makes the endpoint of the haptic device act like a spring when one applies a force to it. In contrast, admittance control would be the control of the position in function of the force applied on the haptic device.

9. The Xitact IHP is a surgery device while the Novint Falcon is an entertainment device. This last one is way less precise but the delta robot structure and the robustness of the software allow a lot of applications for virtual reality and other haptic applications.

10. CHAI 3D is a software that allow the user to visualize his interaction with the haptic device. It is in fact very convenient to watch this interaction and gives an advantageous additional visual feedback. CHAI 3D proposes also many different interesting features like the simulation of viscosity.

11. Multithreading is necessary because not all interfaces muss be dealt with at the same period. For instance, the visual data muss be transmitted to the computer only at 20Hz while the loop for the force feedback muss be running a lot faster, at about 1000Hz.

4 Discussion

The experiment allowed us to feel the real time feedback given by a haptic device. Our code worked and allowed us to feel the simulated spring force feedback. We used a simplified model and thus faced lack of robustness because of the singularities which occurred at the extremities of the 2D plane covered by the pantograph. It worked quite well around the initial position but it became unstable on the edges. More complex models can be used to fix those problems. Another interesting force feedback control could also be done with artificial neural networks. One could teach (train) the haptic device to react in a particular and personalized way and thus the next user would be able to feel the teacher's force feedback through the device.

5 Conclusion

This lab has allowed us to really get the fundamentals of the state of the art of a haptic device. We learnt about how the hardware is built and we implemented a code to apply a torque feedback control from the position of the endpoint of the haptic device.