BME 315 Biomechanics Experiment 3. Fall 2006

Kinetics-Analysis of limb motion in 2-D

Pre-lab assignment and review

Please bring a 3.5" floppy disk or a Zip disk to the session to record data.

Review concepts from calculus as suggested in class. Familiarize yourself with calculating velocity, acceleration and joint angles. Recall that if you know the position (x) of a point as it moves through time, and you know what that time (t) is, you can calculate the point's velocity v = dx/dt and acceleration a = d^2x/dt^2. Similarly, if you know the position of several on a rigid body, you can extend the physics to calculate how the body rotates in space and with respect to other bodies. Therefore, the challenge is only to measure the position of each point.

Scientists use similar kinematics and kinetics analysis for a variety of functions. For example, by analyzing the movements of athletes, they can prevent injuries and improve athletic performance. Such analysis can also be used in the production of computer-generated animations used in movies.

Another example has been to help surgeons navigate through difficult or delicate anatomy in the operating room. By monitoring an exposed end of a surgical tool, they can calculate the position of the business end during surgery—even though the cutting or drilling edge may not be visible. A computer can do the calculations in real time to help guide the surgeon during a delicate and difficult operation to improve accuracy. This technology is currently popular in surgeries in the brain and near the spinal cord.

Introduction

To analyze the body motion in question, a human subject will be first marked with points which then be tracked during the motion in question by the camera. To mark each point, we will use reflectors to send infrared light back to be captured by a digital camera. The camera will send an analog signal to the computer. We will then use the Motus software to help digitize the appropriate points. The software will calculate their relative coordinates for each frame. The software can also be set to calculate the velocities, accelerations and joint angles, but this will be left up for the student to calculate. If the software is not available, in its place, a VCR and videotape will be available that the students can manually determine the locations of the points.

Equipment

To mark each point, we will use reflectors to send infrared light back to be captured by a digital camera. The camera is different this year, so its speed is also different. Look at the documentation to determine the speed.

First of all, you want the camera positioned to capture all of the movement as accurately as possible. Therefore, place the camera close enough to the motion without missing anything outside the frame of view.

The camera will send a signal to the computer. Then we will use software to help digitize the appropriate points. The software will calculate their relative coordinates for each frame. The software can also be set to calculate the velocities, accelerations and joint angles, but this will be left up for the student to calculate. If the software is not available, in its place, a VCR and videotape can be used to manually determine the locations of the points.

Set-up

Proper equipment set up is essential to minimize errors. First of all, you want the camera position to capture all of the movement as accurately as possible. In other words, you want the camera to be close enough to the motion without missing anything outside the frame of view. Secondly, calibration of the motion traveled is extremely important. An object of known size is typically used in the plane of motion. Lastly, the subject will have reflective markers located at the joints and ends of segments. The placement of the marks is important because you want to have them located at the joint centers and ends of each segment. Preferably, they will be placed on the skin and not clothing to reduce additional errors caused by relative movement of clothing with respect to the skin. Calibration is always important! What distances are you working with and how does that translate to the computer units? Detailed instructions for the software are given on the appended sheet.

Testing

Measure the distance between the camera and the area for subject action. Have each student perform a movement. This could include a jump, walk, run, boxing punch, arm curl, karate chop, etc. If you choose to do an arm curl motion, try it with and without a meaningful weight in your hand. Measure 3 points, with one being a joint. If the computer is used analyze a second of the movement. If the computer is not available, measure at least 20 frames.

Analysis

1. Plot the y coordinates versus the x coordinates for each point on the same graph. Does this look like the movement you viewed?
2. Calculate the velocity and acceleration for each point chosen. Graph each of these with respect to time. Choose a coordinate system. What direction or directions is your system sensitive to? Make a sketch of light rays from the subject to the camera. Are they parallel? How do the ray paths influence your interpretation of data?
3. How are the differentiations used in calculation of velocity and acceleration affected by random error in the displacement? Hint: suppose that a segment of the motion of the motion can be described by $x_{true} = v_0 t + at^2$, and that the error is $x_{err} = Q \sin wt$. Suppose the error in the displacement represents 5% of the total. What would be the percent error in the velocity and acceleration?

Questions

1. What is the resolution of the position measurement? Is the smallest measurable distance influenced by the pixel density in the video capture system? How much distance does one pixel correspond to?
2. What are some inherent errors that would reduce the accuracy in this experiment? Recall the distinction between accuracy and precision.
3. How might you estimate the error magnitude?
4. What can you do to minimize these errors?
5. Are we recording in 2D or 3D? How could we record in the other dimension?
6. What can we learn from analysis of human motion? What diseases do you think would substantially affect human movement? How might motion analysis be used in rehabilitation?
7. What are the disadvantages if camera speed were slower or faster?
8. Some baseball pitchers can throw a baseball at 100 mph. A moderate walking speed is about 3 mph. How do the maximum speeds found in your tests compare?
9. Why is it important to place the markers as close to the joint centers as possible?

The data that you have are in 9 columns. The first 3 columns are the X,Y, and Z coordinates of point 1. Actually, the Z column isn't the same coordinates as we are used to seeing. (It couldn't be, right, since we only have one camera. We never communicated the Z distances to the computer.) For our purposes, you can probably ignore the Z column. The second 3 columns of data are the X, Y, and "Z" coordinates, respectively of the second point. The final 3 columns would be for the 3rd point. Manually calculate the time scale. You can do this, because you know the speed at which you recorded the frames.(1 Hz : 1 frame per second. You need to know what Hz you recorded in.) Each row of data represents one frame.

The units of your coordinate data come from how you entered the data into the computer. When you were calibrating the computer, you told the computer the distance between two points in the plane of motion. What units were these points in? (cm, in, miles, etc.) The computer then calculated a scale factor for you relating a certain number of computer pixels to real world distances. You told the computer to save the data in scaled coordinates. This should save the data already converted to the units you were using. If you save the raw data, unscaled or untransformed, the data will be in the original pixel units and you will have to manually scale the data yourself.