Human movement

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1 Statistics

1.1 Theory

Statistical analysis of data is a key point in biomechanics research. Indeed, the analysis is supposed to represent the human race behavior. As such, it is impossible to establish a general result based on the study of a single sample. In case of motion studies, at least 10 subjects are needed. In case of morphology studies, hundreds of subjects classified according to gender, ethnics and age are needed in each category.

Statistical analysis of a set of data is based on two main values : the mean and the standard deviation. Let X_i be the result of the i-th experiment (i = 1..N).

– Mean value :

$$\bar{X} = \frac{1}{N}\sum_{i=1}^{N} X_i$$

– Sample standard deviation :

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(X_i - \bar{X})^2}$$

1.2 BSP estimation

Measure of the Body segment parameters (BSP) will be estimated based on the statistical results extracted from each student measurements.

1. Recall the definition of the modified Hanavan model: experimental parameters, BSP.
2. Measure on your actor the 41 parameters needed to establish your modified Hanavan predictive model of mass distribution.
3. Comparing your data with all the data obtained by the other students on your actor, draw a graph giving the 41 parameters in abscissa, and the values obtained in ordinate.
4. Extract mean and standard deviation values.
5. Conclude: which values will you take to establish the modified Hanavan model of your actor? Comment the obtained results.
6. How did you proceed for these measurements? What are your comments on these practical measurements?

2 Programing

2.1 Theory

Your objective is to program the code to calculate the dynamics of the human motion from the Newton-Euler equations. You will test the validity of the human model and the hypotheses made, by comparing the calculation of the ground reaction force (GRF) to real measured data (force plate). All calculations will be made in the reference frame R_0 for any body S_k, and the kinetic and potential energies will be estimated too. Recall the theory based on homogeneous transformation and the flow chart to calculate human dynamics (inputs, outputs, calculations, etc.)

2.2 Application to Hanavan model

To check the validity of the program, simple examples should be applied. Let us consider an inverted pendulum: a point mass m attached to a rotational joint (2d motion) by a massless rod.

1. Realize a program calculating the dynamics (efforts at the joint) with time of the pendulum oscillating movement in the reference frame: extract the external forces (with time) knowing the kinematics of the body (trajectory, velocity, acceleration). Velocity and acceleration can be obtained using numerical derivation: second order central finite differences. Calculate the kinetic and potential energies, check the validity of your model.
2. Realize a program simulating the motion of the observed body (visual animation).
3. Application to the double pendulum case, redo questions 1 and 2. Analyze the obtained results in terms of forces and moments. For similar trajectories, make variations of velocities and accelerations, and verify the effects on the efforts.
4. Extension to the human whole body using the Hanavan representation (17 bodies)

3 Experimentation

3.1 Theory

We have seen during the lecture where to place the makers as close as possible to the body landmarks. In the available motion capture systems, rigid bodies can be fixed to the segments and body landmarks are not needed. The objective of motion analysis is to check the validity of the mathematical model used to model human dynamics. The first step is then to recall the hypotheses made to write the model, and check their rightfulness.

3.2 Analysis

1. Recall the working hypotheses. How could each be checked using an experimental protocol?
2. Describe the experimental conditions and devices.

3. Equip a subject with the whole body markers suit.
4. Clearly explain to the actor the experimental protocol.
5. Realize two or three trials with the actor to check that the motion is being performed correctly.
6. Register motion data (kinematics from motion capture and ground reaction forces from the force plate).
7. Calculate joints forces and moments, the ground reaction efforts (forces and moments).

The effect of motion velocity and acceleration can be evaluated when choosing the sample motions that will be studied. We propose the following applications:

1. Simple arm motion: waving with the right arm: at slow, medium and fast velocities.
1. Simple slow motion: giving a slow kick with the right foot, with no arms motion: at slow, medium and fast velocities.
2. Simple slow motion: giving a slow kick with the right foot, with arms motion: at slow, medium and fast velocities.
3. Sitting down on a chair: slow velocity.
4. Vertical jump without counter movement: short jump, medium jump, jump as high as possible in extension, jump while bringing the feet as high as possible.
5. Vertical jump with counter movement: short jump, medium jump, jump as high as possible in extension, jump while bringing the feet as high as possible.

Analyze your results in terms of joints characteristics (trajectories, velocities, accelerations), ground reaction efforts and energy cost.When analyzing the vertical jump motions, explain how the human body damps the vertical impact with the ground at touchdown.

Caution: when trying a similar motion at different velocities, it is very important to check that the actor performs the same action (check starting and ending joint angles carefully).

4 Synthesis

Conclude while extracting the key points of your analysis, the difficulties you encountered, the facts that you have validated during this experimental session. You may propose a conclusion comparing the reaction forces obtained by the mathematical model based on kinematics, and the measurements from the force plate. Also extend your conclusions to the validity of the energy cost calculated by your model. To understand better your problem, comparing your results with the other group results may give a help. Remember that **the results on one actor are not representative of all human beings' behaviors**.