Method of Successful Sharing of Experimental Kinematic Data Between Cooperative Laboratories

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Introduction
Motion laboratories with different hardware and software configurations have traditionally been limited in their ability to easily share or directly compare data with each other. By formulating a structured model-based approach, we have successfully analyzed three-dimensional kinematic data collected from two different commercial motion analysis systems, obtaining identical numerical and graphic results from analyses performed using two different software packages.

Statement of Clinical Significance
The ability to analyze data in one motion system that has been collected in another allows the flexibility to share kinematic data, combine clinical series, and perform longitudinal studies on subjects who move from one institution to another.

Methodology
A unique 3D biomechanical model was created (in this case, of the head, trunk, and upper extremities), with intrinsic axes and segment definitions, defined joint center displacements from surface markers, and defined rotational decomposition sequences. Using Motion Analysis Corporation (MAC) ExpertVision project file definitions (Northern California) and VICON Body Builder software (Portland), we defined "virtual markers" that represented joint centers by calculating displacements from actual surface markers. Both software systems use vector cross-products to generate axes, which were defined for each segment according to the *biomechanical model*, and not according to the local software conventions of the laboratories or commercial manufacturers.

Using the defined axes, segmental parent-child rotational sequences were calculated using local software options. It was necessary to perform experiments at this stage to assure that differing commercial programs yielded identical angular results.

Debugging was initially done using electronic file transfer between laboratories. However, in later stages of the project it became necessary for investigators to meet so that each step in the characterization of the adopted model was confirmed and agreed upon.

Both systems produce accurate ASCII files of 3D marker trajectories in a format that is reasonably similar. Using EXCEL, Portland trajectory data was modified to serve as 3D input into the Northern California system. Using C3D Server and Editor (Motion Lab Systems), the Northern California output file was edited to be read by Body Builder. The local segment rotation calculation software and display software were used to analyze the other laboratory's data.

Results
After debugging the individual software processes, we were able to generate identical graphical and numerical output from the data collected at the other laboratory. We were also able to load and display stick figures and virtual markers as if the data had been generated locally.

Discussion
Generating identical internal analytical results from externally generated data seems a straight-forward task, but in practice there are many barriers. Measurement units, axis definitions, rotational sequence decomposition, and other conceptual issues are superimposed on commercial software packages that sometimes seem to have a "black box" approach, in that certain computational processes are invisible to the user.

We circumvented these issues by agreeing beforehand on a uniquely defined model. Rather than relying on commercial generation of segments, we used the software to define all the individual segment axes of our model, using these axes these to perform our analyses.

The successful cooperative effort required agreement on the model, willingness to work with spatial coodinate and axis definitions that might differ from those used locally, and intimate knowledge of vector algebra and local software programing. It also required the ability to look beyond commercial model "defaults" that are suggested by individual vendors of motion analysis equipment.

It should be noted that an alternative method exists for achieving a similar goal. 3D marker trajectory data can be imported into EXCEL, and a Visual Basic program can be created to perform the entire analysis and generate displays. While this is computationally straight-forward, it represents a level of effort that seems excessive given the availability of excellent flexible commercial software that is packaged with commercial analysis systems.

References
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