ADJUSTING A FULL BODY MODEL TO MITIGATE INVERSE KINEMATICS ARTIFACTS IN OPENSIM

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BACKGROUND: In support of Vibration Isolation and Stabilization (VIS) system development for Human Health Countermeasures (HHC) exercise systems in space, such as the European Enhanced Exploration Exercise Device (E4D) [1], dynamic quantities required to model the response of a proposed VIS while considering the effect of VIS motion on the forces between the human and VIS platform were obtained using motion capture data [2]. On occasion, large-amplitude oscillatory spikes were found in the subject's linear and angular momentum derivatives, affecting analyses that depend on forces and moments derived from motion capture. The purpose of this investigation was to identify causes of these artifacts and techniques for their resolution.

METHODS AND RESULTS: To obtain the required human dynamic quantities to drive the VIS simulation, motion capture data was collected containing recorded trajectories of passive retroreflective markers on body landmarks of an exercising subject. Since the full body Rajagopal model [3] was originally used to enhance gait analysis, upper body joints did not require large Ranges of Motion (ROM). We thus modified the Rajagopal model [4, 5] to allow it to be used for upper body intensive exercises like those common to the E4D. OpenSim Inverse Kinematics (IK) [6] was performed using these scaled subject models to generate the joint angles throughout the exercise while minimizing marker error. At times, the arms were observed to 'snap' from one configuration to another, causing spike artifacts. Following IK, a custom OpenSim plugin [7] was used to determine the required dynamic quantities including the rates of change of the linear and angular momenta of the human. Since motion capture is recorded at a larger time step than required by the VIS simulation, the human center of mass location was fit with splines and a second derivative taken to obtain the momentum derivative, allowing the VIS simulation to maintain conservation of momentum when appropriate. In a few cases during this stage, artifacts much larger than the expected noise of the second derivatives were introduced.

Investigation of cases containing artifacts revealed several modifications that could be made to the OpenSim model to improve IK results. Since OpenSim models use Euler angles and rotation sequences, 'gimbal lock' would be encountered in the arms when raised 90 degrees to the side (e.g., T-pose, some hang clean exercise, etc.). This was resolved by reorienting the horizontal axes at the shoulder joint by 45 degrees, placing 'gimbal lock' outside common arm ROM, with the arm ROMs adjusted following this change. Elbow and wrist ROMs could also be adjusted to allow realistic motion while at the same time limiting the likelihood of unrealistic orientations. On occasion, the arms flipped backwards when raised above the head. This was prevented by using medial elbow markers in scaling and IK. When medial markers were not available, the acromial joint location in the unscaled model was shifted before model scaling to better align the arm with available markers. Lastly, artifacts which became apparent after taking the second derivatives of spline-fit data were found to occur in cases when the pelvis rotation limit prevented the full range of motion of an exercise. These issues were resolved by unclamping the pelvis rotation limit. Through this investigation, an understanding of conditions leading to IK artifacts was acquired allowing the automation of artifact detection. These artifact detection and mitigation techniques can be applied toward modeling of upper body motions in aerospace and other fields for improved IK results.

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