Problem 6:

Kinematics and forces are usually not consistent due to incorrect modelling assumptions and measurement errors. Also, the balance between external and inertial forces and moments becomes inconsistent due to several sources of modelling and experimental errors. The net joint torques obtained from an inverse dynamic analysis starting at the unconstrained end of a chain of segments and ending at the feet are different from those obtained when the analysis is started at the feet. This problem arises because of the system of equations of motion for a complete linked segment model is overdetermined. A system of equations is considered overdetermined if there are more equations than unknowns. The main sources of error in calculations of net joint torques are inaccuracies in segmental motions and estimates of anthropometric body segment parameters. Errors affecting the trajectories of joint centres, the orientation of joint functional axes, the joint angular velocities, the accuracy of inertial parameters and force measurements, can weigh differently in the estimation of joint moments. Errors comprised in joint parameters include the position of the joint centres, and the position and direction of the joint axes of rotations affects both joint kinematics and dynamics. Selection of the coordinate system influences inverse dynamic analysis (IDA) and this influence can arise from the definition of coordinate system used to

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describe body segment anatomy. Uncertainty in estimated net joint torques derived from IDA, range from 6% to 232% of the peak net torque and thereby it becomes necessary to address this residual errors to ~~bete~~ make the system "dynamically consistent". However, in certain tasks, these residual errors are quite large and therefore strategies based on motion or force variation are applied. In high-speed tasks generally these errors ~~get~~ are high and causes to invalidate the conclusions of the dynamic analysis. Uncertainty in the joint torque could also result because of foot mass and ground reaction forces. This large effect of error arises due to the swing phase while performing a vertical jump.

<u>Bonus question</u>: Ways to minimize the magnitudes of the three components of the "Hand of God"

→ Several ways have been implemented to minimize the errors which leads to dynamical inconsistency. Adding low-value residual pelvis (force and torque) actuators could deal with such problem. Optimization control algorithm can be used for tracking problem, in which implicit form of dynamics is used. Equations of motion ~~of~~ are introduced as path constraints, as well as residual forces and moments acting can be used as path constraints. These algorithms can deal

with dynamic inconsistency in high-speed tasks, obtaining low residual forces and moments while keeping similar kinematics. The constrained optimization algorithm ensures a consistent description of forces and kinematics, thereby improving the validity of calculated net joint torques.
Also, another way of computing first approximations of body segment parameters using a series of short calibration motions. These refined optimal body segment parameters derived from combination of motion profiles helps in improving net joint torque calculations and reducing the error of magnitudes of the three components of the "Hand of God".