Controller-based Tracking of Multimodal Motion Data

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Summary

We present a controller-based tracking approach for analyzing multimodal motion data. Using synthetic data (position/ velocity data), simulation results with small kinematic errors and small residuals were calculated for noise-free data as well as in the presence of measurement noise or systematic errors.

Introduction

Tracking methods transfer motion data onto musculoskeletal models. When doing so, errors occur which result in residuals or deviation of measurement data. Multimodal input data [1] as well as forward dynamic simulations (FD) [2] may be useful for minimizing these errors. In this paper, we present a controller-based tracking method for tracking and analyzing kinematic and dynamic motion data simultaneously using FD.

Methods

A planar model of a leg (three bodies: HAT (head, arm, trunk), femur, tibia) with six degrees of freedom, actuated by activation coordinate actuators, was used. Synthetic motion data (squat motion) and ground reaction forces serve as input for the controller-based tracking method. Starting from an initial state, deviations between model position and velocity marker data from the current state and of the subsequent measurement frame are calculated. Using a PD (proportional derivative)-controller, excitation values are calculated which result in generalized forces based on linear activation dynamics. The system is integrated over the full measurement using the current state of the model and the calculated generalized forces. For each degree of freedom and frame excitation values ($u(t)$) are calculated using equation 1:

$$u(t)_{pos/vel} = K_P \cdot e(t) + K_D \, {}^{de(t)}/_{dt}$$

where t is the current time step, e is the marker data deviation (either position or velocity data), and K_p and K_D are the proportional and differential error gains. In order to obtain a single feedback excitation value, a weighted sum of both excitation values (based on position and velocity deviations) is calculated. In addition to the noise-free data, the effect of marker jumps in the input data and marker registration errors (erroneous position of model markers) were investigated. To analyze the approach's performance, the root mean square error (RMSE) between calculated and reference joint angle and marker data as well as the integral of residuals (change of angular momentum/impulse) were calculated.

Results and Discussion

Table 1 shows RMSEs and integral values of residuals, which were small overall. Figure 1 depicts joint angles for all three situations. For all angles, good correspondence between reference and computed results can be observed. The results suggest that the approach may help produce simulation results with small residuals while staying close to the input data.

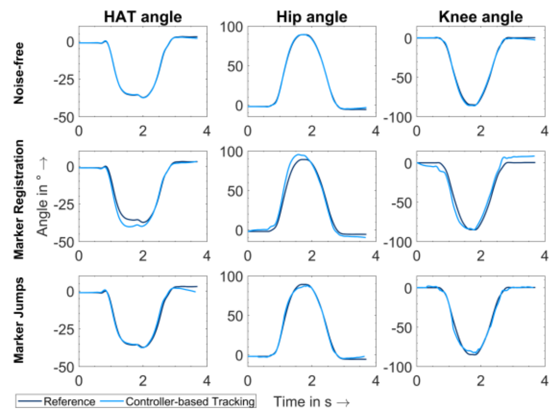

Figure 1: Comparison of reference and calculated joint angle data.

Conclusions

The proposed approach resulted in good tracking results and small residual forces for both noise-free and error-loaded input data. Future work will determine the performance of the approach in handling experimental sensor data and should show if it can produce reliable simulation results with small residuals and measurement data deviations.

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References

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Table 1: Mean marker and joint angle RMSE and change of angular momentum and impulse.

	Mean marker RMSE (m)	HAT angle RMSE (°)	Hip angle RMSE (°)	Knee angle RMSE (°)	ΔM_z (kg m^2/s)	ΔF_x (kg m/s)	ΔF_y (kg m/s)
Noise-free	0.0021	0.81	1.39	0.33	0.0004	0.0528	0.0095
Marker jumps	0.0126	5.60	6.73	2.54	0.0237	0.2705	0.0879
Marker registration	0.0049	1.94	2.76	1.39	0.0238	3.5584	2.1457