The Design of a Cell-Phone Based Balance-Training Device

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Postural imbalance can result from various vestibular (central and peripheral), neurological, orthopedic, and vascular disorders, as well as sensory conflicts, head injuries, infections, medications, and aging. Balance rehabilitation has been shown to improve the quality of life of individuals with balance disorders by facilitating the development of compensatory strategies which mitigate dizziness, improve balance, and increase the ability to perform activities of daily living. The goal of this work is to design a cell phone based balance training device that can be used in the home to assist a patient with therapist-assigned balance exercises or in an environment where access to balance therapy is limited (i.e., rural regions in the developing world). The prototype comprises an iPhone (iPhone SDK, Apple), an auxiliary pager motor (Samsung GH31-00154C), and an audio amplifier (Analog Devices SSM2301). Body motion is detected by on-board tri-axial accelerometers, and a tilt estimate is computed using a low-pass filter. The phone's native pager motor and an auxiliary pager motor are used to provide real-time vibrotactile cues of body tilt along a single axis. The phone is worn on the small of the back to provide anterior-posterior vibrotactile trunk tilt feedback during stance, and worn near the right hip to provide medial-lateral vibrotactile trunk tilt feedback during gait. Auditory files direct the user through a series of standard balance rehabilitation exercises. A summary of the user's performance is displayed on the phone's screen following completion of the exercise.

Smooth Anatomical Models From 3D Imaging

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3D imaging has become a standard tool in medical diagnostics and, while software is available to visualize volumetric data sets, we do not yet have software that can efficiently transform 3D scan data to solid models that are useful for engineering design and analysis. Why not? Currently, deriving solid models from 3D scans involves 3 steps: (1) segmentation: identification of voxels associated with the structure; (2) polygonization: computing a set of polygons that approximate the surface of the structure; and (3) repair: removing stray voxels and polygons, specifying connectivity, and establishing consistent orientation. Significant progress has been made on accurate, automated segmentation (recent work by Hu et al. (Image Segmentation and Registration for the Analysis of Joint Motion From 3D MRI," Proc SPIE **6141**, pp. 133–142, Medical Imaging: Visualization, Image-Guided Procedures, & Display, 2006), combining graph cuts with level sets is of particular interest) but effective polygonization cannot be guaranteed. In the worst case, manual repairs are needed to patch holes and remove stray elements. Even if a valid boundary representation (b-rep) model is obtained, accurate models contain so many polygons that modeling operations become unfeasible. Moreover, regardless of accuracy, the surface of a polyhedral model will never be truly smooth. In previous work (Storti, D., et al., Artifact vs. Anatomy: Dealing With Conflict of Geometric Modeling Descriptions," SAE 2007 Transactions Journal of Passenger Cars: Electronic and Electrical Systems, Paper No. 2007-01-2450, Vol. 116, pp. 813–823, 2007), we proposed overcoming the barriers to creating solid models from 3D scans by employing a new solid modeling description, wavelet SDF-reps, that lies much closer to the native 3D scan format and eliminates polygonization. Here, we focus on the ability to produce models with smooth surfaces that are important for various biomedical simulations. For example, careful studies of joint function involve detailed modeling of ligament wrapping; i.e., connective tissue moving across bone surface as the joint configuration changes. Realistic behavior cannot be obtained if the ligament is snagging on or snapping across convex vertices of a polyhedral model. Similarly, haptic simulation of a catheter navigating through the circulatory system cannot be realistic if the catheter gets stuck in concave vertices of the anatomical model. How can the new modeling format address such issues? Wavelet SDF-reps take advantage of a by-product of the segmentation algorithm (Hue et al.) which converts the raw voxel intensity values to a grid of signed distance values. Applying an appropriate interpolant such as Daubechies wavelets (Daubechies, I., *Wavelets*, CBMS-NS Series in Applied Mathematics, SIAM Publications, Philadelphia, 1992) then produces an implicit or function-based (f-rep) solid model of the segmented structure. Wavelet SDF-reps are inherently multi-resolution and support significant data compression and medial axis computation. We illustrate the capability of wavelet SDF-reps to support smooth models and enable analysis of curvature features.

