FOOT INTER-SEGMENT ANGLES AND ROTATION AXES BASED ON DYNAMIC 3D SURFACE POINT CLOUDS

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Introduction

Assessment of foot kinematics is still a complex time-consuming issue, in research as well as in clinical practice. A practical and quick method to perform a thorough dynamic analysis is needed. Dynamic 3D surface scanning is a technique which has gained more interest over the last years. Such a scanner can deliver images of the entire foot surface during loading phase in walking, at a maximum frequency of 49 Hz [Schmeltzpfenning, 2009]. The output is a point cloud of the foot surface for each time frame. The most challenging issue is performing robust quantitative data analysis useful in foot research and clinical practise.

Different methods has been proposed. Direct automatic landmark detection [Witkowski, 2006] appeared to be not stable enough for the huge variety of feet. An attempt for a more sophisticated processing using an optical flow-based foot model [Van den Herrewegen, 2012] also failed at robustness, and was too time-consuming.

Our research uses an ICP (iterative closest point) -based algorithm to find joint angles and rotation axes of a scanned foot step.

Methods

The presented algorithm makes use of a manually defined multi-segment foot model. Four segments (shank, rearfoot, forefoot, toes) are selected on a static foot scan of the subject. This first selection is important so it should be executed carefully. Subsequently, these segments are identified in the dynamic foot frames of the subjects' step. For this, the well-established ICP algorithm is used [Kjer and Wilm, 2010]. The result is a dynamic multi-segment model of the foot step. Intersegment angles and rotation axes are calculated from this model.

The algorithm ran on 5 subjects, each performing 6 steps. Intersegment angles in the frontal, sagittal and transversal plane are calculated. Rotation axes between shank-rearfoot and forefoot-toes are computed during midstance and propulsion respectively.

Results

The automatic algorithm runs on 30 scanned footsteps. Results show that the angles follow the same curve within the 6 trials of a subject. Kinematics at the start and end of the step are far more variable, mainly due to artefacts in the scans.

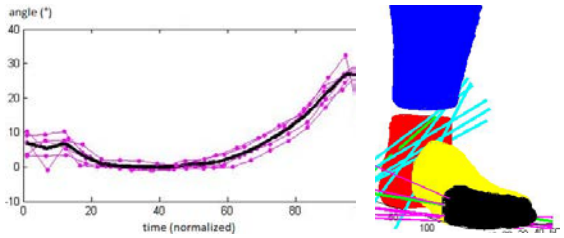

Figure 1: 6 steps of the same subject and mean value. (L) time-normalized intersegment angle forefoot-toes. (R) Rotation axes between shank and rearfoot (cyan), and between midfoot and toes (magenta).

Discussion

Considering the enormous variety of foot shapes, a manual preselection is a necessary effort in the analysis of dynamic scans. The automatic process of calculating foot kinematics is being optimized at the moment, and validated on an artificial foot with known segments. Furthermore, scans should be of higher frequency in order to capture also heel down and toe off moments more robustly.

References

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