3-D MOTION ANALYSIS AND SYNTHESIS FROM INERTIAL GYROSCOPES AND IMAGE DATA

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Summary

A new method using miniature gyroscopes with synchronized video cameras is proposed. Combining gyroscopic signals in the sagittal plane and 3D information from the cameras lets us recover leg motion not only in the sagittal plane but also in the frontal one.

Conclusions

We proposed a new approach for 3D tracking applicable in gait analysis. The approach takes advantage of both markerless stereo imaging and miniature body-mounted sensors. We show that this fusion significantly improves tracking stability and robustness, over that of either modality alone.

INTRODUCTION

Markerless and high-speed tracking of human movements during gait is a very complex task. Current optical motion analysis systems are very expensive, require wearing reflective markers by the subject, the measurements are restricted to a laboratory environment, and the markers are easily obscured from vision. In this study we presented an inexpensive and easy-to-use solution by integrating body-mounted sensors and vision tracking technologies. Our system is based on combining the output of a very limited number of inertial gyroscopes with inexpensive and commercially available synchronized cameras. Our philosophy is to combine the respective strengths of body-mounted sensors [1] and image-based technologies [2]: The former is robust but impractical to attach enough sensors for capturing all degrees of freedom of human motion. The latter provides more aspects of motion, yet it is usually less reliable due to obscuring body segments from vision resulting in incomplete data. Our ultimate goal is to allow the measurement of changes in the biomechanics of the prosthesis by noting the effect of these changes on clinical findings and day-living patient activity.

PATIENTS/MATERIALS and METHODS

We tested two patients with posterior-stabilized total knee arthroplasty. The patients performed specific activities such as walking at different speeds and climbing stairs while 5 gyroscopes were mounted respectively on their shanks, thighs and trunk, and in parallel being filmed by 2 synchronized video cameras. For a given time step, the system extracts clouds of 3D points from our synchronized input video sequences using a correlation-based approach. The tracking process adjusts the model's joints angles (thigh, shank) by minimizing the objective function with respect to the joint angles relative to that frame in order to superpose the 3D model on the cloud. This modified posture serves as the initialization for the next one. For the legs we update this position with the prediction given by the integration of the gyroscopes signal.

RESULTS

As shown in the figure, the motion parameters in the sagittal plane is recovered using a few sensors whose output is refined to include frontal motion by taking into account the 3-D information derived from the video sequences. More specifically, the kinematic data allows robust motion recovery in the sagittal plane, while using imagery allows us to refine the description by incorporating motions in the frontal plane, which is just as significant for diagnostic purposes.

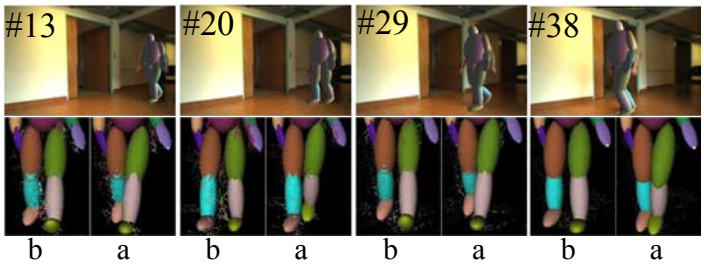

Fig.1 *First row: Several frames of a walking sequence with the projected 3D model Second row: For each frame, frontal view of the limbs before (b) and after (a) using the 3-D information. Note the frontal motion clearly visible in the (a) frames.*

DISCUSSION

We have shown that combining gyroscopes with cameras allows us to model patient's motion in more details than either modality alone. In its final form, the system we are developing will produce synthetic 3D animations that clearly represent the patient's condition and help the physician diagnose and treat it. We expect this to foster progress because there are currently no truly effective, automated and easy-to-use tools for functional assessment of patients with locomotion disability and for the outcome of orthopedic replacement surgery.

REFERENCES

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