USE OF MARKER-LESS MOTION CAPTURE APPROACH FOR CONSTRUCTION FIELD WORKERS’ BIOMECHANICAL ANALYSIS

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INTRODUCTION

We propose computer vision-based biomechanical analysis for construction field workers. Taking into account the fact that the number of fatalities in construction is the highest among all industries [1], and that the unsafe acts and behavior of workers cause 80% to 90% of accidents in construction [3,5,7], the systematic understanding of field construction workers’ unsafe behavior has great potential to contribute to the reduction of injuries and fatalities in construction. Though techniques do exist to study unsafe acts (e.g., surveys, focus groups, video analysis, and laboratory experiments), these techniques may not be suitable for measuring the physical demands exerted on workers under real conditions (i.e., biomechanical analysis). To address this issue, we aim to develop a computer vision-based marker-less biomechanical analysis system, which will extract workers’ skeletons (without any marker attached to the workers) captured from ordinary network surveillance video cameras; the skeletons will be used for biomechanical analysis with estimated force information. The paper first compares the accuracy of the proposed marker-less motion tracking system with that of a commercial system with ladder climbing in the lab. Second, it demonstrates how postures determined using marker-less motion tracking can be used to evaluate biomechanical loads for a quasi-static case.

METHODS

We use two ordinary network surveillance cameras to record a subject climbing a ladder. 2D skeletons are extracted from each video set using an articulated pose estimation algorithm with flexible mixtures-of-parts [2]. In this algorithm, the human body is decomposed into local body parts such as the upper arm, lower arm, torso, upper leg, and lower leg. The local body parts are represented by a non-oriented pictorial structure that illustrates the relationships among them. Then, the 2D skeleton is inferred based on the detected body parts. Once we have 2D skeletons from each video set, 3D skeletons are reconstructed using a Euclidean reconstruction algorithm [4]. Figure 1 illustrates the reconstructed 3D skeleton from a ladder climbing.

![Figure 1: 3D reconstruction of 2D skeletons from ordinary network cameras.](image)

With the 3D skeletons, biomechanical analysis can be performed using estimated (or assumed) force information. First, the body segment angles, which can be obtained from each pose in a frame, are calculated using 3D skeleton joint coordinates. The force data are assumed based on the climbing pattern. For example, if the hand or foot is in the air, the external load of this hand or foot can be assumed to be zero. In addition, one hand force can be assumed to be 11.5% of body weight [6], and foot force can be range between 48% and 60% [8] (based on the data close to the subject). With such force and pose information in each frame, the quasi-static biomechanical analysis was implemented using the University of Michigan 3D SSPP [9].

RESULTS AND DISCUSSION

We compared the accuracy of 3D skeletons developed with our marker-less approach to those developed with the commercial marker-based motion capture system (i.e., VICON). One possible...
A way for accuracy measurement is comparing each body segment’s length between the two systems. To do this, we measure one female subject’s the mean length of the head, trunk, upper left and right arms, lower left and right arms, upper left and right legs, and lower left and right legs (1,000 frames). The average of the Normalized Root Mean Square Error (NRMSE: RMS divided by max-min value) of these segments between anthropometry data of the subject and VICON’s output is 0.163 (0 is perfect agreement), while the average of the NRMSE between the anthropometry data and the proposed approach is 0.317. The head, trunk, and lower left and right legs showed high accuracy (less than 0.1 in NRMSE), but the lower left and right arms and upper left and right legs showed low accuracy (0.26-0.46 in NRMSE). This is because the lower left and right legs and upper left and right legs are susceptible to occlusions in ladder climbing. We performed quasi-static biomechanical analysis using the first 50 frames in 3D SSPP (see Figure 2). Based on this analysis, the elbow and shoulder are the parts that regularly endure forceful exertion during this climbing process (10% and 17% capable respectively - see Figure 2). In addition to their important role in climbing, the shoulder and elbows are common sites of work-related injuries.

CONCLUSIONS
A computer vision-based marker-less motion capture approach is proposed. Based on the preliminary study, its feasibility is demonstrated, illustrating how biomechanical analysis can be achieved using ladder climbing. This analysis was based on a static analysis. We are currently working on improving the accuracy of 3D skeletons and the use of OpenSim for dynamic analysis [10].

REFERENCES

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