学　位　論　文　内　容　の　要　旨

博士の専攻分野の名称　　博士（情報科学）　　氏名　Bilesan Alireza

学　位　論　文　題　名

Development and Accuracy Analysis of a Human Motion Capturing Method Using a Single IR Camera
（単眼 IR カメラを用いた人間のモーションキャプチャー手法の開発と精度解析）

Motion capture systems are used to measure the kinematic features of motion in numerous fields of research. Despite the high accuracy of commercial systems, these systems are costly and used in limited conditions. Kinect has been proposed as a low-cost markerless motion capture sensor, and its accuracy has been assessed compared to previous motion capture systems like Vicon and OptiTrack. Kinect comes with a software development kit (SDK) that helps determine the human skeleton structure from the point cloud of the body using machine learning algorithms. Since the Kinect skeleton model detected by the SDK is different from the skeleton model estimated by the traditional motion capture systems, the incompatibilities in determining the human joint angles in different motion capture systems can cause imprecision in the accuracy assessment results reported in previous researches. To achieve a proper accuracy evaluation of the Kinect as a motion capture camera, we applied the inverse kinematics techniques in both skeleton models represented by Kinect and a traditional system (Vicon) to estimate lower body joint angles of a human during gait. The results indicated acceptable accuracy for Kinect in tracking knee and hip flex-extension angles using Vicon data as the true value. However, Kinect showed major errors in capturing delicate motions like ankle and pelvic joint angles. We developed a marker-based motion capture system using the Kinect IR camera to overcome these inaccuracies in human motion capture using Kinect skeleton. We introduced joint use of the Kinect IR camera as a pinhole camera model and its depth data in order to determine the 3-dimensional coordinates of retroreflective markers placed on the leg of a humanoid robot. This method helped us estimate the ankle joint angle of the robot accurately, which paved the way for a breakthrough in capturing other delicate joint angles.

Due to the limited number of detected joints by the Kinect algorithm and the inaccuracy in estimating the 3D position of the joints' centers, Kinect could not achieve the same level of accuracy as traditional systems. Joint use of the Kinect skeleton algorithm and Kinect-based marker tracking method was developed to track the 3D coordinates of multiple landmarks on human subjects using a single Kinect. By applying the joint constraints and inverse kinematics techniques on the acquired landmarks' 3D positions, the motion's kinematic parameters of five human subjects and a humanoid robot were calculated during gait trails. The humanoid robot test was used to evaluate the accuracy of the proposed method and a traditional system (OptiTrack) compared to the robot data used as true value. The results of the robot test assured the high-level accuracy of the OptiTrack system. Furthermore, the advantage of applying joint constraints on the captured data by the Kinect was demonstrated. Finally, the full accuracy assessment of the proposed method was done in capturing lower-body joint angles of five

healthy subjects during ten gait trials for each subject. The OptiTrack data were used as ground-truth while the accuracy of the proposed Kinect-base system was compared to the Kinect skeleton model used in previous researches and an IMU-based system (Perception Neuron). The absolute agreement and consistency between each optical system and the robot data in the robot test and between each motion capture system and OptiTrack data in the human gait test were determined using intraclass correlations coefficients (ICC). The reproducibility between systems was evaluated using Lin's concordance correlation coefficient (CCC). The correlation coefficients with 95% confidence intervals (CI) were interpreted substantial for both OptiTrack and the proposed method (ICC>0.75 and CCC>0.95) in the humanoid test. The results of the human gait experiments demonstrated the advantage of the proposed method (ICC>0.75 and RMSE=1.1460°) over the Kinect skeleton model (ICC<0.4 and RMSE=6.5843°) and Perception Neuron (ICC<0.4 and RMSE=4.2396°).