Non Rigid-Body Motion Detection Using Single 6-DOF Data From Skin Based Markers for Brain Imaging

Aditya Singh[1], Brian Keating[1], Benjamin Zahneisen[1], Michael Herbst[1], and Thomas Ernst[1]
[1]*John A. Burns School of Medicine, University of Hawaii, Honolulu, Hawaii, United States*

INTRODUCTION: Tracking of head movement during brain MRI provides valuable information that can be used for prospective or retrospective motion correction [1]. Many external motion tracking systems use one or multiple markers to provide single 6-DOF information [2-3]. The markers are attached to the skin directly or through contraptions such as headbands or glasses. However, skin attachment is susceptible to non rigid-body motion (changes in facial expression), which can introduce errors in pose relative to the brain. Although, detection of skin movement is possible using multiple markers [5], physical constraints (e.g. marker size) may prevent placing more than one marker on the subject. Therefore, we evaluated the feasibility of classifying head motion into rigid-body and non rigid-body motion ("skin movement" or "squints"), using single 6 DOF information and various motion classifiers.

METHODS: An MR compatible tracking system (Metria Innovation Inc., US, [4]) provided 6-DOF head pose data for two separate markers attached to the forehead of a volunteer inside the scanner. The relative rotation between markers was used as the "gold standard" for detecting squints [5]. The subject was asked to1) perform different facial expressions without moving his head, and then 2) move his head without performing any skin motions. The motion included side to side motion, nodding, and lifting and sliding the head. The premise behind the new algorithm is that the onset of squints will be associated with unique, highly correlated motion components, as well as high rotational velocity around the scanner y-axis [6].Using these parameters and their standard deviations, an algorithm was developed in MATLAB® to classify the motion, by counting the number of individual components exceeding heuristically determined thresholds. The algorithm was also tested on involuntary motion data from 6 neonates and 1 adult patient (all non-sedated).

RESULTS

- At the onset of skin motion, the correlation coefficients between the selected seven motion components are very high (threshold 0.85).
- The y rotation velocities (scanner frame) are usually higher for skin movement as compared to regular head motion.
- For markers placed on the forehead, most facial expressions result Z translations to be the maximum component (standard deviation was used to ascertain if Z translation was maximum).

Figures 1 and 2 show the results from the "skin motion only" and "rigid body motion only" experiments. Figure 3 shows the receiver operating characteristic (ROC) curve [7] for the single marker algorithm as compared to the gold standard for all 8 datasets. All points lie in the "good" region (left of identity). The mean TPR was 0.38 and FPR was 0.09. The precision or positive predictive value (PPV) of the algorithm over all datasets was calculated to be 0.86.

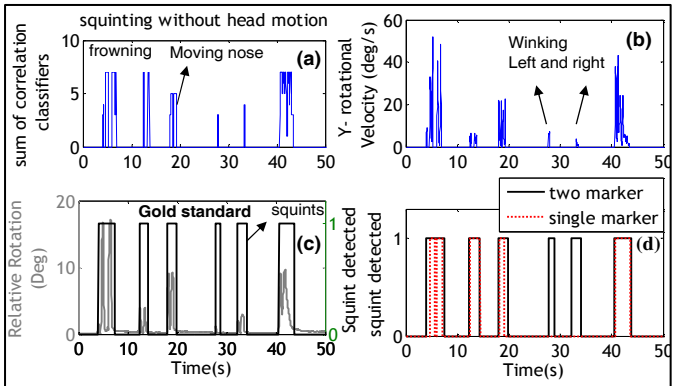

Figure 1. (a) Sum of correlation classifiers (maximum = 7) calculated for periods of significant motion. Each corresponds to a correlation coefficient >0.85 between certain motion components. (b) The y-rotational velocity for the marker. (c) Relative rotation between two markers and the detected squints. (d) the detected squints using single marker algorithm as compared to that detected using two markers.

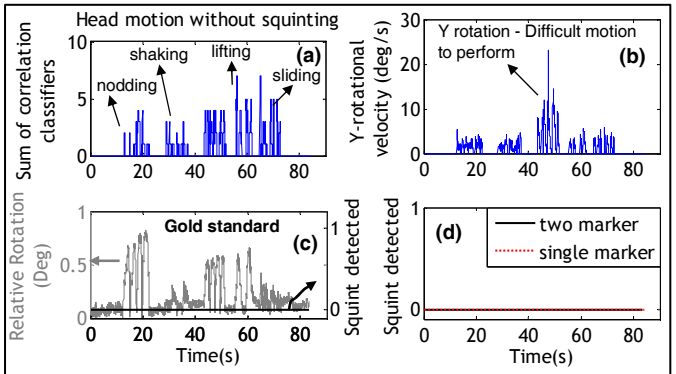

Figure 2. (a) sum of correlation classifiers (correlation>0.85) calculated for periods of significant motion for rigid body motion. The number of correlated components rarely exceed 6. (b) The rotational velocity around Y axis does not exceed 5-8 deg/s for nodding, shaking, lifting or sliding . (c) No squints detected using the gold standard. (d) No squints detected by the single marker algorithm.

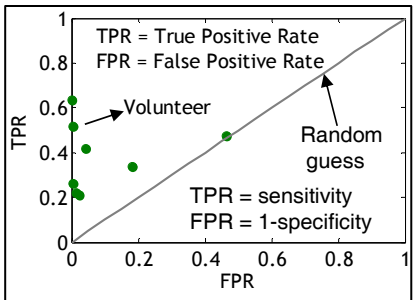

Figure 3. ROC curve for the analyzed data.

CONCLUSION: The feasibility of head motion classification based on a single tracking stream is demonstrated. The effect of tuning parameters on the performance of the algorithm needs to be studied in further detail. The classification algorithm is causal and hence can be implemented in real time. Reliable detection of skin motion would help in determining appropriate processing of raw data in real time or retrospectively for motion correction.

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