Real-time fMRI Motion Tracking: should I stop and restart the scan?

Submission No:

5128

Submission Type:

Abstract Submission

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Introduction:

Excessive head motion is the main reason for discarding fMRI data [1], [2]. As researchers, we regularly ask volunteers to stay inside the scanner for a long period of time and attempt to not move their head, which is especially difficult for children and some clinical populations. Preprocessing of functional neuroimaging data has been consistently improving [3], however, if the noise levels are too high due to head motion, there is only so much it can correct. Collecting good data surpasses any preprocessing strategy.
Typically, with a real-time fMRI software [4], [5] it is possible to monitor head motion through graphs (3- translation and 3-rotation or Framewise Displacement [FD] plots [6]). Nonetheless, using this type of system is not straightforward on deciding if a run where a subject is moving their head should be interrupted or not. This decision is typically subjective. Considering that we would want to perform an fMRI session as quickly as possible and not have to repeat an entire run, can we predict within a short amount of time if an fMRI run will later be discarded? If so, for how long should we run the scan before we interrupt the run an remind the subject to not move their head?
Our group developed software that advises the researcher if a scan should be interrupted or not based on head motion. We quantified the utility of this tool on a large study with children.

Methods:

Our group developed a software (Python and Shell Scripting), that can be included as an add-on to AFNI's real-time fMRI system [7]. The software is configurable to the amount of time that should be waited until a decision to continue or not with the run as well as threshold levels.
Our software can be downloaded here: https://github.com/neuroimagem-pucrs/Real-time-fMRI.
Two resting state fMRI runs from 738 subjects of the Healthy Brain Network [8] were used to test if it is possible to predict at the beginning of a run if the scan will be discarded. These data include children aged 6-21. Each run has a duration of 5 min with a TR=0.8s. Motion estimation was calculated though FD by Power's method [6] by using the C-PAC [9]. Subject data was labeled based on whether it would be discarded or not based on excessive head motion. The first method measured at each frame if it passed a specified FD threshold. If more than X percent of the time-series is above this threshold, the run would be discarded. The second method discards the run if the average FD is above a

specific threshold.
ROC analysis assesses if it is possible to predict if a run would be discarded based on data from the beginning of each run. This was tested at different FD and censoring levels.

Results:

Fig 1 shows a screenshot of the developed software. The software has been tested and validated to work on a GE Signa HDxt MRI scanner. Movement parameters measured by the tool are nearly identical to that obtained by preprocessing the data.
ROC curves of different thresholds are shown in Fig 2. In all threshold levels, ROC curves show that with 60 seconds of data, you can achieve at least a 0.85 True Positive ratio with at most a 0.15 False Positive ratio.

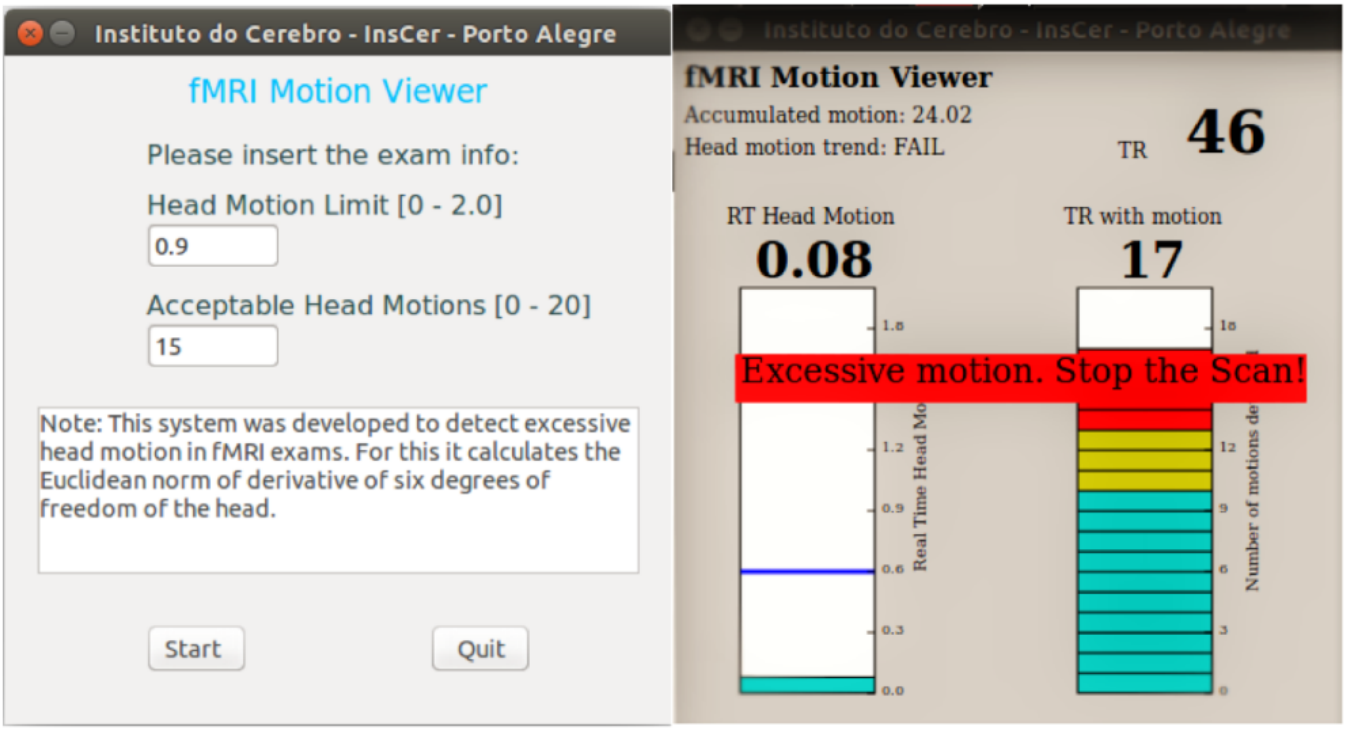

Figure 1: Screenshot of the motion detection tool. On the left is a configuration screen. On the right, shows the warning of when a run should be interrupted.

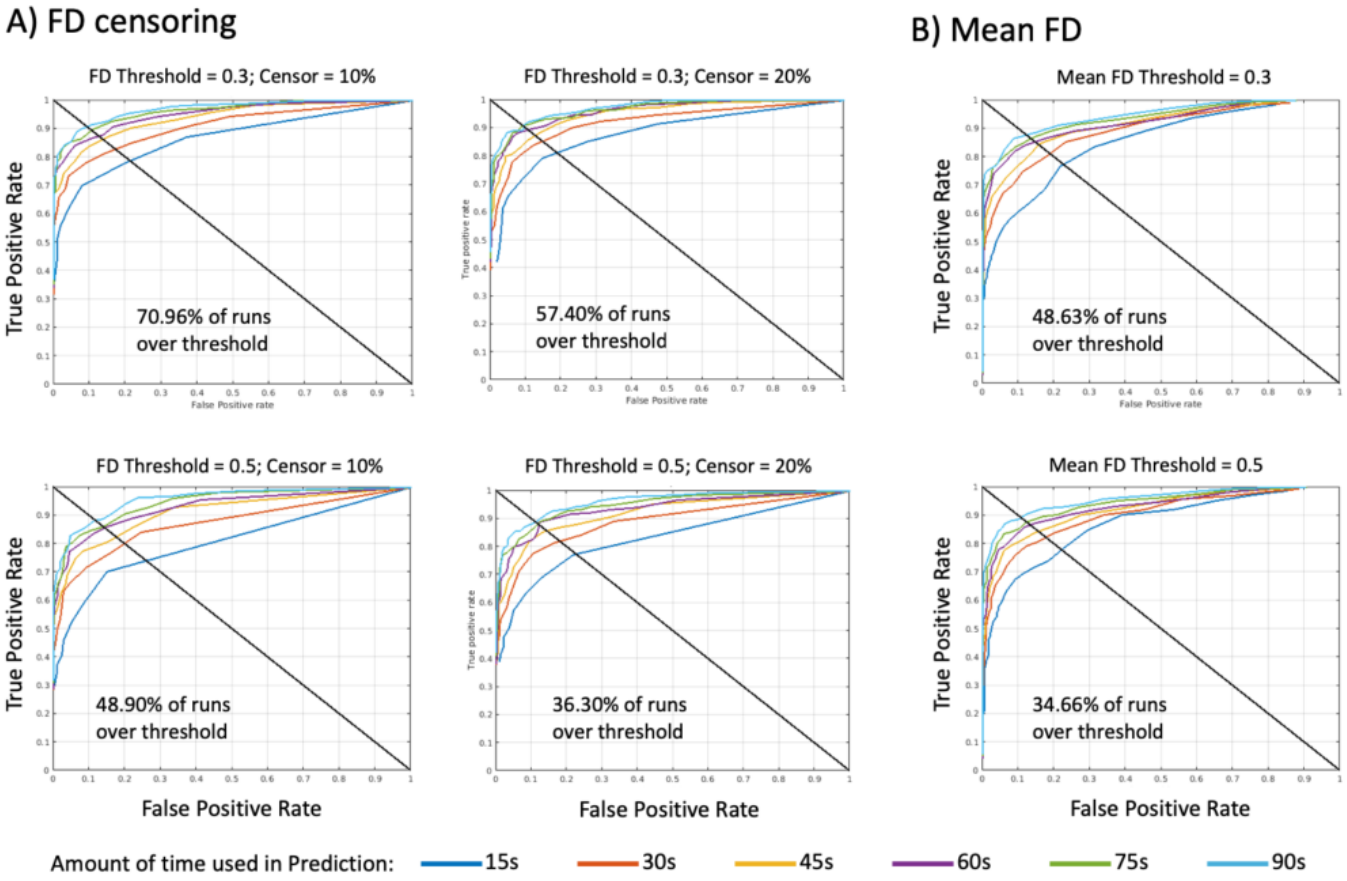

Figure 2: ROC curves by discarding data based on censoring (A) or by mean FD (B). Each panel indicates the percentage of the 1476 runs that would be discarded by that threshold. Colored lines indicate the amount of time necessary to make a prediction if a run would be correctly interrupted or not.

Conclusions:

We have shown that by using software developed by our group, you can accurately predict by collecting only 1 minute of data if a subject's fMRI scan will be discarded or not. This will assist in making a decision if a run should be interrupted based on head motion and minimize the amount of poor-quality data that is collected.
Other solutions include giving subject feedback through visual stimuli [10] or extending the run until enough good data is collected [5]. However, these might not be adequate for task-based or movie watching experiments. There is no guarantee that interrupting a run, reminding the subject that they are moving, and restarting the run will result in a motionless dataset. But, if the scan was not stopped at the beginning of the run, this will almost certainly result in data that will have to be later discarded.

Imaging Methods:

BOLD fMRI

Informatics:

Informatics Other [2]

Modeling and Analysis Methods:

Motion Correction and Preprocessing [1]

Keywords:

Acquisition
Data analysis
FUNCTIONAL MRI
Informatics

[1|2]Indicates the priority used for review