Introduction

The CheckMotion scripts are a quality checking tool for 4D fMRI images saved in the nifti format. They are intended to summarize subject motion using the motion parameter files generated from the realignment stage in preprocessing. The scripts are written in Matlab and include a template and central file like other MethodsCore scripts. The user only needs to set the variable values in the template file to run CheckMotion.

Template File

The template file is an m-file in which the user has to set each variable value listed in it. Each variable includes a description of its purpose above it in the template file, so hopefully setting the values is self-explanatory. The variables to specify path names use a standardized format. The file "**Path Template Documentation.pdf**" directly in the MethodsCore repository explains the standardized format.

We will only go over some variables that need further clarification. **SubjDir** is an Nx3 cell array where N is the number of subjects included and the columns are separated by commas. Column1 lists the subject name as it appears on disk. Column 2 is the subject's number. Its value is not used, so it can be set to any scalar value if needed. Column3 is a vector and lists the runs to include as indexed into the variable **RunDir**. RunDir is a cell array that lists all possible runs as they appear on disk. Below gives example values for SubjDir and RunDir:

```
SubjDir = {
'5001/Tx1/', 1, [1 2 3];
'5002/Tx1/', 1, [1 3];
};

RunDir = {
'run_01';
'run_02';
'run_03';
'run_04';
'run_05';
};
```

In SubjDir, there are two subjects listed and RunDir lists five runs. For the first subject, the runs to include vector is [1 2 3]. These values are indexed into RunDir, so the included runs for subject 5001/Tx1/ are run_01, run_02, and run_03. Similarly, for subject 5002/Tx1, the included runs are run_01 and run_03. Notice both subjects have the same subject number (column 2). While this is not good practice, the script will still run, because this value is not used.

The variables **LeverArm**, **FDLeverArm**, **FDcriteria**, **FramesBefore**, and **FramesAfter** set the values for the assumptions made when summaryizing motion. Typically these variables do not need to be changed from the default. The metrics used to

summarize motion are Euclidean displacement and frame displacement (FD). For more information about Euclidean displacement, check the file MethodsCore/matlabScripts/euclideandisplacement.pdf. Frame displacement is a single scalar value which summarizes motion for one frame relative to the previous frame (Power et al 2011). It is in units of millimeters and is given by the following equation:

$$FD_i = |\Delta d_{ix}| + |\Delta d_{iy}| + |\Delta d_{iz}| + |\Delta \alpha_i| + |\Delta \beta_i| + |\Delta \gamma_i|$$

where $\Delta d_{ix} = d_{(i-1)x} - d_{ix}$ and

$d_{ix} = x\ translational\ parameter\ at\ volume\ i$
$d_{iy} = y\ translational\ parameter\ at\ volume\ i$
$d_{iz} = z\ translational\ parameter\ at\ volume\ i$
$\alpha_i = pitch\ rotational\ parameter\ at\ volume\ i$
$\beta_i = yaw\ rotational\ parameter\ at\ volume\ i$
$\gamma_i = roll\ rotational\ parameter\ at\ volume\ i$

Rotational displacements are converted from degrees to millimeters by calculating displacement on the surface of a sphere or radius given value of the variable **FDLeverArm**.

Output

CSV File

A csv file is written to the location set by the variable **OutputPathTemplate**. Figure 1 displays an example csv file opened in Open Office. The top row is the header and labels what each column is. Each run for a subject is summarized along the remaining rows. Table 1 describes the meaning of each column.

	A	B	C	D	E	F	G	H	I	J
1	Subject	Run	maxSpace	meanSpace	sumSpace	maxAngle	meanAngle	sumAngle	meanFD	SupraThresholdFD
2	CF1229CHR	run_01/	0.11	0.03	6.42	0.21	0.05	9.62	0.09	14
3	CF1229CHR	run_02/	0.24	0.06	11.55	0.31	0.09	18.08	0.16	121
4	CF1244CHR	run_01/	0.31	0.05	10.25	0.25	0.05	11.25	0.12	57
5	CF1244CHR	run_02/	0.17	0.04	8.58	0.28	0.06	12.73	0.12	46
6	CF1250CHR	run_01/	0.23	0.08	17.5	0.25	0.08	16.82	0.19	175
7	CF1250CHR	run_02/	1.1	0.1	20.31	0.71	0.11	21.97	0.24	196
8	CF1265CHR	run_01/	0.31	0.05	10.33	0.21	0.06	12.13	0.12	64
9	CF1265CHR	run_02/	0.14	0.04	7.68	0.15	0.05	9.58	0.1	21
10	CF1269CHR	run_01/	0.07	0.02	4.64	0.14	0.04	7.71	0.06	0
11	CF1269CHR	run_02/	0.13	0.03	5.92	0.14	0.05	9.85	0.08	20
12	CF1272CHR	run_01/	0.98	0.08	16.92	1.56	0.09	19.2	0.2	150
13	CF1272CHR	run_02/	0.74	0.1	20.14	1.2	0.11	24	0.25	164

Figure 1. An example output csv from CheckMotion.

Censor Vector Mat File

The variable **OutputCensorVector** sets the name and path for the output censor vectors. The output is a mat file containing a vector of 0's and 1's where 1 indicates a

volume to censor. These mat files are primarily used as input to ConnTool. If **OutputCensorVector** is left as an empty string (‘’), no mat files will be written to disk.

Table 1.

Column Name	Description
Subject	subject name
Run	run name as listed in **RunDir** variable
maxSpace	calculated from translational parameters only; maximum Euclidean displacement between volumes; units of millimeters
meanSpace	calculated from translational parameters only; mean Euclidean displacement between volumes for whole run; units of millimeters
sumSpace	calculated from translational parameters only; sum of Euclidean displacment between volumes for whole run; units of millimeters
maxAngle	calculated from rotational parameters only; maximum Euclidean displacment between volumes; units of millimeters
meanAngle	calculated from rotational parameters only; mean Euclidean displacment between volumes for whole run; units of millimeters
sumAngle	calculated from rotational parameters only; sum of Euclidean displacement between volumes for whole runs; units of millimeters
maxFDpre	maximum frame displacement for a run before censoring; units of millimeters
stdFDpre	standard deviation of frame displacement for a whole run before censoring; units of millimeters
meanFDpre	mean frame displacement for a run before censoring; units of millimeters
maxFDpost	maximum frame displacement for a run after censroing; units of millimeters
meanFDpost	mean frame displacement for a run after censoring; units of millimeters
stdFDpost	standard deviation of frame displacement for a whole run after censoring; units of millimeters
SupraThresholdFD	number of volumes that exceed the frame displacement value set for the variable **FDcriteria**
TotalVolume	number of volumes in the run
ScrubRatio	fraction of volumes censored (volumes that exceed **FDcriteria)**

Motion PDF Plot

The variables **OutputPlotPath**, **OutputPlotFile**, **RealignType**, and **PreRealignTemplate** are used to create translational and rotational plots for each subject. Motion parameters are concatenated across runs for each subject in each plot. The plots will be saved as a pdf file in the folder specified by OutputPlotPath and with file name OutputPlotFile. The output directory is not created and must exist before the

motion template file is run. If OutputPlotPath is set to an empty string (‘’), no motion plots will be created. RealignType states what program (FSL or SPM) was used to realign the functional images. This is important, because SPM and FSL write the rotational and translational parameters in different orders. Also, functional images realigned in SPM require the motion between runs to be recalculated, and the functional images input into SPM for realignment are needed to perform this calculation. SPM should have created mat files for the pre-realigned functional images and these also must still exist on disk in order to calculate the motion between runs. The PreRealignTemplate variable points to the pre-realigned functional images for each run; typically, this is the slice-timed corrected functional file. To output the best formatted pdf file, it is best not to run Matlab with the –nodisplay argument. Figures 2 and 3 show example translational and rotational plots respectively.

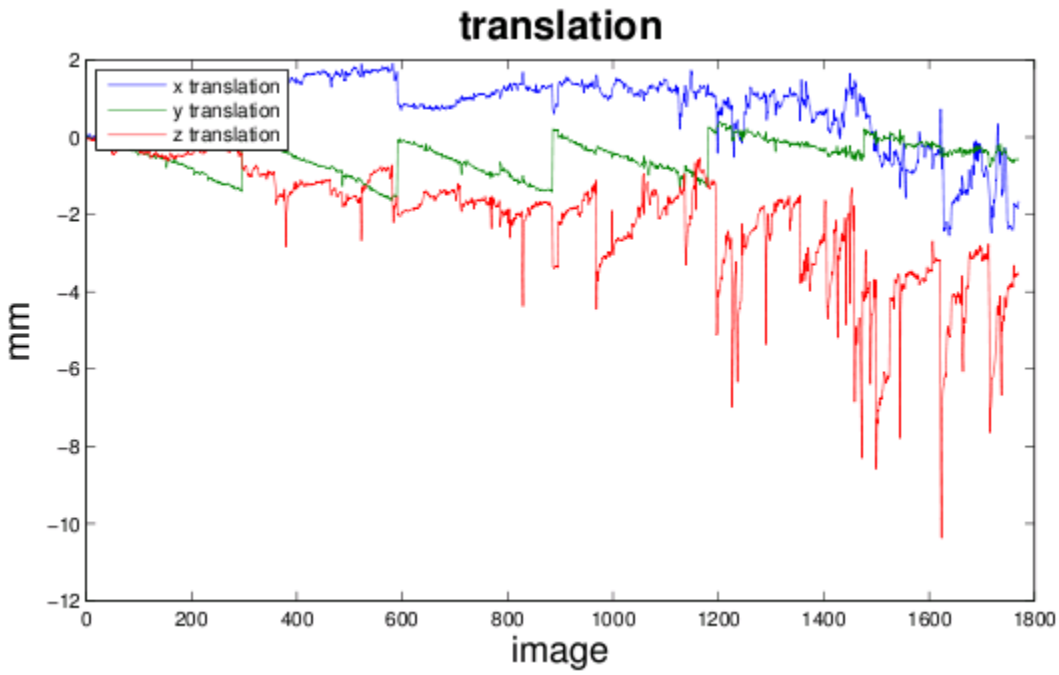

Figure 3. Example translational plot.

fdOutliers.csv

For each run a csv file named fdOutliers.csv is written in the same folder where the motion parameters are located. Each row represents one volume in the run. Each column is a regressor to censor one volume with frame displacement exceeding the FDcriteria. There is the same number of columns as there are volumes which have frame displacement values that exceed the FDcriteria. The regressors equal 0 at all rows except at a volume where its frame displacement value is greater than the FDcriteria value. These csv files are primarily intended to be used in the first level template file to censor volumes high motion.

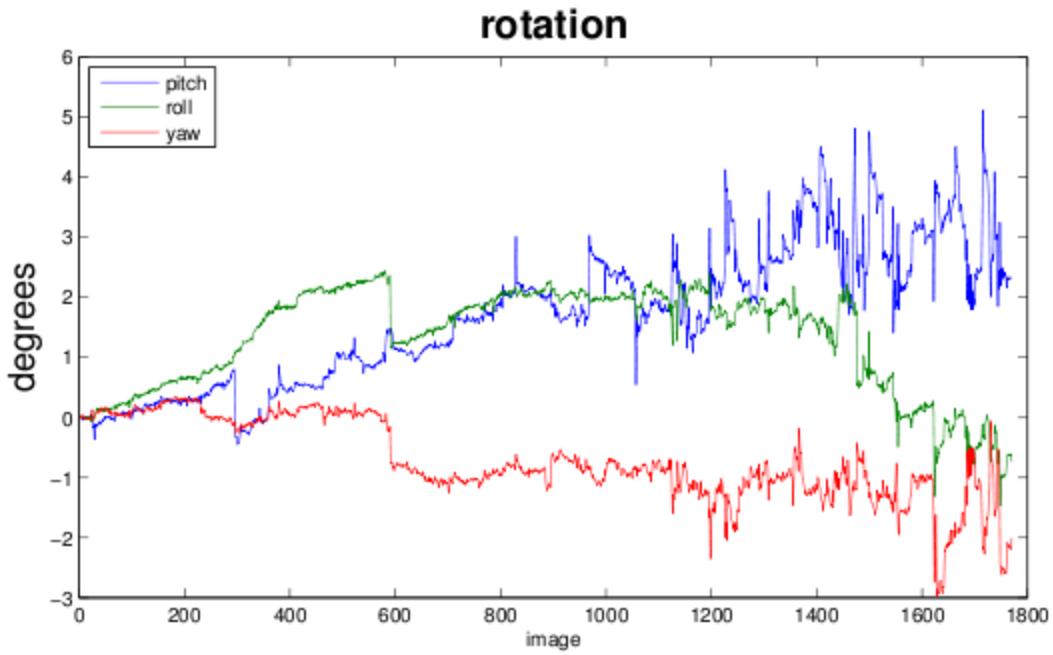

Figure 4. Example rotational plot.

Additional Help

If additional help is required email methodscore@umich.edu

The following link demonstrates how to use the CheckMotion toolbox:
http://youtu.be/UXsq1T1L7IQ