1 Program 3dfim

1.1 Purpose

Program 3dfim calculates a functional image from a 3d+time data file by cross correlation of each voxel time series with a user specified reference time series. The functional image may then be used as input to program afni to provide a visual display of the locations of those voxels showing a statistically significant correlation of intensity with the reference time series.

1.2 Usage

The command line format for program 3dfim is as follows:

3dfim [-im1 num] -input fname -prefix name -ideal fname [-percent p] [-ort fname]

1.3 Options

-im1 num 'num' is the index of the first image to be used in time series correlation; prior images will be ignored. The default is 1.

-input fname 'fname' is the filename of a 3d + time data file for input. This is the source of the $\mathbf{x}$ data time series mentioned above (for each voxel).

-prefix name 'name' is the prefix of the filename for saving the output functional data.

The output file is an *AFNI* "fico" dataset; i.e., a 2 sub-brick data file, where the first sub-brick consists of the unnormalized image intensity (which is used to choose overlay colors), and the second sub-brick contains the partial correlation coefficient for each voxel. This may be represented schematically by:

$$\textit{AFNI}\ \text{“fico” dataset} \quad \left\{ \begin{array}{l} \boxed{\alpha = \dfrac{\langle \mathbf{Pr}, \mathbf{Px} \rangle}{|\mathbf{Pr}|^2}} \\ \\ \boxed{\rho = \dfrac{\langle \mathbf{Pr}, \mathbf{Px} \rangle}{|\mathbf{Pr}|\,|\mathbf{Px}|}} \end{array} \right.$$

where

$\mathbf{x}$ = data time series (as a vector),
$\mathbf{r}$ = reference (ideal) time series,
$\mathbf{S}$ = matrix formed from 'ort' time series (including polynomials),
$\mathbf{P}$ = projection matrix that removes undesired components of signal
$= \mathbf{I} - \mathbf{S}[\mathbf{S}^T\mathbf{S}]^{-1}\mathbf{S}^T$,
α = unnormalized image intensity, used to choose overlay colors,
ρ = partial correlation coefficient.

-ideal fname 'fname' is the filename of a time series to which the image data is to be correlated. This is the source of the **r** reference (ideal) time series mentioned above. More than one ideal time series may be used (see below).

-percent p The -percent command provides an alternative output value for the intensity sub-brick. If this command is used, then the program calculates the percentage change of the input time series, relative to the baseline, accounted for by the ideal time series. If more than one ideal time series is specified, then this calculation uses the ideal which is most highly correlated with the input time series. The number p specifies the *maximum* value allowed for the calculated percentage (i.e., if the calculated percentage is greater than p, then it is set equal to p). Obviously, it is required that $p > 0$.

The output file is an *AFNI* "fico" dataset; i.e., a 2 sub-brick data file, where the first sub-brick consists of the percentage change, and the second sub-brick contains the partial correlation coefficient for each voxel.

$$\textit{AFNI}\ \text{“fico” dataset} \quad \left\{ \begin{array}{l} \boxed{\% = 100 \cdot \dfrac{|\alpha|(r_{\max} - r_{\min})}{baseline}} \\[2em] \boxed{\rho = \dfrac{\langle \mathbf{Pr}, \mathbf{Px} \rangle}{|\mathbf{Pr}|\,|\mathbf{Px}|}} \end{array} \right.$$

where
$r_{\max}$ = maximum value of the reference (ideal) time series,
$r_{\min}$ = minimum value of the reference (ideal) time series,
baseline = absolute value of the average of the input data time series, i.e.,

$$baseline = |\bar{x}| = \left| \frac{1}{n} \sum_{i=1}^{n} x_i \right|$$

-ort fname 'fname' is the filename of a time series to which the image data is to be orthogonalized. The 'ort' time series is used to create the **S** matrix mentioned above. More than one 'ort' time series may be used (see below). Note: whether or not an ort time series is specified by the user, the program will always remove a constant plus linear trend from the image time series data.

Note that it is possible to specify more than one ideal time series file. Each ideal time series is separately correlated with the image time series and the one most highly correlated is selected for each voxel. Multiple ideals are specified using more than one '-ideal fname' option, or by using the form '-ideal [fname1 fname2 ...]' – this latter method allows the use of wildcarded ideal filenames. The '[' character that indicates the start of a group of ideals can actually be any ONE of these: [{/% and the ']' that ends the group can be:]}/%

The file containing the ideal time series must be in the following format:

- ASCII; one number per line;
- Same number of lines as images in the time series;
- Any value over 33333 means "don't use this image in the analysis".

It is also possible to specify more than one 'ort' time series file. The image time series is orthogonalized to each ort time series. Multiple orts are specified using more than one '-ort fname' option, or by using the form '-ort [fname1 fname2 ...]' – this latter method allows the use of wildcarded ort filenames. The '[' character that indicates the start of a group of ideals can actually be any ONE of these: [{/% and the ']' that ends the group can be:]}/%

The file containing the ort time series must be in the following format:

- ASCII; one number per line;
- At least same number of lines as images in the time series.

1.4 Examples

Example 1. Suppose that file fred.ts+orig.BRIK contains 3D+time data, and that the user wishes to determine which voxels are correlated with the reference time series in file cos7.25.1D (a cosine waveform). File cos7.25.1D might have the following appearance:

$$\begin{array}{c} 100000 \\ 100000 \\ 100000 \\ 100000 \\ -195 \\ 555 \\ 980 \\ 831 \\ 195 \\ -555 \\ -980 \\ -831 \\ -195 \\ \text{etc.} \end{array}$$

Since the first 4 numbers in the file are greater than 33333, this tells program 3dfim to ignore the first 4 images.

The command line sequence to correlate this reference time series with the image data in file fred.ts+orig.BRIK is given by

```
3dfim -ideal cos7.25.1D -prefix fred.tscorr -input fred.ts+orig
```

The resulting output will be stored in file fred.tscorr+orig.BRIK (and .HEAD). Now, this output will show which voxels are correlated with the given reference time series, which is a cosine waveform of a specific frequency and phase. The frequency of the cosine wave is, of course, that of the task which was used during the experiment.

Example 2. (Continuation of previous example). Since the time delay will vary from voxel to voxel, it would be more meaningful to correlate the image time series with cosine waves of the same frequency, but having different phases (corresponding to different time delays). This is accomplished by using more than one ideal time series. Suppose that files cos7.00.1D, cos7.25.1D, cos7.50.1D, cos7.75.1D, cos8.00.1D, cos8.25.1D, cos8.50.1D, and cos8.75.1D contain copies of the cosine waveform, all at the same frequency, but with different phase shifts. Then, to find the best correlation at each voxel of the image time series with each of these ideal times series, one could use the command line:

```
3dfim -ideal [ cos7.00.1D cos7.25.1D cos7.50.1D \
cos7.75.1D cos8.00.1D cos8.25.1D cos8.50.1D cos8.75.1D ] \
-prefix fred.tscorr -input fred.ts+orig
```

where the list of ideal time series files is contained between the '[' and ']' symbols. Assuming that no other files in this directory begin with 'cos', this command line may be abbreviated by using the 'wildcard' symbol '*' as follows:

```
3dfim -ideal \[cos*\] -prefix fred.tscorr -input fred.ts+orig
```

In both cases, the output file fred.tscorr+orig.BRIK (and .HEAD) contains the *AFNI* 'fico' dataset, where, for each voxel, the image intensity α and the partial correlation coefficient ρ correspond to the ideal time series to which the voxel time series is most highly correlated.

(Note that '[' and ']' are special characters to the C-shell and so must be escaped (with '\' characters) on the command line.)

Example 3. The user suspects that external physiological activity is interfering with the signal analysis; specifically, that breathing and heart rate may be "contaminating" the true neurological response. In order to remove these unwanted effects from the data, suppose that measurements of breathing and heart rate, time synchronized with the fMRI data, are stored in files lung.1D and heart.1D. Then the '-ort' command is used to remove the influence of these factors:

```
3dfim -ideal [ cos7.00.1D cos7.25.1D cos7.50.1D \
cos7.75.1D cos8.00.1D cos8.25.1D cos8.50.1D cos8.75.1D ] \
-ort [ heart.1D lung.1D ] \
-prefix fred.tscorr -input fred.ts+orig
```

The output file fred.tscorr+orig.BRIK (and .HEAD) contains the *AFNI* 'fico' dataset, where, for each voxel, the image intensity α and the partial correlation coefficient ρ correspond to the ideal time series to which the voxel time series is most highly correlated, *after* the effect of the heart and lung data has been removed from the image data.