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This archive contains binary executables that can be used to extract, match and visualize scale-invariant features in volumetric images. Additionally, input data and expected output data are provided for verification.

Executables are compiled for Windows (static *.exe), Ubuntu Linux (static *.ubu) and Mac OSX 10.9.2 (*.mac).

This code provides an implementation of applications and functionality described in the following references:

- M. Toews, W.M. Wells III. “Efficient and Robust Model-to-Image Alignment using 3D Scale-Invariant Features”, Medical Image Analysis, 17(3), 2013, pp 271-282.

- M. Toews, L. Zöllei, W.M. Wells III. "Invariant Feature-based Alignment of Volumetric Multi-modal Images", Image Processing in Medical Imaging (IPMI), 2013, pp. 25-36, 2013.

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DISCLAIMER

OASIS Data Usage Agreement (DUA) www.oasis-brains.org

Several images from the Open Access Structural Imaging Series (OASIS) are used as example data. Data users must recognize & agree to the following points:

1. The quality and completeness of the data cannot be guaranteed. Users employ these data at their own risk.
2. Users shall respect restrictions of access to sensitive data. Users will make no attempt to identify the individuals whose images are included in OASIS data sets.
3. Users must acknowledge the use of OASIS data and data derived from OASIS data when publicly presenting any findings or algorithms that benefited from their use. Such presentations include but are not limited to papers, books, book chapters, conference posters, and talks.
   When publishing findings that benefit from OASIS data, please include the following grant numbers in the acknowledgements section and in the associated Pubmed Central submission: P50 AG05681, P01 AG03991, R01 AG021910, P20 MH071616, U24 RR021382.
4. Redistribution of original OASIS data is permitted so long as the data are redistributed under the same terms and conditions are described in this DUA.
5. Data derived from original OASIS data may be distributed under terms and conditions established by the creators of the data. Users must comply with the terms and conditions of use set by the creators of the data.

********** Files **********

Binary Executables

featExtract.(exe/ubu)	– feature extraction
featMatchMultiple.(exe/ubu)	– feature matching
featView.(exe/ubu)	– feature viewing
featResample.(exe/ubu)	– image resampling

Sample Brain Images (from the OASIS data set)

OAS1_0001.hdr OAS1_0001.img
OAS1_0002.hdr OAS1_0002.img
OAS1_0003.hdr OAS1_0003.img

Extracted keyponts for each image (generated by featExtract.exe)

OAS1_0001.key
OAS1_0002.key
OAS1_0003.key

Keypoints transformed to the reference image OAS1_0001.key (generated by featMatchMultiple.exe)

OAS1_0002.key.update.key
OAS1_0003.key.update.key

Report on number of inliers found for each image match (generated by featMatchMultiple.exe)

report.txt

Lists of matching features found for each image and reference image (generated by featMatchMultiple.exe)

OAS1_0002.key.matches.img1.txt – matches in reference image (OAS1_0001.key)
OAS1_0002.key.matches.img2.txt – matches in image (OAS1_0002.key)
OAS1_0003.key.matches.img1.txt – matches in reference image (OAS1_0001.key)
OAS1_0003.key.matches.img2.txt – matches in image (OAS1_0003.key)

Global similarity transform between image and reference image (generated by featMatchMultiple.exe)

OAS1_0002.key.trans.txt	– transform mapping OAS1_0002.key to OAS1_0001.key
OAS1_0002.key.trans-inverse.txt	– transform mapping OAS1_0001.key to OAS1_0002.key
OAS1_0003.key.trans.txt	– transform mapping OAS1_0003.key to OAS1_0001.key
OAS1_0003.key.trans-inverse.txt	– transform mapping OAS1_0001.key to OAS1_0003.key

Visualization of a feature in OAS1_0001.hdr in pgm format (featView.exe)

view_test.pgm.OAS1_0001.hdr_x100_y100_z100.pgm

********** Command Line Examples **********

Run the following command line examples to extract features, match features, view feature matches, and to resample images.

```
>featExtract.exe -qto_xyz .\OAS1_0001.hdr .\OAS1_0001.key
>featExtract.exe -qto_xyz .\OAS1_0002.hdr .\OAS1_0002.key
>featExtract.exe -qto_xyz .\OAS1_0003.hdr .\OAS1_0003.key
```

These commands extract features in each image, and produce output keypoint files *.key
The -qto_xyz option specifies feature output coordinates in millimeter units in world coordinate space, according to the NIFTI / ANALYZE header.

```
>featMatchMultiple.exe OAS1_0001.key OAS1_0002.key OAS1_0003.key
```

These commands will match all (*.key) feature files to a reference image / feature file. The reference image / feature file is the first on the command line, here OAS1_0001.key.
The output will be several text files detailing transforms, corresponding features, etc., see below.

Note: wildcards can be used, e.g. `featMatchMultiple.exe *.key`. Be careful here as additional updated/transformed keypoint files (*.update.key) maybe be present.

```
>featResample.exe OAS1_0001.hdr OAS1_0002.hdr OAS1_0002.key.trans-inverse.txt
OAS1_0001_0002.hdr
```
This will resample OAS1_0002.hdr into reference space OAS1_0001.hdr, using the OAS1_0002.key.trans-inverse.txt file generated by featMatchMultiple.exe
The output file is OAS1_0001_0002.hdr, it should be a slightly shifted/rescaled version of OAS1_0002.hdr

```
>featView.exe –qto_xyz OAS1_0001.hdr 100 100 100 10 view_test
```
This will output a visual display image of a feature at xyz=(100,100,100), scale 10, located in image OAS1_0001.hdr.
Produces an output image in pgm format view_test.OAS1_0001.hdr_x100_y100_z100.pgm
The -qto_xyz option specifies feature output coordinates in millimeter units in world coordinate space, according to the NIFTI / ANALYZE header. If this option was used in featExtract.exe, it should be used here.

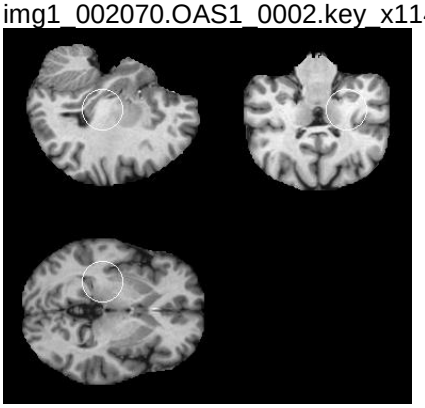
```
>featView.exe OAS1_0002.key.matches.img2.txt
```
This will output a visual display of all features from OAS1_0002.key that matched to OAS1_0001.key during featMatchMultiple.exe
Input is text file OAS1_0002.key.matches.img2.txt created by featMatchMutiple.exe
Produces 33 output images in *.pgm format

```
>featView.exe OAS1_0003.key.matches.img2.txt
```
This will output a visual display of all features from OAS1_0003.key that matched to OAS1_0001.key during featMatchMultiple.exe
Input is text file OAS1_0003.key.matches.img2.txt created by featMatchMutiple.exe
Produces 70 output images in *.pgm format

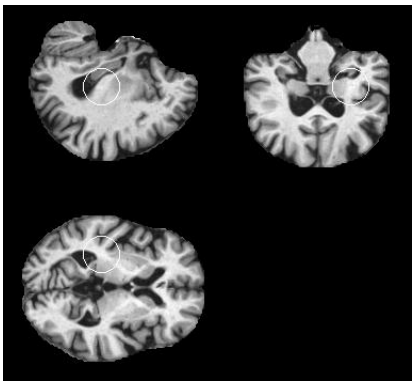
********** Notes **********

Note 1: There should be two visualization images beginning with 'img1_002070'. This means that there are features in OAS1_0002.key and OAS1_0003.key that mapped to the same feature 2070 in the reference image OAS1_0001.key. This indicates the presence of image structure that is similar in geometry and appearance in all three images, see white circles shown below in sagittal, axial and coronal views.

img1_002070.OAS1_0002.key_x114_y093_z076.pgm



img1_002070.OAS1_0003.key_x118_y092_z076.pgm



Note 3: algorithms results differ slightly from one operating system to another, apparently due to small differences in floating point math processing.

Note 4:

********** Future ToDo **********

1. Feature-based morphometry application.
2. Feature-based model construction application.
3. Conversion between voxel and world coordinates.