Contrast Enhanced Magnetic Resonance Imaging of Gastric Emptying and Motility in Rats

This document describes the main source code (built under Matlab r2015a) related to Lu et al., 2017. Example datasets (gastric MRI images collected in rats) are provided along with the source code. The scripts are organized according to prefixes:

Global scripts: Path to root folder, parameters necessary for image processing, etc.
Amri scripts: Image processing scripts for main processing and sub-functions.
Tools scripts: functions for general purposes.

GLOBAL scripts:

```
global_getcfg.m
```

This is the function which defines a Matlab structure containing the parameters necessary for the analysis pipeline. Example inputs include spatial resolution of the images, parameters for fuzzy c-means clustering, parameters for localized active contour, and options for segmentation methods, etc.

```
global_path2root.m
```

This is the function which defines a Matlab structure containing the path to volume/motility data.

AMRI scripts:

```
amri_volume_main.m
```

This is the main script for segmenting and partitioning 3D gastric MRI image (i.e. the volume scan). The script was developed in Red Hat Linux. The script contains the following procedures:

0: set global variables
1: load data
2: anisotropic smoothing (optional)
3: image segmentation using fuzzy c-means clustering and refine using localized active contour
4: stomach/intestine separation
5: partition of stomach into forestomach, corpus and antrum
6: calculate pylorus diameter

```
amri_volume_segmentation.m
```

This Matlab code segments the gastrointestinal tract in contrast-enhanced MR images. Note that some voxels in large veins with much shortened T1 and those in the renal medulla because of systemic Gd absorption might be mistakenly included in the above segmentation. Such spurious voxels need to be manually identified and excluded for proper calculation of the GI volume. In

addition, the heterogeneous image intensity (e.g. feces with unenhanced and/or partly enhanced image intensity) in the colon raised difficulty in proper quantification of the colonic volume; hence, voxels in the colon are suggested to be removed as well.

amri_volume_GIseparation.m

This Matlab code partitions the segmented GI tract into the stomach and the intestines (duodenum, ileum and jejunum) by using a morphological approach (erosion followed by dilation) to disconnect the two compartments at the pylorus. Depending on the size of the pylorus, users will need to adjust the size of the kernel for proper delineation.

amri_volume_stomachPartition.m

This Matlab code partitions the segmented stomach into the forestomach, the corpus and the antrum.

amri_volume_calcPylorusArea.m

This Matlab code allows users to manually determine the cross-sectional area at the pylorus within the selected slices in the MR image.

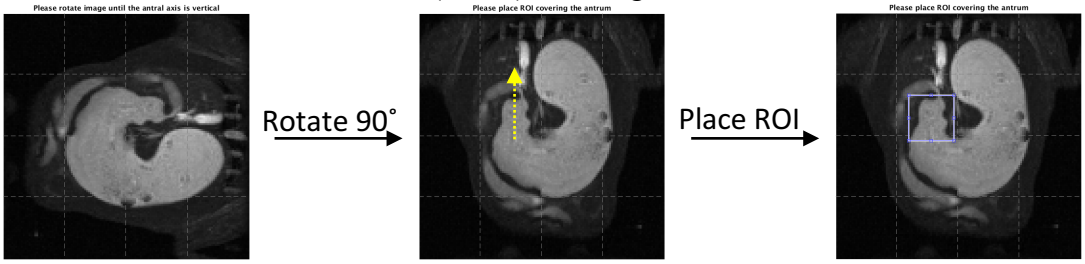
amri_motility_main.m

This is the main script for segmenting the antrum from the 4D gastric MRI image (i.e. the motility scan) and for computing the contraction frequency, contraction amplitude and the velocity of the propagating contraction wave. The script was developed in Red Hat Linux. The script contains the following procedures:

0: set global variables
1: load data
2: motion correction (optional)
3: antrum segmentation
4: construct spatio-temporal motility map
5: compute motility statistics (contraction frequency/amplitude/velocity)

amri_motility_createROI.m

This Matlab code allows users to rotate (orient) the image and draw an ROI at the antrum.



amri_motility_segmentation.m

This Matlab code segments the gastrointestinal tract in contrast-enhanced MR images. Segmentation methods include Otsu segmentation (faster but requires a better contrast of image quality) and fuzzy c-means clustering followed by localized active contour (slower but capable of dealing with blurrier images with weak edges).

amri_motility_selectTimeseries.m

This Matlab code allows users to extract contraction time series from the condensed motility map.

amri_motility_calcIndex.m

This Matlab code computes contraction frequency, contraction amplitude and velocity of propagating contraction wave.

Tools scripts:

tools_anisodiff3D.m

This function performs anisotropic diffusion filtering on gray scale images.

tools_displayImage.m

This function display 4D (3D + time) images with a specified frame rate.

tools_FCM.m

This function performs fuzzy-c-means clustering on N-D images.

tools_filterfft.m

This function performs low-pass, high-pass, or band-pass filtering using a pair of forward and inverse Fourier transform.

tools_getLargestCc.m

This function computes and returns N largest connected-components in the input N-D matrix.

tools_KM.m

This function performs k-means clustering on N-D images.

tools_localActiveContour.m

This function performs localized active contour segmentation on 2D images.

tools_MotionCorrection.m

This function performs regid registration on 4D (3D+time) images.

tools_otsuSeg.m

This function is adapted from Matlab's built-in Otsu segmentation. This function is capable of performing Otsu segmentation within a given mask.

tools_peakdet.m

This function detects peaks and valleys in a time series given a threshold.

tools_phdiffmeasure.m

This function measures phase difference between two signals.

tools_psd.m

This function computes the power spectrum density of a signal.

tools_sliceview.m

This function displays 3D (2D slices) in a mosaic view.

References:

[1] Lu K-H, Cao J, Oleson S, Powley TL, Liu Z., "Contrast enhanced magnetic resonance imaging of gastric emptying and motility in rats," IEEE Transactions on Biomedical Engineering, 64(11): 2546-2554, 2017.

[2] Lu K-H, Cao J, Oleson S, Ward P, Phillips RL, Powley TL, Liu Z., "Vagus nerve stimulation promotes gastric emptying by increasing pyloric opening measured with magnetic resonance imaging," Neurogastroenterology and Motility, doi: 10.1111/nmo.13380, 2018.