QUALITY ESTIMATION OF MOTION CORRECTION FOR PET BRAIN IMAGES

S. Anishchenko [1, 2], R. Hui [2, 3], Y.K. Liang [3], Z.M. Tian [3], W.S. Lu [3], R. Comley [2], X. Gao [2]
[1]A.B.Kogan Research Institute for Neurocybernetics, Southern Federal University,
Rostov-on-Don, Russia, sergey.anishenko@gmail.com
[2]School of Engineering and Information Sciences, Middlesex University,
London, NW4 4BT, UK, x.gao@mdx.ac.uk
[3]Chinese PLA Navy General Hospital,
Beijing, China, huirui2002@163.com

Patient's movement during the acquisition of Positron Emission Tomography (PET) can significantly degrade image quality. Hence, development of a motion correction system is an essential task for preserving image information and thereafter improving diagnosis accuracy. Performance evaluation is a required step in such a development. In this paper a simulation-based technique for evaluation of motion correction of PET brain images is described, whereas the sum of optical flow technique has been developed to measure the correction.

Introduction

With the advent of modern imaging technology, PET has become a more accurate procedure and can reach 2mm spatial resolutions [1, 3] for brain scanning. However, patient's movement becomes a major factor that degrades the image quality. Thus it is important to take movements into account and respectively correct PET-data. As a result, it will benefit PET-based diagnosis considerably and make research more reliable and accurate.

In general during the procedure of PET scanning, a few types of motion can occur:

1. Motion caused by the respiratory cycle.
2. Motion due to patient's uncontrollable medical conditions.
3. Motion due to the subject's accidental movement.

Each type needs its own specific approach to correct images. This research focuses on the third type of movement during the brain imaging procedure which in turn can fall into two groups:

1. Drifting. Slow changing of head position.
2. Spontaneous movement. Fast head pose changing.

These two types of movement affect the resulting brain images in different ways and therefore need different strategies for correction. This paper deals with the spontaneous movement, i.e., the second type of movements.

Correction can be performed in (1) list-mode or (2) frame-mode. The advantage of list-mode is that erroneous events can be corrected before image reconstruction (thus the reconstruction algorithm does not accumulate errors). But it was shown that list-mode correction sometimes can yield image artifacts [1]. Also in most cases it is impossible to get access to list-mode raw data. On the contrary, the frame-mode data is always available from a PET scanner. An intra-frame movement cannot be taken into account in frame-mode, but the frames can be reconstructed based on motion-free data, while the data corrupted by motion can be discarded.

With this in mind, image correction algorithms can fall into three groups according to the data used for motion estimation:

1. Emission data.
2. Transmission data.
3. External motion tracker.

Algorithms developed for the first group process data in frame-mode. One frame should be chosen as a reference whereas all the others can be realigned with reference to the chosen frame. Intra-frame movement cannot be taken into consideration in this case.

The second type of algorithms uses transmission data as a reference to realign PET data in the frame-mode. The main disadvantage of this method is that there is no exact metric to compare emission and transmission data due to their different nature [2].

An external motion tracker can be used for PET-data correction in both frame- or list-mode. It is an attractive technique and will become the constituent part of high-resolution PET brain scanners in the near future. It is particularly important for dedicated brain scanners. Comparing with multipurpose scanners, it can use smaller detectors and, therefore, produce higher-resolution images [3].

A simulation-based evaluation technique for motion correction of PET brain images is described below. It is assumed that an external motion tracker is used to detect a patient's head pose.

Experimental setup

In this work real PET data was used to perform computer simulation. Data was collected in the PET-CT centre of the Chinese PLA Navy General Hospital during real scan procedures on a GE Discovery ST PET/CT system.

To capture video clips monitoring a patient's head during PET scanning, extra equipment (one stereo rig and one photo camera) was installed behind the gantry (Fig. 1.1).

For the stereo rig, two Genius 1.3 Mpx web cameras were used. A SONY DSC-H5 7.2 Mpx camera was used for the photo rig.

In total, video data was collected for 12 patients. Each patient at first was scanned using CT (whole body scanning, duration ~ 20 minutes). After that the patient was scanned using PET (brain scanning only, duration ~ 5 minutes). Such a short period of PET scanning was used because the purpose was to check for metastasis in the brain and 5 min is enough for this task. After scanning, the PET data for 3 patients was reconstructed in 2 seconds frames.

Computer Simulation

The evaluation of a motion correction system for PET brain imaging is a challenging task due to many reasons and one of them is the absence of a "gold standard". In other words to check correction precision we need to know how brain images look in both cases with and without motion. It is impossible in a real PET scanning procedure but can be done using computer simulation.

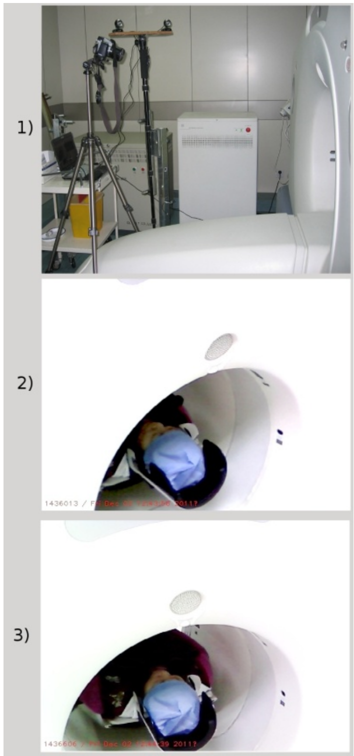


Fig. 1. (1) experimental setup: PET-scanner equipped with one camera and one stereo rig to monitor patient's head during scanning; (2) patient's photo taken from left camera of stereo rig, (3) right camera photo.

In this work a set of reconstructed motion-free PET frames was used to simulate images in the presence of head motion during scanning. Furthermore, the simulated images were realigned based on the information from a simulated head tracker taking into account its precision. The quality of image realigning was estimated using metrics based on Optical Flow [4]. Below the computer simulation is described in detail.

Input data

From the recorded dataset, as described above, the part (3 minutes scanning of one patient) of motion-free PET data reconstructed in 2 seconds per frame was extracted. So, 90 frames were extracted for each slice (n=47). Consequently, the total number of brain images was 4230. Those images were converted from DICOM format to bitmap image files (bmp) and saved for further processing.

Processing

To simulate head rotation, the input images were rotated to a predefined angle ρ.

Thus, to simulate movement correction using the external tracker, the obtained images were realigned using angle φ which is a random angle generated in the interval from ρ-λ to ρ+ λ, where λ is the head tracker precision. The parameter λ corresponds to the head pose estimation system precision described in [5] and equal to 5 in this research.

Output data

After processing three sets of PET brain images are available:

1. Initial motionless images.
2. Images obtained by simulation of head rotation.
3. Images obtained by realigning (2) taking into account the performance of the head movement tracking system.

Output data analysis

To analyze the quality of the frame realignment an appropriate metric must be used which allows the comparison of two images of the same object in different poses. Using such a metric, the initial image can be compared with both simulated and realigned images to estimate the difference.

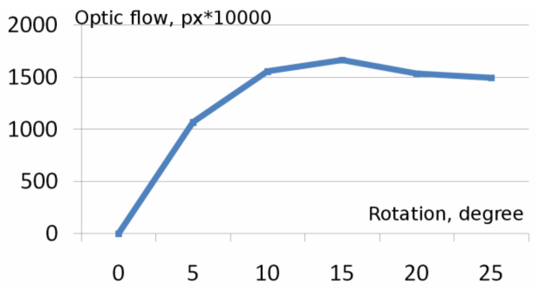


Fig. 2. SOF over PET frame rotation degree. SOF grows until the rotation reaches 15 degrees. Therefore, it is incorrect to use metric if the rotation more than 15 degrees.

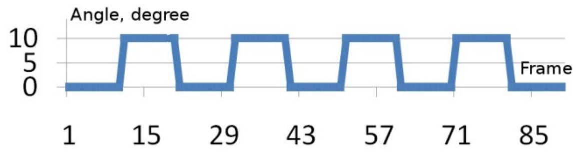
Since the metric should reflect the magnitude of each pixel offset, it should grow if rotation is growing. It was shown that Sum of Optical Flow (SOF) can be used as such a metric if the rotation of an image is less than 15 degrees (for image resolution 128x128 pixels). In Fig. 2. the SOF over rotation is shown. The SOF can be thought of as a total amount of pixel offset on the two compared images.

Assumptions

There are several assumptions in the simulation framework described here. The head rotation happens only in one plane and relative to one axis. In real conditions, head movement can happen in any direction and in the future it must be taken into account in the framework.

Results

Two experiments were conducted. In the first one the simulated head rotation ($\rho=10^o$) was bigger than the motion tracker precision ($\lambda=5^o$). The number of head movements during the scan was eight (top plot in Fig. 3.). The SOF for corrected frames was 177244, for uncorrected – 550142 (bottom plot in Fig. 3).



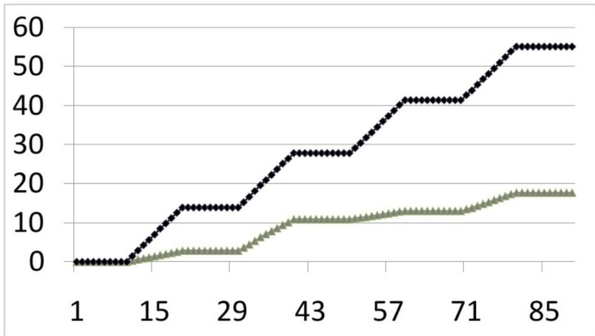


Fig. 3. The top plot shows simulated head rotation over frames (the case when rotation is bigger than head pose tracker precision). The bottom plot shows the value of the metric over frames for both cases corrected (lighter) and uncorrected (darker) frames. It is obvious that uncorrected images contain more shifted pixels.

In the second experiment the simulated head rotation ($\rho=1^o$) was smaller than the motion tracker precision ($\lambda=5^o$). The number of head movements during the scan was eight (top graph in Fig. 4.). The SOF for corrected frames was 93510, for uncorrected – 90874 (bottom plot in Fig. 4). It is obvious that frame realignment should not be applied when motion tracker precision is less than head rotation angle.

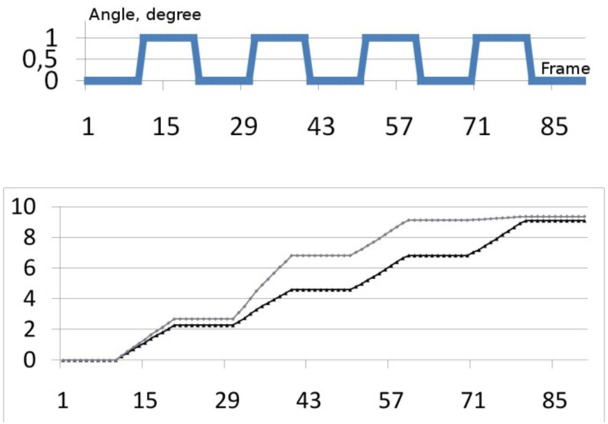


Fig. 4. The top plot shows simulated head rotation over frames (the case when rotation is less than head pose tracker precision). The bottom graph shows the value of the metric over frames for both cases corrected (lighter) and uncorrected (darker). It is obvious that correction should not be applied if head movement is less than head pose tracker precision.

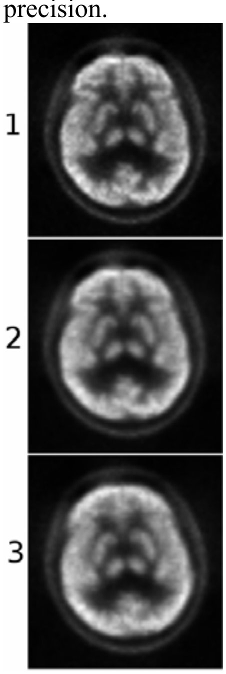


Fig. 5. PET brain images: (1) initial motion free PET brain image, (2) created using simulation of movement correction, (3) created using head rotation simulation without correction. It is obvious that the uncorrected image has more artifacts and is more blurred.

Output PET data of the first experiment also was visualized to qualitatively estimate the influence of rotation and correction. The obtained brain image for one slice is shown in Fig. 5. It is obvious that the uncorrected image has more artifacts and is more blurred.

Conclusion

The developed simulation framework allows a qualitative and quantitative estimation of the quality of a system for head motion correction for PET imaging. The real scanning data in frame-mode is used. It was shown that motion can introduce blurriness and artifacts which can be reduced using a head pose estimation system. The metric for quantitative estimation of the changes in brain images introduced by motion is described. It is based on computing the Sum of Optic Flow.

The results show that correction should not be applied if head movement is less than head tracker precision, otherwise new additional blurriness will be introduced. Therefore if a tracker has a movement detection module it should not detect movements that are less than the tracker precision.

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