Original Article

Design and Evaluation of MeVisLab Networks for Co-Registration and Cropping of Positron Emission Tomography/Computed Tomography Scans

Abstract

Objective: The aim of the present study was to design and evaluate two MeVisLab networks, one for co-registration of positron emission tomography/computed tomography (PET/CT) images and second for cropping the co-registered PET/CT images. **Materials and Methods:** Two MeVisLab networks, one to co-register and export PET/CT DICOM images and second for cropping the co-registered PET/CT images were designed using different modules of registration toolkit MERIT. One hundred and twenty-five PET/CT studies were exported from Siemens and GE scanners in DICOM format. These images were co-registered and cropped with our designed networks. The images co-registered with our network were compared visually with the co-registered images of same PET/CT studies on vendor provided workstations by an experienced nuclear medicine physician (NMP). The perfection of the cropping of co-registered images was also assessed visually. **Results:** Visually, NMP found all 125 images co-registered using the network designed in our study similar to the co-registered images of vendor provided workstations. Furthermore, the cropping of all co-registered images was perfectly done by our network. **Conclusion:** Two MeVisLab networks designed and evaluated in the present study can be used for co-registration of PET/CT DICOM images and cropping the co-registered PET/CT images.

Keywords: *Image co-registration, MeVisLab, positron emission tomography/computed tomography*

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Introduction

Image registration in multimodality medical imaging techniques is the foremost requirement for the interpretation of images.[1] Positron emission tomography/computed tomography (PET/CT) has become a major medical imaging technique.[2,3] PET and CT images are co-registered and then PET image overlaid on CT image is used for interpretation. The process of co-registration and overlaying of PET and CT images is usually performed on vendor provided workstations which are used for both routine reporting and research work. Vendor provided terminals having processing capability are relatively costly, and hence, these terminals are limited in numbers with each nuclear medicine facility.

Nowadays, personal computers and laptops have very good computational power and are available at comparatively less price compared to vendor provided workstations. Open source software for multimodality image registration can be installed on personal computers or laptops. Thus, using open source software, visual interpretation and quantification of functional parameters can be performed on personal computer also.

MeVisLab is open source software which provides a powerful, modular framework for image processing research (like segmentation, registration, volumetry as well as quantitative morphological and functional analysis) with a special focus on medical imaging. MeVisLab provide modules which need to be combined via graphical user interface to form complex image processing networks. It has an image registration toolkit called MERIT for co-registration of multimodality images.[4,5]

In this study we have designed two MeVisLab networks, (1) To register PET and CT images, and export the registered images and (2) To crop the registered PET ad CT images. We validated the

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performance of the networks by visually comparing the registered images with our designed network with that of registered images using the software available at Siemens and GE PET/CT scanners.

Materials and Methods

MeVisLab has several modules in which each module has input and output port. Output of one module can be connected to the input of another module through graphical user interface. This makes it user-friendly and produces result reasonably fast.

MeVisLab (Tool Version 2.8.2 [MeVis Medical Solutions AG, Bremen, Germany])[5] was installed on personal computer (central processing unit [CPU]-Intel ® core (7M) i3-2120 @ 3.30GHz, 8 GB RAM, 64-bits operating system) and two laptops (CPU-Intel Pentium quad core processor 2.42GHz, and 8GB RAM on windows 10, 64-bits operating system). Direct Dicom Import, Reference bypass, SaveImage, MERIT, View Registration Results modules were combined as network to perform the registration and save registered PET ad CT image data. For cropping co-registered images, Local Image, SubImage, Switch, SaveImage, Sychroview2D modules were used to construct the network. These MeVisLab network were designed ad used for co-registration and cropping PET ad CT studies.

Several modules of MeVisLab used in our networks are briefly explained below:

1. DirectDicomImport: This module reads the Dicom files. It automatically reads the image data and its attributes and loads into memory
2. ReferenceByPas: This module transfers the reference image to another module
3. SaveImage: It allows user to provide the path of folder in which image will be saved and automatically gives a filename which can be overwritten by the user
4. SubImage: It allows the user to select a part of three-dimensional (3-D) image. User can select a range of slices in Z-direction and also range of pixels in X-and Y-direction, and hence can crop the desired image region
5. MERIT: MERIT performs image registration based on several algorithms. Two input images (reference and template) are mandatory inputs. It registers the template to the reference image which is sent for display or can be saved. There are several parameters that influence result of registration and MERIT allows user to select these parameters
6. ViewRegistrationResult/Registration Manual: This module displays the result of registration based on the input parameters supplied to MERIT, and also allows user to perform registration manually if user is not satisfied with the result of registration.

One hundred and twenty-five PET/CT studies (20 performed on GE Discovery 710 PET/CT scanner [GE Healthcare, Waukesha WI] with 64 slice CT and 105 performed on Siemens Biograph mCT PET/CT scanner [Siemens Healthcare, Erlangen, Germany] with 64-slice CT) were co-registered and cropped with our designed MeVisLab networks [Figures 1 and 2]. The images co-registered with our MeVisLab network were visually compared with same set of images co-registered with vendor provided

Table 1: MERIT parameters for positron emission tomography and computed tomography image registration

Parameters	Value
Component settings	
Transformation*	
Type	Affine
Dimensions	2-D
Similarity	
Type	Normalized mutual information
NMI bins	32
Interpolation*	
Internal	Nearest neighbor
Output	Nearest neighbor
Plugin*	
Registration type	Linear
Settings*	
Multi resolution	
Number of levels	1
Stop level	0
Scale factor	0.63
Accelerations	
Open MP threads	2
Initialization	
Mode	Image center equalization
Optimizer settings*	
Affine-linear optimizer	
Optimizer	Newton
Finite difference*	
Translation	1
Rotation	0.01
Scale	0.01
Shear	0.01
Stop criteria*	
Termination tau	1×10^{-05}
Maximum runtime (s)	−1
Iterations*	
Minimum per level	2
Maximum overall	200
Last level minimum	1
Last level maximum	5
Stepsize control*	
Step size control mode	Armijo
Start step size	1
Minimal step size	1×10^{-07}
Reduction factor	0.5
Decrease	0.001

*Default parameters incorporated in MERIT. NMI: Normalised Mutual Information, MP: Multiple Processor

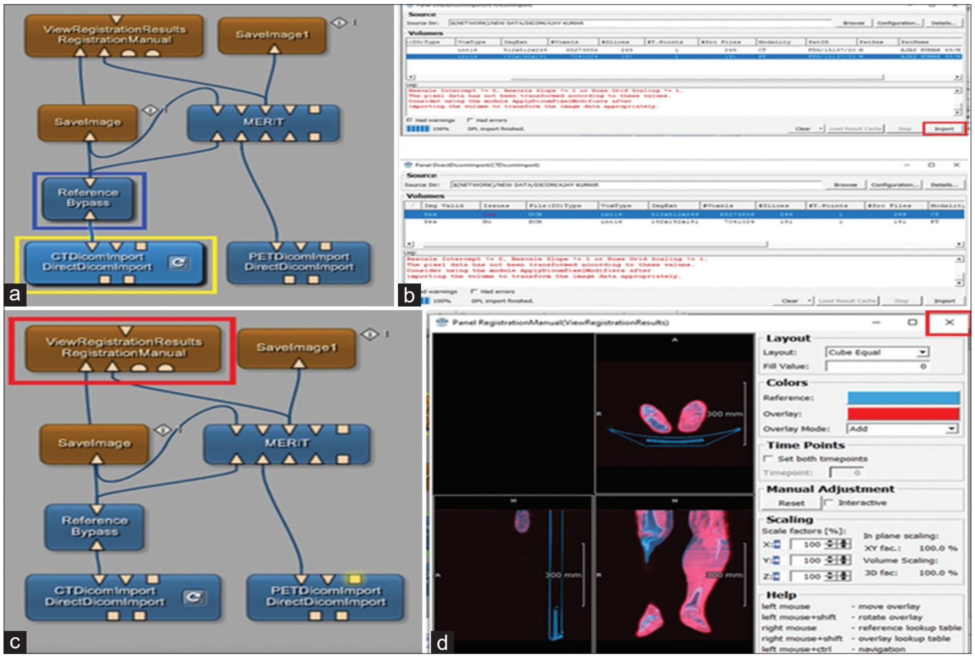

Figure 1: Network designed for co-registration of positron emission tomography and computed tomography images (a) Showing the highlighted DirectDicomImport module, which provides option to browse and load computed tomography and positron emission tomography DICOM files, (b) Window opens up after selecting DirectDicomImport module in which one can select computed tomography DICOM study and positron emission tomography DICOM study to import one by one, (c) After importing computed tomography and positron emission tomography studies the co-registered images can be viewed using ViewRegistrationResults module, (d) Window opens up after selecting ViewRegistrationResults module to review the co-registered images. Selecting SaveImage module will save co-registered computed tomography and positron emission tomography studies in DICOM format

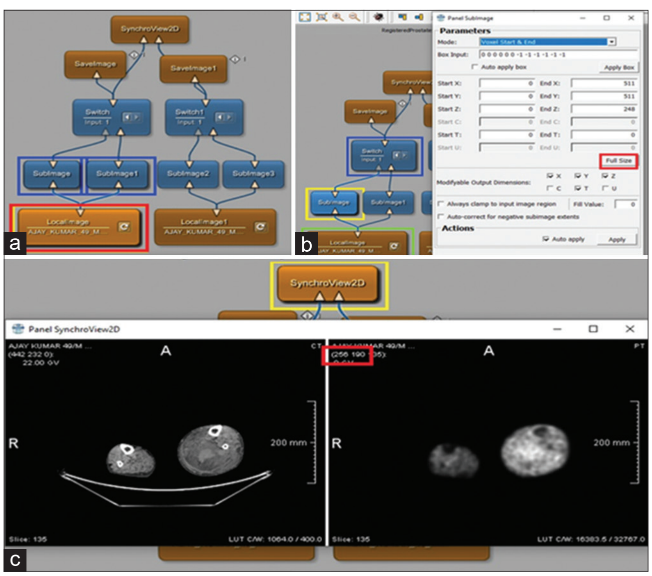

Figure 2: Network designed for cropping of co-registered positron emission tomography and computed tomography images (a) LocalImage and LocalImage1 provides option to browse and load saved co-registered positron emission tomography and computed tomography studies, (b) Selecting Subimage modules opens up the window in which user will have to click on Full Size option and then can specify the range of X-, Y-and Z-axis, (c) Showing the co-registered computed tomography and positron emission tomography images opened up on selecting SynchroView2D on which user can decide range of X-, Y-and Z-axis

workstations. Visual comparison was performed by an experienced nuclear medicine physician (NMP).

We did not quantify the accuracy of registration on numerical scale.

Results

Networks designed for co-registration of PET and CT studies and cropping of co-registered images are shown in Figures 1 and 2, respectively. In our networks, we used default parameters of MERIT which are given in Table 1.

Using the two networks constructed in this study, PET and CT images were co-registered and co-registered images were further cropped in following steps:

Steps followed for co-registration are given in Figure 1

1. Select "DirectDicomimport" module. There are two "DirectDicomimport" modules, one to import CT DICOM file and other is to import PET DICOM file [Figure 1a] so that two DICOM files can be connected. Selecting one of them will open a window [Figure 1b] in which we can select either CT DICOM file or PET DICOM File accordingly and then select "import"
2. After finishing the import of CT and PET DICOM files, select "Registration Manual" to view the registration results [Figure 1c]. After selecting "Registration Manual" a window showing co-registered PET/CT images will be displayed [Figure 1d] in which we can scroll the image and confirm the accuracy of registration
3. After reviewing the co-registered images, we can select "SaveImage" module to save the co-registered PET and CT ".DCM" files.

Steps followed for cropping of co-registered whole body PET/CT images are given in Figure 2

1. By selecting options "local image" and "local image1" the co-registered CT and PET images can be loaded [Figure 2a]
2. All the four "Subimage" modules need to be selected one by one to select "full size" option in all of them [Figure 2]
3. The area of interest is decided by visualizing the co-registered PET and CT image in SynchroView2D. Initially, range of Z-axis was decided by scrolling the image and looking the number of slices that includes the entire Region of interest (ROI). For example, if a tumor lies between slice number 100-–140, then 100 should be entered in Start Z and 140 should be entered in End Z of all the four subimage panels. Next step is to enter the range of X and Y-axis. The Start X and Y-axis was decided by keeping the cursor on left upper margin of ROI on the slice having the longest diameter. This X- and Y-axis value was enter in Start X and Y in subimage 1 and subimage 3 panel. Then, the cursor was moved to right lower margin of ROI, and the values of X- and Y-axis were noted and entered in End X and Y in Subimage 1 and Subimage 3.

In this way, Subimage and Subimage 2 gives CT and PET images cropped in only Z-axis whereas, Subimage 1 and Subimage 3 gives final image cropped in all three axis. Thus, to save the CT and PET images cropped in only Z-axis and in all three axes separately we used Switch and Switch1 modules.

Results of visual assessment

All the registered PET/CT images with our network were visually found comparable with registered PET/CT images of vendor provided work stations by NMP. Although the accuracy of co-registration of images by our network was not quantified numerically, all the images were found perfectly co-registered visually by NMP. Figure 3 is showing the registered images using our network [Figure 3a and b], Siemens workstation (Syngo. via, Siemens Healthcare, Erlangen, Germany) [Figure 3c and d] and GE workstation (AW Volumeshare 7, GE Healthcare, Chicago, United States) [Figure 3e and f].

The cropped area of PET/CT images focusing only on area of interests was also found to be correct in all images. Figure 4 is showing the result of MeVisLab network used for cropping of registered CT and PET images [Figure 4a], of a patient with prostate cancer. In this case our area of interest was prostate.

Discussion

In the present study we have designed two MeVisLab networks, one for registration of PET and CT images and another for cropping of registered PET/CT images. With the help of these networks, we can save the co-registered PET and CT studies separately. This is especially helpful when one needs to quantify co-registered PET, CT and PET/CT fused images separately. For example, during the calculation of texture parameters on PET, CT and PET/CT fused images, mask of ROI can be created from PET image and can be used to extract the ROI from CT and PET/CT fused images. This can only be possible if we have co-registered PET and CT images saved separately.

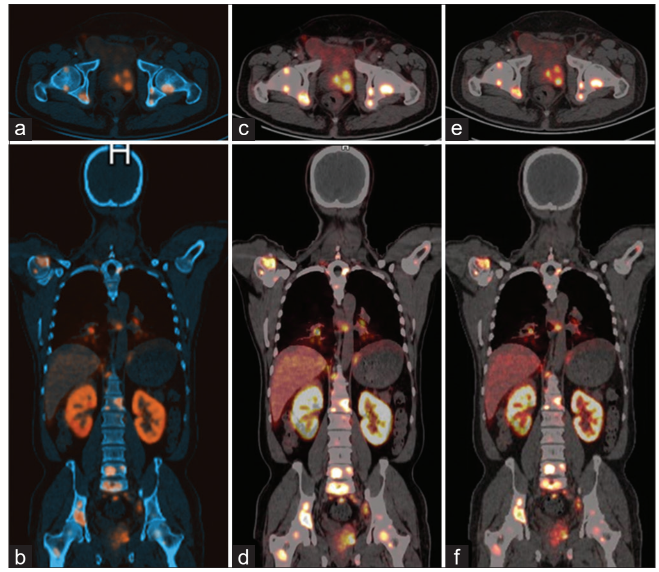

Figure 3: Co-registered positron emission tomography/computed tomography images (a and b) are images co-registered with our network, (c and d) are images co-registered using Seimens workstation, (e and f) are images co-registered using GE workstation

We compared the accuracy of co-registration of images obtained from MeVisLab network with the co-registration of same images obtained using software available on workstations provided by GE and Siemens. On visual inspection, we observed that the performance of our MeVisLab network was equivalent to the performance of GE and Siemens workstations for co-registration of PET and CT images. Furthermore, the cropping of images resulting in the region of interest was accurate in all the images.

Studies are present in the literature showing the role of MeVisLab in medical image processing. Sertel *et al*. segmented the magnetic resonance images in DICOM format using ITK, VTK, and MeVisLab software and connected threshold region growing technique. They successfully segmented and visualized the white matter, gray matter, and multiple sclerotic lesions.[6] Silva *et al*. briefly illustrated how MeVisLab is being used as a prototyping platform to develop a semi-automatic segmentation algorithm to extract the left ventricle from 4D multidetector computed tomography images of the heart and then build a simple framework to perform a preliminary evaluation of the obtained results.[7] In our study, we developed and used two frameworks in MeVisLab for PET

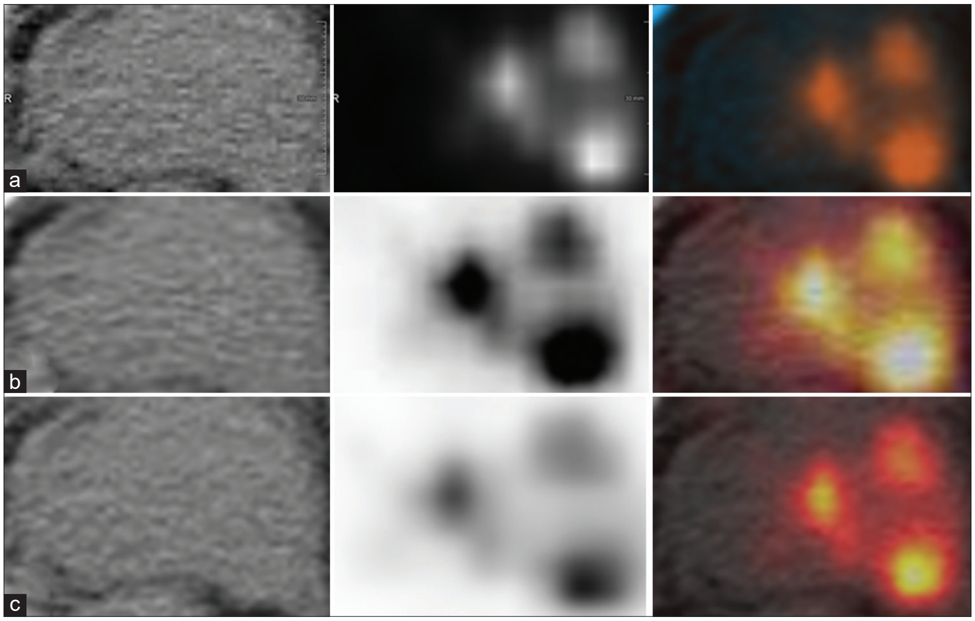

Figure 4: (a) Is showing the result of MeVisLab network developed for cropping in positron emission tomography/computed tomography DICOM images of prostate cancer. With this MeVisLab network cropped images can be saved in DICOM format; (b and c) Are showing the cropped images of Seimens workstation and GE workstation, respectively. The facility of copping of images in DICOM format is not available on Seimens and GE workstations. Co-registered images were saved in JPEG format from Siemens and GE workstation and have been cropped and displayed so that effective visual comparison can be made

and CT image registration and cropping of images to limit it to region of interest.

Various open source softwares are available which can be used for medical image processing. Out of them AMIDE, OSIRIX and Image J are the most widely used for image registration.[8-10] Apart from these three softwares, other open source softwares for image registration might also be present which readers can explore.[11] In the present study our idea was only to design MeVisLab network for PET and CT image registration and cropping and was not the comparison of MeVisLab with other open source softwares available for registration.

The strength of MeVisLab network developed in present study is that with this, the registered PET and CT images can be saved separately. With vendor provided workstations one can only view the co-registered PET and CT images along with the fused PET/CT images but the facility to save co-registered images in DICOM format and/or transfer the co-registered images is not present. Apart from registration, the segmentation process is also an important step for various image processing research which is time-consuming and complex process. With the help of cropping network, user can reduce the size of the 3-D PET or CT study, and hence in turn reduce the time of image segmentation. We hope that, research personnels interested in working in the area of image registration and quantification of functional parameters will be benefitted from this study.

The observed limitation while using MeVisLab in the present study was that, occasionally it hangs or gives slow response. However, it is to be noted that, this particular problem can be experienced with any software. We have not assessed and compared it with other software as it was not the objective of the study.

Conclusion

Two MeVisLab networks designed and evaluated in the present study can be used for co-registration of PET/CT DICOM images and cropping the co-registered PET/CT images.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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