VV, a 4D slicer

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Abstract. VV (`http://vv.creatis.insa-lyon.fr/`) is an open-source and cross platform image viewer, designed for fast and simple visualization of spatio-temporal images: 2D, 2D+t, 3D and 3D+t (or 4D) images. VV enables qualitative evaluation of image processing algorithms, e.g. simulation, registration and segmentation, via image fusion, vector field visualization, complementary colors overlays and contours display. With a modern graphic card, navigation is fast and smooth.

Research in medical image processing requires qualitative and quantitative assessment of developed algorithms. Quantitative assessment is a well-known research problem which has lead to numerous publications, e.g. [3]. In contrast, qualitative assessment is rather a development problem for which researchers wish to spend little efforts. However, visualization tools play a crucial role during research investigations in medical imaging and they might also be required for quantitative evaluation.

In the past decade, a lot of effort has been put in the development of open source software toolkits (ITK, VTK, etc.) and programs for medical imaging. Among them, numerous image viewers have been developed, e.g. Slicer (`www.slicer.org`), Med-Inria and Osirix (`www.osirix-viewer.com`). However, in 2008, none of the mentioned viewers met our requirements for our research in Image-Guided Radiotherapy of lung cancers [2].

Therefore, the CREATIS laboratory in Lyon embarked on the development of VV [4], an open-source and cross platform image viewer designed for fast and simple visualization of spatio-temporal images. The software uses Qt (`qt.nokia.com`) for the graphical user interface, the Insight ToolKit (`www.itk.org`) for Inputs/Outputs and image processing as well as the Visualization ToolKit (`www.vtk.org`) for visualization. This paper is an overview of the current status of the on-going VV project.

1 Main window

The manipulation of VV resolves around a main window displaying four image slices (Figure 1). The slice orientations are defined by the vectors of the image coordinate system which can be changed with key shortcuts (F2, F3 and F4). When relevant, the spatial and the temporal slice index can be adjusted with adjacent sliders as well as arrow keys. The color display (window/level and colormap) of images is managed with a unique toolbar of the main window. All images can be spatio-temporal and pressing the *Play* button in the toolbar animates the time series at a chosen speed. Zoom, pan, slice indexes and crosshair position can be linked between pairs of images using the *Link* tab.

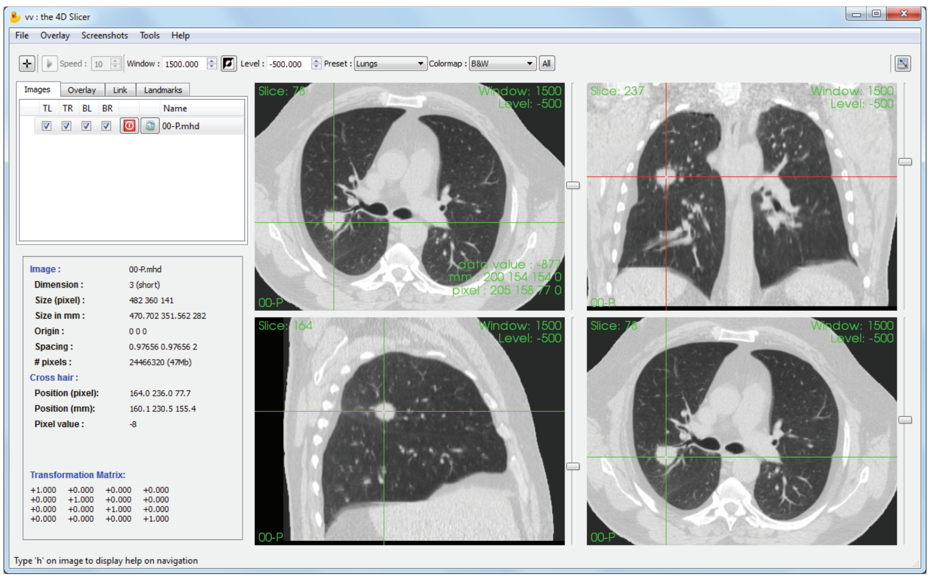

Fig. 1. The main window of VV.

Any number of images within memory limitations can be simultaneously opened in VV. The opened images are enlisted in an image tree on the left hand side. In this tree, checkboxes allow the selection of images displayed in each slicer, next to *Close* and *Refresh* buttons and image filenames. Additional information is provided below for the currently selected image in the file list: image information (dimension, origin, spacing, etc.), information at cross hair (location and pixel value) as well as the image affine transformation matrix in homogeneous coordinates. This matrix is either defined in a text file with the same basename as the image file and a `.mat` extension, or in the header of the image (see `itk::Image<>::GetDirection` for more information).

Further functionalities include overlay on each image (*Overlay* in the main menu or mouse right click on an image): image fusion with complementary colors or transparency and vector field. Each overlaid image will appear in a second level of the tree of file lists. Examples of such overlays are provided in Figure 2.

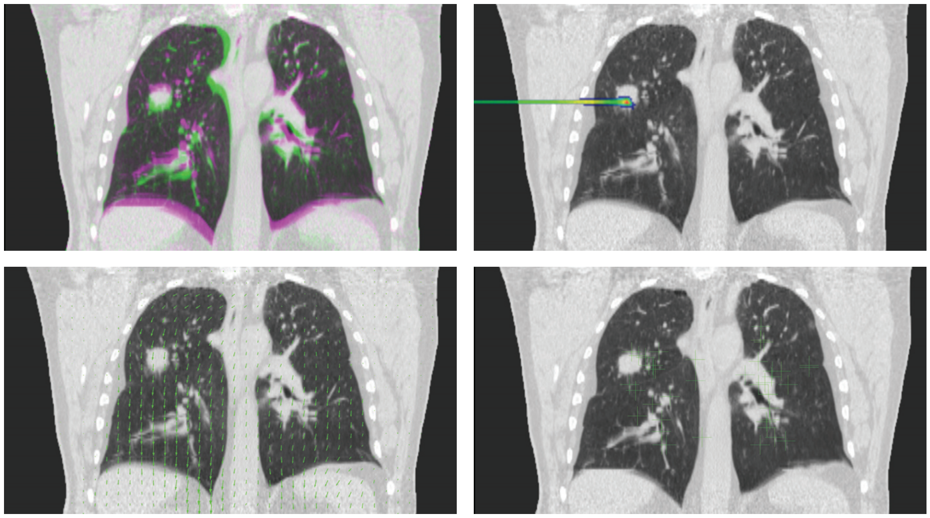

Fig. 2. Overlays available in VV: complementary colors overlay of two frames of a 4D CT image before registration (top left), transparency overlay of the dose of a proton beam spot simulated with GATE [1] (top right), vector field of the respiratory motion estimated with deformable registration [5] (bottom left) and landmarks of the POPI model [6] projected on the current slice (bottom right).

The controls of these overlays are available in the *Overlay* tab. Additionally, landmark points can be manipulated in the *Landmark* tab.

2 Inputs and outputs

VV has adopted the ITK framework to handle its inputs and outputs although it internally connects the resulting ITK image object to a VTK image object for visualization. Therefore, all file formats recognized by ITK are recognized by VV. In addition, ITK offers a mechanism called *Pluggable Factories* to extend reading to other file formats. We have added reading capabilities for DICOM-RT dose maps and images of cone-beam CT systems used in Image-Guided RadioTherapy. Implementation of additional file formats can easily be achieved.

A basic browser for DICOM files is available in the *File* menu. It automatically browses a pre-selected folder and groups DICOM files in consistent image series. The *File* menu offers another set of useful features for dealing with image series: splitting an nD image into an (n-1)D+t time serie, e.g. a 3D image as a 2D+t sequence, or merging a set of nD images in an nD+t time serie, e.g. a set of 3D images in a 3D+t sequence. Similar options are available for splitting and merging spatial images.

3 Image contours and regions-of-interest

Display of regions of interest and contours is a necessary step of image segmentation visualization. We have developed two features in VV to handle them. First, one can import contours delineated in an other software using DICOM-RT structure format, e.g. a treatment planning system (Figure 3, left). Second, a specific tool (*Tools* $\rightarrow$ *Display ROI*) handles the overlay of a set of Regions-Of-Interest on an image. A ROI is defined as a binary image with one intensity chosen as the background, the other intensities forming the foreground.

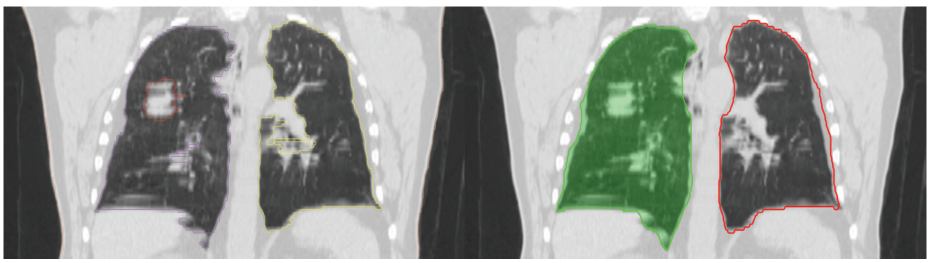

Fig. 3. Illustration of the contours and ROI capabilities of VV on the treatment CT of a patient with motion artifacts. Left: gross tumor volume (red), right lung (purple), left lung (yellow) and patient (orange) imported in VV from a treatment planning system using a DICOM-RT file. Right: right (green) and left (red) lungs segmented automatically using the algorithm developed for the LOLA challenge.

4 Image tools

Basic operations can be performed on the opened images in the *Tools* menu. So far, resampling, thresholding, cropping, maximum intensity projection and basic arithmetic operations have been implemented. Whenever possible, visual feedback is provided to manually adjust the parameters of the operation.

C++ developers can add new tools in this menu in a relatively simple way. They essentially need to inherit from a base tool class and overload functions to get access to a loaded image. To remain simple and robust across the different architectures, such tools are not implemented as dynamic plug-ins, but can easily be enabled or disabled at compile time.

5 Conclusion

We are developing a simple, fast, open-source and cross platform viewer for spatio-temporal images. This is an on-going project with regular releases. Feedback as well as new developments are welcomed! All the necessary information is available on the website: `http://vv.creatis.insa-lyon.fr/`.

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