Med-LIFE: A System for Medical Imagery Exploration

J. New and E. Hasanbelliu
{newj, erioni}@ksl.jsu.edu
Knowledge Systems Laboratory
Mathematical, Computing, and Information Sciences Department
Jacksonville State University, Jacksonville, AL 36265

Faculty Mentor: Dr. Mario Aguilar

Abstract

We present a system known as Med-LIFE (Medical applications of Learning, Image Fusion, and Exploration) currently under development for medical image analysis that provides enhanced understanding and reduced workload. This pipelined system contains three processing stages that make possible multi-modality image fusion, learning-based segmentation and identification, and exploration of results in two and three dimensions. The fusion stage supports the combination of multi-modal medical images into a single color image while preserving information present in the original single-modality images. The learning stage allows experts to train the system in the segmentation and recognition of task-relevant features. This learning system creates pattern recognition agents capable of segmenting a single image. The explorer stage facilitates intuitive navigation of the fused and computer-segmented imagery.

Introduction

As more powerful imaging techniques grow ever more pervasive, medical experts often find themselves overwhelmed by the large number of images being produced. In addition, many of these images are significantly complementary and often lead to an increase in workload. Experts typically have to view and analyze multiple images which force them to follow a tedious scanning procedure. Inadvertently, this work overload leads to a decrease both in the quantity and quality of care that can be provided.

Methods

For this investigation, we used both morphological and functional imaging modalities [3] obtained from the Whole Brain Atlas (WBA) web site [4]. The imagery obtained was spatially registered across modalities by the original authors of the WBA. Here, the imagery obtained included functional MRI and SPECT modalities. Furthermore, the MRI imagery included three different modalities (PD, T1, and T2) that provide distinct information content (see [1] for details.) In total, there were four different modalities available for each image slice in the data set.

The system is implemented as a pipeline of three main stages: fusion, learning, and exploration. Each stage is implemented as an independent interface mode in the graphical user-interface (GUI) (e.g. a tabbed window) to assist the user in understanding and organizing workflow. The processing sequence is implied by the order in which the modes are enabled. This follows a logical order by allowing fusion of original image modalities, computer segmentation and identification of the fused results, and then exploration of the learned results only in that order. The GUI was developed using the Qt GUI platform to allow for the development of a machine-independent interaction system. The back-end of the system uses the Visualization Toolkit library (VTK), implemented in C, for image processing, fusion, and volume manipulation. Also, all images and required information is loaded as soon as a case The following subsections describe in more detail each of the three processing stages. In the following figures, GUI elements are categorized into logical groups for ease of reference.

Fusion Stage

A fusion system was developed which first contrast enhances the original medical imagery via within-band competition. Second, these images undergo an across-modality competition to establish "color" contrast enhancement. These processes are based on the neuro-physiological organization of the primate visual system. Our fusion architecture uses a *shunt* neural network to model the inhibitory process of these competitions [5, 6]. In the first layer, within-band competition is used to enhance each input band. In the second layer, lateral inhibition is used to decorrelate and combine image modalities.

As can be seen in Figure 1, the visualization system presents several elements for the rapid understanding of patient information. Group A displays the result of the fusion process for the slice of interest. This default 4-band fusion image can be zoomed and panned with the mouse to permit analysis of an area of interest. Group B is the slice slider and allows traversal of available slices in groups A and F. Group C allows the user to select the type of fusion result he/she would like to calculate and view. Group D consists of the fuse button which is used to generate/regenerate the desired fusion results. Group E is a scrollable text box which displays case relevant information. Group F contains the original images used in the fusion process as well as the ability to swap one of the images with group A to allow magnified and customized viewing of imagery data. Once the desired fusion result is selected, the user may proceed to the learning stage.
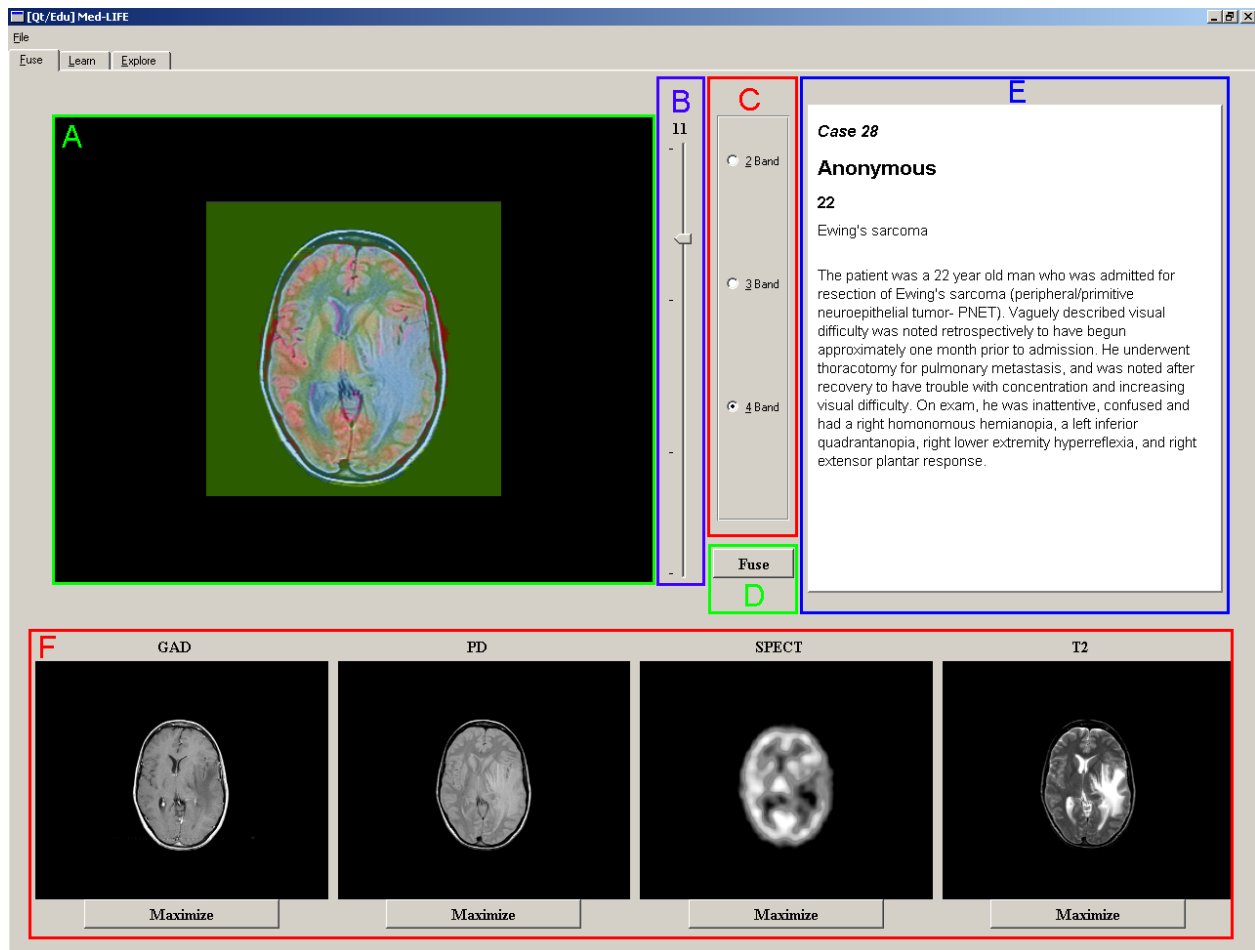

Figure 1. Fusion Stage Screenshot

Learning Stage

This system is currently a work in progress. Its purpose is to use principles of image mining and supervised learning to enable the computer to identify objects in the imagery. This is done by providing a GUI to allow the expert to mark pixels as examples and counterexamples of an object of interest. By doing this, the agent can leverage off the expert to solve the specific task of identifying the sampled structure across all available modalities. This information may then be used to train an ART-based neural network agent to recognize this type of object. In addition, this agent can be saved and loaded later to pre-screen images by highlighting areas of potential interest for the current image.

A sample screenshot of functionality under development for the learn window is shown in Figure 2. Group A consists of the fuse result selected in the previous pipeline stage. This fusion slice has a transparent overlay which allows the user to freely mark pixels as examples or counter examples to be used as inputs into the learning system. Group B is the slice slider which allows navigation of all available slices. Group C consists of checkboxes to allow for customized viewing of the examples and counterexamples marked in groups A and D to more easily recognize features of interest. The group also allows the option to clear all examples/counterexamples and start over. Group D consists of a magnified view of a selected portion in Group A that can be toggled on or off. The magnified view allows more precise selection of opposing features. Group E is the mediator between group D and group A, allowing the user to select a magnification region while retaining spatial context. Group F consists of the agent interface tools. These consist of a learning or confidence threshold to train the agent on all available modalities to recognize the object of interest. This agent can also be saved and loaded later to highlight regions of interest in the current image or potentially an entire database of images for prescreening purposes.
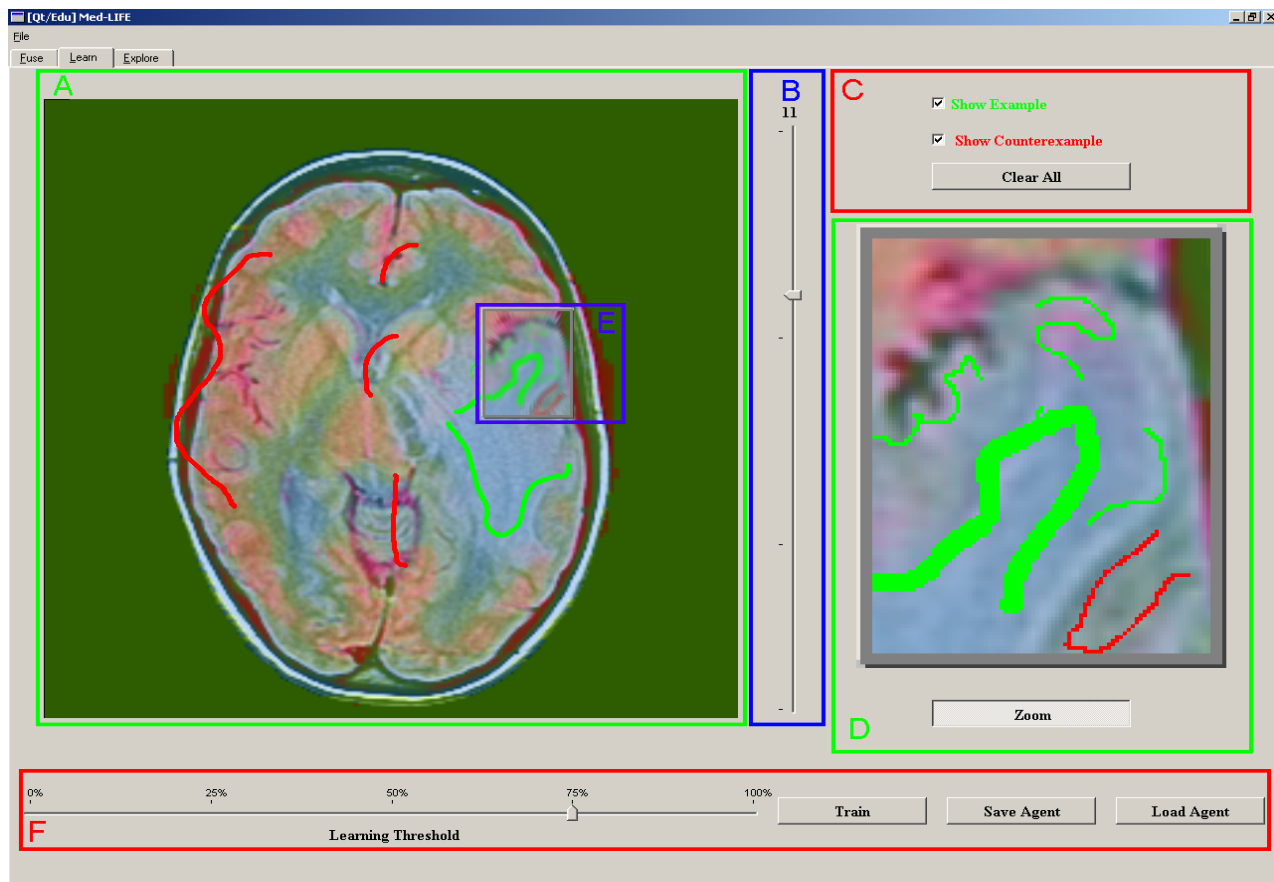

Figure 2. Learn Stage Screenshot

Exploration Stage

In an effort to present the fusion and learned results in an intuitive interface, a cranial volume was computed from the PD modality of the patient due to the high-resolution structural information. By embedding the fusion imagery into the generated volume, contextual navigation of the fusion stage output is made possible. The VTK implementation of the exploration stage consists of the following sub stages: image import, noise cleaning, contouring/volume generation or loading, image slice viewing, and transparency-based blending of SPECT imagery [3]. The skull generator has the ability to save the cranial volume for future use and load in order to save computation time.

The exploration stage, as can be seen in Figure 2, is used to display a multitude of information in a powerful and intuitive interface. Group A contains the generated skull with the slices of interest imbedded within the skull for contextual navigation. These embedded slices consist of the desired fusion image combined with a SPECT overlay and a transparent overlay of highlighted regions that the loaded agent has been trained to identify. This group can intuitively be rotated, zoomed, and panned with a 3-button mouse. Group B contains the usual slice slider which is used to updated groups A, E, and F. Group C consists of the SPECT transparency slider. This slider allows customized view of the SPECT overlay in group A so that the desired amount of metabolic information may be displayed. Group D consists of our viewing options for the exploration stage. Here the user may select the desired fusion result for display in groups A and F, remove the skull if it is not needed or hinders the view, remove the raw images in group E, or remove the SPECT overlay in group A. Group E consists of the original images for the slice of interest. Group F consists of the fusion slice of interest, as well as the slices above and below for contextual slice navigation.
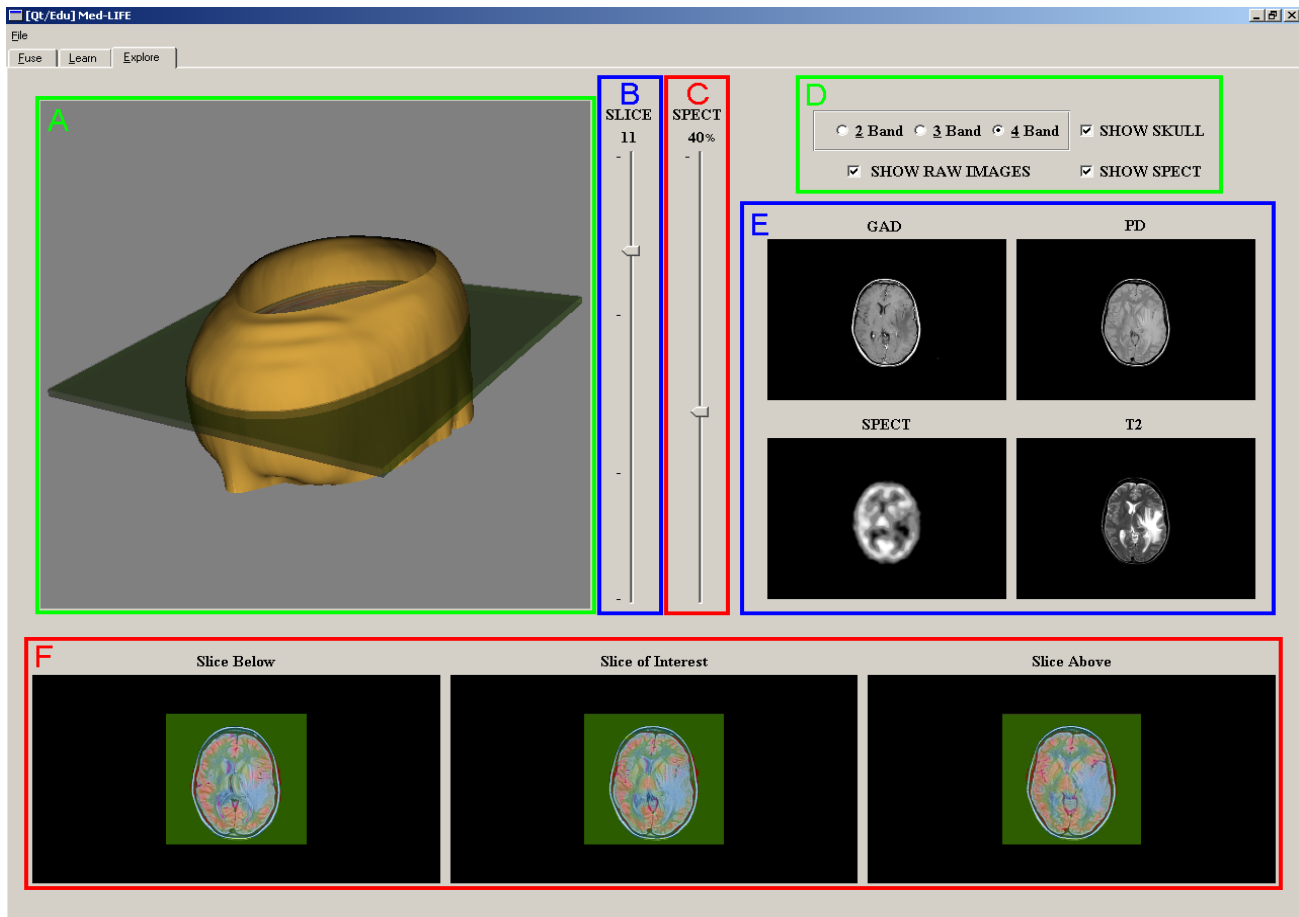

Figure 3. Explorer Stage Screenshot

Results and Conclusion

The original imaging modalities used for this paper were attained from the Whole Brain Atlas, run through the fusion architecture, and stored into the appropriate file structure for use by the Med-LIFE system. The fusion architecture using VTK is complete, but it has not yet been integrated with the fusion window GUI. This fusion architecture remains a subject of continuing research. Current research efforts are directed toward adapting the current fusion architecture to perform a 3-dimensional fusion technique across slices for use in volumetric data. For more extensive information on methods such as a discussion on the currently implemented fusion system, the reader is referred to [1] (or http://ksl.jsu.edu/projects/medical/fusion.html). The learning stage is currently under development. Proofs of concept have been demonstrated in C and Matlab, but have yet to be integrated with the Med-LIFE system. The explore window has been successfully implemented and is fully functional with the exception that no input from the learning stage is displayed.

The pipelined system promises to be a powerful tool in leveraging professional expertise for use with computational techniques. The ease of use and capabilities of this system will provide an essential step towards providing processing solutions to ease the demand and workload of medical personnel, thereby increasing the quantity and quality of medical care.

References

[1] M. Aguilar and A.L. Garrett, "Biologically-based sensor fusion for medical imaging." In *Proceedings of SPIE Conference on Sensor Fusion Architectures, Algorithms, and Applications* V, **4385**, 2001.

[2] S. Grossberg and G. Carpenter, "The ART of Adaptive Pattern Recognition by a Self-Organizing Neural Network" In *Computer*, March 1988.

[3] M. Aguilar and A. Garrett, "Visualization of Fused fMRI and SPECT Imagery." In *Proceedings of International Conference on Mathematics and Engineering Techniques in Medicine and Biological Sciences*, 2001.

[4] K.A. Johnson and J.A. Becker, Whole Brain Atlas, http://www.med.harvard.edu/AANLIB/home.html, 1999.

[5] S.A. Ellias and S. Grossberg, "Pattern formation, contrast control, and oscillations in the short memory of shunting on-center off-surround networks", *Biological Cybernetic*s, **20**, pp. 69-98.

[6] S. Grossberg, Neural Networks and Natural Intelligence, Cambridge, MA: MIT Press, 1988.