Developing Computer-aided Image Processing and Analysis Tools to Compute Quantitative Image Markers or build Machine Learning-based Prediction Models

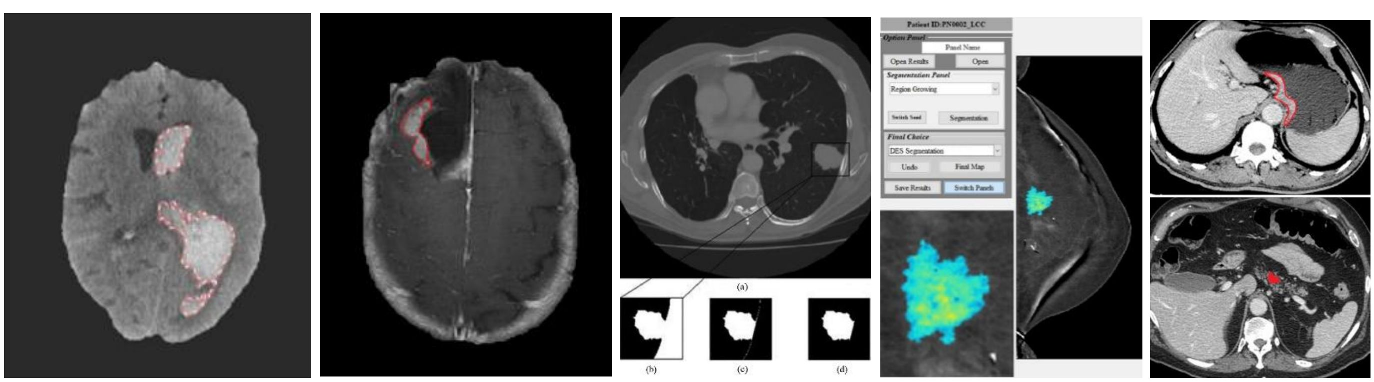
Introduction: Medical Imaging Technology Development Core (MITDC) of medical imaging COBRE in OU Norman Campus includes a subsection that aims to develop and provide the shared image processing and quantitative machine learning capability and service to COBRE projects and broad research communities in two OU campuses. We will develop, optimize and provide following computer-aided detection (CAD) modules or tools.

1. Segment Images and Compute Quantitative Image Features or Measurement Markers

OBJECTIVE: To automatically segment disease regions (2D) or volume (3D) from medical images (i.e., Mammograms, CT, MRI, Ultrasound and digital pathology images) and compute quantitative image features or measurement markers to replace subjective qualitative assessment of clinicians (i.e., radiologists).

EXAMPLES: We have developed CAD modules to segment (1) volume of aneurysmal subarachnoid hemorrhage (aSAH) from brain CT images and (2) visceral fat areas (VFA) and subcutaneous fat areas (SFA) from abdominal CT images. From image segmentation results, CAD modules compute size of the segmented volume, mean density values and standard deviation, and other clinicians-required or recommended image features or measurement indices. These modules have helped clinical researchers in OUHSC to process CT images and compute quantitative image markers in their translational clinical research and published 9 research papers in the clinical journals (i.e., Translational Stroke Research and Gynecologic Oncology).

<u>Following are a few examples</u> of segmentation of diseased regions of interest using existing image segmentation modules. **From left to right:** Segmenting (1) aSAH lesions from brain CT image, (2) residual tumors from brain MRI, (3) lung tumor from chest CT image, (4) breast lesion from contrast-enhanced digital mammogram and (5) gastric tumor (top) and pancreatic tumor (bottom) from abdominal CT images.



SERVICE: Upon the specific requirement of the researchers, we can apply the existing or develop/optimize custom-based image segmentation modules to segment the targeted diseased regions or volume (i.e., brain tumors) and compute clinically relevant quantitative image features as required or recommended by the researchers.

2. Compute Radiomics Image Features

OBJECTIVE: Since radiomics concept has been widely accepted and used in medical imaging research, our objective is to develop and provide CAD modules to compute standardized radiomics image features, which can directly link to the image segmentation modules. Thus, it can support researchers to develop machine learning-based prediction models using radiomics features.

TASKS: We have conducted and published many radiomics-related studies. We will organize and integrate the previously used schemes to build a comprehensive module that can more flexibly and efficiently help researchers to compute whole or selective sets of radiomics features.

SERVICE: We provide consulting service to help researchers compute radiomics features based on their specific research projects or goals.

3. **Compute Deep-transfer-learning Generated Automated Features**

OBJECTIVE: Since deep learning has also been attracted broad research interest in medical imaging research, our objective is to build a library of popular deep learning models as the automated feature extractors. The goal is to support researchers to develop machine learning-based prediction models using automated features.

TASKS: We have conducted and published several deep transfer learning studies. We will organize and integrate the previously used models to build a new platform to help researchers select most effective deep learning models as automated feature extractors.

SERVICE: We provide consulting service to help researchers extract automated features based on their specific research projects or goals.

4. **Select or Generate Optimal Feature Vectors from Radiomics or Automated Feature Pools**

OBJECTIVE: Since identifying a small set of optimal and clinically relevant image features is crucial to develop highly performed and robust machine learning-based prediction models, our objective is to build a set of modules that can be used to more efficiently help select or regenerate optimal image feature vectors by removing low-performed and redundant features.

EXAMPLES: We recently have applied a random projection algorithm (RPA) to medical image analysis field and published two papers in IEEE Transactions on Biomedical Engineering, and Computer Methods and Programs in Biomedicine, which demonstrates that RRA is an effective method to help select optimal feature vectors from the large pools of features (i.e., radiomics or automated features).

SERVICE: We provide consulting service to help researchers build optimal and non-redundant image feature vectors for their specific research projects or goals.

5. **Train and Test Machine Learning Models Using Image and/or Other Feature Data**

OBJECTIVE: To develop a new platform that integrates variety of machine learning models or classifiers (i.e., including Weka data mining programs) to help improve efficiency of researchers to build and test machine learning-based prediction models that fuse multiple features computed or extracted from one or more imaging or other testing modalities.

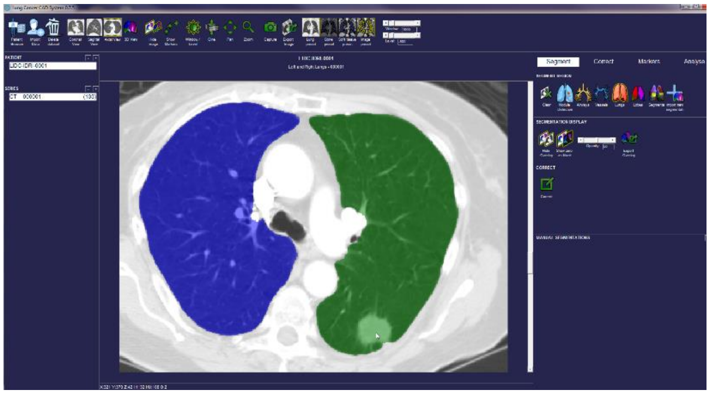
TASKS: We will build and test a new integrated platform to combine many commonly used machine learning models (i.e., ANN, SVM, RF, KNN, BBN, etc.) and add more in future research efforts.

SERVICE: We provide consulting service to help researchers select and test most effective machine learning models or classifiers for their specific research projects or goals, as well as how to optimally validate or test robustness of the machine learning models.

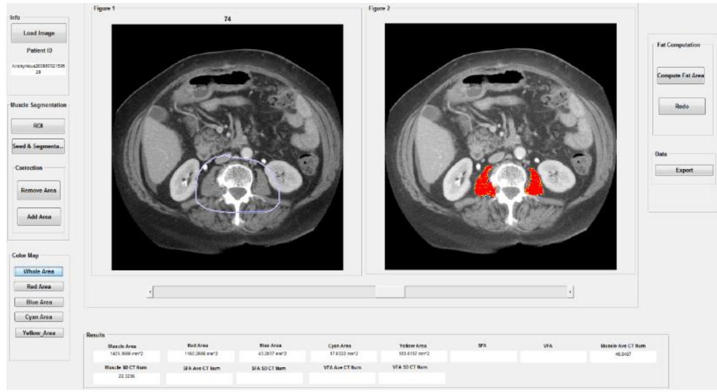
6. **Design and Implement Interactive Graphic User Interface (GUI) Tools**

OBJECTIVE: To avoid or overcome limitation of the "black-box" AI tools, our interactive CAD schemes with graphic user interface (GUI) tools can provide users (i.e., physicians or researchers) visual aid tools to visually examine image segmentation results and manually change boundary conditions to guide CAD schemes to modify image segmentation results and recompute quantitative image markers.

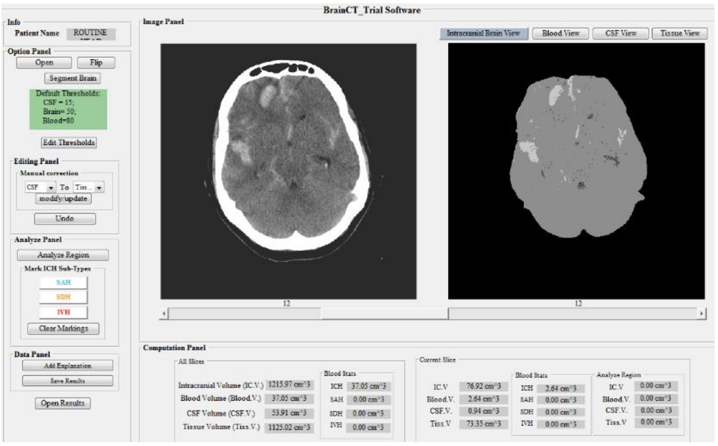
EXAMPLES: <u>Following are 4 examples of GUI tools</u> previously developed in our CAD lab in which (a) detect lung nodules and other lung diseases, (b) segment and quantify strength of total psoas area for predicting efficacy of chemotherapy, (c) segment and quantify severity of aneurysmal subarachnoid hemorrhage, and (d) predict short-term breast cancer risk (*i.e.*, 78% likelihood of having cancer detected in the next annual screening for this case).



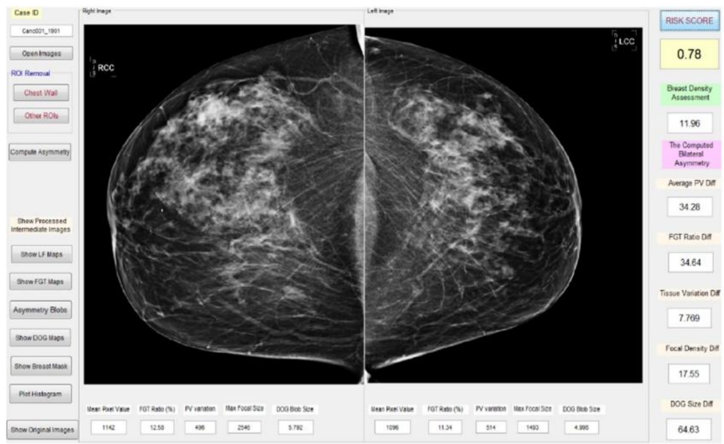
(a)



(b)



(c)



(d)

SERVICE: We can design and build GUI tools applying for different image processing and analysis tasks based on the specific requirement of the researchers.

Summary: Using the existing medical image processing and quantitative analysis modules or tools plus the new modules and integrated platform, the medical imaging technology development core aims to provide service and support researchers in two OU campuses to more effective or efficiently conduct the translational clinical research projects using the quantitative image markers or advanced machine learning prediction models.

Our Supporting Service can be Divided into Two Levels.

LEVEL 1: We need a small set of sample images (i.e., <50 cases). Using these images, we can provide researchers the modules to segment images, compute quantitative image features and an interactive GUI. The researchers can use this GUI tool to compute and acquire several quantitative image markers to replace current subjective ratings in read and interpreting medical images.

LEVEL 2: We need a large set of clinical images (i.e., >100 – 200 cases). Using more images, we can compute radiomics or automated features, select optimal feature vectors and train machine learning models. Then, the machine learning models/classifiers will be integrated into interactive GUI tool that can be used as a new decision-making supporting tool.