4Q Computer Vision User Guide

Introduction

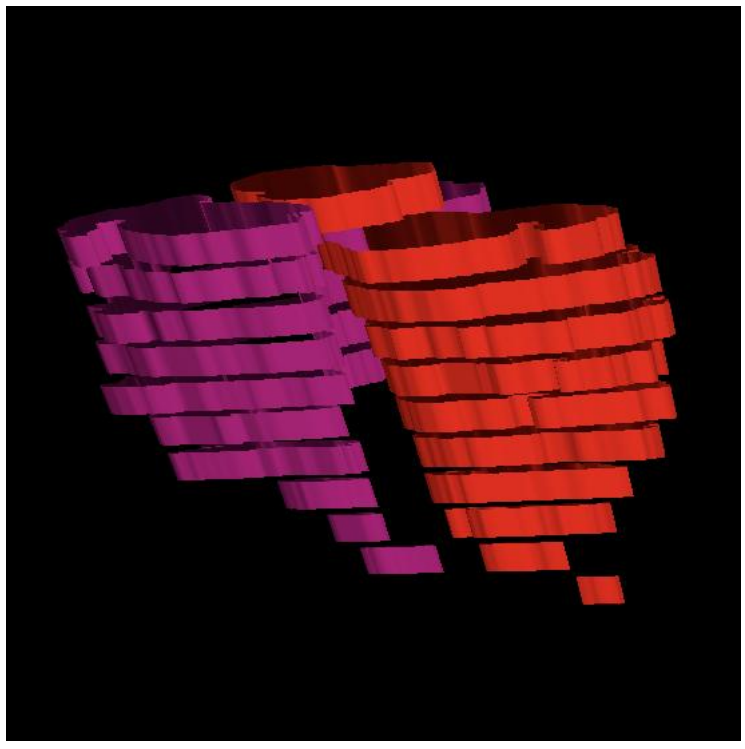
Use this application to view, analyze, and recognize tissue objects in medical image data. The interface uses a dissection paradigm to guide the placement of menu and toolbar items and the use of a pointer on displayed images. The application window is a dissection pan in which you can display and manipulate tissues as dissected parts. Edge detection uses a published technique to separate tissues at the pixel level. Pixel-level information is used in all processing and presentation of segmentation results. The computer brain is taught by the user to recognize and label tissue objects. Multiple tissue objects are observed until the brain begins to recognize them automatically. Teaching observations are stored on disk, where they are reused and maintained by each individual user. The application contains its own DICOM reader and will only process images with DICOM metadata.

The Interface

The interface uses a dissection paradigm to suggest where to place windows, menus, and toolbar items. A single window with a black background is a dissection pan. The cursor, acting as a pointer, is used to manipulate, cut, and remove tissue parts in the pan.

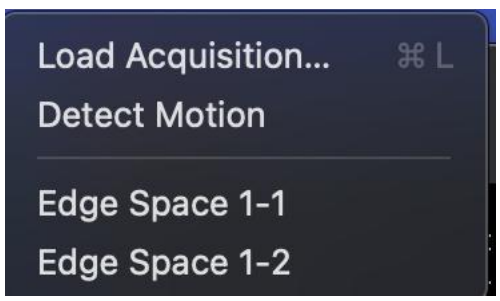
A computer software “brain” is capable of recognizing and labeling tissue objects in the pan. Training data is maintained in recorded memory.

This example 3D display was automatically created from a cardiac MRI heart study depicting the left and right heart blood pools. Blood is a tissue that is manipulated as a solid object. Volumetric numbers are automatically calculated from multiphase studies.



Load Image Data

Use the **File** pull-down menu to load image data.

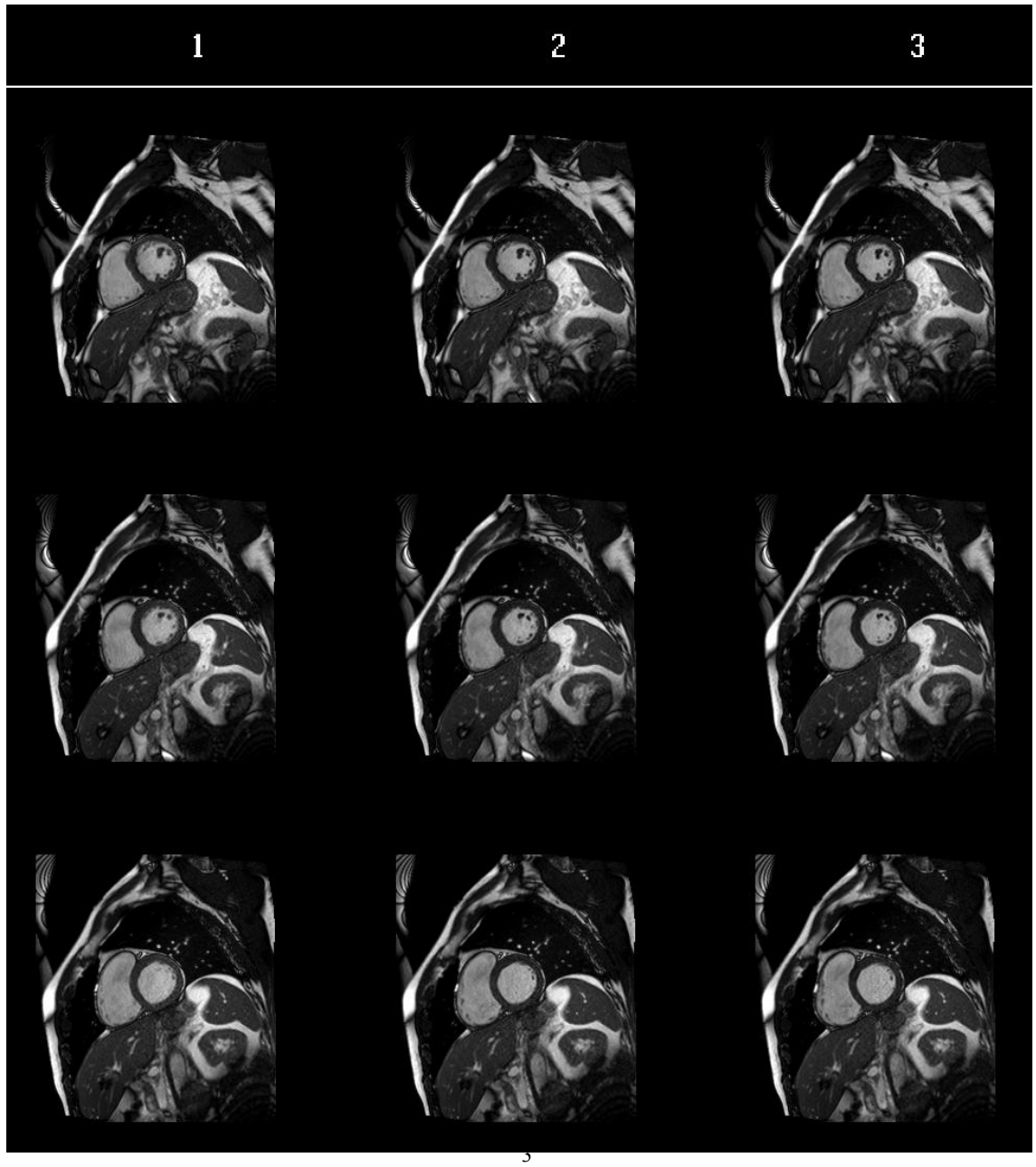


Load Acquisition uses a standard file access window to load images along with their DICOM metadata into memory. Images are displayed immediately in the dissection pan in a standardized 2D format. More than one study can be loaded.

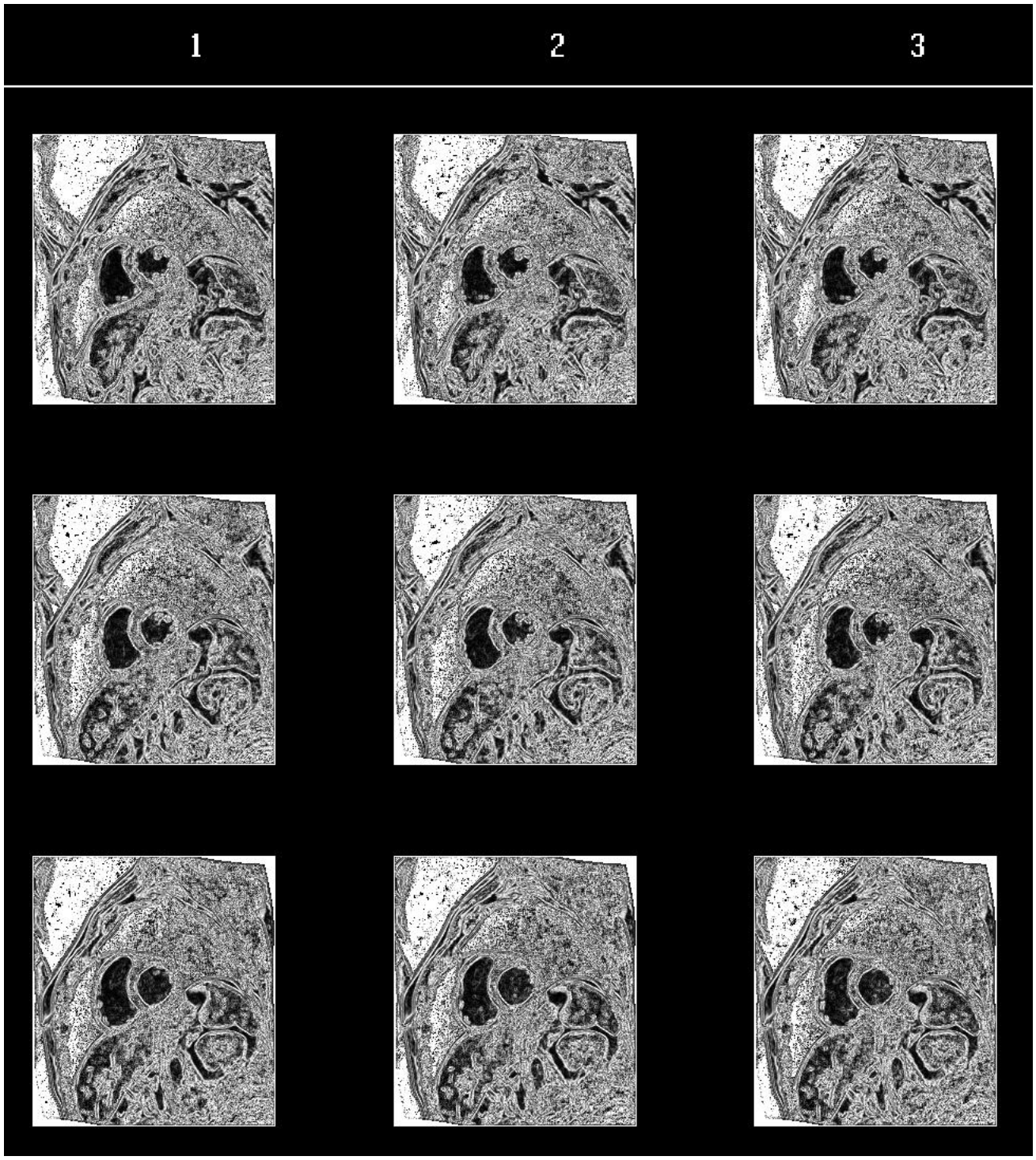
Detect Motion creates a multi-phase subset of images centered on anything that is moving.

Edge Contrast 1-1 and 1-2 depict the edge contrast spaces used by edge detection. The default is 1-1.

Raw image data



Edge contrast space



Images centered on maximum motion

View Image Data

Use the **View** pul down menu to manage the viewing area.

Freely select **2D**, **3D**, or **4D**. Use the circular slider in the toolbar to view low-intensity parts of 2D images.

Raw resets the display back to the original 2D. All images are displayed in a 4D format in the dissection pan. Multi-phase image sets are displayed in 4D. Grab and drag with the pointing device to rotate any 3D object. Zoom in 3D to better view details at the pixel level.

Tissue object regions and region flyaways from dissection are displayed in the same 4D format. Display stacked slice edges as ribbons or outlines. Rotate 3D objects using the pointing device.

Move the image display up, down, left**,** or right with the arrow keys.

T**oggle Slice Order** in any multi-slice format.

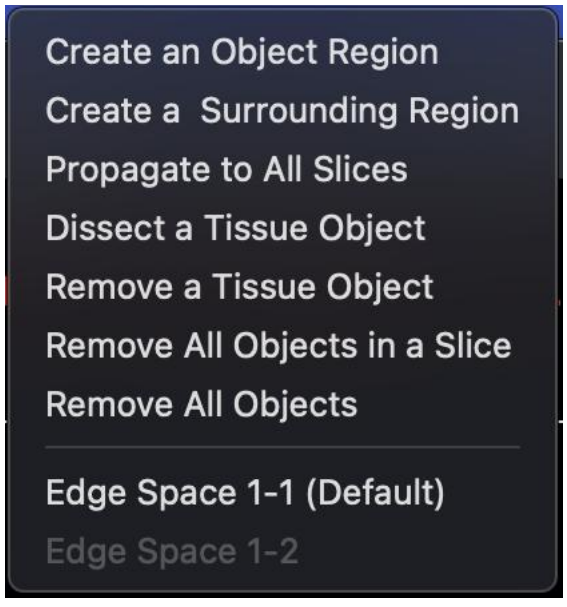
Zoom with **Zoom In** and **Zoom Out** in 3D.

Fly Away, **Edge Surface,** and **Edge Lines** display segmentation results. Grab and drag to rotate the depicted tissue objects.

Volumetric Curves depict volumetric analysis results from multiphase studies in a labeled multi-curve format.

Dissect

Dissect tissue parts in the dissection pan with the pointing device. Use it like a scalpel.



Create an Object Region. Locate a part by selecting it with the pointing device.

A region will be created by expanding from the one-touch location to the surrounding edge pixels and displayed over the tissue area. Segmentation of the tissue part is remembered in the computer as a tissue object.

Auto Label in the Brain menu will automatically see and label tissue objects.

Create a Surrounding Region. Select a tissue object, then locate the surrounding area.

Propagate to All Slices automatically propagates locations to adjacent slice images. Tissue objects are automatically created.

Dissect a Tissue Part to initiate cutting. Press the pointing device down and drag to cut. Remove a piece by selecting it with the pointing device. Be careful that you recognize the piece you are removing. The edge space might be trying to tell you something.

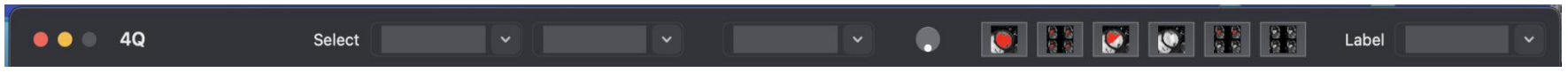
Remove a Tissue Part by selecting the object with the pointing device.

Remove All Parts in a Slice. Select anywhere in an image in any phase.

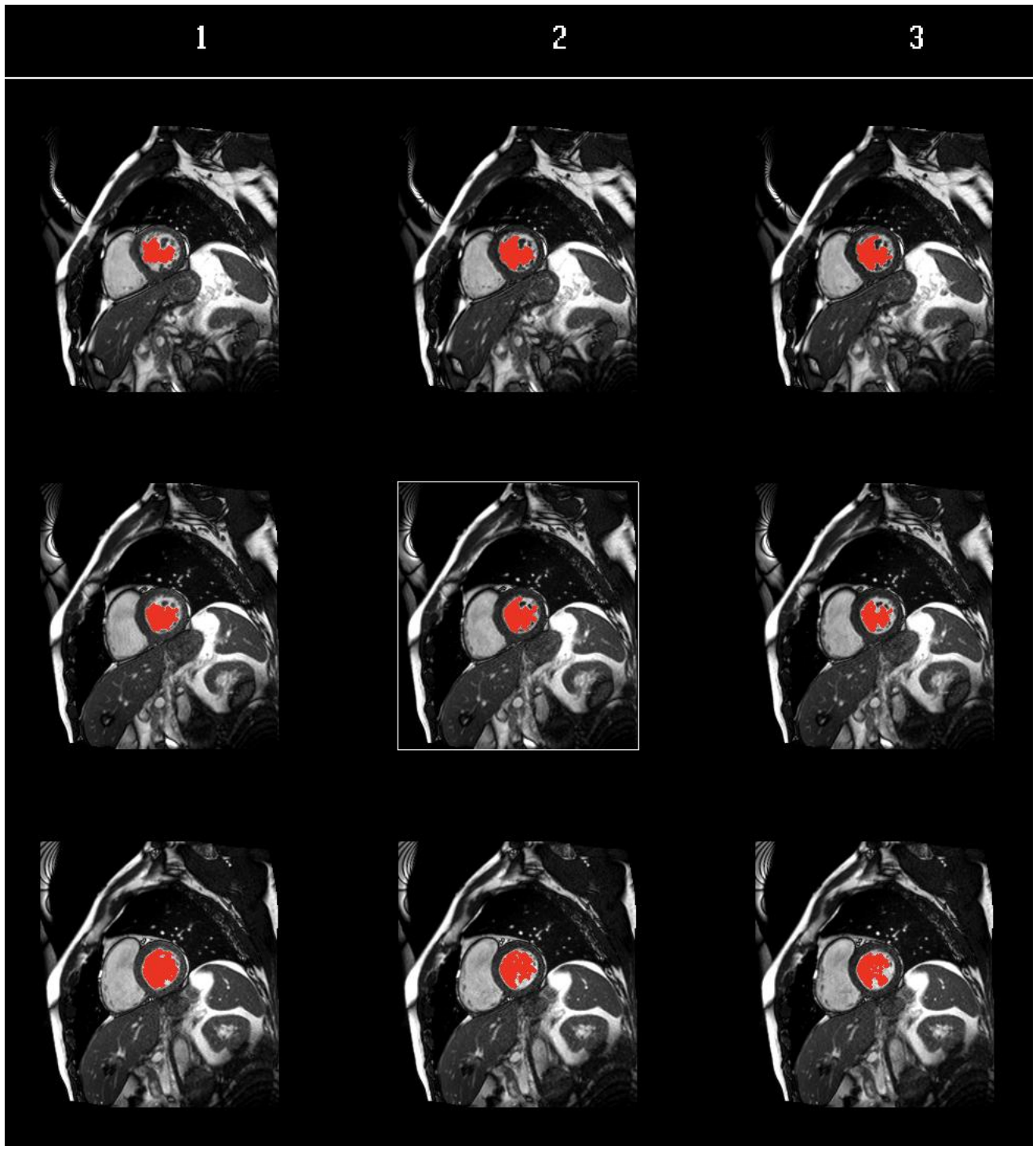
Remove All Parts. Remove all tissue objects.

Toggle edge space display to **Edge Space 1-1** or **Edge Space 1-2**.

Use toolbar convenience buttons to perform the same operations.



Tissue locations are automatically propagated, and parts are segmented.



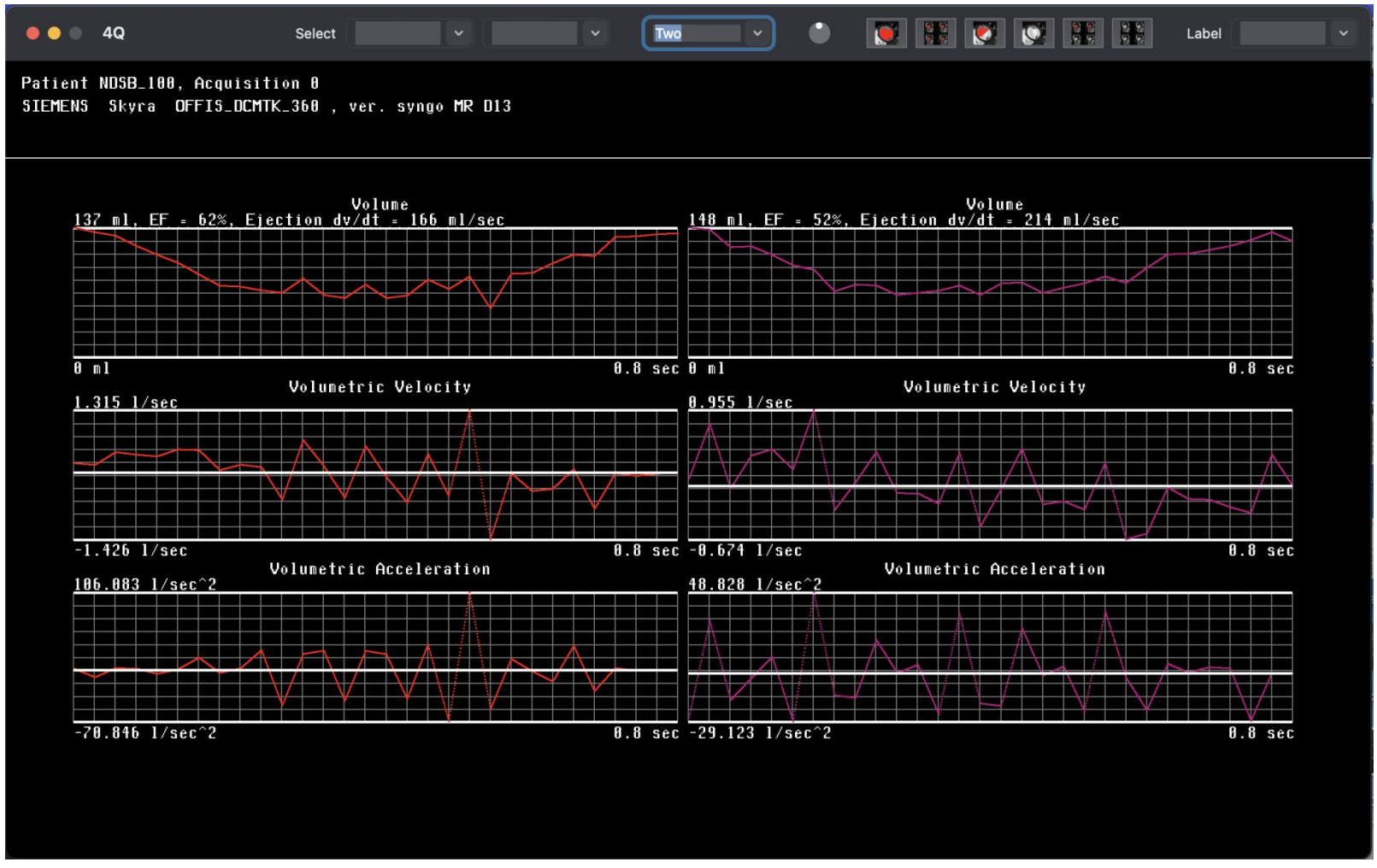
Analyze Image Data

Tissue objects are 3D entities that have volume. A multi-phase study contains multiple series of tissue objects. During propagation, each object's location is derived from a neighboring location, and the object is created in the adjacent slice and phase. A stack of slice images contains stacks of tissue objects. Object volumes in an object stack are summed to create a 3D volume number. This is repeated for each phase to produce volume/phase curves for volumetric studies. Here is the voxel volume calculation code. Slice thickness, slice spacing, and pixel spacing are taken from the DICOM metadata.

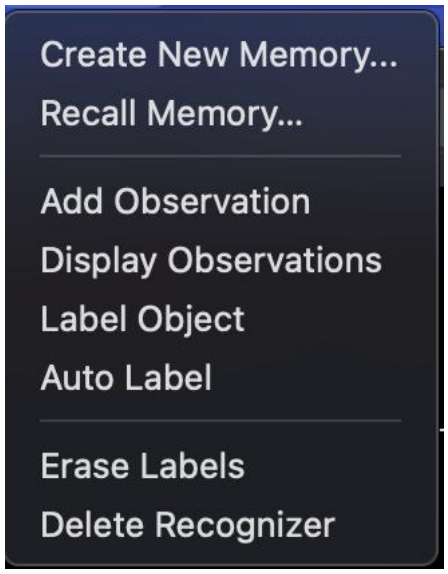
```
        if slices.count == 1 {
            voxelDepth = slices[0].thickness
        } else if sliceSpacing != 0 {
            voxelDepth = sliceSpacing
        } else if sortedSlices[0].scaledLocation != 0 {
            voxelDepth = abs(sortedSlices[1].location -
sortedSlices[0].location)
        } else {
            voxelDepth = 0
        }
        voxelVolume = slices[0].pixelSpacing1 * slices[0].pixelSpacing2 *
voxelDepth / 1000.0
```

Use **View** -> **Volumetric Curves** to display curves in the multi-curve format. Stacks of volumetric curves are depicted for each part from left to right. Each stack contains volume, volume flow rate, and volume acceleration curves. Parameters are calculated and shown automatically. This example from MRI has two stacks, the first for the left ventricle and the second for the right ventricle. All curves are from the same acquisition.

Volumetric Curves



Brain



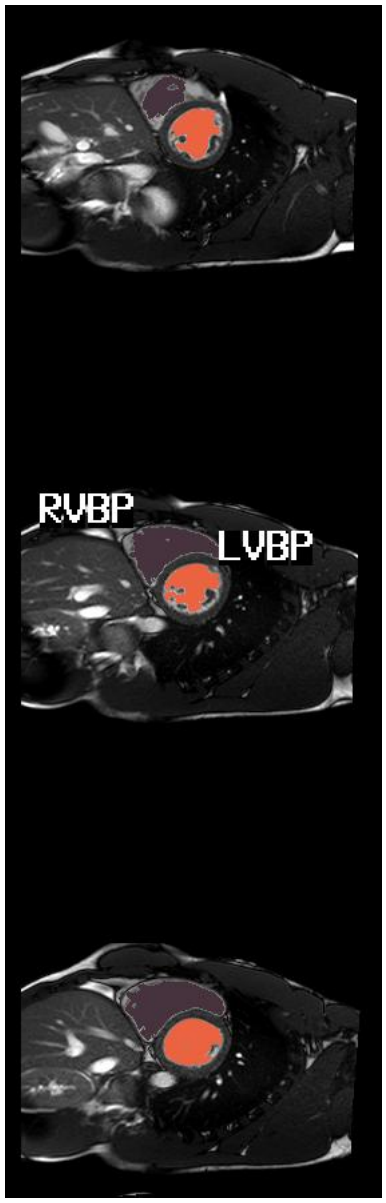
The computer has a brain that conceives tissue objects. It has way more than the 200 nerve cells a tardigrade has (~200) but about half that of the brainy fruit fly (139,255 neurons). A single eye has a retina with a fixed visual field of view (FOV) and no lens. Receptor neurons cover the entire field. Fovea receptors are in the center, and peripheral receptors surround FOV receptors.

Each neuron has a number of dendrites for input and a single axon for output. Each neuron performs a simple analysis of dendrite input and fires pulses out its axon to other neurons. A receptor neuron has a single dendrite that receives a single pixel intensity value and passes it on to a perceptor neuron. Perceptor neurons collect these values and distribute them to edge detection and eye movement neurons for full processing.

The brain has to be taught to recognize tissue objects. Tissue object receptor neurons sense tissue object discriminator values and pass them on to recognizer neurons as observations. Recognizer neurons are accessed, labeled, and taught with a number of observations determined by you. Recognizer neuron observation data are stored in memory in a disk file named by you. Observations are automatically stored as they are made. You can have as many memory files as you like.

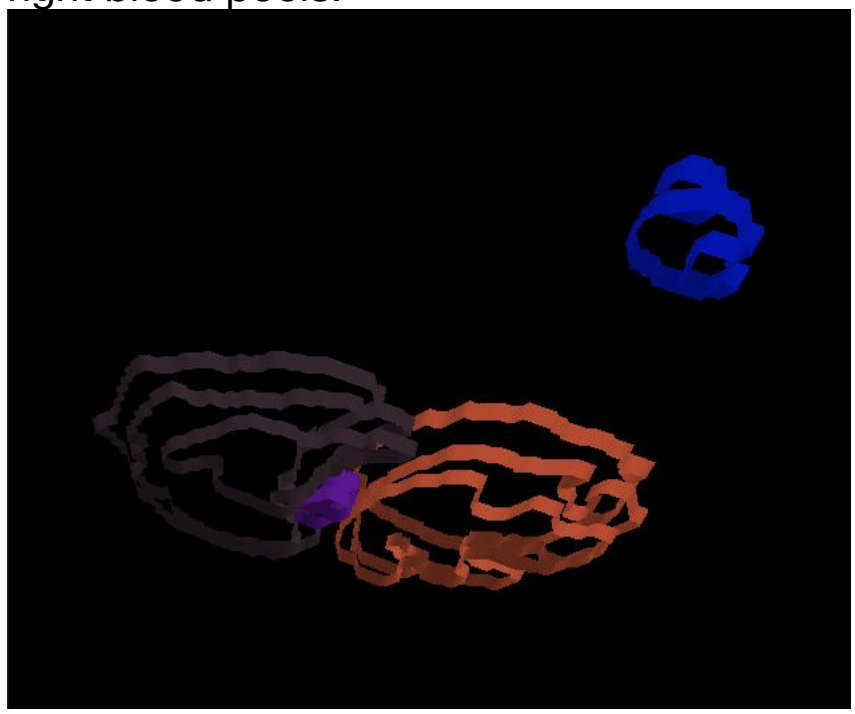
Use **Create New Memory…** to create a new memory file or **Recall Memory…** to read one. Memory files have a .4qm file extension. Recognizer neurons are accessed and labeled using **Add Observation.** Tissue object discriminator values are sensed, added to memory, and written to the file automatically. Values are displayed using **Display Observations**. At least 3 observations are required to attempt recognition of a tissue object. Observations can be added at any time. Use **Label Object** to recognize and label an object.

The brain controls eye movement with saccadic eye movements. Start stepping with **Auto Label**. The first location is the center of the selected slice image. The brain will sense the periphery for a location to create the next tissue object and continue to step from there. The object is automatically recognized and labeled at each step.



The two blood pools in this three-slice volume were recognized and labeled using **Label Object**. Propagation occurred automatically.

Here saccadic eye movement using **Auto Label** took 4 steps and recognized the left and right blood pools, The other two tissue objects were not recognized. The brain was taught to recognize only left or right blood pools.



About the Author

H. Ross Singleton has a twenty-year history in medical imaging. He graduated from Purdue University with a BS in Engineering Sciences Engineering later renamed Aero Astro & Mechanical Engineering. He left the university with a commission as an Ensign in the USNR and served in the Supply Corp as a Disbursing Officer, the civilian equivalent of a financial manager for approximately 500 sailors. He is a Vietnam veteran, having spent two nine-month tours aboard a guided missile frigate in and around North Vietnam and North Korea. Upon discharge, he entered the University of Michigan and graduated with an MS in Bioengineering. He was recruited by Medical Data Systems, a startup office in Ann Arbor, Michigan. There, he became deeply involved in Nuclear Cardiology. He developed Serial Mode that led to the first commercial scintillation camera multiple gated acquisition software termed MUGA. After leaving the office, he was recruited by the University of Alabama at Birmingham Cardiology Division to do research in Cardiac Nuclear MRI. Work in this technology led to numerous publications on edge detection and related applications. Upon leaving the university, he became a professional software and systems engineer (CSEP), working with BellSouth, SAIC (Ford Motor Company), SAIC (Army), CSC (IRS) and TASC (FAA). Ross is now happily retired in Bloomfield Hills, MI, as Owner/Developer of medical imaging computer vision software.