Loats Associates, Inc.

3D BrainStation: An Overview

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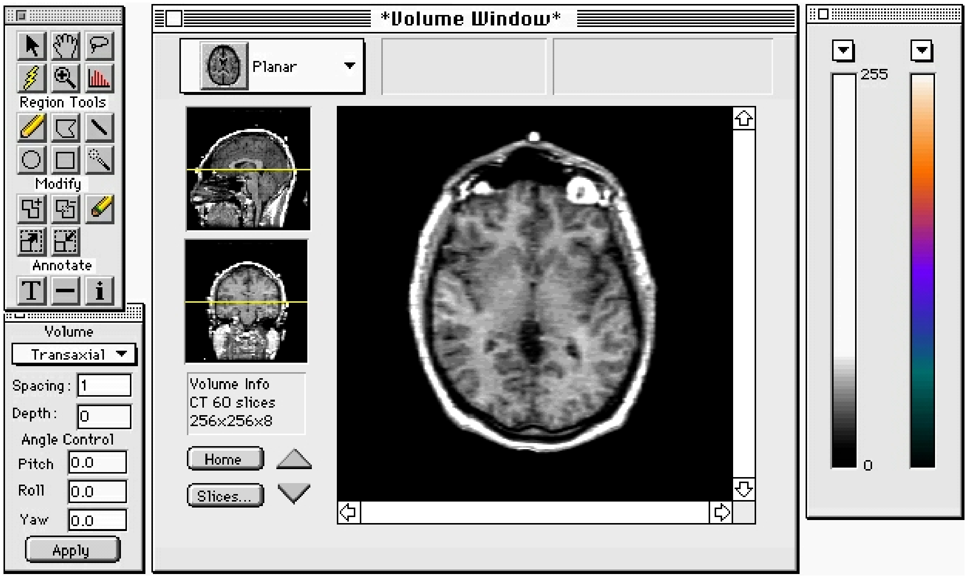
3D BrainStation



Introduction

3D BrainStation allows you to treat brain image data (multi-slices from single subjects) as a coordinated volume structure to:

- implement unimodal and multimodal image registration,
- implement surface viewing and analysis,
- aid in the understanding of behavioral connectivity of cortical and subcortical regions, and
- provide an easy interface for statistical analysis.

3D BrainStation automates the analysis and display of uni-modal and multi-modal brain volume image data sets.

It implements:

- conversion of planar (multi-slice) brain image data sets acquired by nuclear medicine and radiologic imaging into aggregated (coordinated) 3D volume data sets,
- orthogonal image projections along standard reference planes or at interactive user-specified orientations,
- registration of different imaging modalities to a common reference coordinate system,
- creation of single modality or fused (overlay of metabolic and anatomical) surface images for display and analysis,
- also, it creates region-of-interest (ROI) sampling sets (coupled to different slice views and thicknesses) for automated data analysis, and
- it implements the development of single subject or group atlas ROI sets.

Overview

Metabolic (PET/SPECT) and anatomic (MRI/CT) brain images contain complementary information necessary to interpret brain function and pathology. Magnetic Resonance Imaging and X-ray Computed Tomographic (MRI, CT) provide information with relatively high spatial resolution with respect to the anatomy of the brain. MRI provides good soft-tissue discrimination, while CT provides good definition of bony structures, with reduced contrast for soft-tissue. Positron Emission Tomography and Single-Photon Emission Tomography (PET, SPECT) contain physiologic information (local glucose metabolism, local protein synthesis, cerebral blood flow, cerebral oxygen utilization, in vivo receptor binding), but with lower resolution than the anatomic images.

3D BrainStation overcomes the shortcomings of single mode image analysis by combining the features of more than one imaging modality. This enables researchers to answer many important clinical and research questions related to the brain. 3D BrainStation correlates and superimposes the behaviorally-based physiologic information from PET/SPECT images onto an anatomical image substrate derived from registered MRI/CT images so that both can be viewed, sampled and analyzed simultaneously.

There are four major applications which require or benefit from 3D volume anatomic/functional image registration and fusion techniques:

•1 Functional Dissection - Functional dissection is the partitioning of functional images - metabolic PET (FDG,bloodflow, etc) - based on anatomical landmarks found in 1) registered MRI or 2) stereotactic atlases. The major objective is to map the activation fields related to specific tasks or pathology onto the cytoarchitecture of the brain to isolate metabolic response.

•2 Functional Pattern Mapping - The volume data structure of 3D BrainStation allows the identification of the distributed brain structures involved in specific behavioral tasks and pathologies. One of the benefits of relating functional activation to anatomic landmarks is to allow individual experiment comparisons with a large previously acquired body of brain mapping information related to the brain's cytoarchitecture.

•3 Development of Group Statistics - 3D BrainStation has implemented techniques to facilitate the process fo developing statistics from a group fo similar subjects.

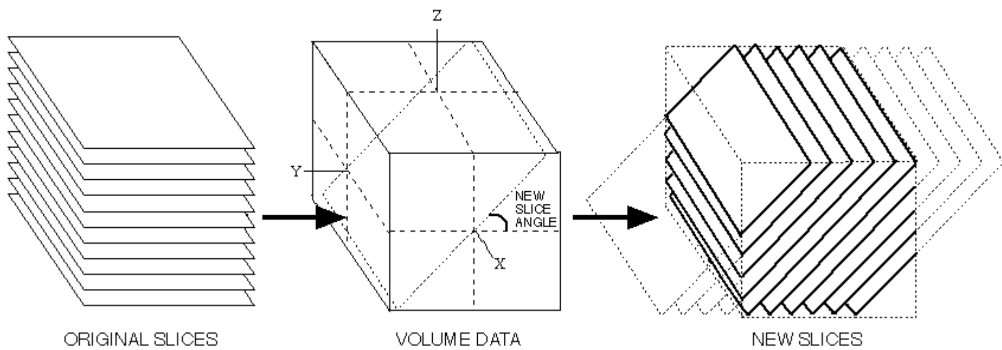
•4 Development and visualization of brain surface 3D structures.

Volume Data Sets

Images are acquired as a group of slices with predetermined thickness, resolution and spacing. 3D BrainStation imports these images and treats them as a single 3-dimensional data set. This means that all aspects of the size and resolution of the images are taken into account to create a volume data set that can be used to create new slices at any angle or to create surface views of the brain. The same slices or surfaces can be generated from registered data sets.

Reslicing Volume Data

The user views single planes of data or complete serial data sets at a specified angle that can be adjusted to most accurately visualize any structure within the brain. Any angle and depth can be used to slice the brain ata given location. The angle can also be adjusted to accomodate a reference coordinate system.

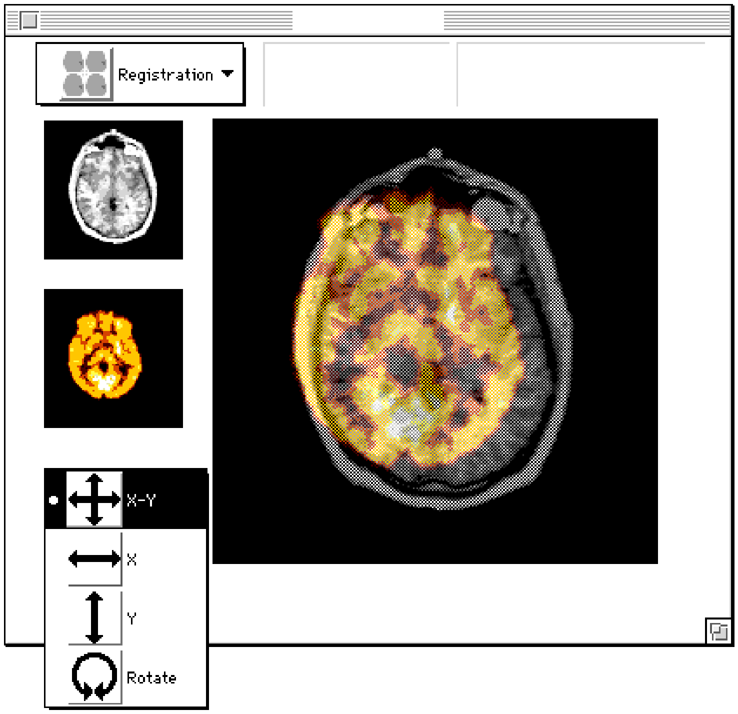


Construct 3D Volume Data Sets from Serial PET and MRI Image Data Sets

Registration of Two Data Sets

Without reference to anatomical landmarks, it is difficult to correctly correlate the activity presented in the PET or SPECT images to specific anatomic regions. The metabolic activity images often do not present features which exactly correlate with recognizable anatomic features and so are not easily interpreted. This reference to anatomical landmarks generally from images derived from MRI requires registration of the physiologic (PET, etc.) and anatomic (MRI, etc.) image data sets. Accurate registration forms the basis for image correlation.

Registration can be accomplished either prospectively or retrospectively. In the prospective method, external reference points are pre-established for both imaging modalities. When registering after imaging, both external fabricated fiducials or natural anatomical landmarks are used with a manual fitting procedure in order to accomplish registration.



Register different Image Modalities for Easy Correlation

In general, registration involves three steps:

1) extraction of common features (natural, fiducial or user-defined) in the target and object image,

2) determination of the transformation parameters by matching the common features in the target and object images, and

3) mathematical transformation and digital remapping of the images.

Simple registration is implemented by determining from three to six coordinate sets (3 translations, 3 rotations), and using these parameters to calculate the transformed coordinates of the base image.

Image Fusion

Fusion is a process of image superposition. The primary objective of visual (on-screen) fusion is to facilitate the anatomical interpretation of functional images. Image fusion permits the direct, simultaneous review of various image modalities, each of which is represented by a different color palette and highlights different but complementary information. Image fusion portrays the functional (PET, SPECT) information in an anatomic context provided by the MRI or CT images. Given registered image data sets, overlay of congruent planes portray both metabolic activity or blood flow related to the underlying anatomy.

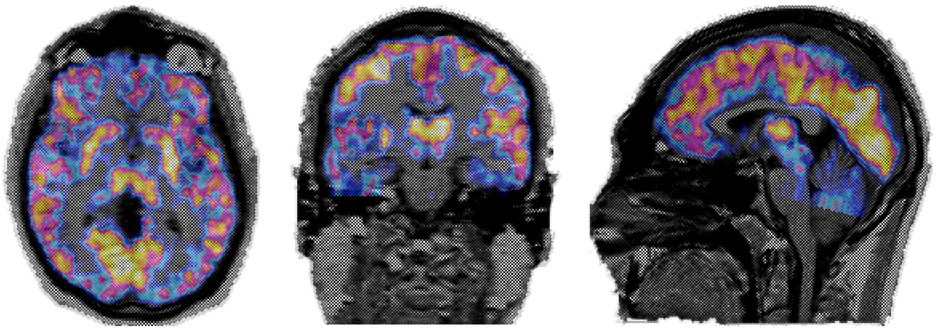


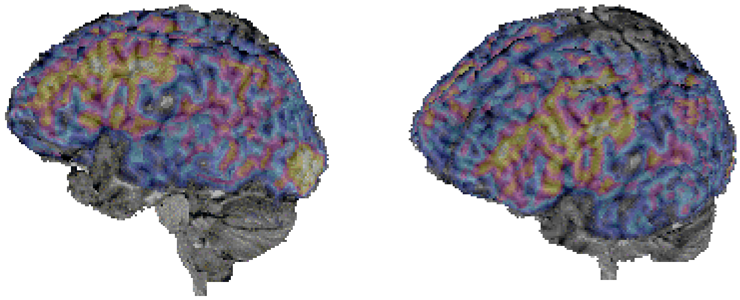
Image Fusion Facilities Anatomical Interpretation Of Function Images

Fusion is simplified by partitioning the display palette into distinct color regimes, each representing the level/content of a single modality. The display palette defines the color or grayscale mapping representation. For ease of review and because of general familiarity, the anatomic image is usually assigned a gray scale palette and forms the background image. The functional image is displayed in an overlay fashion in a visually contrasting palette. This is usually a color palette which assigns activity levels to colors which are easily interpreted as being ordered.

An ordered color palette assigns the "cooler" colors to low values and the "hotter" colors to higher activity values. Automation of the display allows individual image planes to be suppressed or enhanced as required. The colors representing the functional (PET) and anatomic (MRI) images are blended for optimum visual contrast. The contrast of either or both image planes can be adjusted to highlight function or anatomy.

Surface Generation

Surface projections can be created from the volume data by either automatic edge detection or user-specified edge detection of the brain.



Create Fused Surfaces

Cortical Surface Pattern Mapping

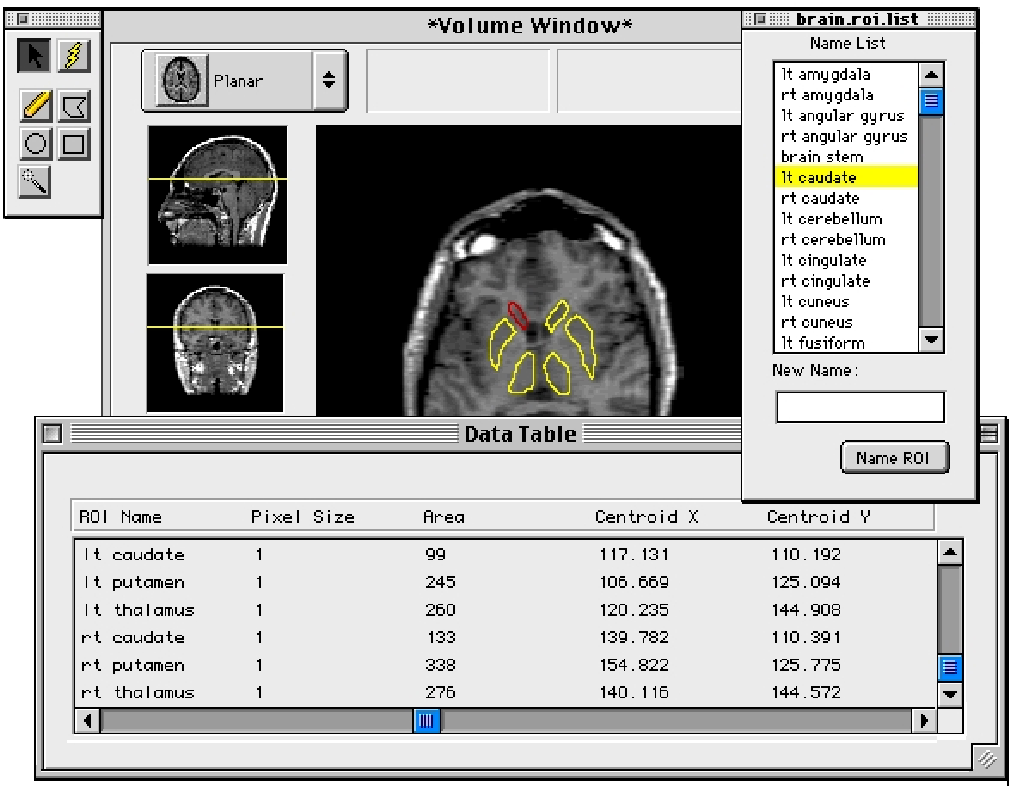
The generation of surface views of the brain makes possible the measurement of the activity found in a specific gyrus or the mapping of the whole cortical surface. The cortical pattern mapping can be used to compare the cortical response of two subjects with similar pathologies. It can also be used to map the metabolic activity relating to a specific task in many subjects, and thereby locate areas of brain response.

Sampling Regions-of-Interest

ROI Creation

A benefit in providing correlation of functional/anatomical information is the capability to develop subject specific anatomic atlas overlays. The development of subject specific atlases provides a technique for automated region-of-interest sampling since the anatomically derived regions-of-interests match all successive registered image data sets.

Surface images clearly show identifiable sulcal landmarks which can serve as a basis for a cortical surface atlas. Atlases can be used in automatic region-of-interest sampling by projection of the digitally obtained regions from the anatomical substrate onto the functional images.



Sample with List-Directed Regions

Based on the Regions-of-Interest selected, metabolic activity measurements may be generated for any PET/SPECT data.

