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List of functionalities – nordicICE 4.1

Introduction

nordicICE 4.1 (nordic Image Control and Evaluation) is a viewing, analysis and processing software package, used to evaluate image data in DICOM and nifti format. In addition to a wide range of basic image processing and analysis functions, including batch analysis functionality, nordicICE provides comprehensive functionality for dynamic image analysis of functional MR data (e.g. perfusion, DCE, ASL, DWI, DTI, BOLD fMRI, Resting state).

nordicICE 4.1 is a research-only application.

Main focus areas include:

Perfusion: Perfusion analysis can be used to obtain qualitative as well as (semi-) quantitative perfusion maps based on the dynamic (first-pass) effect of a contrast agent. The module includes:
- Perfusion analysis of both T1 and T2 first-pass effects
- Optional correction for measured arterial input function using different state-of-the-art deconvolution techniques
- Manual or automatic detection of AIF (arterial input function), or use of population based AIFs.
- Various methods for corrections for contrast agent leakage to extravascular space.

DCE: The Dynamic Contrast Enhanced (DCE) analysis can be used to obtain qualitative as well as (semi-) quantitative maps of several parameters related to vascular permeability and intra- extravascular volumes based on the dynamic effect of a contrast-enhancing agent. The module includes:
- Measurement of qualitative dynamic curve parameters such as peak up-slope (wash-in), down-slope (wash-out), area under the curve (AUC), time-to-peak enhancement (TTP), peak enhancement.
- Various parametric tracer kinetic models of the dynamic CA response for estimation of kinetic parameters such as K^{trans}, k_{ep}, extravascular extracellular space (v_e) and plasma volume (V_p).
- Optional correction for measured arterial input function with manual or automatic detection of AIF, or use of population based AIFs, and possibilities for doing venous output detection for partial volume corrections.

Arterial Spin Labelling (ASL): Pseudo-continuous ASL (pCASL) and pulsed ASL (PASL –QIPPS II) are supported, in order to calculate the blood flow map based on the technique where the blood itself is labelled and used as an intrinsic contrast agent.

T1- and T2-relaxation (T1 and T2-mapping): To analyze the relaxivity properties in tissue. T1-relaxation can be done based on multiple data types: inversion recovery, saturation recovery or multiple flip-angles. Both modules include advanced analysis methods and several output maps.

DWI: Diffusion weighted analysis to visualize the degree of local water diffusion. Mono- or bi-exponential analysis can be done, with advanced options and multiple output maps.

BOLD fMRI: BOLD analysis is used to highlight small magnetic susceptibility changes in the human brain in areas with altered blood-flow resulting from neuronal activity.

Resting state: Resting state analysis is done to explore correlations between activity in different parts of the brain using seed-based analysis.

DTI/Fiber Tracking: Diffusion tensor analysis is used to visualize the degree of anisotropic water diffusion in different regions. Fiber tracking utilizes the directional dependency of the diffusion to display the white matter structure in the brain.

Batch functionality: For processing of many datasets. Once settings are specified, analysis of several datasets can be run automatically without the need for user interactions. This module includes analyses such as perfusion, DCE, T1 relaxation, ASL analysis, DWI, image conversions, co-registration, pre-processing as well as various image analysis tools.

List of features:

Key features

- Module-based post-processing and analysis of Perfusion, DCE, ASL, BOLD fMRI, DWI, DTI and Relaxation.
- User-friendly interface for step-by-step analysis.
- Batch module for effective analysis of many datasets.
- DICOM database for easy image/data retrieval and saving.
- Support for image data in both DICOM and NIFTI formats.

Image Loading and Saving

- Compatibility with all major MR vendors
- Can read a variety of image formats:
    - Dicom, NIFTI, RAW, BMP, JPEG, TIFF
    - Ability to render most DICOM formats including lossless jpeg compressed, RGB, mosaic and multi-frame formats.
- Image loading through several types of interfaces, depending on image type and user preferences.
- Easy transfer of image data to other Windows applications.
- Dicom header modification prior to saving (e.g. patient anonymization, etc).
- Database with query/retrieve, import, export and send functionality.
- Possibility for storing images in different formats including DICOM, NIFTI, jpg, bmp, raw, avi.
- Image conversions (DICOM -> NIFTI and NIFTI -> DICOM)

Perfusion module

- "One-button" perfusion analysis using pre-defined settings (ctrl+p)
- Fast generation of output maps including

- o Relative blood flow (rBV)
- o Relative blood volume (rBV)
- o Mean transit time (MTT)
- o Time to peak (TTP)/Delay
- o Leakage map (apparent contrast agent permeability (Ktrans) map)
- o Chi-square map
- Multiple additional output maps for advanced analysis and quality control
- Relative or (semi-) quantitative analysis
- Multiple state-of-the-art deconvolution techniques
  - o Standard SVD (singular value deconvolution)
  - o Delay insensitive SVD
- Optional automatic normalization to automatically segmented white matter, grey matter or both.
- Choice of manual or fully automatic (slice-wise or whole volume) selection of arterial input function (AIF), or population based AIF.
- Visual inspection of dynamic curves from AIF-pixels/ROI.
- Methods for leakage correction.
- Vessel segmentation
- Optional gamma-variate fitting of input function and tissue curves
- Integrated motion correction
- Easy image fusion (drag & drop) of perfusion maps and structural images

Dynamic contrast enhanced (DCE) module

- State-of-the art deconvolution techniques for arterial input function (AIF) corrected kinetic analysis.
- Fast generation of both quantitative and qualitative output maps including
  - o K^{trans}
  - o K_{ep}
  - o Distribution volume (V_e)
  - o Plasma volume (V_p)
  - o Area under the curve (AUC)
  - o Time to peak
  - o Peak enhancement
  - o Wash-in/wash-out rates
- Choice of manual or fully automatic selection of arterial input function (AIF), or population based AIF.
- Visual inspection of dynamic curves from AIF-pixels/ROI, and partial volume corrections.
- Integrated motion correction
- Large range of advanced processing options
- Easy image fusion (drag & drop) of perfusion maps and structural images.

Diffusion weighted analysis (DWI) module

- Diffusion analysis of diffusion weighted MRI with one or three directions.

- Any number of b-values can be used
- Mono- or bi-exponential (IVIM) curve fitting with possibilities for non-uniform weighting of data points.
- Pre-processing steps include
    - Spatial smoothing
    - Temporal smoothing
    - Automatic noise level cutoff
- Apparent Diffusion Coefficient (ADC) curve fitting including possibilities for advanced parameter modeling if the highest b-value is close to the noise level
- Possibility for removal of spike images
- Output maps include
    - ADC, ADC (fast), ADC (slow)
    - Volume fractions (fast and slow)
    - bMax and T2-corrected bMax
    - 'Anisotropy': a pseudo anisotropy based on the three diffusion gradient directions
    - Chi-square

ASL

- Perfusion map (CBF) is produced
- Pseudo-continuous ASL (pCASL) and pulsed ASll (PASL –QIPPS II) are supported
- Easy drag & drop interface
- Integrated motion correction and M0 -> ASL coregistration
- Qualitative or quantitative analysis
    - Quantitative analysis by using dedicated M0 image, or from ASL control image
- Possibility for creating time-series from ASL input data
- Outlier detection, smoothing and noise level thresholding
- Automatic detection of image and slice order, which can be changed manually if needed.

Batch analysis

- Run analysis of several datasets of the same type without user interaction
- Data is loaded from file and output maps are saved in dedicated folders in a logical data structure
- DICOM and NIFTI formats can be used
- Analysis available in batch include
    - Perfusion, DCE, ASL, T1 mapping, DWI
    - Image conversion, downsampling, resampling
    - Pre-processing, motion correction, co-registration
    - Normalize and mask, ROI analysis, pixel extraction

T1 relaxation analysis

- T1 relaxation from multiple input data types: inversion recovery, saturation recovery or multiple flip-angles.

- Advanced options including outlier removal, spatial and temporal smoothing and noise level detection.
- Possibility for curve analysis with uneven least-square weighting.
- Generation of T1 map, R1 map, M0 map and Chi-square map.

T2 relaxation analysis

- T2 and T2* relaxation analysis
- Baseline correction, outlier elimination, spatial and temporal smoothing and noise detection.
- Possibility for curve analysis with least-square weighting with non-uniform weighting.
- Generation of T2/T2*map, R2/R2* map, M0 map and Chi-square map.

Diffusion tensor analysis (DTI) module

- DTI pre-processing steps includes
  - Motion correction
  - Eddy current correction
  - Automatic noise threshold detection
  - Smoothing of images
- Integrated correction scheme for motion and eddy current artifacts
- Co-registration between DTI series and structural datasets.
- Easy configuration of diffusion gradient configuration
  - Automatic attempt to extract diffusion gradient configuration from DICOM header
  - Custom configuration possible, including uploading from file
- Fast generation of parametric maps:
  - Color-coded DTI
  - Fractional anisotropy (FA)
  - Apparent diffusion coefficient/Mean diffusivity (ADC)
  - Trace weighted
  - Tensor eigenvalues (λ_1, λ_2 and λ_3)
- 3D tractography using seed/target approach or exhaustive search (FACT-algorithm).
- Optimize tracking results by selection of termination criteria (FA-value, tract turning angle and minimum fiber length).
- 3D visualization of white matter fiber tracts superimposed on various underlay volumes (structural, FA, color-coded eigenvector maps etc.).
- Interactive selection of specific white matter fiber bundles using Region-of-Interest tools.
- Superimposing of 3D BOLD fMRI activations.
- Saving parametric maps, 3D snapshots or animations to various file formats or directly to PACS.

BOLD fMRI module

- Possibility for importing, creating or editing BOLD design files including:
  - BOLD paradigm and contrasts
  - Preprocessing steps

- fMRI pre-processing steps includes
    - Slice time correction
    - Motion correction
    - Gaussian smoothing
    - High-Pass filtering
- BOLD analysis with the General Linear Model
- 2D/3D visualization or activations overlaid structural datasets
- Combined 3D visualization of BOLD activations and white matter fiber tracts from Diffusion Tensor Imaging studies.
- Interactive thresholding of statistical maps
- Automated co-registration of functional and structural datasets.
- Possibilities for saving statistical maps, 3D snapshots and animations to various file formats and/or to PACS.

Resting state module

- Resting state preprocessing steps includes
    - Motion correction
    - Gaussian smoothing
    - Band-pass filtering
- Interactive correlation study
- Seed-based analysis of correlation
- Interactive thresholding of correlation maps
- Possibilities for saving of correlation maps

Wizards

- BOLD/DTI wizard for easy guidance through all steps of a BOLD and DTI analysis (selecting patient – selecting series – editing settings – analyze – visualizing results).

Image Viewing

- Display of medical images from a variety of image sources
- Easy sorting and scrolling through 3- or 4-dimensional datasets
- Multiple viewing formats
- Cine / movie loop display
- Display /copy relevant image information (e.g. from Dicom header)
- Possibility for opening MR series in multi-planar reconstructed (MPR) view
- 3D visualization of BOLD activations and DTI fibers
- Easy interaction with the MPR/3D viewer for visualization of any orientation

Image Manipulation

- Flexible and intuitive tools for basic image manipulation

- o Image size, Zoom, Pan
- o Smoothing
- o Window width/level
- o Change color palette

Image Analysis

- Qualitative or quantitative analysis of certain features in an image or an image set:
  - o Region of interest (ROI) analysis:
    - ▪ Multiple ROI types
    - ▪ Easy and reproducible ROI analysis of large datasets
    - ▪ Easy transfer of ROI data to other Windows applications (e.g. Excel)
    - ▪ Dynamic ROI analysis (time-intensity curves, etc.)
      - Advanced curve fitting of dynamic ROI data to relevant algorithms: Proton relaxation analysis
      - Kinetic modeling of contrast agent enhancement
      - other advanced MR analysis models
    - ▪ ROI Histogram analysis
  - o Volume of interest (VOI) analysis
  - o Intensity line profile analysis
  - o Pixel segmentation analysis
  - o Image masking
  - o Segmentation and pixel editing

Image Processing

- Applying defined processing algorithms to an image or image set, producing derived images or image sets
- Multi-planar reformatting (MPR)
- Maximum/ minimum intensity projections (MIP, mIP)
- Image arithmetics (subtraction, addition, etc.)
- Comprehensive dynamic image analysis package
- Image overlays
  - o Any number of overlays on a given dataset
  - o Individual adjustments of each overlay (color palette, transparency, etc.)
  - o Compatibility with SPM /Analyze image formats
- Co-registration
  - o Direct co-registration of overlays based on Dicom geometry information
  - o Manual adjustment of overlay position, if needed
- Re-slicing of nifti-coregistered data