MINC 2.0: A modality independent format for multidimensional medical images

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Introduction

The MINC (Medical Imaging NetCDF) file format, libraries, and tools provide a framework for manipulating medical images independent of modality. MINC 1.0 was created in 1993 to meet the needs of the brain imaging research community. The format is extremely flexible, providing a range of voxel data types, arbitrary dimensions, and a rich set of supporting data. New functionality and data fields can be added to the specification without requiring the modification of existing files or software. MINC 1.0 files define both a "voxel" coordinate system and a transformation to a "world" or stereotaxic coordinate system. Voxel data may include an optional range conversion from an integer storage format to a floating-point memory format.

Key features in MINC 1.0
•Extensible header with flexible metadata
•Physical vs. logical coordinate system
•Flexible image dimension properties and ordering
•Suitable for multiple modalities

MINC 2.0 is a major revision of the software and file format, drawing upon ten years of experience with MINC 1.0. The increasing complexity of functional imaging experiments, continuing improvements in the resolution of medical imaging scanners, and the proliferation of micro-imaging devices for preclinical and ex-vivo work has pushed data volumes beyond what current file formats can efficiently address. MINC 2.0 adds new data types, improved processing of huge files, and enhanced flexibility for future expansion. By altering the internal layout of the image data, MINC 2.0 enables existing computing resources to process these large datasets.

Design

MINC 2.0 is a specialization of the HDF5 (Hierarchical Data Format 5) format [1], but also provides backward compatibility for MINC 1.0 files, which use the NetCDF format [2].

Building MINC 2.0 using HDF5 allows for improved data compression, non-scalar voxel data, and a hierarchical file structure. This file hierarchy permits storage of voxel data at several resolutions, so lower-resolution "thumbnail" images may be automatically computed and stored as part of the image data. MINC 2.0 also provides 64-bit addressing as needed for huge data files such as 3D mouse imaging or macrocryotome data, and block addressing for more efficient extraction of sub-blocks of data.

MINC 2.0 files may restrict the domain of voxels to an enumerated set of discrete values which can be associated with a textual name. These "labelled" images are appropriate for representing tissue classes or structural information.

The MINC 1.0 library and tools have been extended to interoperate with files conforming to either version of the format. By simply rebuilding an application against the new library, most existing MINC tools and applications will gain the ability to read and write MINC 2.0 format files.

New features in MINC 2.0
•Enumerated, array, and complex voxel types
•64-bit file size
•Multiresolution storage
•Internal compression
•Optional block-structured organization
•Fully interoperable with MINC 1.0

Conclusion

Over the last ten years, the MINC file format has formed the basis for a medical image analysis research environment. Scientists at the Montreal Neurological Institute and over 20 other institutions worldwide use many modalities and methodologies in a single analysis environment built around MINC. The format combines generality and extensibility with a conceptual framework that promotes inter-operability among programs.

MINC 2.0 forms the basis for further enhancement and extension of this software environment. Future work will allow the manipulation of MINC files within scripting languages such as Perl and Python. We are also actively exploring methods for integrating MINC with database systems, and standardizing methods for representing MINC using XML.

Future goals for MINC
•Additional programming language support
•Optional XML metadata representation
•RDBMS integration

An active development community contributes to the expansion of MINC capabilities; a recent MINC workshop held in advance of the MINC 2.0 release had 180 attendees.

MINC software and documentation is available for free download at: **http://www.bic.mni.mcgill.ca/minc/**

References

[1] Folk et al., 2003 (http://hdf.ncsa.uiuc.edu/HDF5/).

[2] Rew et al., 1997 (http://www.unidata.ucar.edu/packages/netcdf/guidec/).