CIFTI-2 Connectivity File Formats

Appendices

CIFTI working group

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Appendix A: Table of NIfTI Intent Codes and Names for CIFTI

NIfTI Intent Code	Value	Intent_name	Extension
NIFTI_INTENT_CONNECTIVITY_UNKNOWN	3000	ConnUnknown	User's choice
NIFTI_INTENT_CONNECTIVITY_DENSE	3001	ConnDense	.dconn.nii
NIFTI_INTENT_CONNECTIVITY_DENSE_SERIES	3002	ConnDenseSeries	.dtseries.nii
NIFTI_INTENT_CONNECTIVITY_PARCELLATED	3003	ConnParcels	.pconn.nii
NIFTI_INTENT_CONNECTIVITY_PARCELLATED_SERIES	3004	ConnParcelSries	.ptseries.nii
NIFTI_INTENT_CONNECTIVITY_DENSE_TRAJECTORY	3005	ConnDenseTraj	.dtraj.nii
NIFTI_INTENT_CONNECTIVITY_DENSE_SCALARS	3006	ConnDenseScalar	.dscalar.nii
NIFTI_INTENT_CONNECTIVITY_DENSE_LABELS	3007	ConnDenseLabel	.dlabel.nii
NIFTI_INTENT_CONNECTIVITY_PARCELLATED_SCALAR	3008	ConnParcelScalr	.pscalar.nii
NIFTI_INTENT_CONNECTIVITY_PARCELLATED_DENSE	3009	ConnParcelDense	.pdconn.nii
NIFTI_INTENT_CONNECTIVITY_DENSE_PARCELLATED	3010	ConnDenseParcel	.dpconn.nii
NIFTI_INTENT_CONNECTIVITY_PARCELLATED_PARCELLATED_SERIES	3011	ConnPPSr	.pconnseries.nii
NIFTI_INTENT_CONNECTIVITY_PARCELLATED_PARCELLATED_SCALAR	3012	ConnPPSc	.pconnscalar.nii

Note: the 'misspelling' of 'ConnParcelSries' and 'ConnParcelScalr' is intentional, due to the 15 character limit of the header field

Note 2: the '.dtraj.nii' type is not currently used or specified, but was reserved in CIFTI-1

Appendix B: List of changes from CIFTI-1

Major changes:

1. Switch the dimension order in the nifti header
   The order in which cifti 1.0 specifies dimensions in the nifti header (number of rows, number of columns) will cause a standard nifti-2 reader to scramble the matrix if it isn't square. Correcting the row and column dimensions to nifti specification (length of row, length of column) in CIFTI-2 will make it easier for other software applications to support cifti.

2. Modified format for parcellated connectivity files
   In CIFTI-1, parcellated connectivity (*.pconn.nii) and parcellated time series (*.ptseries.nii) files can be used to represent data that are mapped to brain parcels (e.g., cortical areas, subcortical nuclei). For CIFTI-2, we propose adding a requirement to include information that

maps each parcel to an explicit set of brainordinates (voxels and/or surface nodes). While this will use more space in the extension, the total file size will still be modest compared to other cifti types. The benefit comes from the ease of displaying parcellation-related data without reference to a separate file that encodes the parcel-to-brainordinate mapping.

3. Disallow compressed row storage (CRS) and gzipped row storage
The options for compressing matrix data specified in CIFTI-1 are incompatible with NIfTI design constraints (CRS consists of multiple arrays of different length; gzipped data is not numeric). Neither of these compression options have actually been utilized to date for CIFTI-based analyses, as far as we are aware. Hence, disallowing them should not pose problems for existing cifti datasets.

4. Switch AppliesToMatrixDimension meanings for "0" and "1"
Previously, "0" described the mapping that applied along the length of a "column", which is actually the second CIFTI matrix dimension. To reduce confusion, these will be changed such that the mapping with AppliesToMatrixDimension "0" applies along the first matrix dimension, "1" applies along the second, "2" along the third, etc.

5. Move the "Volume" XML element to be a child of MatrixIndicesMap
The previous location of the Volume XML element prevented the dimensions of the CIFTI file from being able to have different voxel grids.

6. Remove "CIFTI_INDEX_TYPE_TIME_POINTS" value for the "IndicesMapToDataType" attribute, replace with more general "CIFTI_INDEX_TYPE_SERIES"
To support data regularly sampled in other domains than time (for instance, frequency), the time points mapping was replaced with a more general mapping type that accepts additional units.

7. Remove "CIFTI_INDEX_TYPE_FIBERS" value for the "IndicesMapToDataType"
This mapping type is not currently used because sparse storage is effectively mandatory to use it for the intended purpose (trajectory data), and sparse storage in NIfTI-2 is not allowed in CIFTI-2. Some proposed methods of storing trajectory data involve needing additional information about the encoding in the XML, so the workings of the mapping type cannot yet be specified.

8. Change "Nodes" to "Vertices" and "Node" to "Vertex" in XML element and attribute names
"Node" has been deemed as more ambiguous than "Vertex", and in order to keep the document from referring to "surface vertices", while using the term "Nodes" in the XML, the XML was changed to reflect this terminology.

Minor changes:

1. Remove the "LabelTable" element from "CiftiMatrix"
CIFTI-2 parcel files will not include an embedded label table. A new file type for cifti label files is proposed, which also does not use the file-global label table. The global label table is therefore no longer used for any CIFTI type. This is a minor change because as far as we know, no CIFTI files have been generated that include it.

2. Eliminate pconn requirement for symmetric matrices

In CIFTI-1, the parcellated connectivity specification applies a single map element to both dimensions. This requires the two dimensions of the pconn to be of the same length and have the same meaning. The reformulation of CIFTI-2 parcels avoids this limitation.

3. Use a single specification for allowed datatypes for all cifti files, and allow more than just float32

All cifti files with standard (not sparse) matrices will be able to use floating point (32 and 64 bit) or integer (signed or unsigned, 8, 16, 32, and 64 bit) types. The recommended type for general use is float32. For dense connectomes, 8-bit integer (signed or unsigned) is a notable possibility for reducing file size, and 8 or 16-bit integer is a possibility for dense label files. The nifti scl_slope and scl_inter header fields should, as for all NIfTI files, be examined in order to interpret the raw matrix values correctly.

4. Add “SeriesStart” value required attribute to “MatrixIndicesMap” XML element for new mapping type “CIFTI_INDEX_TYPE_SERIES”

This allows the representation of timeseries that don’t start at zero seconds, and other similar situations for other series types.

5. Add "NumberOfSeriesPoints" as a required attribute to <MatrixIndicesMap> for new mapping type “CIFTI_INDEX_TYPE_SERIES”

This fixes an inconsistency in how CIFTI-1 used mapping types. Most mapping types had enough information to figure out the dimensions, whereas timeseries did not. This change will allow the XML by itself to describe the layout of the CIFTI file, making it easier for ConnectomeDB to provide timeseries data over the network.

6. Change “TimeStep” and “TimeStepUnits” to “SeriesStep”, “SeriesExponent” and “SeriesUnit” for new mapping type “CIFTI_INDEX_TYPE_SERIES”

Since there are now 2 attributes that use the units specified, the word “step” is not appropriate in the attribute describing the units. The word “time” is replaced by “series” to reflect the more general nature of the new mapping type. Additionally, the units no longer rely on NIfTI to specify valid units, and remove the need for explicit SI prefixes by the numeric SeriesExponent attribute.

7. Remove “NumberOfMatrices” attribute from “CIFTI” element

The number of matrices can be derived from the number of “Matrix” tags encountered, so it was redundant. There are currently no plans for more than one matrix element in CIFTI.

8. Make the “TransformationMatrixVoxelIndicesIJKtoXYZ” element required, and only allow it once in a “Volume” element

It is ambiguous to have a volume without a transformation from voxel indices to a coordinate system, but also, having multiple such transformations is more likely to add confusion than utility.

9. Remove the “DataSpace” attribute from the “TransformationMatrixVoxelIndicesIJKtoXYZ” XML element

This attribute does not make sense for the matrix describing the voxel grid, because the raw voxel indices are never a meaningful stereotaxic space.

10. Remove the “TransformedSpace” attribute from the “TransformationMatrixVoxelIndicesIJKtoXYZ” XML element

This attribute is restrictive of the possible spaces the voxels could be in, and is burdensome to actually set correctly. Removing it makes things simpler, so that code for writing CIFTI files doesn't need to know what type of space the voxels are in.

11. Change "UnitsXYZ" attribute of "TransformationMatrixVoxelIndicesIJKtoXYZ" element to "MeterExponent"
Using a numeric exponent with a fixed unit allows more flexibility and simplicity for this purpose than the very few SI prefixes for meter that NIfTI defines.

12. Remove the special cases for BrainModel when the list of nodes/voxels is missing
It is not anticipated that anyone will want to store an entire volume in CIFTI, and the medial wall is usually excluded on surfaces, such that a nodes list must be present. Removing these special cases, which are not currently in use, makes the handling of the BrainModel element simpler.

Additions:

1. Scalar mapping type
This new mapping type gives a name and optional metadata to each index along the dimension. It is used to make the equivalent of a metric (.func.gii) file for CIFTI.

2. Label mapping type
This new mapping type is similar to scalar, but additionally includes a label table for each index along the dimension. It is used to make the equivalent of a label file (e.g., GIFTI *.label.gii) file for CIFTI.

3. New CIFTI intent codes
New intent codes have been added to provide options for 'dense scalar', 'dense label', 'parcellated dense connectivity', 'dense parcellated connectivity', 'parcellated trajectory', 'parcellated scalar', 'parcellated connectivity series', 'parcellated connectivity scalar', and 'unknown cifti' file types. The 'unknown cifti' code will be valid for any CIFTI file not matching other types within the version of the CIFTI specification used. Developers desiring the assignment of a new intent code should consult with the CIFTI working group (hcp-cifti@humanconnectome.org).

4. Specializations of scalar maps
Structured data with a specialized meaning can be given its own extension, but use generic mapping types. Some of the special extensions that are in use (or are planned for use), and the details of their data, are provided.

Appendix C: Alphabetical List of CIFTI XML Elements

BrainModel Element

- *Description* – Maps a range of indices to surface vertices or voxels when IndicesMapToDataType is "CIFTI_INDEX_TYPE_BRAIN_MODELS."
- *Attributes*
- **IndexOffset** - The matrix index of the first brainordinate of this BrainModel. Note that matrix indices are zero-based. Note that matrix indices are zero-based.
- **IndexCount** – Number of surface nodes or voxels in this brain model, must be

positive.

- **ModelType** – Type of model representing the brain structure (surface or voxels). Valid values are listed in the table below.
- **BrainStructure** – Identifies the brain structure. Valid values for BrainStructure are listed in the table below. However, if the needed structure is not listed in the table, a message should be posted to the CIFTI Forum so that a standardized name can be created for the structure and added to the table.
- **SurfaceNumberOfVertices** - When ModelType is CIFTI_MODEL_TYPE_SURFACE this attribute contains the actual (or true) number of vertices in the surface that is associated with this BrainModel. When this BrainModel represents all vertices in the surface, this value is the same as IndexCount. When this BrainModel represents only a subset of the surface's vertices, IndexCount will be less than this value.

- *Child Elements*
- **VertexIndices** (0…1)
- **VoxelIndicesIJK** (0…1)
- *Text Content: [NA]*
- *Parent Element* – **MatrixIndicesMap**

ModelType Values

ModelType	Description
CIFTI_MODEL_TYPE_SURFACE	Modeled using surface vertices.
CIFTI_MODEL_TYPE_VOXELS	Modeled using voxels.

BrainStructure Values

BrainStructure
CIFTI_STRUCTURE_ACCUMBENS_LEFT
CIFTI_STRUCTURE_ACCUMBENS_RIGHT
CIFTI_STRUCTURE_ALL_WHITE_MATTER
CIFTI_STRUCTURE_ALL_GREY_MATTER
CIFTI_STRUCTURE_AMYGDALA_LEFT
CIFTI_STRUCTURE_AMYGDALA_RIGHT
CIFTI_STRUCTURE_BRAIN_STEM
CIFTI_STRUCTURE_CAUDATE_LEFT
CIFTI_STRUCTURE_CAUDATE_RIGHT
CIFTI_STRUCTURE_CEREBELLAR_WHITE_MATTER_LEFT
CIFTI_STRUCTURE_CEREBELLAR_WHITE_MATTER_RIGHT
CIFTI_STRUCTURE_CEREBELLUM
CIFTI_STRUCTURE_CEREBELLUM_LEFT
CIFTI_STRUCTURE_CEREBELLUM_RIGHT
CIFTI_STRUCTURE_CEREBRAL_WHITE_MATTER_LEFT
CIFTI_STRUCTURE_CEREBRAL_WHITE_MATTER_RIGHT
CIFTI_STRUCTURE_CORTEX
CIFTI_STRUCTURE_CORTEX_LEFT
CIFTI_STRUCTURE_CORTEX_RIGHT
CIFTI_STRUCTURE_DIENCEPHALON_VENTRAL_LEFT
CIFTI_STRUCTURE_DIENCEPHALON_VENTRAL_RIGHT
CIFTI_STRUCTURE_HIPPOCAMPUS_LEFT

CIFTI_STRUCTURE_HIPPOCAMPUS_RIGHT
CIFTI_STRUCTURE_OTHER
CIFTI_STRUCTURE_OTHER_GREY_MATTER
CIFTI_STRUCTURE_OTHER_WHITE_MATTER
CIFTI_STRUCTURE_PALLIDUM_LEFT
CIFTI_STRUCTURE_PALLIDUM_RIGHT
CIFTI_STRUCTURE_PUTAMEN_LEFT
CIFTI_STRUCTURE_PUTAMEN_RIGHT
CIFTI_STRUCTURE_THALAMUS_LEFT
CIFTI_STRUCTURE_THALAMUS_RIGHT

CIFTI Element

- *Description* – The root of the CIFTI XML.
- *Attributes*
- **Version** – Indicates version of the CIFTI XML. Value is "1" or "2".
- *Child Elements*
- **Matrix** (1). At this time, there is only one Matrix child. Future versions of CIFTI may allow more than one Matrix child.
- *Text Content: [NA]*
- *Parent Element: [NA]*

Label Element

- *Description* – Associates a label key value with a name and a display color.
- *Attributes*
- **Key** – Integer, data value which is assigned this name and color.
- **Red** – Red color component for label. Value is floating point with range 0.0 to 1.0.
- **Green** – Green color component for label. Value is floating point with range 0.0 to 1.0.
- **Blue** – Blue color component for label. Value is floating point with range 0.0 to 1.0.
- **Alpha** – Alpha color component for label. Value is floating point with range 0.0 to 1.0.
- *Child Elements: [NA]*
- *Text Content* – Name of the label.
- *Parent Element* – **LabelTable**

LabelTable Element

- *Description* - Used by NamedMap when IndicesMapToDataType is "CIFTI_INDEX_TYPE_LABELS" in order to associate names and display colors with label keys. Note that LABELS is the only mapping type that uses a LabelTable. Display coloring of continuous-valued data is not specified by CIFTI-2.
- *Attributes: [NA]*
- *Child Elements* – **Label** (0…N)
- *Text Content: [NA]*
- *Parent Element* – **NamedMap**

MapName Element

- *Description* – Contains a map name.

- *Attributes: [NA]*
- *Child Elements: [NA]*
- *Text Content* – The name of the map.
- *Parent Element* - **NamedMap**

Matrix Element

- *Description* – Contains child elements that describe the meaning of the values in the matrix.
- *Attributes: [NA]*
- *Child Elements*
- **MetaData** (0…1)
- **MatrixIndicesMap** (1…N)
- *Text Content: [NA]*
- *Parent Element* – **CIFTI**

MatrixIndicesMap Element

- *Description* – Provides a mapping between matrix indices and their interpretation.
- *Attributes*
- **AppliesToMatrixDimension** – Lists the dimension(s) of the matrix to which this MatrixIndicesMap applies. The dimensions of the matrix start at zero (dimension 0 describes the indices along the first dimension, dimension 1 describes the indices along the second dimension, etc.). If this MatrixIndicesMap applies to more than one matrix dimension, the values are separated by a comma.
- **IndicesMapToDataType** – Type of data to which the MatrixIndicesMap applies.
- **NumberOfSeriesPoints** - Indicates how many samples there are in a series mapping type. For example, this could be the number of timepoints in a timeseries.
- **SeriesExponent** - Integer, SeriesStart and SeriesStep must be multiplied by 10 raised to the power of the value of this attribute to give the actual values assigned to indices (e.g., if SeriesStart is “5” and SeriesExponent is “-3”, the value of the first series point is 0.005).
- **SeriesStart** - Indicates what quantity should be assigned to the first series point.
- **SeriesStep** - Indicates amount of change between each series point.
- **SeriesUnit** – Indicates the unit of the result of multiplying SeriesStart and SeriesStep by 10 to the power of SeriesExponent.
- *Child Elements*
- **BrainModel** (0…N)
- **NamedMap** (0…N)
- **Parcel** (0…N)
- **Surface** (0…N)
- **Volume** (0…1)
- *Text Content: [NA]*
- *Parent Element* – **Matrix**

IndicesMapToDataType

Value	Description
CIFTI_INDEX_TYPE_BRAIN_MODELS	The dimension represents one or more brain models.
CIFTI_INDEX_TYPE_PARCELS	The dimension represents a parcellation scheme.
CIFTI_INDEX_TYPE_SERIES	The dimension represents a series of regular samples.
CIFTI_INDEX_TYPE_SCALARS	The dimension represents named scalar maps.

CIFTI_INDEX_TYPE_LABELS	The dimension represents named label maps.

SeriesUnit

Value
SECOND
HERTZ
METER
RADIAN

MD Element

- *Description* – A single metadata entry consisting of a name and a value.
- *Attributes: [NA]*
- *Child Elements*
- **Name** (1)
- **Value** (1)
- *Text Content: [NA]*
- *Parent Element* – **MetaData**

MetaData Element

- *Description* – Provides a simple method for user-supplied metadata that associates names with values.
- *Attributes: [NA]*
- *Child Elements*
- **MD** (0…N)
- *Text Content: [NA]*
- *Parent Elements* – **Matrix, NamedMap**

Name Element

- *Description* – Content is the name of a metadata entry.
- *Attributes: [NA]*
- *Child Elements: [NA]*
- *Text Content* – Name of metadata element.
- *Parent Element* – **MD**

NamedMap Element

- *Description* – Associates a name, optional metadata, and possibly a LabelTabel with an index in a map.
- *Attributes: [NA]*
- *Child Elements*
- **MapName** (1)
- **LabelTable** (0…1)
- **MetaData** (0…1)
- *Text Content: [NA]*
- *Parent Element* – **MatrixIndicesMap**

Parcel Element

- *Description* – Associates a name, plus vertices and/or voxels, with an index.
- *Attributes*
- **Name** – The name of the parcel
- *Child Elements*
- **Vertices** (0…N)
- **VoxelIndicesIJK** (0…1)
- *Text Content: [NA]*
- *Parent Element* – **MatrixIndicesMap**

Surface Element

- *Description* – Specifies the number of vertices for a surface, when IndicesMapToDataType is "CIFTI_INDEX_TYPE_PARCELS." This is separate from the Parcel element because there can be multiple parcels on one surface, and one parcel may involve multiple surfaces.
- *Attributes*
- **BrainStructure** – A string from the BrainStructure list to identify what surface structure this element refers to (usually left cortex, right cortex, or cerebellum).
- **SurfaceNumberOfVertices** – The number of vertices that this structure's surface contains.
- *Child Elements: [NA]*
- *Text Content: [NA]*
- *Parent Element* – **MatrixIndicesMap**

TransformationMatrixVoxelIndicesIJKtoXYZ Element

- *Description* – Contains a matrix that translates Voxel IJK Indices to spatial XYZ coordinates (+X=>right, +Y=>anterior, +Z=> superior). The resulting coordinate is the center of the voxel.
- *Attributes*
- **MeterExponent** - Integer, specifies that the coordinate result from the transformation matrix should be multiplied by 10 to this power to get the spatial coordinates in meters (e.g., if this is "-3", then the transformation matrix is in millimeters).
- *Child Elements: [NA]*
- *Text Content* - Sixteen floating-point values, in row-major order, that form a 4x4 homogeneous transformation matrix.
- *Parent Element* – **Volume**

The transformation matrix below is encoded into the XML as "m1 m2 m3 m4 m5 m6 m7 m8 m9 m10 m11 m12 m13 m14 m15 m16". The last row, elements [m13, m14, m15, and m16] will always be [0, 0, 0, 1].

```
m1   m2   m3   m4
m5   m6   m7   m8
```

```
 m9 m10 m11 m12
m13 m14 m15 m16
```

Value Element

- *Description* – Content is the value of a metadata entry.
- *Attributes: [NA]*
- *Child Elements: [NA]*
- *Text Content* – Value of metadata element.
- *Parent Element* – **MD**

VertexIndices Element

- *Description* – Contains a list of vertex indices for a BrainModel with ModelType equal to CIFTI_MODEL_TYPE_SURFACE.
- *Attributes: [NA]*
- *Child Elements: [NA]*
- *Text Content* – The vertex indices (which are independent for each surface, and zero-based) that are used in this brain model, with each index separated by a whitespace character. The parent BrainModel's IndexCount attribute indicates the number of indices in this element's content.
- *Parent Element* – **BrainModel**

Vertices Element

- *Description* – Contains a BrainStructure type and a list of vertex indices within a Parcel.
- *Attributes*
- **BrainStructure** – A string from the BrainStructure list to identify what surface this vertex list is from (usually left cortex, right cortex, or cerebellum).
- *Child Elements: [NA]*
- *Text Content* – Vertex indices (which are independent for each surface, and zero-based) separated by whitespace characters.
- *Parent Element* – **Parcel**

Volume Element

- *Description* – Provides information about the volume for any mappings that use voxels.
- *Attributes*
    - **VolumeDimensions** – Three integer values separated by commas, the lengths of the three volume file dimensions that are related to spatial coordinates, in number of voxels. Voxel indices (which are zero-based) that are used in the mapping that this element applies to must be within these dimensions.
- *Child Elements*
- **TransformationMatrixVoxelIndicesIJKtoXYZ** (1)
- *Text Content: [NA]*
- *Parent Element* – **MatrixIndicesMap**

VoxelIndicesIJK Element

- *Description* – Identifies the voxels that model a brain structure. Note that IndexCount, an attribute of the parent BrainModel element, indicates the number of voxels contained in the element.
- *Attributes: [NA]*
- *Child Elements: [NA]*
- *Text Content* – IJK indices (which are zero-based) of each voxel in the brain model or parcel, with each index separated by a whitespace character. There are three indices per voxel. If the parent element is BrainModel, then the BrainModel element's IndexCount attribute indicates the number of triplets (IJK indices) in this element's content.
- *Parent Elements* – **BrainModel**, **Parcel**

Appendix D: CIFTI XML Examples

Example Dense Connectivity XML

This example Dense Connectivity XML contains symmetric connectivity data for two brain structures, a three vertex left cerebral cortex and a two voxel left thalamus. The connectivity data is symmetric in this example, so there is one MatrixIndicesMap with its AppliesToMatrixDimension attribute set to "0,1".

```
<CIFTI Version="2">
    <Matrix>
        <MetaData>
            <MD>
                <Name>UserName</Name>
                <Value>Joe User</Value>
            </MD>
        </MetaData>
        <MatrixIndicesMap AppliesToMatrixDimension="0,1"
            IndicesMapToDataType="CIFTI_INDEX_TYPE_BRAIN_MODELS">
            <Volume VolumeDimensions="176,208,176">
                <TransformationMatrixVoxelIndicesIJKtoXYZ
                    MeterExponent="-3">
                    -2.0   0.0  0.0  126.0
                    0.0  -2.0  0.0  128.0
                    0.0   0.0  2.0  -66.0
                    0.0   0.0  0.0    1.0
                </TransformationMatrixVoxelIndicesIJKtoXYZ>
            </Volume>
            <BrainModel IndexOffset="0"
                     IndexCount="3"
                     ModelType="CIFTI_MODEL_TYPE_SURFACE"
                     BrainStructure="CIFTI_STRUCTURE_CORTEX_LEFT"
                     SurfaceNumberOfVertices="7">
                <VertexIndices>
                    0 2 4
                </VertexIndices>
            </BrainModel>
            <BrainModel IndexOffset="3"
                     IndexCount="2"
                     ModelType="CIFTI_MODEL_TYPE_VOXELS"
                     BrainStructure="CIFTI_STRUCTURE_THALAMUS_LEFT">
```

```
                <VoxelIndicesIJK>
                    27 38 40
                    27 39 40
                </VoxelIndicesIJK>
            </BrainModel>
        </MatrixIndicesMap>
    </Matrix>
</CIFTI>
```

Example Dense Data Series XML

This example Dense Data Series XML contains data for two brain structures along columns, a three vertex left cerebral cortex and a two voxel left thalamus. Along rows, there is a dataseries with three time points with two seconds between each time point, starting at 0 seconds.

```
<CIFTI Version="2">
    <Matrix>
        <MetaData>
            <MD>
                <Name>UserName</Name>
                <Value>Joe User</Value>
            </MD>
        </MetaData>
        <MatrixIndicesMap AppliesToMatrixDimension="0"
            IndicesMapToDataType="CIFTI_INDEX_TYPE_SERIES"
            NumberOfSeriesPoints="3"
            SeriesExponent="0"
            SeriesStart="0.0"
            SeriesStep="2.0"
            SeriesUnit="SECOND">
        </MatrixIndicesMap>
        <MatrixIndicesMap AppliesToMatrixDimension="1"
            IndicesMapToDataType="CIFTI_INDEX_TYPE_BRAIN_MODELS">
            <Volume VolumeDimensions="176,208,176">
                <TransformationMatrixVoxelIndicesIJKtoXYZ
                    MeterExponent="-3">
                    -2.0   0.0  0.0  126.0
                    0.0  -2.0  0.0  128.0
                    0.0   0.0  2.0  -66.0
                    0.0   0.0  0.0    1.0
                </TransformationMatrixVoxelIndicesIJKtoXYZ>
            </Volume>
            <BrainModel IndexOffset="0"
                 IndexCount="3"
                 ModelType="CIFTI_MODEL_TYPE_SURFACE"
                 BrainStructure="CIFTI_STRUCTURE_CORTEX_LEFT"
                 SurfaceNumberOfVertices="7">
                <VertexIndices>
                    0 2 4
                </VertexIndices>
            </BrainModel>
            <BrainModel IndexOffset="3"
                 IndexCount="2"
                 ModelType="CIFTI_MODEL_TYPE_VOXELS"
```

```
                    BrainStructure="CIFTI_STRUCTURE_THALAMUS_LEFT">
                <VoxelIndicesIJK>
                    27 38 40
                    27 39 40
                </VoxelIndicesIJK>
            </BrainModel>
        </MatrixIndicesMap>
    </Matrix>
</CIFTI>
```

Example Parcellated Connectivity XML

This Parcellated Connectivity XML contains a partitioning scheme with two parcels, V1 and V2. In this case, the parcellated file is symmetric, so there is only one MatrixIndicesMap that applies to both dimensions.

```
<CIFTI Version="2">
    <Matrix>
        <MetaData>
            <MD>
                <Name>UserName</Name>
                <Value>Joe User</Value>
            </MD>
        </MetaData>
        <MatrixIndicesMap AppliesToMatrixDimension="0,1"
            IndicesMapToDataType="CIFTI_INDEX_TYPE_PARCELS">
            <Volume VolumeDimensions="176,208,176">
                <TransformationMatrixVoxelIndicesIJKtoXYZ
                    MeterExponent="-3">
                    -2.0   0.0  0.0  126.0
                    0.0  -2.0  0.0  128.0
                    0.0   0.0  2.0  -66.0
                    0.0   0.0  0.0    1.0
                </TransformationMatrixVoxelIndicesIJKtoXYZ>
            </Volume>
            <Surface BrainStructure="CIFTI_STRUCTURE_CORTEX_LEFT"
                SurfaceNumberOfVertices="32492"/>
            <Surface BrainStructure="CIFTI_STRUCTURE_CORTEX_RIGHT"
                SurfaceNumberOfVertices="32492"/>
            <Parcel Name="V1">
                <Vertices
                    BrainStructure="CIFTI_STRUCTURE_CORTEX_LEFT">
                    0 1 2 3
                </Vertices>
                <Vertices
                    BrainStructure="CIFTI_STRUCTURE_CORTEX_RIGHT">
                    4 5 6 7
                </Vertices>
                <VoxelIndicesIJK>
                    22 25 30
                </VoxelIndicesIJK>
            </Parcel>
            <Parcel Name="V2">
                <Vertices
```

```
                    BrainStructure="CIFTI_STRUCTURE_CORTEX_LEFT">
                    9 10 11 12
                </Vertices>
                <Vertices
                    BrainStructure="CIFTI_STRUCTURE_CORTEX_RIGHT">
                    20 21 22
                </Vertices>
                <VoxelIndicesIJK>
                    23 28 32
                </VoxelIndicesIJK>
            </Parcel>
        </MatrixIndicesMap>
    </Matrix>
</CIFTI>
```

Example Parcellated Data Series XML

This Parcellated Data Series XML contains two parcels along columns and three timepoints along rows with two seconds between each timepoint, starting at 0.0 seconds.

```
<CIFTI Version="2">
    <Matrix>
        <MetaData>
            <MD>
                <Name>UserName</Name>
                <Value>Joe User</Value>
            </MD>
        </MetaData>
        <MatrixIndicesMap AppliesToMatrixDimension="0"
            IndicesMapToDataType="CIFTI_INDEX_TYPE_SERIES"
            NumberOfSeriesPoints="3"
            SeriesExponent="0"
            SeriesStart="0.0"
            SeriesStep="2.0"
            SeriesUnit="SECOND">
        </MatrixIndicesMap>
        <MatrixIndicesMap AppliesToMatrixDimension="1"
            IndicesMapToDataType="CIFTI_INDEX_TYPE_PARCELS">
            <Volume VolumeDimensions="176,208,176">
                <TransformationMatrixVoxelIndicesIJKtoXYZ
                    MeterExponent="-3">
                    -2.0   0.0  0.0  126.0
                    0.0  -2.0  0.0  128.0
                    0.0   0.0  2.0  -66.0
                    0.0   0.0  0.0    1.0
                </TransformationMatrixVoxelIndicesIJKtoXYZ>
            </Volume>
            <Surface BrainStructure="CIFTI_STRUCTURE_CORTEX_LEFT"
                SurfaceNumberOfVertices="32492"/>
            <Surface BrainStructure="CIFTI_STRUCTURE_CORTEX_RIGHT"
                SurfaceNumberOfVertices="32492"/>
            <Parcel Name="V1">
                <Vertices
                    BrainStructure="CIFTI_STRUCTURE_CORTEX_LEFT">
```

```
                    0 1 2 3
                </Vertices>
                <Vertices
                    BrainStructure="CIFTI_STRUCTURE_CORTEX_RIGHT">
                    4 5 6 7
                </Vertices>
                <VoxelIndicesIJK>
                    22 25 30
                </VoxelIndicesIJK>
            </Parcel>
            <Parcel Name="V2">
                <Vertices
                    BrainStructure="CIFTI_STRUCTURE_CORTEX_LEFT">
                    9 10 11 12
                </Vertices>
                <Vertices
                    BrainStructure="CIFTI_STRUCTURE_CORTEX_RIGHT">
                    20 21 22
                </Vertices>
                <VoxelIndicesIJK>
                    23 28 32
                </VoxelIndicesIJK>
            </Parcel>
        </MatrixIndicesMap>
    </Matrix>
</CIFTI>
```

Example Dense Scalar XML

This example Dense Scalar XML describes a matrix that has brain models along columns and two named maps along rows.

```
<CIFTI Version="2">
    <Matrix>
        <MetaData>
            <MD>
                <Name>UserName</Name>
                <Value>Joe User</Value>
            </MD>
        </MetaData>
        <MatrixIndicesMap AppliesToMatrixDimension="0"
            IndicesMapToDataType="CIFTI_INDEX_TYPE_SCALARS">
            <NamedMap>
                <MapName>raw myelin map</MapName>
                <MetaData>
                    <MD>
                        <Name>Comment</Name>
                        <Value>excluded at 2.0 sigma</Value>
                    </MD>
                </MetaData>
            </NamedMap>
            <NamedMap>
                <MapName>corrected myelin map</MapName>
                <MetaData>
```

```
                    <MD>
                       <Name>Comment</Name>
                       <Value>neighborhood threshold 2.0 sigma</Value>
                    </MD>
                </MetaData>
            </NamedMap>
        </MatrixIndicesMap>
        <MatrixIndicesMap AppliesToMatrixDimension="1"
            IndicesMapToDataType="CIFTI_INDEX_TYPE_BRAIN_MODELS">
            <Volume VolumeDimensions="176,208,176">
                <TransformationMatrixVoxelIndicesIJKtoXYZ
                    MeterExponent="-3">
                    -2.0   0.0  0.0  126.0
                    0.0  -2.0  0.0  128.0
                    0.0   0.0  2.0  -66.0
                    0.0   0.0  0.0    1.0
                </TransformationMatrixVoxelIndicesIJKtoXYZ>
            </Volume>
            <BrainModel IndexOffset="0"
                     IndexCount="3"
                     ModelType="CIFTI_MODEL_TYPE_SURFACE"
                     BrainStructure="CIFTI_STRUCTURE_CORTEX_LEFT"
                     SurfaceNumberOfVertices="7">
                <VertexIndices>
                    0 2 4
                </VertexIndices>
            </BrainModel>
            <BrainModel IndexOffset="3"
                     IndexCount="2"
                     ModelType="CIFTI_MODEL_TYPE_VOXELS"
                     BrainStructure="CIFTI_STRUCTURE_THALAMUS_LEFT">
                <VoxelIndicesIJK>
                    27 38 40
                    27 39 40
                </VoxelIndicesIJK>
            </BrainModel>
        </MatrixIndicesMap>
    </Matrix>
</CIFTI>
```

Example Dense Label XML

This example Dense Label XML describes a matrix that has brain models along columns and two label maps along rows. Note that the MetaData element, being optional inside the NamedMap tag, is absent on one of the two label maps.

```
<CIFTI Version="2">
    <Matrix>
        <MetaData>
            <MD>
                <Name>UserName</Name>
                <Value>Joe User</Value>
            </MD>
        </MetaData>
```

```
<MatrixIndicesMap AppliesToMatrixDimension="0"
    IndicesMapToDataType="CIFTI_INDEX_TYPE_SCALARS">
    <NamedMap>
        <MapName>subcortical areas</MapName>
        <MetaData>
            <MD>
                <Name>Comment</Name>
                <Value>derived from freesurfer</Value>
            </MD>
        </MetaData>
        <LabelTable>
            <Label Key="0" Red="1" Green="1" Blue="1"
                Alpha="0">???</Label>
            <Label Key="18" Red="0.4" Green="1" Blue="1"
                Alpha="1">amygdala left</Label>
            <Label Key="26" Red="1" Green="0.65" Blue="0"
                Alpha="1">accumbens left</Label>
        </LabelTable>
    </NamedMap>
    <NamedMap>
        <MapName>visual areas</MapName>
        <LabelTable>
            <Label Key="0" Red="1" Green="1" Blue="1"
                Alpha="0">???</Label>
            <Label Key="18" Red="0.68" Green="1" Blue="0"
                Alpha="1">V1</Label>
            <Label Key="26" Red="1" Green="0.65" Blue="0"
                Alpha="1">V2</Label>
        </LabelTable>
    </NamedMap>
</MatrixIndicesMap>
<MatrixIndicesMap AppliesToMatrixDimension="1"
    IndicesMapToDataType="CIFTI_INDEX_TYPE_BRAIN_MODELS">
    <Volume VolumeDimensions="176,208,176">
        <TransformationMatrixVoxelIndicesIJKtoXYZ
            MeterExponent="-3">
            -2.0   0.0  0.0  126.0
            0.0  -2.0  0.0  128.0
            0.0   0.0  2.0  -66.0
            0.0   0.0  0.0    1.0
        </TransformationMatrixVoxelIndicesIJKtoXYZ>
    </Volume>
    <BrainModel IndexOffset="0"
             IndexCount="3"
             ModelType="CIFTI_MODEL_TYPE_SURFACE"
             BrainStructure="CIFTI_STRUCTURE_CORTEX_LEFT"
             SurfaceNumberOfVertices="7">
        <VertexIndices>
            0 2 4
        </VertexIndices>
    </BrainModel>
    <BrainModel IndexOffset="3"
             IndexCount="2"
```

```
                    ModelType="CIFTI_MODEL_TYPE_VOXELS"
                    BrainStructure="CIFTI_STRUCTURE_THALAMUS_LEFT">
                <VoxelIndicesIJK>
                    27 38 40
                    27 39 40
                </VoxelIndicesIJK>
            </BrainModel>
        </MatrixIndicesMap>
    </Matrix>
</CIFTI>
```