

Binary Vessels

Abstract

Conversion of the existing 5D plane-based model to an nD chunk-based model.

Existing Model

- The existing model consists of a single Pixels element for every Image
- The existing Pixels type requires for 5 dimensions to be present, X, Y, Z, T and C
- X, Y and Z also have unique attributes in PhysicalSize and Unit
- Time has unique properties in Increment and Unit

PixelsType		
ID	PixelsID	
DimensionOrder	(DimensionOrderType)	
Type	PixelType	
SignificantBits	PositiveInt	
Interleaved	boolean	
BigEndian	boolean	
SizeX	PositiveInt	
SizeY	PositiveInt	
SizeZ	PositiveInt	
SizeC	PositiveInt	
SizeT	PositiveInt	
PhysicalSizeX	PositiveFloat	
PhysicalSizeXUnit	UnitsLength	
PhysicalSizeY	PositiveFloat	
PhysicalSizeYUnit	UnitsLength	
PhysicalSizeZ	PositiveFloat	
PhysicalSizeZUnit	UnitsLength	
TimeIncrement	float	
TimeIncrementUnit	UnitsTime	
Channel	[0..*]	(ChannelType)
BinData	[1..*]	(BinDataType)
TiffData	[1..*]	(TiffDataType)
MetadataOnly	[1..1]	anyType
Plane	[0..*]	(PlaneType)

- Multiple Channel elements can be present per Pixels element

(ChannelType)		
③ ID	ChannelID	
③ Name	string	
③ SamplesPerPixel	PositiveInt	
③ IlluminationType	(IlluminationTypeType)	
③ PinholeSize	float	
③ PinholeSizeUnit	UnitsLength	
③ AcquisitionMode	(AcquisitionModeType)	
③ ContrastMethod	(ContrastMethodType)	
③ ExcitationWavelength	PositiveFloat	
③ ExcitationWavelengthUnit	UnitsLength	
③ EmissionWavelength	PositiveFloat	
③ EmissionWavelengthUnit	UnitsLength	
③ Fluor	string	
③ NDFilter	float	
③ PockelCellSetting	int	
③ Color	Color	
LightSourceSettings	[0..1]	(LightSourceSettingsType)
DetectorSettings	[0..1]	(DetectorSettingsType)
FilterSetRef	[0..1]	(FilterSetRefType)
AnnotationRef	[0..*]	(AnnotationRefType)
LightPath	[0..1]	(LightPathType)

- The Pixels element also contains a list of either TiffData, BinData or MetadataOnly
- TiffData contains information about the location of pixel data within the Tiff structure

(TiffDataType)		
③ IFD	NonNegativeInt	
③ FirstZ	NonNegativeInt	
③ FirstT	NonNegativeInt	
③ FirstC	NonNegativeInt	
③ PlaneCount	NonNegativeInt	
UUID	[0..1]	(UUIDType)

How does this look with the existing model and HDF5:

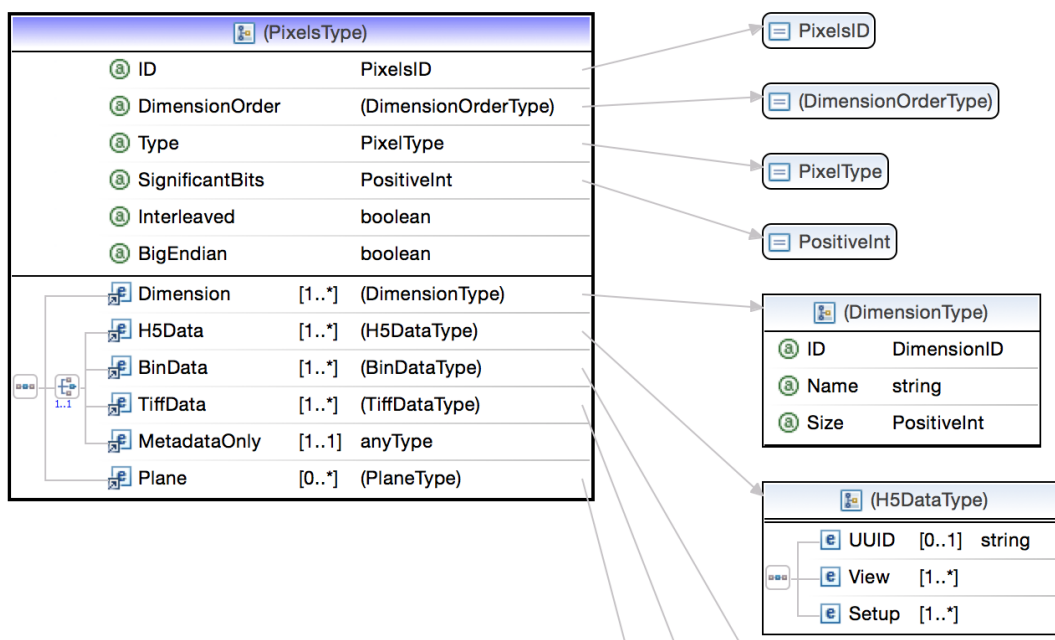
- For existing HDF5 formats we create a new image and a new Pixels element for each image volume
- In the case of BDV for example, a filesset with 4 views each with 4 resolutions would result in 16 Images, each displayed as 3D volume with X,Y and Z.
- All of the available metadata could potentially be stored using Annotations

What is required:

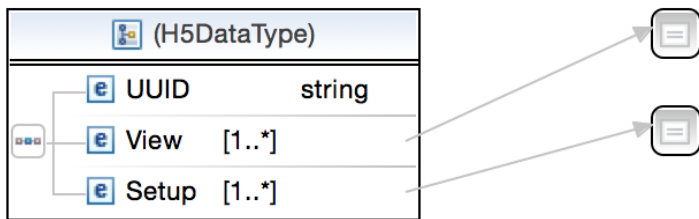
- A means to represent n dimensions rather than 5 as present
- A way to represent multiple volumes as a single image
- The ability and flexibility to add user defined dimensions and attributes
- Required to be backwards compatible so must maintain all existing metadata

Proposed Changes

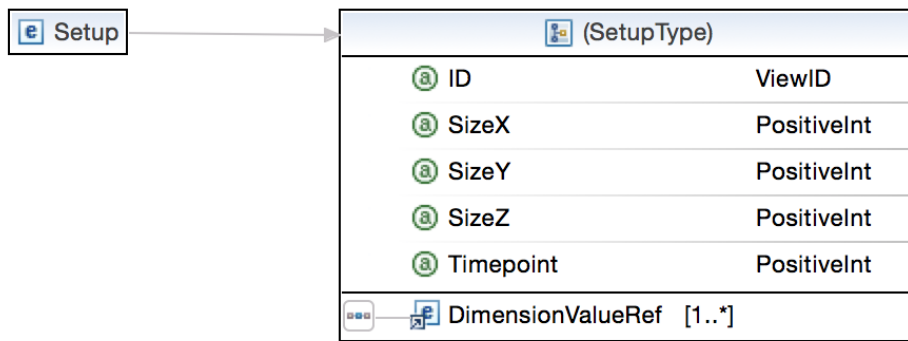
- The bulk of the changes will occur at the Pixels element level
- The existing attributes for X, Y, Z, T and C are removed
- Instead they are replaced by a series of new Dimension elements
- DimensionOrder is kept but this could be removed if the order is implied by the order of the new Dimension elements



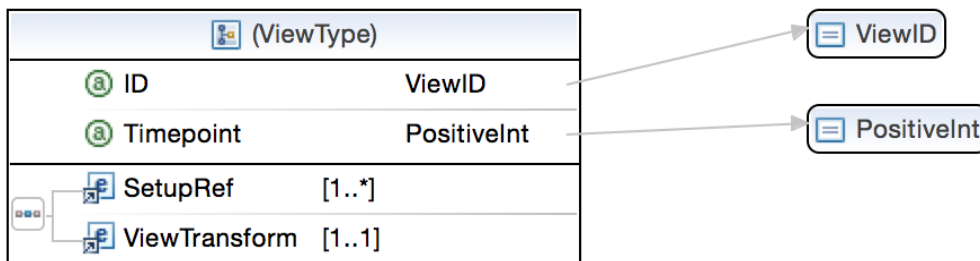
- The Dimensions will be flexible requiring a Name, Size and a series of DimensionValues
- A DimensionValue will represent for example a particular Channel or Angle
- To maintain backwards compatibility it is proposed that existing dimensions would be special cases, extending the DimensionType
- This would allow for SpatialDimension to be used to represent X, Y and Z, providing the additional physical size properties for example
- The existing ChannelType would largely be retained also, but as an extension of DimensionValue
- These Dimension elements could be additionally extended to allow for flexible Attributes if required



- To maintain backwards compatibility the existing TiffData element is left unchanged
- A new HDF5 Data type is added
- Each of the new HDF5 DataTypes will contain a series of Setups and Views
- These concepts are based on the existing BDV model



- The Setup element will require an X, Y and Z values
- This assumes that the size of image volumes will not be constant
- Physical sizes however are assumed to be the same and are stored in the X, Y and Z dimensions
- Additionally a list of defined DimensionValues representing a given Setup (for example the given Channel, Acquisition angle etc)



- The concept of a View is introduced, a View would contain a reference to a Setup, along with a timepoint and a Transform. Each View would represent a single image volume.
- The benefit of having Time as a required dimension at this level is that it avoids unnecessary duplication within the setup elements

Implementation

- A new version of the OME schema will be required to represent the new model
- Transforms to upgrade and downgrade to and from the new model will be needed
- Updates will be required for the code generation, most notably to provide extra API methods using Id rather than index for getters and setters
- All of the Bio-Formats repos will require updates to use the newly generated model and API. In the bioformats repo this impacted over 150 files.
- The first new format to be supported will be BDV with a new reader targeting the existing 'Version 1' specification
- The first draft of this work will be focused on reading existing formats but long term the plan will be to providing an additional writing interface similar to the existing Tiff functionality but for HDF5

Examples

BDV sample file

BDV SpimData XML	Proposed OME Design
<pre> <ViewSetups> <ViewSetup> <id>40</id> <size>1466 1689 1870</size> <voxelSize> <unit>um</unit> <size>0.3518820106983185 0.3518820106983185 0.3518820106983185</size> </voxelSize> <attributes> <illumination>2</illumination> <channel>0</channel> <tile>0</tile> <angle>5</angle> </attributes> </ViewSetup> <ViewSetup> <id>41</id> <size>1466 1689 1870</size> <voxelSize> <unit>um</unit> <size>0.3518820106983185 0.3518820106983185 0.3518820106983185</size> </voxelSize> <attributes> <illumination>2</illumination> </pre>	<pre> <?xml version="1.0" encoding="UTF-8"?><OME xmlns="http://www.openmicroscopy.org/Schemas/OME/2016-0 6" xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance" xsi:schemaLocation="http://www.openmicroscopy.org/Schem a s/OME/2017-12 http://www.openmicroscopy.org/Schemas/OME/2016-06/ome.x sd> <Image> <Pixels> <Dimension Name="illumination" Size="1"> <DimensionValue ID="illumination:2" Name="Fused_2"/> </Dimension> <Dimension Name="tile" Size="1"> <DimensionValue ID="tile:0" Name="0"/> </Dimension> <Dimension Name="angle" Size="1"> <DimensionValue ID="angle:5" Name="Fused_5"/> </Dimension> <TimeDimension Name="t" Size="1"/> <SpatialDimension ID="x:0" Name="x" PhysicalSize="0.3518820106983185" PhysicalSizeUnit="µm"/> <SpatialDimension ID="y:0" Name="y" PhysicalSize="0.3518820106983185" PhysicalSizeUnit="µm"/> <SpatialDimension ID="z:0" Name="z" PhysicalSize="0.3518820106983185" PhysicalSizeUnit="µm"/> <ChannelDimension> <Channel Name="488"/> </pre>

```

<channel>1</channel>
<tile>0</tile>
<angle>5</angle>
</attributes>
</ViewSetup>
<ViewSetup>
<id>42</id>
<size>1466 1689 1870</size>
<voxelSize>
<unit>um</unit>
<size>0.3518820106983185 0.3518820106983185
0.3518820106983185</size>
</voxelSize>
<attributes>
<illumination>2</illumination>
<channel>2</channel>
<tile>0</tile>
<angle>5</angle>
</attributes>
</ViewSetup>
<ViewSetup>
<id>43</id>
<size>1466 1689 1870</size>
<voxelSize>
<unit>um</unit>
<size>0.3518820106983185 0.3518820106983185
0.3518820106983185</size>
</voxelSize>
<attributes>
<illumination>2</illumination>
<channel>3</channel>
<tile>0</tile>
<angle>5</angle>
</attributes>
</ViewSetup>
<Attributes name="illumination">
<illumination>
<id>2</id>
<name>Fused_2</name>
</illumination>
</Attributes>
<Attributes name="channel">
<Channel>
<id>0</id>
<name>488</name>
</Channel>
<Channel>
<id>1</id>
<name>405</name>
</Channel>
<Channel>
<id>2</id>
<name>561</name>
</Channel>
<Channel>
<id>3</id>

```

```

<Channel Name="405"/>
<Channel Name="561"/>
<Channel Name="638"/>
</ChannelDimension>
<H5Data BasePath="/Users/dgault/Documents/Sample
Images/bdv/">
<Setup ID="Setup:0">
<DimensionValueRef ID="illumination:2"/>
<DimensionValueRef ID="tile:0"/>
<DimensionValueRef ID="angle:5"/>
</Setup>
<Setup ID="Setup:1">
<DimensionValueRef ID="illumination:2"/>
<DimensionValueRef ID="tile:0"/>
<DimensionValueRef ID="angle:5"/>
</Setup>
<Setup ID="Setup:2">
<DimensionValueRef ID="illumination:2"/>
<DimensionValueRef ID="tile:0"/>
<DimensionValueRef ID="angle:5"/>
</Setup>
<Setup ID="Setup:3">
<DimensionValueRef ID="illumination:2"/>
<DimensionValueRef ID="tile:0"/>
<DimensionValueRef ID="angle:5"/>
</Setup>
<View ID="View:0" Timepoint="0">
<SetupRef ID="Setup:0"/>
<ViewTransform type="affine">
<Name>fusion bounding box</Name>
<affine>1.0 0.0 0.0 -822.0 0.0 1.0 0.0 -845.0 0.0 0.0 1.0
-1119.0</affine>
</ViewTransform>
</View>
<View ID="View:1" Timepoint="0">
<SetupRef ID="Setup:1"/>
<ViewTransform type="affine">
<Name>fusion bounding box</Name>
<affine>1.0 0.0 0.0 -822.0 0.0 1.0 0.0 -845.0 0.0 0.0 1.0
-1119.0</affine>
</ViewTransform>
</View>
<View ID="View:2" Timepoint="0">
<SetupRef ID="Setup:2"/>
<ViewTransform type="affine">
<Name>fusion bounding box</Name>
<affine>1.0 0.0 0.0 -822.0 0.0 1.0 0.0 -845.0 0.0 0.0 1.0
-1119.0</affine>
</ViewTransform>
</View>
<View ID="View:3" Timepoint="0">
<SetupRef ID="Setup:3"/>
<ViewTransform type="affine">
<Name>fusion bounding box</Name>
<affine>1.0 0.0 0.0 -822.0 0.0 1.0 0.0 -845.0 0.0 0.0 1.0
-1119.0</affine>
</ViewTransform>
</View>
</H5Data>
</Pixels>
</Image>
</OME>

```

```

    <name>638</name>
  </Channel>
</Attributes>
<Attributes name="tile">
  <Tile>
    <id>0</id>
    <name>0</name>
  </Tile>
</Attributes>
<Attributes name="angle">
  <Angle>
    <id>5</id>
    <name>Fused_5</name>
  </Angle>
</Attributes>
</ViewSetups>
<Timepoints type="range">
  <first>0</first>
  <last>0</last>
</Timepoints>
</SequenceDescription>
<ViewRegistrations>
  <ViewRegistration timepoint="0" setup="40">
    <ViewTransform type="affine">
      <Name>fusion bounding box</Name>
      <affine>1.0 0.0 0.0 -822.0 0.0 1.0 0.0 -845.0 0.0 0.0 1.0
-1119.0</affine>
    </ViewTransform>
  </ViewRegistration>
  <ViewRegistration timepoint="0" setup="41">
    <ViewTransform type="affine">
      <Name>fusion bounding box</Name>
      <affine>1.0 0.0 0.0 -822.0 0.0 1.0 0.0 -845.0 0.0 0.0 1.0
-1119.0</affine>
    </ViewTransform>
  </ViewRegistration>
  <ViewRegistration timepoint="0" setup="42">
    <ViewTransform type="affine">
      <Name>fusion bounding box</Name>
      <affine>1.0 0.0 0.0 -822.0 0.0 1.0 0.0 -845.0 0.0 0.0 1.0
-1119.0</affine>
    </ViewTransform>
  </ViewRegistration>
  <ViewRegistration timepoint="0" setup="43">
    <ViewTransform type="affine">
      <Name>fusion bounding box</Name>
      <affine>1.0 0.0 0.0 -822.0 0.0 1.0 0.0 -845.0 0.0 0.0 1.0
-1119.0</affine>
    </ViewTransform>
  </ViewRegistration>
</ViewRegistrations>

```

Backwards compatibility with TIFF

<https://downloads.openmicroscopy.org/images/OME-TIFF/2016-06/tubhiswt-4D/>

Existing Model	Proposed Design
<pre><Pixels BigEndian="false" DimensionOrder="XYZTC" ID="Pixels:0" Interleaved="false" SignificantBits="8" SizeC="2" SizeT="43" SizeX="512" SizeY="512" SizeZ="10" Type="uint8"> <Channel Color="-1" ID="Channel:0:0" SamplesPerPixel="1"> <LightSourceSettings ID="urn:lsid:loci.wisc.edu:LightSource:OWS1"/> <DetectorSettings ID="urn:lsid:loci.wisc.edu:Detector:OWS1"/> <LightPath/> </Channel> <Channel Color="-1" ID="Channel:0:1" SamplesPerPixel="1"> <LightSourceSettings ID="urn:lsid:loci.wisc.edu:LightSource:OWS1"/> <DetectorSettings ID="urn:lsid:loci.wisc.edu:Detector:OWS2"/> <LightPath/> </Channel> <TiffData FirstC="0" FirstT="0" FirstZ="0" IFD="0" PlaneCount="1"> <UUID FileName="tubhiswt_C0_TP0.ome.tif">urn:uuid:45c8bf18-6aa2 -478c-9080-e0b0d3eb1f70</UUID> </TiffData> </Pixels></pre>	<pre><Pixels BigEndian="false" DimensionOrder="XYZTC" ID="Pixels:0" Interleaved="false" SignificantBits="8" Type="uint8"> <SpatialDimension ID="X:0" Name="X" Size="512"/> <SpatialDimension ID="Y:0" Name="Y" Size="512"/> <SpatialDimension ID="Z:0" Name="Z" Size="10"/> <TimeDimension ID="T:0" Name="T" Size="43"/> <ChannelDimension ID="C:0" Name="C" Size="2"> <Channel Color="-1" ID="Channel:0:0" SamplesPerPixel="1"> <LightSourceSettings ID="urn:lsid:loci.wisc.edu:LightSource:OWS1"/> <DetectorSettings ID="urn:lsid:loci.wisc.edu:Detector:OWS1"/> <LightPath/> </Channel> <Channel Color="-1" ID="Channel:0:1" SamplesPerPixel="1"> <LightSourceSettings ID="urn:lsid:loci.wisc.edu:LightSource:OWS1"/> <DetectorSettings ID="urn:lsid:loci.wisc.edu:Detector:OWS2"/> <LightPath/> </Channel> </ChannelDimension> <TiffData FirstC="0" FirstT="0" FirstZ="0" IFD="0" PlaneCount="1"> <UUID FileName="tubhiswt_C0_TP0.ome.tif">urn:uuid:45c8bf18-6aa2 -478c-9080-e0b0d3eb1f70</UUID> </TiffData> </Pixels></pre>

Backwards compatibility with CellH5

Existing Model	Proposed Design
<pre><Image ID="Image:0" Name="P_H2b_aTub_MD20x_exp911, W_0_0038"> <Pixels BigEndian="false" DimensionOrder="XYZTC" ID="Pixels:0" Interleaved="false" SignificantBits="8" SizeC="2" SizeT="206" SizeX="1392" SizeY="1040" SizeZ="1" Type="uint8"> <Channel ID="Channel:0:0" SamplesPerPixel="1"> <LightPath/> </Channel> <Channel ID="Channel:0:1" SamplesPerPixel="1"> <LightPath/> </Channel> <MetadataOnly/> </Pixels> <ROIRef ID="ROI:0"/> <ROIRef ID="ROI:1"/></pre>	<pre><Image ID="Image:0" Name="P_H2b_aTub_MD20x_exp911, W_0_0038"> <Pixels BigEndian="false" DimensionOrder="XYZTC" ID="Pixels:0" Interleaved="false" SignificantBits="8" Type="uint8"> <SpatialDimension ID="X:0" Name="X" Size="1392"/> <SpatialDimension ID="Y:0" Name="Y" Size="1040"/> <SpatialDimension ID="Z:0" Name="Z" Size="1"/> <TimeDimension ID="T:0" Name="T" Size="206"/> <ChannelDimension ID="C:0" Name="C" Size="2"> <Channel ID="Channel:0:0" SamplesPerPixel="1"> <LightPath/> </Channel> <Channel ID="Channel:0:1" SamplesPerPixel="1"> <LightPath/> </Channel> </ChannelDimension> <MetadataOnly/> </Pixels> <ROIRef ID="ROI:0"/> <ROIRef ID="ROI:1"/></pre>

User interface changes

- New design will be a breaking change for the model and generated API
- Most notable changes in the metadata API will be to the dimension getters and setters in MetadataStore and MetadataRetrieve
- Generated API functions currently are based on providing an index
- Due to having Dimensions in an unknown order it will also be required to provide additional functions to access by ID
- In order to write OME in HDF format there will be additional writers alongside the existing Tiff interface

Continuous integration, Testing and other changes

- All existing CI should remain unaffected by these changes
- As this will be a major development effort running alongside the existing Bio-Formats project it would be useful to have a separate CI build similar to the breaking queue
- All changes should be backwards compatible and the existing test framework and data repo tests will remain.
- New tests will be required for the upgrade and downgrade to and from the new data model
- New tests will be required for writing in the new HDF format
- Longer term performance testing of writing the new format would be required
- New filesets will be required for the data repo for the addition of any new formats supported
- Documentation updates required
- New sample OME-XML and sample OME-TIFF would need to be generated and made available to users
- Integration into downstream applications such as OMERO, FIJI, updated MATLAB toolbox

Status

- Initial design included in this document is a first draft and open for review
- Many areas such as dealing with resolutions have not been fleshed out
- Initial prototyping of the discussed proposal is in progress