CGNS Tutorial

Unstructured Grids

CFD General Notation System (CGNS)

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Outline

- Introductory grid example
  - Showing simple hex grid written both structured and unstructured (to compare the two methods)
- Unstructured Grid
- Element Connectivity
- Boundary Conditions
- Flow Solution
- Summary

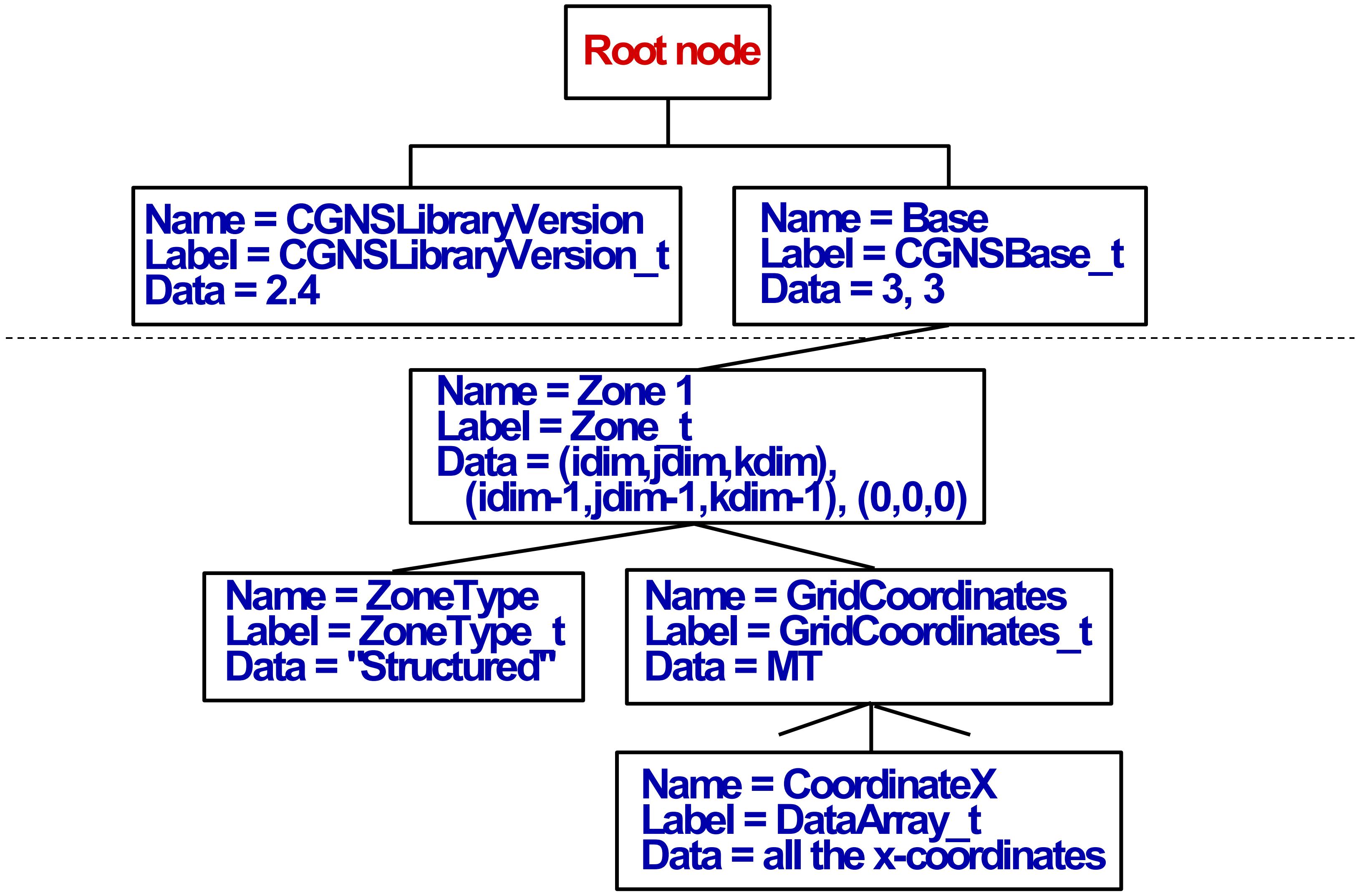
Writing structured grids

```
double x[kdim][kdim][idim], y[kdim][jdim][idim], z[kdim][jdim][idim];
int isize[3][3];
strcpy(zonename,”Zone 1”);
/* vertex size (structured grid example) */
isize[0][0]=idim;
isize[0][1]=jdim;
isize[0][2]=kdim;
/* cell size (structured grid example) */
isize[1][0]=isize[0][0]-1;
isize[1][1]=isize[0][1]-1;
isize[1][2]=isize[0][2]-1;
/* boundary vertex size (always zero for structured) */
isize[2][0]=0;
isize[2][1]=0;
isize[2][2]=0;
```

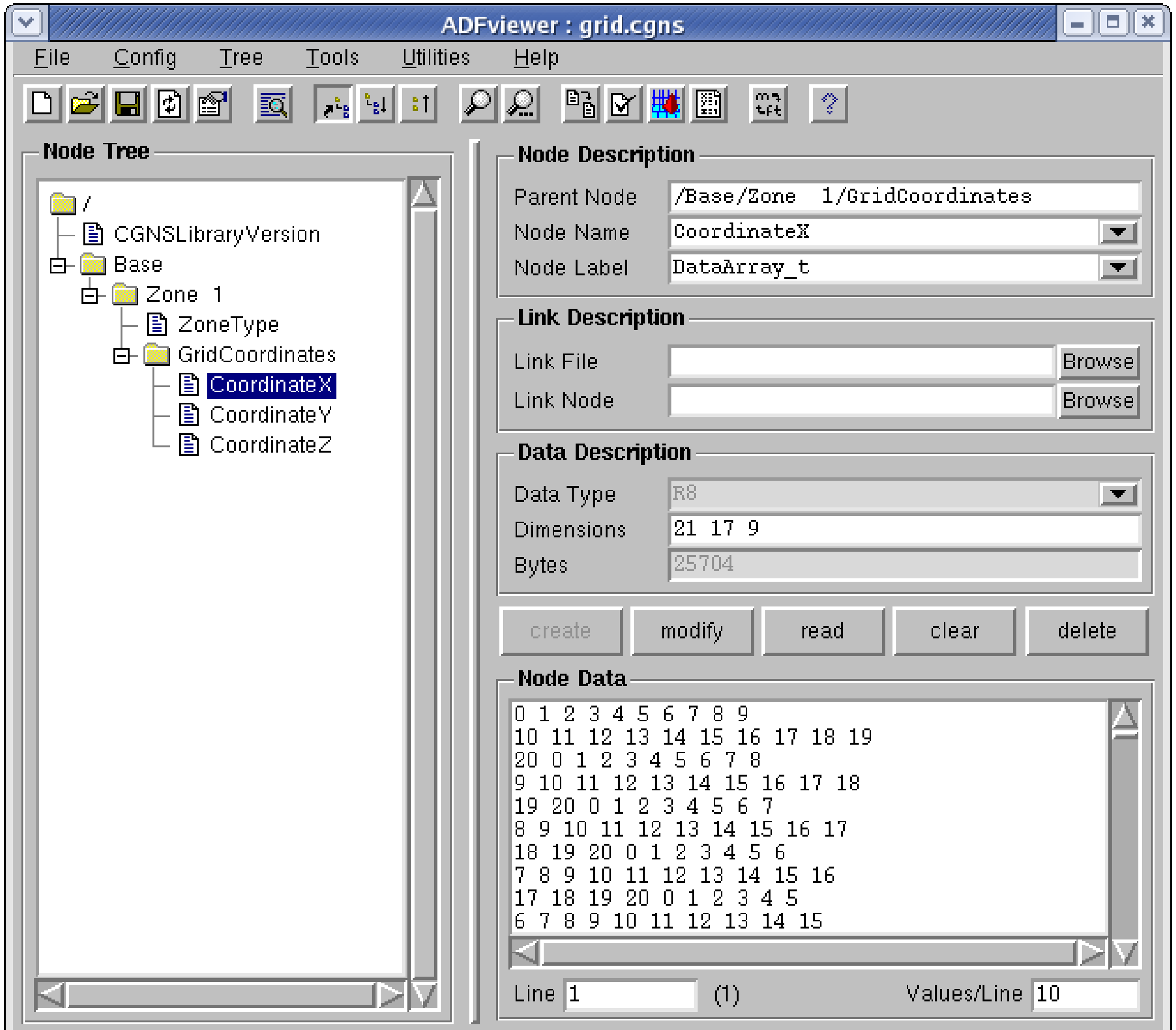
Writing structured grids
(cont'd)

```
/* create zone */
cg_zone_write(indexf, indexb, zonename, isize[0], Structured, &indexz);
/* write grid coordinates */
cg_coord_write(indexf, indexb, indexz, RealDouble, "CoordinateX", x,
    &indexcx);
cg_coord_write(indexf, indexb, indexz, RealDouble, "CoordinateY", y,
    &indexcy);
cg_coord_write(indexf, indexb, indexz, RealDouble, "CoordinateZ", z,
    &indexcz);
```

What the file looks like…



What the file looks like in adfviewer…



Writing unstructured grids

```
/* this is an example for HEXA_8 (cube-like) elements
double x[maxnodes], y[maxnodes], z[maxnodes];
int isize[3], ielem[maxelem][8];
strcpy(zonename,"Zone 1");
/* vertex size (unstructured grid example) */
isize[0]=inodedim;
/* cell size (unstructured grid example) */
isize[1]=icelldim;
/* boundary vertex size (zero if elements not sorted) */
isize[2]=ivbdy;
```

Writing unstructured grids (cont'd)

/* create zone */

cg_zone_write(indexf, indexb, zonename, isize, Unstructured, &indexz);

/* write grid coordinates */

cg_coord_write(indexf, indexb, indexz, RealDouble, “CoordinateX”, x, &indexcx);

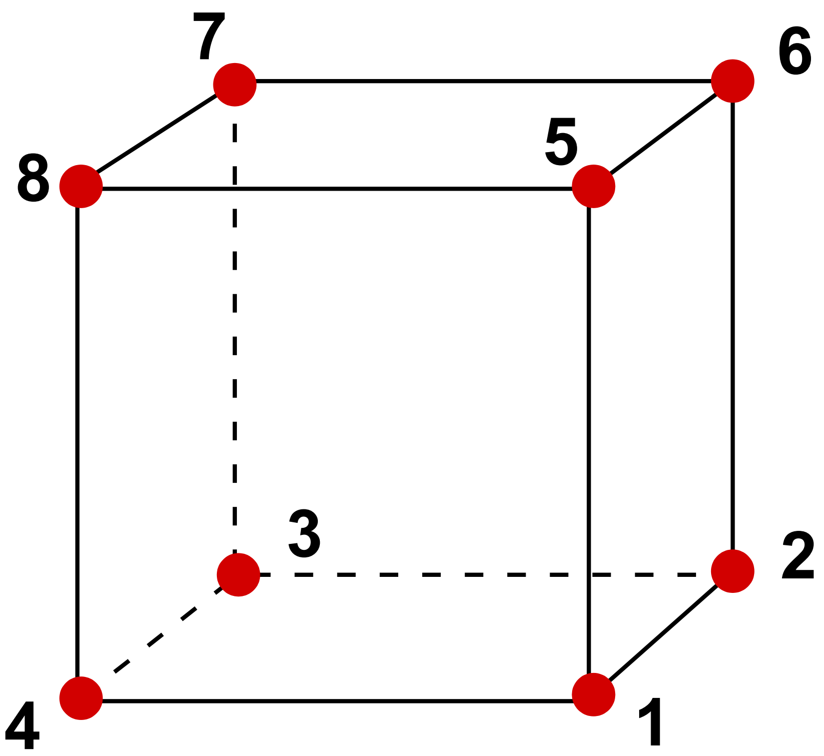
cg_coord_write(indexf, indexb, indexz, RealDouble, “CoordinateY”, y, &indexcy);

cg_coord_write(indexf, indexb, indexz, RealDouble, “CoordinateZ”, z, &indexcz);

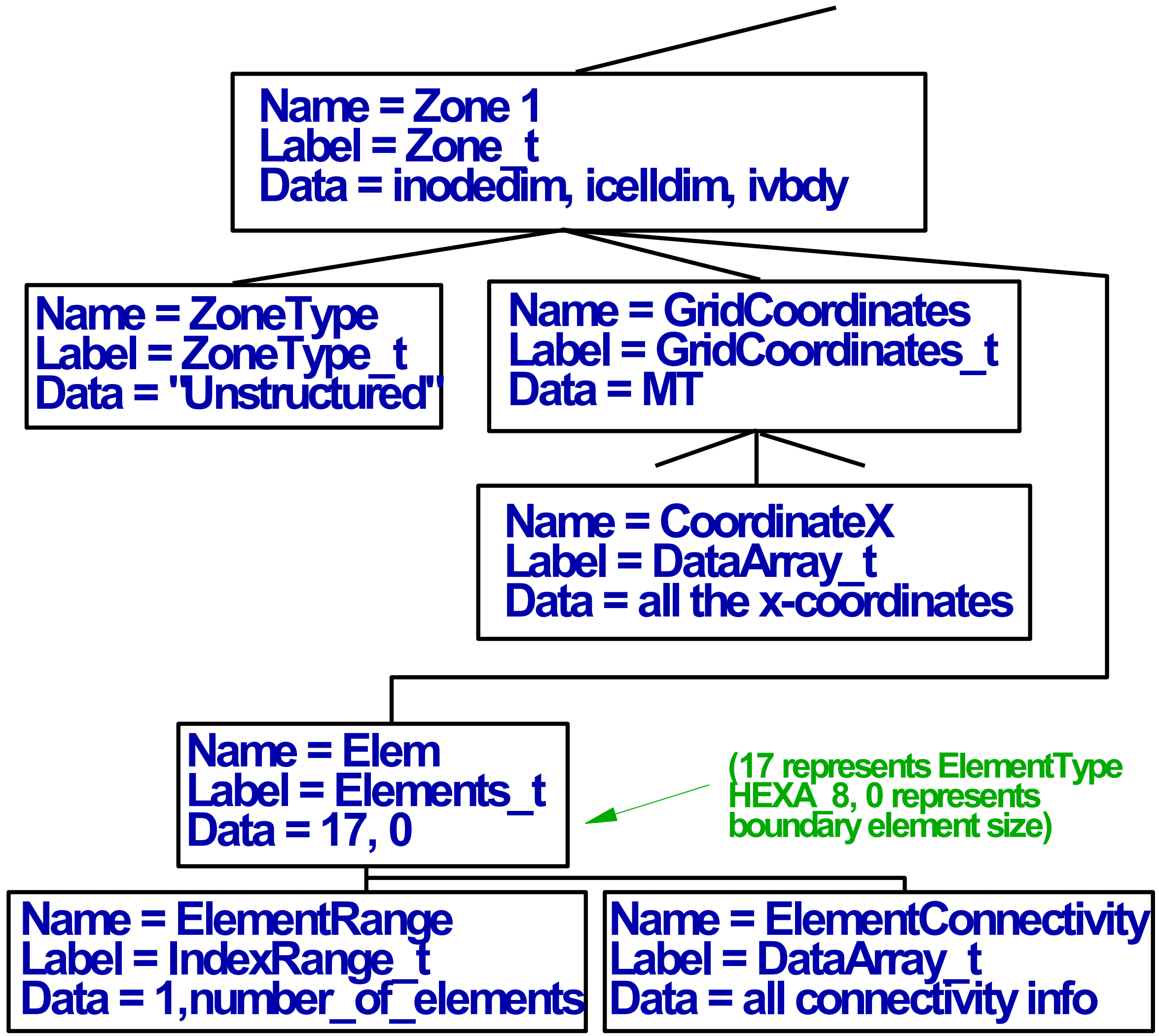
/* write element connectivity */

cg_section_write(indexf, indexb, indexz, “Elem”, HEXA_8, nelem_start, nelem_end, nbdyelem, ielem[0], &indexe);

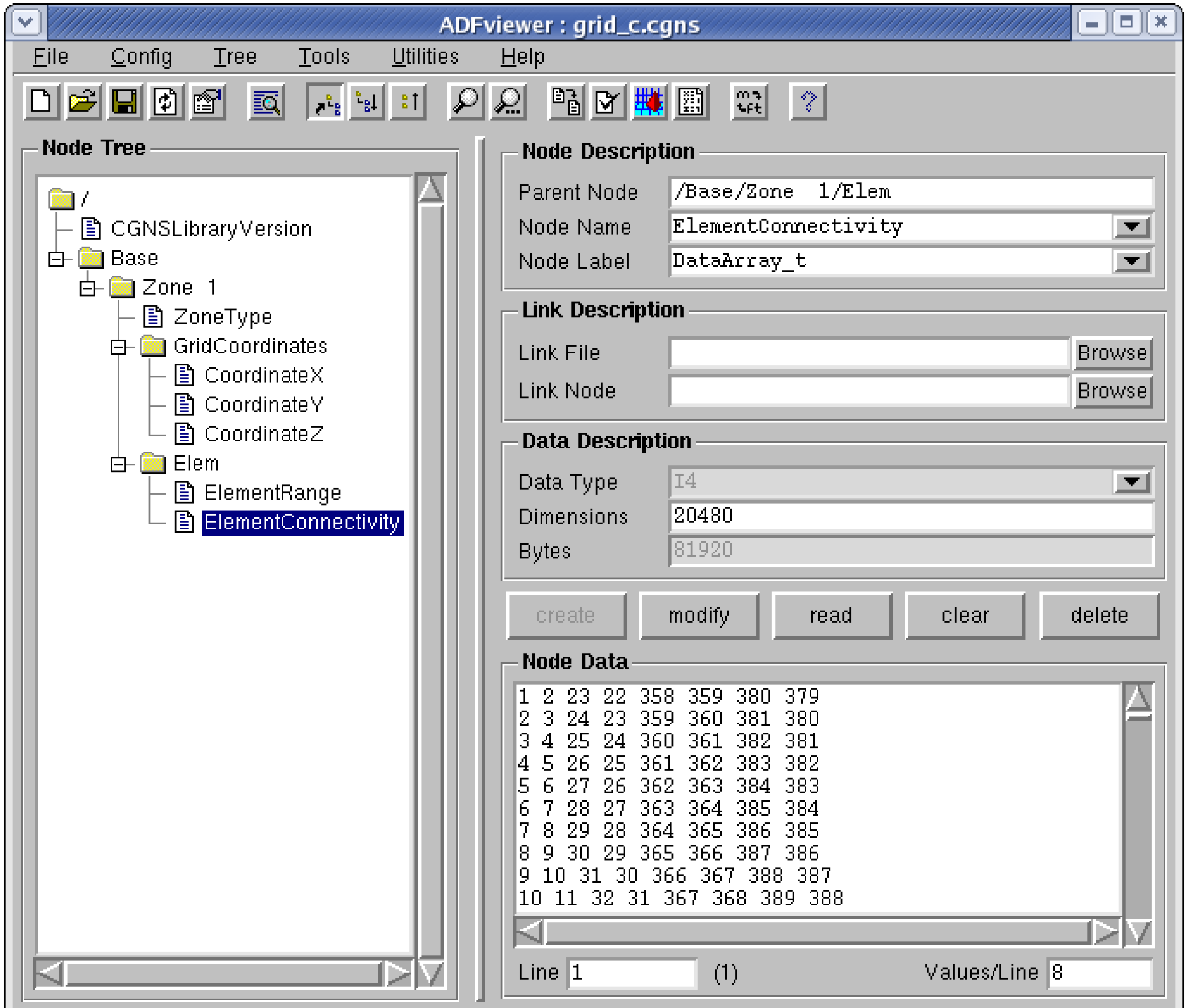
Element connectivity for HEXA_8



What the file looks like… (below Base)



What the file looks like in adfviewer…



Unstructured Grid

GridCoordinates_t< int IndexDimension, int VertexSize[IndexDimension] > :=
{
List(Descriptor_t Descriptor1 ... DescriptorN) ; (o)
Rind_t<IndexDimension> Rind ; (o/d)
List(DataArray_t<DataType, IndexDimension, DataSize[]>
DataArray1 ... DataArrayN) ; (o)
DataClass_t DataClass ; (o)
DimensionalUnits_t DimensionalUnits ; (o)
List(UserDefinedData_t UserDefinedData1 ... UserDefinedDataN) ; (o)
} ;

- Overall SIDS definition same for both structured and unstructured grids
- For unstructured: IndexDimension always 1, VertexSize=number of nodes (excluding any rind points)

Unstructured Grid, MLL

For 3-D structured:

cg_zone_write(indexf, indexb, zonename, isize, Structured, &indexz);

isize is dimensioned [3][3]:

idim, jdim, kdim

idim-1, jdim-1, kdim-1

0, 0, 0

For 3-D unstructured:

cg_zone_write(indexf, indexb, zonename, isize, Unstructured, &indexz);

isize is dimensioned [1][3]:

#nodes

#cells

optional boundary vertex size

Element Connectivity

- Grid points alone are not enough for unstructured grids: element connectivity information is also required
  - Uses global numbering system under a given Zone_t (i.e., all elements in a zone must have a unique number, beginning at 1)

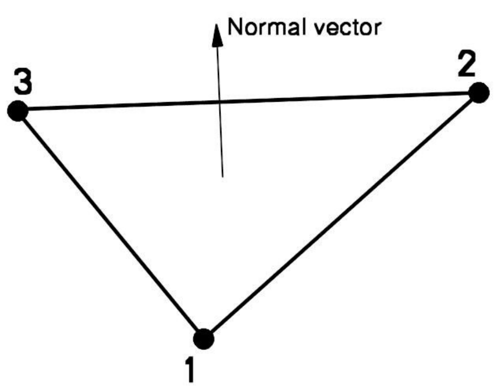
```
Elements_t :=
  {
  List( Descriptor_t Descriptor1 ... DescriptorN ) ;                (o)
  Rind_t<IndexDimension> Rind ;                                     (o/d)
  IndexRange_t ElementRange ;                                       (r)
  int ElementSizeBoundary ;                                         (o/d)
  ElementType_t ElementType ;                                       (r)
  DataArray_t<int, 1, ElementDataSize> ElementConnectivity ;        (r)
  DataArray_t<int, 2, [ElementSize, 4]> ParentData;                 (o)
  List( UserDefinedData_t UserDefinedData1 ... UserDefinedDataN ) ; (o)
  } ;
```

Element Connectivity, cont'd

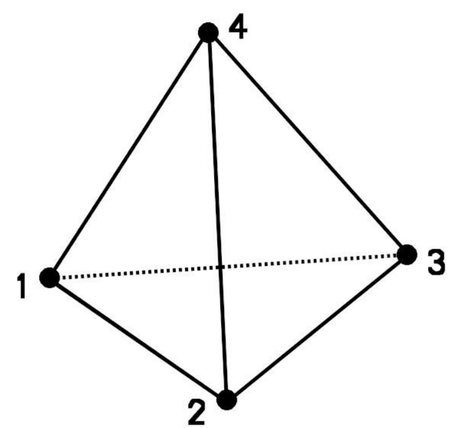
- Current element types supported:

ElementType_t := Enumeration(
Null, NODE, BAR_2, BAR_3,
TRI_3, TRI_6, QUAD_4, QUAD_8, QUAD_9,
TETRA_4, TETRA_10, PYRA_5, PYRA_14,
PENTA_6, PENTA_15, PENTA_18,
HEXA_8, HEXA_20, HEXA_27, MIXED, NGON_n, UserDefined);

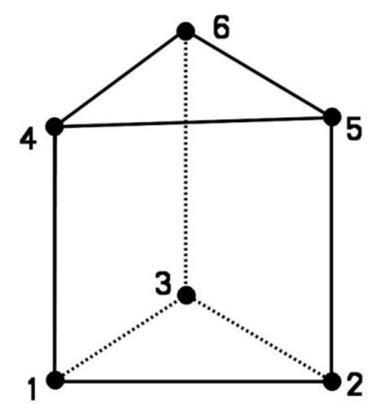
TRI_3



TETRA_4



PENTA_6



Element Connectivity, cont'd

For most element types:

ElementConnectivity =

Node11, Node21, ... NodeN1,	← nodes for element 1
Node12, Node22, ... NodeN2,	← nodes for element 2
...	
Node1M, Node2M, ... NodeNM	← nodes for element M

For MIXED:

ElementConnectivity =

Etype1, Node11, Node21, ... NodeN1,
Etype2, Node12, Node22, ... NodeN2,
...
EtypeM, Node1M, Node2M, ... NodeNM

Element Connectivity = MIXED

```
count=1
! first element is HEXA_8
element(count)=HEXA_8
        do i=1,8
            count = count + 1
            element(count)=...
        enddo
! second element TETRA_4
        count = count + 1
        element(count)=TETRA_4
        do i=1,4
            count = count + 1
            element(count)=...
        enddo
! write element connectivity
call cg_section_write_f(indexf, indexb, indexz, 'Elem', MIXED, nelem_start, nelem_end,
      nbdyelem, ielem, indexe, ier)
```

Element Connectivity, cont'd

NEW... For arbitrary polyhedra:

The NGON_n element type is used to specify all the faces in the grid, and the NFACE_n element type is then used to define the polyhedral elements as a collection of these faces. Except for boundary faces, each face of a polyhedral element must be shared by another polyhedral element.

I.e., for NGON_n, the data array ElementConnectivity contains a list of nodes making up each face in the grid, with the first value for each face defining the number of nodes making up that face:

```
ElementConnectivity =  Nnodes1, Node11, Node21, ... NodeN1,
                       Nnodes2, Node12, Node22, ... NodeN2,
                       ...
                       NnodesM, Node1M, Node2M, ... NodeNM
```

where here M is the total number of faces, and Ni is the number of nodes in face i. The ElementDataSize is the total number of nodes defining all the faces, plus one value per face specifying the number of nodes making up that face.

Element Connectivity, cont'd

NEW... For arbitrary polyhedra (cont'd):

Then for NFACE_n, ElementConnectivity contains the list of face elements making up each polyhedral element, with the first value for each element defining the number of faces making up that element.

ElementConnectivity = Nfaces1, Face11, Face21, ... FaceN1,
Nfaces2, Face12, Face22, ... FaceN2,
...
NfacesM, Face1M, Face2M, ... FaceNM

where now M is the total number of polyhedral elements, and Ni is the number of faces in element i. The sign of the face number determines its orientation (i.e., the direction of the face normal

Notes

- BEST PRACTICE: When writing unstructured grids, always include boundary elements and try to give each boundary type as a separate node if possible
  - Helps others decipher the file
  - Extremely useful when using plotting packages like Tecplot
  - Also helps establish boundary condition locations when reading the file

Element Connectivity, MLL
example

/* write element connectivity */

cg_section_write(indexf, indexb, indexz, “Elem”, HEXA_8, nelem_start1, nelem_end1, nbdyelem1, ielem, &indexe);

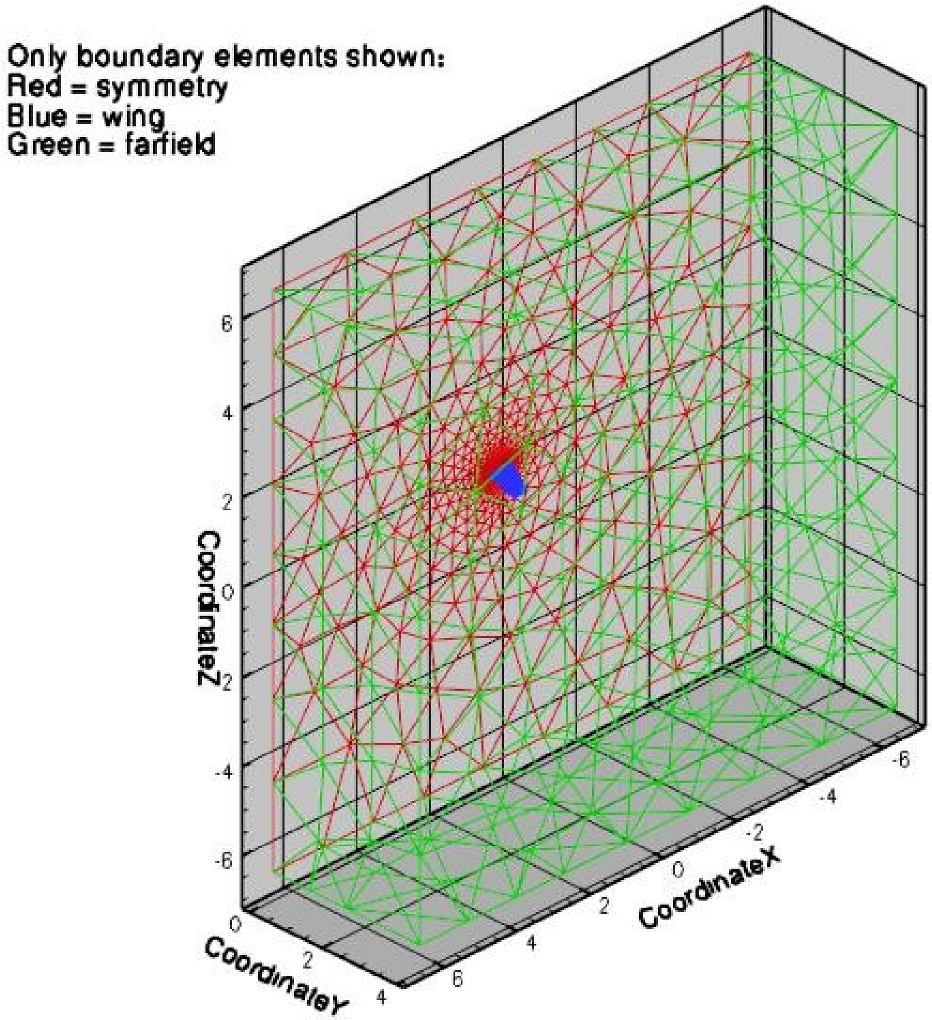
/* add element connectivity for all boundaries */

cg_section_write(indexf,indexb,indexz,“BdyWalls",QUAD_4,nelem_start2, nelem_end2, nbdyelem2, kelem, &indexe);

cg_section_write(indexf,indexb,indexz,“BdyFarfield",QUAD_4,nelem_start3, nelem_end3, nbdyelem3, lelem, &indexe);

cg_section_write(indexf,indexb,indexz,“BdySymm",QUAD_4,nelem_start4, nelem_end4, nbdyelem4, melem, &indexe);

Example viewed with Tecplot



Boundary Conditions, MLL

- BC implementation essentially identical for Structured and Unstructured grids
- However, although it is allowed to list the BCs as a function of the boundary node points (if desired), for Unstructured it often makes more sense to associate the BCs with boundary elements (ElementList or ElementRange) instead
  - It seems that this method of association is the most common practice currently in the unstructured grid community

```
call cg_boco_write_f(index_file,index_base,index_zone,'Ilo',
 + BCTunnelInflow,ElementList,icount,ipnts,index_bc,ier)
```

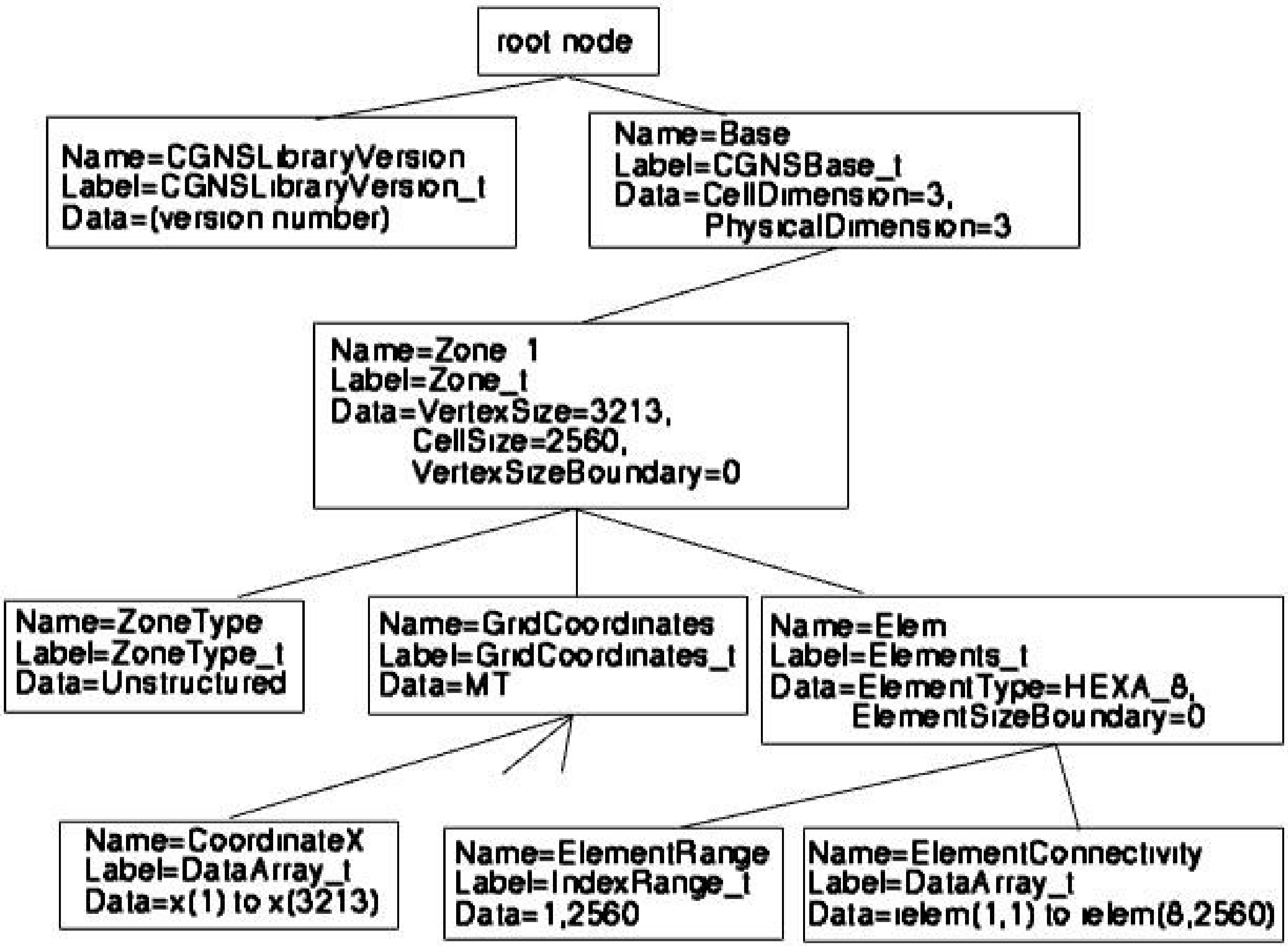
Boundary Conditions (cont’d)

```
ZoneBC_t< int IndexDimension, int PhysicalDimension > :=
  {
  List( Descriptor_t Descriptor1 ... DescriptorN ) ;                    (o)
  List( BC_t<IndexDimension, int PhysicalDimension> BC1 ... BCN ) ;  (o)
  ReferenceState_t ReferenceState ;                                     (o)
  DataClass_t DataClass ;                                               (o)
  DimensionalUnits_t DimensionalUnits ;                                 (o)
  List( UserDefinedData_t UserDefinedData1 ... UserDefinedDataN ) ;  (o)
  } ;
```

Boundary Conditions (cont’d)

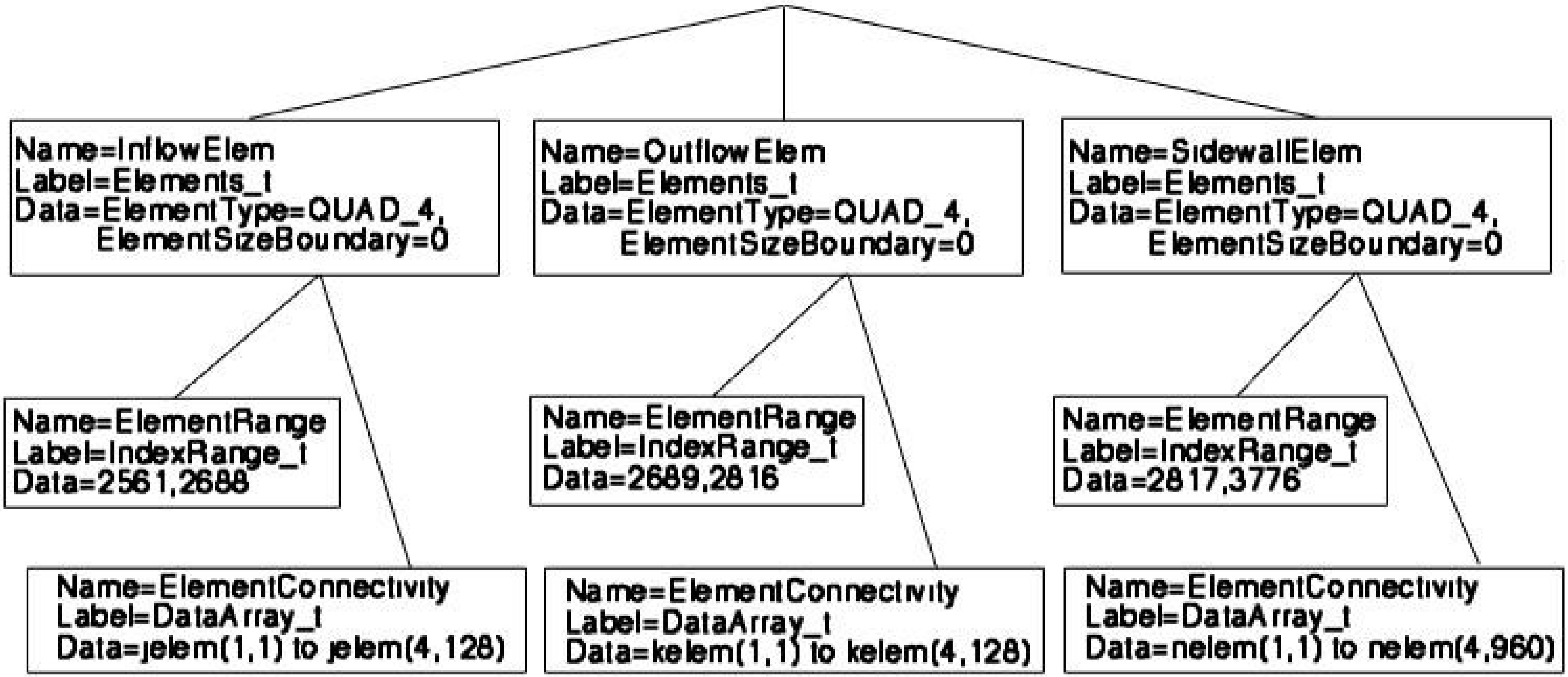
```
BC_t< int IndexDimension, int PhysicalDimension > :=
  {
  List( Descriptor_t Descriptor1 ... DescriptorN ) ;                (o)
  BCType_t BCType ;                                                 (r)
  GridLocation_t GridLocation ;                                     (o/d)
  IndexRange_t<IndexDimension> PointRange ;                         (r:o:o:o)
  IndexArray_t<IndexDimension, ListLength, int> PointList ;         (o:r:o:o)
  IndexRange_t<IndexDimension> ElementRange ;                       (o:o:r:o)
  IndexArray_t<IndexDimension, ListLength, int> ElementList ;       (o:o:o:r)
  int[IndexDimension] InwardNormalIndex ;                           (o)
  IndexArray_t<PhysicalDimension, ListLength, real> InwardNormalList ;   (o)
  List( BCDataSet_t<ListLength> BCDataSet1 ... BCDataSetN ) ;       (o)
  BCProperty_t BCProperty ;                                         (o)
  FamilyName_t FamilyName ;                                         (o)
  ReferenceState_t ReferenceState ;                                 (o)
  DataClass_t DataClass ;                                           (o)
  DimensionalUnits_t DimensionalUnits ;                             (o)
  List( UserDefinedData_t UserDefinedData1 ... UserDefinedDataN ) ;  (o)
  int Ordinal ;                                                     (o)
  } ;
```

Example Unstructured Tree



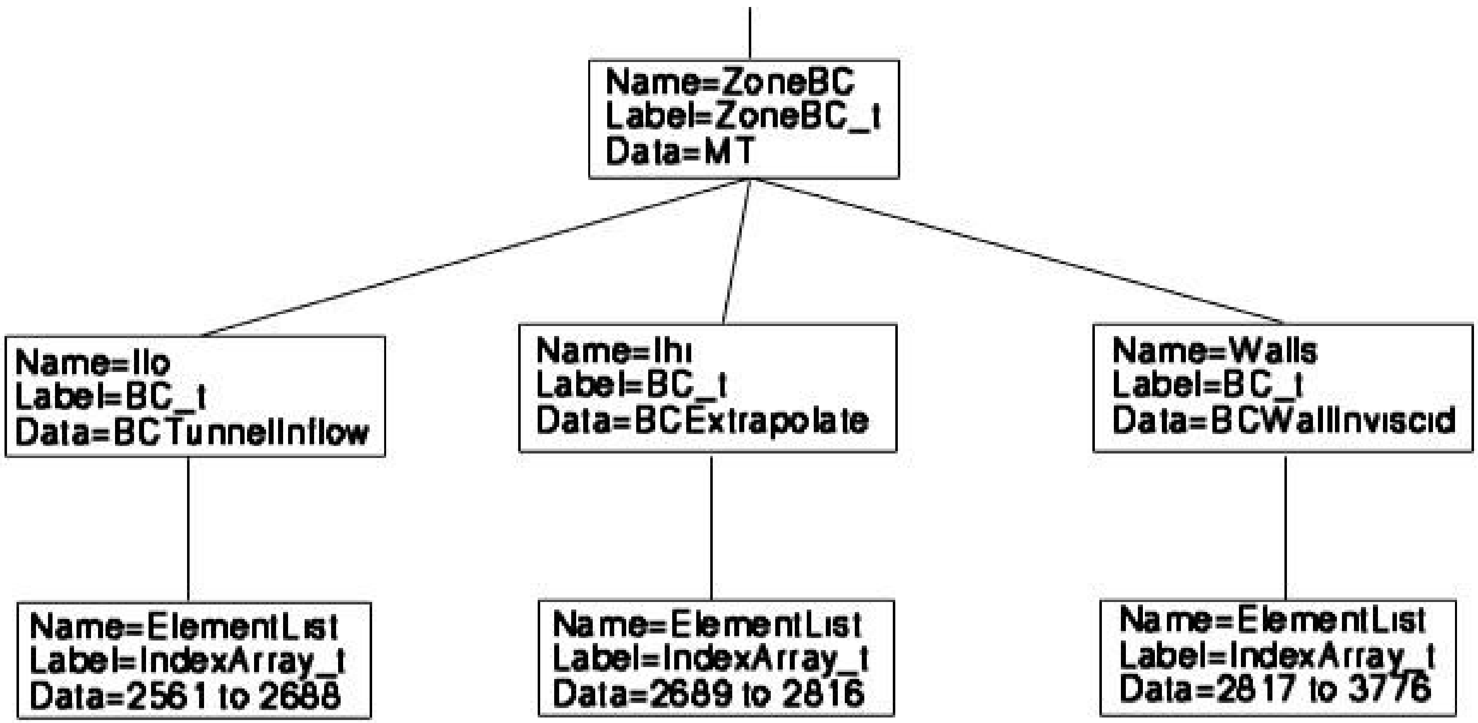
Example Unstructured Tree
(cont'd)

(under Zone_t)



Example Unstructured Tree
(cont'd)

(under Zone_t)



Flow Solution, MLL

- Flow Solution implementation essentially identical for Structured and Unstructured grids

```
/* define flow solution node name (user can give any name) */
strcpy(solname,"FlowSolution");
/* create flow solution node */
cg_sol_write(index_file,index_base,index_zone,solname,Vertex,&indexf);
/* write flow solution (user must use SIDS-standard names here) */
cg_field_write(index_file,index_base,index_zone,index_flow,
    RealDouble,"Density",r,&index_field);
```

Flow Solution (cont'd)

```
FlowSolution_t< int IndexDimension, int VertexSize[IndexDimension],
             int CellSize[IndexDimension] > :=
  {
  List( Descriptor_t Descriptor1 ... DescriptorN ) ;            (o)
  GridLocation_t GridLocation ;                                 (o/d)
  Rind_t<IndexDimension> Rind ;                                 (o/d)
  List( DataArray_t<DataType, IndexDimension, DataSize[]>
      DataArray1 ... DataArrayN ) ;                             (o)
  DataClass_t DataClass ;                                       (o)
  DimensionalUnits_t DimensionalUnits ;                         (o)
  List( UserDefinedData_t UserDefinedData1 ... UserDefinedDataN ) ;  (o)
  } ;
```

Summary

- Unstructured grids written/read using same MLL calls as those for structured grids, except:
  - only one index dimension (instead of three for 3D structured)
  - element connectivity written using cg_section_write
  - arbitrary element types can be specified
  - 2D boundary elements (for 3D geometry) are included as separate element entities