Chapter 2 Data Structure

Tecplot accommodates two different types of data: ordered and finite-element.

2 - 1 Ordered Data

Ordered data is a set of points logically stored in a one-, two-, or three-dimensional array, where I, J, and K are the index values within the array. The number of data points is the product of all of the dimensions within the array.

- **One-dimensional array (I-ordered, J-ordered or K-ordered) -** A single dimensional array of data points where one dimension (I,J or K) is greater than or equal to one and the other dimensions are equal to one. In a one-dimensional array, the total number of data points is equal to the length of the single-ordered array. For example, an I-ordered data set with I=5, J=K=1 has 5 data points.

- **Two-dimensional array (IJ-ordered, JK-ordered, IK-ordered) -** A two-dimensional array of data points where two of the three dimensions (I,J, K) are greater than one and the other dimension is equal to one. The number of data points in a two-dimensional ordered data set is the product of the all of the dimensions. For example, in an IJ-ordered data set, the number of data points is equal to I x J (where K=1).

- **IJK-ordered -** Three-dimensional array of data points where all three of the I-, J-, and K-dimensions are greater than one. The number of data points is the product of the I-, J-, and K-dimensions.

2- 1.1 One Dimensional-Ordered Data Points (I,J, or K)

Data points for XY Line plots are usually arranged in a one-dimensional array indexed by one parameter: I for I-ordered, J for J-ordered, or K for K-ordered, with the two remaining index values equal to one.

For example, in an I-ordered data set (the most common type), the data points are arranged as follows:

I=1 at the first data point,
I=2 at the second data point,
I=3 at the third data point,

...
I=*IMax* for the last point.

At each data point, *N* variables (**`V1, V2, ..., V`***N*) are defined. If you arrange the data in a table where the values of the variables (*N* values) at a data point are given in a row, and there is one row for each data point, the table would appear something like that shown in Figure 2-1. For example, if you wanted to make a simple XY-plot of pressure versus time, `V1` would be time and `V2` would be pressure.

V1	**V2**	**V3**	**...**	**V*N***	**(Values at data point *I* = *1*.)**
V1	**V2**	**V3**	**...**	**V*N***	**(Values at data point *I* = *2*.)**
V1	**V2**	**V3**	**...**	**V*N***	**(Values at data point *I* = *3*.)**
V1	**V2**	**V3**	**...**	**V*N***	
V1	**V2**	**V3**	**...**	**V*N***	
V1	**V2**	**V3**	**...**	**V*N***	
V1	**V2**	**V3**	**...**	**V*N***	**(Values at data point *I* = *IMax*.)**

Table 2-1. Table of values for I-ordered data points (suitable for XY-plots).

2- 1.2 Two Dimensional-Ordered Data Points (IJ, JK, or IK)

The data points for 2D and 3D surface field plots are usually organized in a two-parameter mesh. Each data point is addressable by a set of the two parameters (e.g. I and J for IJ-ordered) and has four neighboring data points (except at the edge of the data). The points are located above, below, to the left, and to the right as shown in Figure 2-1.

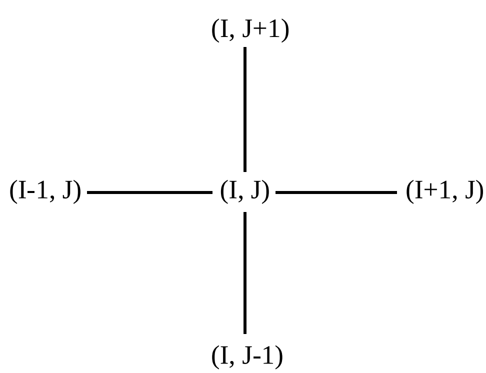


Figure 2-1. IJ-ordered data point neighbors. The layout is identical for JK or IK-ordered

2- 1.3 3 Dimensional-Ordered Data Points (IJK)

The data points for 3D volume field plots are usually organized in a three-dimensional ordered data set. Each point is addressable by a set of three indices (I, J, and K) and has six neighboring data points (except at the edges of the data set). These neighbors are located above, below, left, right, in front of, and behind the data point as shown in Figure 2-2.

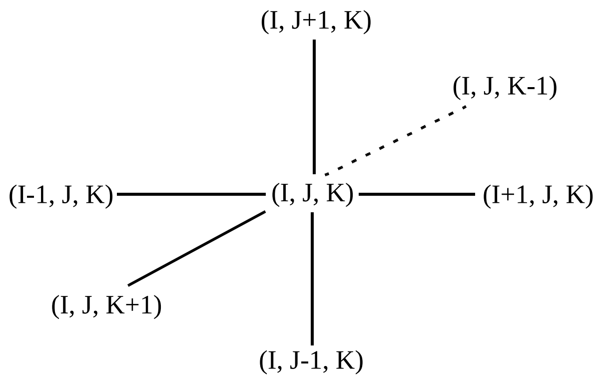


Figure 2-2. IJK-ordered data point neighbors.

At each data point, you define three spatial variables (X, Y, Z) plus (typically) one or more variables such as pressure, vector components, and vorticity.

A mesh plot of IJK-ordered data is displayed in Figure 2-3. The directions of the I-, J-, and K-indices are shown. As you can see, the points that define the mesh can form curved, irregularly spaced, and/or nonparallel paths.

IJK-Ordered Data Plotting

In one- or two-dimensional data sets, all data points are typically plotted. However, there are more plotting options for IJK-ordered data, especially when creating 2D or 3D plots. The ***Surfaces*** page of the **Zone Style** dialog allows you to designate which surfaces of IJK-ordered data will be plotted. You may choose to plot just outer surfaces, or you may select combinations of I-, J-, and K-planes to be plotted. Refer to Section 6- 1.2, “Surfaces” for in-depth information.

2- 1.4 I-, J-, and K-Planes

A K-plane is the connected surface of all points with a constant K-index value. The I- and J-indices range over their entire domains. Similarly for an I-plane and a J-Plane. Examples of I-, J-, and K-planes are shown in Figure 2-3.

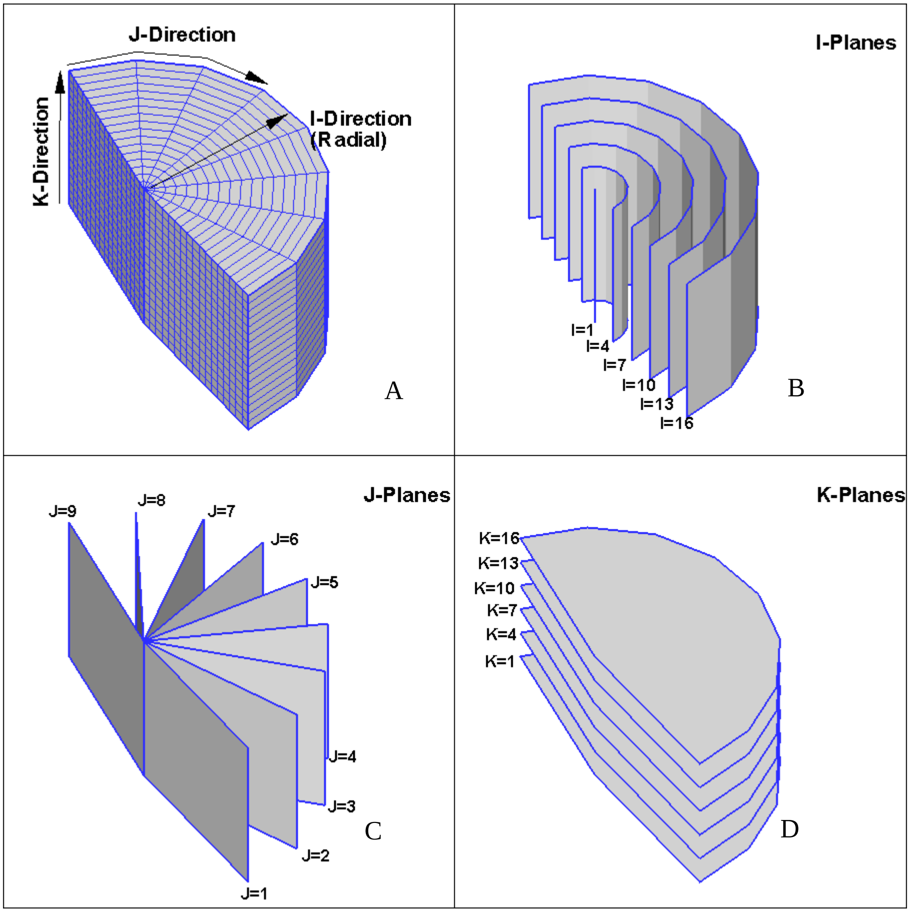


Figure 2-3. An illustration of IJK planes of a semi-circular zone (created by extracting a subzone from a circular zone). (A) shows all 3 planes (*Surfaces to Plot* = Boundary on the **Surfaces** page of the **Zone Style** dialog). (B) *Surfaces to Plot* = I-Planes (C) *Surfaces to Plot* = J-Planes and (D) *Surfaces to Plot* = K-Planes.

Note: I-, J- or K-planes are not necessarily two-dimensional in physical space. They are called planes because they exist as planes in logical (IJK) space. In real (XYZ) space, the planes may be cones, ellipsoids, or arbitrary surfaces.

2- 1.5 Mesh Structure (Ordered Data Only)

A family of I-lines results by connecting all of the points with the same I-index, similarly for J-lines and K-lines. For IJ- ordered data, both families of lines are plotted in a two-dimensional coordinate system resulting in a 2D mesh. When both the I- and J-lines are plotted in a three-dimensional coordinate system, a 3D surface mesh plot results. An example of both meshes is shown in Figure 2-4..

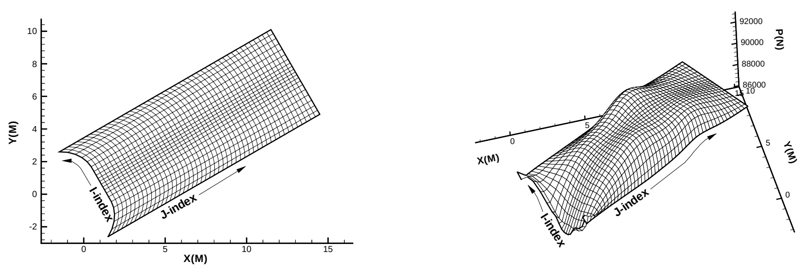


Figure 2-4. Left, a 2D mesh of IJ-ordered data points. Right, a 3D mesh of IJ-ordered data points. **Note**: Ordered axes do not necessarily corresponded to physical axes.

2 - 2 Finite-Element Data

Finite-element data is arranged in two arrays, a variable array and a connectivity matrix. The variable array is a collection of points in 2D or 3D space that are connected into polygonal or polyhedral units called elements. The connections between the nodes are defined by the connectivity matrix.

While finite-element data is usually associated with numerical analysis for modeling complex problems in 3D structures, heat transfer, fluid dynamics, and electromagnetics, it also provides an effective approach for organizing data points in or around complex geometrical shapes. For example, you may not have the same number of data points on different lines, there may be holes in the middle of the data set, or the data points may be irregularly (randomly) positioned. For such difficult cases, you may be able to organize your data as a patchwork of elements. Each element can be independent of the other elements, so you can group your elements to fit complex boundaries and leave voids within sets of elements. Figure 2-4 shows how finite-element data can be used to model a complex boundary.

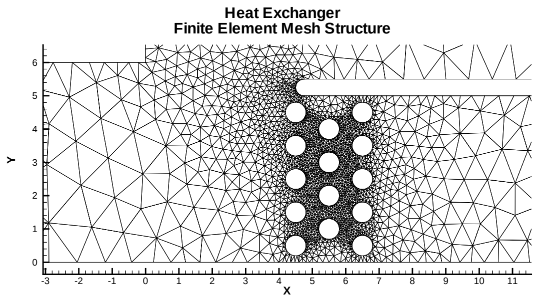


Figure 2-5. Finite-element data used to model a complex boundary.

Finite-element data defines a set of points (nodes) and the connected elements of these points. The variables may defined either at the nodes or at the cell (element) center. Finite-element data can be divided into three types:

- **FE-line -** A set of line segments defining a 2D or 3D line.
- **FE-surface -** A set of triangular or quadrilateral elements defining a 2D field or a 3D surface.
- **FE-volume -** A set of tetrahedral or brick elements defining a 3D volume field.

In Tecplot, each FE data zone must be composed exclusively of one element type. However, you may use a different data point structure for each zone within a data set, as long as the number of variables defined at each data point is the same.

You can simulate zones with mixed element types by repeating nodes as necessary. For example, a triangle element can be included in a quadrilateral zone by repeating one node in the element's connectivity list, and tetrahedral, pyramidal, and prismatic elements can be included in a brick zone by repeating nodes appropriately.

F- 2.5 “Finite-Element Data” on page 789 provides detailed information about how to format your FE data for Tecplot.

2- 2.1 Finite-Element Line Data.

Unlike I-ordered data, a single finite-element line zone may consist of multiple disconnected sections. The values of the variables at each data point (node) are entered in the data file similarly to I-ordered data, where the nodes are numbered with the I-index. This data is followed by another set of data defining connections between nodes. This second section is often referred to as the *connectivity list*. All elements are lines consisting of two nodes, specified in the connectivity list.

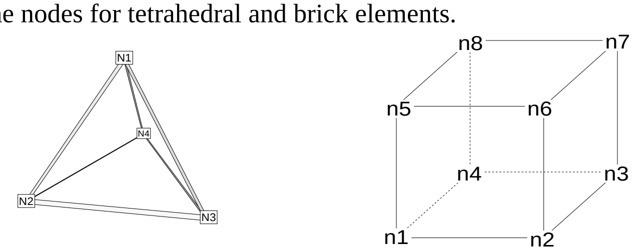
2- 2.2 Finite-Element Surface Data

In finite-element surface data, the values of the variables at each node (data point) and the finite-element connectivity lists are entered in the data file in the same manner as finite-element line data (described above). The difference is in the number of nodes per element.

You can choose (by zone) to arrange your data in three point (triangle) or four point (quadrilateral) elements. The number of points per node and their arrangement are called the element type of the zone. You may repeat a node in the quadrilateral element type to create a triangle if a mixture of quadrilaterals and triangles is necessary.

2- 2.3 Finite-Element Volume Data

Finite-element volume cells may contain four points (tetrahedron) or eight points (brick). The elements in each zone must be either all tetrahedra or all bricks. Figure 2-6 shows the arrangement of the nodes for tetrahedral and brick elements.



Tetrahedral connectivity arrangement.

Brick connectivity arrangement.

Figure 2-6. Connectivity arrangements for FE-volume data sets.

In the brick format, points may be repeated to achieve 4-, 5-, 6-, or 7-point elements. For example, a node list entry of "`n1 n1 n1 n1 n5 n6 n7 n8`" results in a quadrilateral-based pyramid element.

2- 2.4 Finite-Element Data Limitations

Working with finite-element data has some limitations:

- XY-plots of finite-element data treat the data as I-ordered; that is, the connectivity list is ignored. Only nodes are plotted, not elements, and the nodes are plotted in the order in which they appear in the data file.
- Index skipping in vector and scatter plots treats finite-element data as I-ordered; the connectivity list is ignored. Nodes are skipped according to their order in the data file.

2 - 3 Variable Location (Cell-Centered or Nodal)

In ordered or FE-data sets, the value of the variables can be located at either the nodes or the cell-centered.

- For finite-element meshes, cell-centers are the centers (centroids) of elements.
- For I-ordered grids, the cell-centers are at the centers of the lines connecting points (I) and (I+1).
- For IJ-ordered grids, the cell-centers are at the centroids of the quadrilaterals defined by points (I,J), (I+1,J), (I,J+1), and (I+1, J+1).
- For IJK-ordered grids, the cell-centers are at the centroids of the hexahedral-like elements defined by points (I,J,K), (I+1,J,K), (I,J+1,K), (I+1,J+1,K), (I,J,K+1), (I+1,J,K+1), (I,J+1,K+1),and (I+1,J+1,K+1).

For many types of plots, Tecplot internally interpolates cell-centered values to the nodes.

Refer to for "Zone Records" on page 747 for information on specifying the variable location in a data file.

2 - 4 Working with Unorganized Data Sets

Unorganized data sets are loaded into Tecplot as a single I-ordered zone and will be displayed in XY Mode, by default.

To check for irregular data, you can go to the **Data>Dataset Info** dialog (accessed via the **Data** menu). In the lower left quadrant of that dialog Tecplot will show you the values assigned to: *IMax*, *JMax*, and *KMax*. If *IMax* is greater than 1, and *JMax* and *KMax* are equal to 1, then your data is irregular.

> An I-ordered zone is irregular if it is known to have more than one dependent variable. An I-ordered data set with one dependent variable (i.e. an XY or polar line) is NOT an irregular zone.

It is also simple to tell irregular data from the plot. If you are looking at irregular data with the Mesh layer turned on, Tecplot will connect the datapoints using lines and in the order the points appear in the dataset.

There are 4 ways to organize your data set.

1. Manually order the data file using a text editor.

> Use the **Label Points and Cells** feature from the **Plot** menu to see if your data set can be easily corrected using a text editor by correcting the values for I, J and/or K.

2. Use the **Data>Triangulate** feature. (2D only). See 18 - 11 “Irregular Data Point Triangulation” on page 346.

3. Use one of the **Data>Interpolation** options. See 18 - 10 “Data Interpolation” on page 336.

4. Special Cases (use when interpolation results appear skewed):
    - Well data - If points are closely positioned along the depth axis and far apart in physical space, use the ***Tetra Grid*** add-on to create a new zone with all points connected into 3D zones. See 29- 3.12 “Tetra-Grid” on page 623.
    - Fluid Measurements - When measurements are taken of fluid properties or containments, interpolating to a rectangular zone does not yield good results, Use the ***Prism Grid*** add-on to create a 3D volume zone. See 29- 3.8 “Prism-Grid” on page 612.

2- 4.1 Example - Triangulate a Data Set

One common source of finite-element surface data is Tecplot's triangulation option. If you have 2D data without a mesh structure, it is probably simplest to enter your data points as an I-ordered data set, then use Tecplot's triangulation feature to create a finite-element data set. You can then edit the file, and particularly the connectivity list, to obtain the set of elements you want, rather than having to create the entire connectivity list by hand.

We can triangulate a data set as follows:

1. Create a simple ordered data file, as follows:

```
VARIABLES = "X", "Y", "P", "T"
0.0 1.0 100.0 1.6
1.0 1.0 150.0 1.5
3.0 1.0 300.0 2.0
0.0 0.0 50.0 1.0
1.0 0.0 100.0 1.4
3.0 0.0 200.0 2.2
4.0 0.0 400.0 3.0
2.0 2.0 280.0 1.9
```

2. Save the file, with extension *.dat

3. Read the data file into Tecplot and switch the plot type to ***2D Cartesian***.

4. From the **Data** menu, choose **Triangulate**.

5. Select the simple ordered zone as the source zone, and click ***Compute***.

Figure 2-7 shows a plot of the resulting data. With triangulation, we obtain more elements (seven) than when we created the data set by hand (four), and the elements are triangles rather than quadrilaterals..

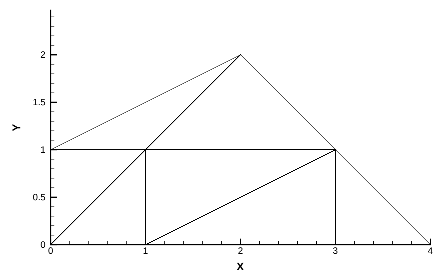


Figure 2-7. Triangulated data from Table F-4.

2- 4.2 Example - Unorganized Three-Dimensional Volume

To use 3D volume irregular data in Tecplot field plots, you must interpolate the data onto a regular, IJK-ordered zone. (Tecplot does not have a 3D equivalent for triangulation.) To interpolate your data, perform the following steps:

1. Place your 3D volume irregular data into an I-ordered zone in a data file.

2. Read in your data file and create a 3D scatter plot.

3. From the **Data** menu, choose **Create Zone>Rectangular** (**Circular** will also work).

4. In the **Create Rectangular Zone** dialog, enter the ***I-***, ***J-***, and ***K-dimensions*** for the new zone; at a minimum, you should enter 10 for each dimension. The higher the dimensions, the finer the interpolation grid, but the longer the interpolating and plotting time.

5. Enter the minimum and maximum X, Y, and Z values for the new zone. The default values are the minimums and maximums of the current (irregular) data set.

6. Click ***Create*** to create the new zone, and ***Close*** to dismiss the dialog.

7. From the **Data** menu, choose **Interpolate>Kriging** (**Linear** or **Inverse distance Interpolation** would also work).

8. In the **Kriging** dialog, choose the irregular data zone as the source zone, and the newly created IJK-ordered zone as the destination zone. Set any other kriging parameters as desired (see Section 18- 10.3, “Kriging,”for details).

9. Click ***Compute*** to perform the kriging.

Once Tecplot completes the interpolation, you can plot the new IJK-ordered zone as any other 3D volume zone. You may plot iso-surfaces, volume streamtraces, and so forth. At this point, you may want to deactivate or delete the original irregular zone so as not to conflict with plots of the new zone.

Figure 2-8 shows an example of irregular data interpolated into an IJK-ordered zone, with iso-surfaces plotted on the resultant zone.

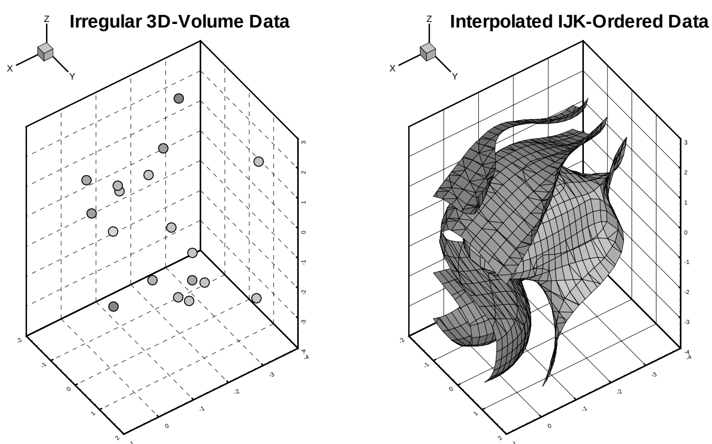


Figure 2-8. Irregular data interpolated into an IJK-ordered zone.