Using ArcGIS 8.3 for Pipelines

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INTRODUCTION

ArcGIS version 8.3 provides many new features that will be useful to pipeline operators. These features include full support for dynamic segmentation, feature topology and disconnected editing. This paper will discuss how these improvements can be applied to solving problems in the pipeline industry.

THE PIPELINE INDUSTRY

The North American pipeline infrastructure consists of more than half a million miles of gas and hazardous liquid pipelines. Some of these pipelines transport product from the wellhead to a production facility; the transmission lines transport from production facility to a distribution location, and distribution lines move the product to homes and industry. Historically, pipeline operators have relied on stationing or chainage to track linear footage of pipe. Especially for transmission pipelines, stationing or chainage is used frequently to identify locations along the pipeline.

DYNAMIC SEGMENTATION

Using a technique often called dynamic segmentation or creating Route Events, pipeline operators can track events that occur along the pipeline in terms of stationing. Events are point or linear features that describe something important – such as physical or operational pipeline attributes, inspection locations, foreign line crossings, etc. Events are simply database tables that reference station locations, and are not typically feature classes. While route events have been supported for many years by Arc/Info and early versions of ArcView, comprehensive linear referencing support has not been fully available in ArcGIS until version 8.3.

ArcGIS 8.3 new linear referencing capabilities include:

- Improved route editing and route creation
- Identification of route measure anomalies
- Ability to identify route locations
- Advanced route event options
- New route calibration tools
- Route hatching
- The ability to create point and linear event tables
- Event aggregation

STATIONS OR MEASURES

There are primarily two approaches used for pipeline linear referencing. The first approach is to directly store pipeline stationing in the polyline measure (M) coordinate attribute. For example, if a pipeline begins at 10+00 and ends at 20+00, 1000 would be the measure of the first vertice and 2000 would be the measure of the last vertice. It is expected that the PolylineM will be digitized in the direction of ascending stationing, but it might run opposite to stationing.

One advantage of this is the obvious simplicity of using stations to find locations and for hatching. When one reviews the vertices, it is very easy to identify the station value. However, there are disadvantages. First, because it is advantageous to have unique measures on the centerline when doing dynamic segmentation, this becomes more challenging when handling station equations – usually forcing the PolylineM to be broken into segments of continuous stationing, often called *series*. When pipeline stationing on the same line is ascending and descending, it can become even more difficult to manage. Another difficulty is that this approach forces all linear attributes to be contained on one polyline feature and not span station equations. On long pipelines, this can be an extra burden to place on the user entering and reviewing the data. It also makes data integration along the entire pipeline, especially with ILI runs, more challenging.

The other approach is to store calculated measures instead of stationing in the PolylineM feature class coordinate. Different from the previous example, if a pipeline begins at 10+00 and ends at 20+00, the first measure would be 0 and the measure of the last vertice would be 1000. This is sometimes referred to as absolute stationing. The calculated measures allow the system to take station equations into account, keeping unique measures along the line – thus creating a PolylineM that spans station equations.

This second approach solves the problem of station equations and linear features that span equations, by allowing any number of equations on a given pipeline. However, it causes a problem when trying to use hatching on measures in ArcGIS 8.3 – because the measure is not necessarily the same value as the station. Using the identify tool and hatching will not provide useful results.

It should be noted that the *Route* table and the *Measure* column in the Station Point table in the PODS data model directly correspond with the ArcGIS route feature class and measures on that route. This provides a convenient method for directly overlaying PODS events on a route feature class.

STATION EQUATIONS

When a reroute is posted to the centerline causing a station equation, it is necessary to adjust the downstream measures on the centerline, if calculated measures are used. If actual stations are

used, as described in the first approach above, it may be necessary to split one PolylineM into two PolylineM records and also split linear features that span the equation.

STATIONS AND CALCULATED MEASURES

An alternative is to use both approaches – stationing and calculated measures. With this approach, stationing can automatically be placed on the PolylineM with appropriate attributes – diameter, wall thickness, MAOP, grade, etc. This is useful for using the hatch tool to show stations corresponding with point and linear attributes. A PolylineM with measures can be used to overlay event features. The advantage of this alternative is that you can take advantage of the strength of each measurement method.

It addition is may be useful to generate other measures along the PolylineM, such as mileposts or mileposts plus footage. Multiple route layers can be stored, each with different measures in a feature class. ArcMap topology can also be used to ensure the routes are coincident as described later.

Therefore, as we have discussed, the two different approaches to relating route measures to stationing can affect how ArcMap is used. The preference of the author is to use the calculated measures, not stationing or the combined approach. While it causes a little extra work in dealing with the data, it is a cleaner approach because it is a better representation of the continuous real pipeline.

TIPS ON USING DYNAMIC SEGMENTATION

There are several quirks about using linear referencing in ArcGIS 8.3 that the author has noticed. The author has had trouble using Route Events in a projected view. As an example, if the route layer has a geographic (Lat/Long) projection, when the Event layer is displayed in this projection everything works fine. If the ArcMap projection is changed to a projected view (i.e. UTM), the event layer is not visible, or maybe only some segments display and no errors are generated. When the view is reset to the geographic projection, the event layer displays again.

Another quirk has to do with how the event table is added to ArcMap. Sometimes, an Access database table that is added through the normal *Add Data* tool fails to display the event layer. However, if the layer is added as an OLE DB connection to Access, the event layer works fine.

Also, when using an Oracle database as the source of the event table, it has been noticed that the most significant digits in a long integer (number 16) value will sometimes be dropped in ArcMap. ArcSDE connections to Oracle work fine for event tables.

The above observations have not yet been confirmed with ESRI, but are reproducible.

ADVANCED DYNAMIC SEGMENTATION

ArcGIS 8.3 has a new *Advanced Options* button on the Add Route Events dialog. This dialog allows the user to obtain the rotation angle of the line for point events and show errors that may have occurred when applying the event theme. While the generate angle field is useful for pipeline crossings, offset distances use the same units as the underlying coordinates. So, if the route feature class is Latitude/Longitude, the offset distance will use decimal degrees, even if the view is in a projected coordinate system. Additionally the advanced option supports multi-point features – which should not happen for pipeline operators.

AGGREGATING EVENTS

The Route Events Geoprocessing Wizard provides the ability to take event tables and aggregate data in various ways. It is important to note that the underlying event tables must be registered with the geodatabase. This has the effect of adding an OBJECTID column to the table – a unique integer that is used in the Wizard. If the underlying event table does not have an OBJECTID (OID), then the Intersect, Union and Dissolve tools cannot be used.

The Intersect, Union and Dissolve tools can be very useful to pipeline operators to integrate linear attribute data. The tools support both point and linear attributes. For example, pipe diameter, MAOP, DOT Class, external coating and pipe-to-soil potential would often be stored in separate attribute tables. The aggregate tool allows these data elements to be combined. One limitation is that only two tables can be processed at a time.

HATCHING EVENTS

Hatching linear measures is a useful tool to easily identify locations along the centerline. As described previously, using different measure schemes can provide the ability to show different linear references at the same time, such as stationing and mileposts or even ILI odometer values.

For systems that use milepost plus station, the hatch labels can be manipulated using the advanced label expression dialog. The VBScript can be used to display customary and meaningful labels for field personnel. This advanced capability seems powerful enough to be applied to other pipeline hatching challenges.

2-D AND 3-D ROUTES WITH MEASURES

It is the understanding of the author that ArcMap only uses the X-Y coordinates when rendering event layers. That is, events are not interpolated using the Z coordinate although the underlying route has Z coordinates. However this is not viewed as a significant shortcoming.

TOPOLOGY

Besides using topology for non-pipeline features, such as property boundaries, environmental areas, and other polygonal data, using topology for pipelines is less obvious when dealing with

event layers.

One useful application of topology is to use several route layers, each with a different linear referencing scheme. Each route feature class in a geodatabase must have a spatial reference. When creating a route feature class in a feature dataset, the user only needs to set the measure domain, which can be different for each route feature class. This allows each one to potentially store a different linear referencing system – such as stationing and mileposts, or feet, meters and miles.

Be careful to properly define the measure domain to allow maximum station values that will be encountered. Often, one decimal place of precision is sufficient for footage stationing.

DISCONNECTED EDITING

The advantages of disconnected editing of ArcGIS geodatabase are fairly obvious. Having the ability for a field user to edit a snapshot of data without being directly connected to the database is a new capability that some have been longing for. However how one uses disconnected editing in a GIS with extensive event themes is not so obvious. In general, there are two approaches. One approach is to actually register the event tables with ArcSDE. Although the author has not yet actually implemented this approach, in theory, it should provide the ability to fully edit the route and associated event data.

Another approach is to only register the route layers and other non-event layers, leaving the event tables unversioned. This approach allows the user to edit the route in a disconnected environment but does not provide for editing event tables in the disconnected environment. Route and event reconciliation must still be done.

ENTERPRISE VS. PERSONAL USE

One of the challenges often faced by GIS users today is in adapting and applying the technology to a repeatable and efficient enterprise workflow. For example, creating a pipeline GIS for a single user or small workgroup is significantly easier than building one on an enterprise level even though the technology is not really that much different. The problem has to do with process scalability.

This scalability complexity becomes more apparent in figuring out the best way to apply ArcGIS 8.3 at an enterprise level. ArcGIS is fundamentally a desktop application although it can access and edit data either in a personal geodatabase or SDE geodatabase.
For example, at the desktop, in a personal geodatabase, the user has great freedom to create new feature classes and new data. New data can be created from many other data elements and through complex geo-processing. This data may be re-created periodically as needed and the burden falls on the GIS analyst to know when data is out of date.

At an enterprise level, the analyst has the same freedom to create new data but less freedom to add this data to the enterprise system. While this new data might be useful to the enterprise it cannot be created and destroyed at will – the data itself needs to be incorporated into a business process that can manage it. Often these new business processes are difficult to define and create.

SUMMARY

ArcGIS 8.3 provides many new and very useful tools for pipeline operators and service providers. With full support for linear referencing, topology and disconnected editing, many of the features that the pipeline industry has been waiting for are finally here. As is usually the case, these tools open new opportunities for processing and analyzing data but present new challenges for figuring out how to best apply an integrate these in an enterprise setting.