Lecture 7

Hydro Networks in GIS: Flow and Referencing

GIS in Water Resources
Spring 2015

ArcGIS Resource Centers
http://resources.arcgis.com

Getting to Readings in ArcGIS Resource Center
Help for Desktop 10
Reading (1)

ArcGIS Resource Center/Desktop 10/Help/Professional Library/Data Management/Geographic Data Types/Geometric Networks – What are geometric networks, A quick tour of geometric networks, Essential geometric networks

What are geometric networks?

Geometric networks offer a way to model common networks and infrastructure. Water flow in a stream or all pieces of resource flows that can be modeled.

What can you do with geometric networks?

Once a geometric network is modeled, you can benefit from performing an example of what might benefit from each kind of analysis.

- **Analysis**
  - Calculate the shortest path between two points.
  - Find all connected or disconnected network elements.
  - Find loops or circuits in the network.
  - Determine flow direction through edges when sources or sinks are set.

Reading (2)

ArcGIS Resource Center/Desktop 10/Help/Professional Library/Guide books/Linear Referencing - What is linear referencing; Essential linear referencing

What is linear referencing?

Linear referencing is the method of storing geographic data in line. Measurements along features are used to locate points at which a point can be located along the line in the graph below:

- 12 units east of measure marker 10 along the line
- 18 units east of measure marker 26 along the line
Raster to Vector Transition

- During the last week, you have been dealing with the flow of water through the landscape based on the raster data structures.
- Today we are making a transition in which we are going to use vector network data to describe water pathways.
- We will connect the land and water flow systems by attaching the catchments and watersheds derived from raster data processing to our vector networks.

Some terminology

- **Hydrography** – the mapping of water features
  - Blue line features on topographic maps (streams, rivers, lakes,…)
  - More generally, hydrography also includes the mapping of bathymetry and extent of estuaries and coastal waters.
- **National Hydrography Dataset (NHD)** – a data model for storing topographic map hydrography
  - Medium resolution (1:100K) is complete for US
  - High resolution (1:24K) is complete for most of the US
- **NHDPlus** – a new data model integrating 1:100K resolution NHD with catchments and derived attributes from the National Elevation Dataset.
National Hydrography Dataset

Five feature classes with NHDFlowline built into a geometric network:

- NHDPoint
- NHDLLine
- NHDArea

NHDPoint, NHDLLine, NHDArea are point, line and area water features on map apart from flowlines and waterbodies.
NHD Waterbody

NHD Geometric Network
Arc Hydro Framework Input Data

Watersheds

Waterbody

Streams

Hydro Points

Arc Hydro Framework For South Florida

Basins

Waterbody (NHD)

Hydro Network (NHD)

Hydro Points

Structure

Monitoring Point
Network Definition

- A **network** is a set of edges and junctions that are topologically connected to each other.

Network Model in GIS

- Three components
  - Geometric model: (x,y,z,m) coordinates of edges and junctions
  - Logical model: which edges are connected to what junctions
  - Addressing model: location on the network using measure
Edges and Junctions

- **Simple feature** classes: points and lines
- **Network feature** classes: junctions and edges
- Edges can be
  - **Simple**: one attribute record for a single edge
  - **Complex**: one attribute record for several edges in a linear sequence

- A single edge cannot be branched
  No!!

Polylines and Edges

This single PolyLine feature will be converted to many SimpleEdge features when the network is built.
Junctions

- Junctions exist at all points where edges join
  - If necessary they are added during network building (generic junctions)
- Junctions can be placed on the interior of an edge e.g. stream gage
- Any number of point feature classes can be built into junctions on a single network

Connectivity Table

<table>
<thead>
<tr>
<th>Junction</th>
<th>Adjacent Junction and Edge</th>
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</thead>
<tbody>
<tr>
<td>J123</td>
<td>J124, E1</td>
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<tr>
<td>J124</td>
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<tr>
<td>J125</td>
<td>J124, E2</td>
</tr>
<tr>
<td>J126</td>
<td>J124, E3</td>
</tr>
</tbody>
</table>

This is the “Logical Network”
Build Network Tables

- Establishes connectivity of Edge and Junction features
- Enables tracing
- Generates Generic Junctions

Geometric Network Wizard in ArcCatalog

Snapping Features
Network Sources and Sinks

Each junction feature class in a network can have junctions which are sources or sinks for flow.

Ancillary Role of Sink
Flow to a sink

Flow direction has been assigned direction of the arrowhead.

This loop could not be solved and the flow was left "indeterminate".

Flags

Junction Flag

Edge Flag

Junction Barrier

Edge Barrier

Flags

Barriers
Trace Solvers

Upstream Trace Solvers

The selected junctions are the features the upstream trace ended at.

The set of all upstream features traced and returned as a graphic layer.
Hydrologic Networks

- Hydrologic data includes:
  - Single-line streams
  - Double-line streams
  - Braided streams
  - Manmade channel systems
  - Waterbodies

Flow Line

Traces movement of water in a one-dimensional flow system
Introduction to the Hydro Network

- **Hydro Edge** – think of Arc
- **Hydro Junction** – think of Node
- **Waterbody** – think of Polygon
Flow Network
A connected set of flow edges

Flowlines and Shorelines

Hydro Networks trace water movement through streams and rivers on Flowlines.

Hydro Networks include centerlines through lakes, swamps, and areas of complex drainage.

Hydro Networks include shorelines for large water bodies.

HydroEdges show flow direction.
Network Building

- Define flow-paths within double-line streams and waterbodies.
- Define network sinks and sources.

Network Connectivity

Find connected

Find loops
Network Flow Direction

- Enable flow in flow-paths.
- Disable flow in shorelines

Flow direction is unknown

Sink

Network Flow Direction

- Enable flow in flow-paths.
- Disable flow in shorelines

Flow direction is known

Sink
Uninitialized Flow Direction

Assigned Flow Direction
Network Tracing

Trace Upstream
Trace Downstream

Trace Path

Find the shortest path between two points on the network
Hydro Network for Holland

Hydro Network for Colorado
River Basin around Lake Travis
Guadalupe Basin Framework Dataset

Network Tracing on the Guadalupe Basin
Schematic Network

Hydro Network Junctions

<table>
<thead>
<tr>
<th>Hydro Network, Junctions</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Generic Junction</strong> is wherever two edges meet.</td>
</tr>
<tr>
<td><strong>Hydro Junction</strong> is where other features are attached to the network.</td>
</tr>
</tbody>
</table>
Connecting Waterbodies using Relationships

Waterbodies in a Hydro Network

Hydro Network through Canyon Lake
Linking Canyon Lake to the Network

Connecting Drainage Areas using Relationships

Drainage Area in a Hydro Network

Watershed is a polygon attached to a junction at its outlet location. JunctionID of watershed is the same as the HydroID of the junction it connects to.
Connecting Drainage Areas to the Network

Area goes to point on line

NHDPlus Reach Catchments $\sim 3\text{km}^2$

- Average reach length = 2km
- 2.3 million reaches for continental US

About 1000 reach catchments in each 8-digit HUC
Reach Attributes

- Slope
- Elevation
- Mean annual flow
  - Corresponding velocity
- Drainage area
- % of upstream drainage area in different land uses
- Stream order

Linear Referencing

Where are we on a line?
Addressing

Relative Addressing
0%  67.2%  100%

Absolute Addressing
0 ft  1434 ft  2134 ft

Coordinates of a 2-D Polyline

<table>
<thead>
<tr>
<th>ID</th>
<th>Sketch Properties</th>
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</tr>
<tr>
<td>10</td>
<td>106427.12, 776307.3113</td>
</tr>
</tbody>
</table>
Coordinates of a 2-D Polyline M

Setting Line Measure
Proportional Aliasing

Distance is measured Relative to the length of the line as a percentage 0% – 100%

Setting Percent Measure

pMSet.SetAndInterpolate MsBetween 0, 100
0 – 100 going upstream

pMSet.SetAndInterpolate MsBetween 100, 0
0 – 100 going downstream
Point and Line Events

Summary Concepts

• A network is a connected set of points (junctions) and lines (edges) that supports tracing functions
  – Three data model components
    • Geographic (x,y,z)
    • Logical (point-line topology connections)
    • Addressing (position m along the line)

• Features can be geometrically connected (network) or relationally connected (HydroID)
Summary Concepts (2)

- Land-water connections
  - Area flows to a line model (one Catchment is connected to one flowline) – used in NHDPlus and by Arc Hydro DrainID connections
  - Area flows to line at a point model (one Watershed contains many streams that drain to a Junction at the outlet) – used in Arc Hydro where HydroID of the HydroJunction is JunctionID of the Watershed

Summary Concepts (3)

- Linear referencing can be used to locate point and line “events” on a network
- This is like \((x,y)\) event themes that you used earlier to map stream gage locations in geographic space
- With linear referencing the locations are in “network space” but can be converted to regular features if necessary