Geospatial analysis in GIS

integrating data
for hydrologic applications
by means of ArcGIS software
Materials for this lecture are compiled using:

- ESRI ArcGIS documentation [manuals of different versions]
GIS is geospatial INFORMATION SYSTEM

- IS = computer system + its environment

- hardware
- know how
- data
- software
- infrastructure
- people
- **database** is an organised collection of logically related data
- data have to be processed to gather **information**

- in order to increase **knowledge** of users
Socrates – Erasmus Summer School: Full Integration of Geodata in GIS

Geospatial analysis in GIS

- Reality model → Conceptual (information) model
- Data model
- Physical data modelling
- Presentation models

Logical level
(independent of software)

Data level
(DBMS specific)

User level
Thematic layers (themes) – a key concept in GIS. A thematic layer is a collection of common geographic elements. Each theme may have its own geographic representations.
Socrates – Erasmus Summer School: Full Integration of Geodata in GIS

Geospatial analysis in GIS

→ **Data model**

- **georelational data model**
  - spatial data and attributive data separately
  - e.g. *shapefiles*:
    - vector data for the features in binary files (.shp)
    - attributes in a data table (.dbf)
    - unique identifiers are used to link them to each other.
Data model

- georelational data model
- **geodatabase data model**
  - all elements are managed in standard DBMS tables using standard SQL data types
  - object-based
    - features, rasters, tables, references etc
  - altogether in a container file (.mdb) as a database
    - objects can have built-in behaviour (objects encapsulation)
    - each table stores a feature class
    - each feature is a row in that table
    - spatially large feature classes can be stored seamlessly not tiled.
Reality model

Conceptual (information) model

Data model

Physical data modelling – a black box for the user

Presentation models

animations
maps
reports
forms
...

Geospatial analysis in GIS

Socrates – Erasmus Summer School: Full Integration of Geodata in GIS
ArcGIS geodatabase model

- datasets

  Feature dataset
  Contains spatially related feature classes together with the topology and network objects that bind them. Feature classes in a feature class collection have a common spatial reference.

  Feature class

  Topology
  Integrity rules that define the behavior of geographically integrated features.

  Network
  Rules for managing connectivity among features in a set of feature classes.

  Raster dataset
  Contains rasters representing continuous geographic phenomena. Raster data can be stored as either a raster dataset or a multirow raster catalog.

  Survey dataset
  Comprehensive survey measurements used to manage computation networks. Can be linked to and used to update feature coordinates.

  Metadata document
  A metadata document can be associated with every dataset in the GIS database.
ArcGIS geodatabase model

Feature dataset
Contains spatially related feature classes together with the topology and network objects that bind them. Feature classes in a feature class collection have a common spatial reference.

Feature class
A table with a shape field containing point, line, or polygon geometries for geographic features. Each row is a feature.

<table>
<thead>
<tr>
<th>Predefined fields</th>
<th>User-defined fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>ObjectID</td>
<td></td>
</tr>
<tr>
<td>Shape</td>
<td></td>
</tr>
</tbody>
</table>

Subtypes let you discriminate types of features in a feature class to control fine-grained behavior through attribute rules, topology rules, network rules, and relationship rules.

Topology
Integrity rules that define the behavior of geographically integrated features.

Table
A collection of rows, each containing the same fields. Feature classes are tables with shape fields.

<table>
<thead>
<tr>
<th>Predefined fields</th>
<th>User-defined fields</th>
</tr>
</thead>
<tbody>
<tr>
<td>ObjectID</td>
<td></td>
</tr>
</tbody>
</table>

Rows

Domain
Defines a set or range of valid values for a field.

<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
</tbody>
</table>

Relationship
Associates objects from a feature class or table to objects in another feature class or table. Relationships can have user-defined attributes.

<table>
<thead>
<tr>
<th>Primary key</th>
<th>Foreign key</th>
</tr>
</thead>
</table>
ArcGIS geodatabase model

- ArcGIS has several template data models
  - census units
  - addresses and locations
  - land cadastre
  - transportation networks
  - hydrography
    - data on water resources inventory approach
    - water as “blood” of landscape behavioural approach

Definitions of hydrology and hydrography are different in different scientific regions
A hydrologic information system connects time series and geospatial data with hydrologic analysis and modeling.
Arc Hydro data model

- Divides water resources data into five components:
  - **Network** – connected sets of points and lines showing pathways of water flow.
  - **Drainage** – drainage areas and stream lines defined from surface topography.
  - **Channel** – a 3D line representation of the shape of river and stream channels.
  - **Hydrography** – the base data from topographic maps and tabular data inventories.
  - **Time series** – tabular attribute data describing time-varying water properties for any hydro feature

- Does not describe constructed water pipe systems
- Has an associated set of tools
  - to support hydrologic simulation modelling
Feature dataset **Network**

- **HydroPointEvents** have relative location.
- Flow direction is assigned going downstream on the hydro network.
- Streams hierarchy may be ordered in different ways (Horton’s, Strahler’s etc.).
Drainage areas have complex hierarchy and different definitions
– to simplify
– to standardise
Basins are set of administratively chosen drainage areas that partition a region for purposes of **water resources management**. Basins are normally named after the principal rivers and streams of the region.
Feature dataset **Drainage**

Watersheds are subdivision of a basin into drainage areas selected for a particular hydrologic purposes.

the same network may have different watersheds
Feature dataset *Drainage*

Catchments are subdivision of a basin into *elementary* drainage areas defined by a *consistent set of physical rules*.

Jüri Roosaare (assoc.prof., University of Tartu)
Feature dataset *Channel*

- Feature dataset *Channel*
  - Line feature class *CrossSection*
  - Line feature class *ProfileLine*

Relationship class *CrossSectionHasEvent*
- One to many

- Table *CrossSectionPoint*
- Table *HydroLineEvent*
- Table *HydroPointEvent*
Feature dataset *Hydrography*

Developed according to US

Socrates – Erasmus Summer School: Full Integration of Geodata in GIS

Geospatial analysis in GIS

Jüri Roosaare (assoc.prof., University of Tartu)
Time series data

- **Point feature class MonitoringPoint**
- **Relationship class MonitoringPointHasTimeSeries**
  - One to many

- **Table TSType**
- **Relationship class TSTypeHasTimeSeries**
  - One to many

- **Table TimeSeries**

The diagram illustrates the concept of time series data in GIS, focusing on the relationship between points, time, and variables. The fixed variables and points are connected through time, indicating the dynamic nature of the data over different points in time.
Time series data

Selected Attributes of TimeSeries

<table>
<thead>
<tr>
<th>OBJECTID</th>
<th>FEATUREID</th>
<th>TSTYPEID</th>
<th>TS_DATETIME</th>
<th>TSVALUE</th>
</tr>
</thead>
<tbody>
<tr>
<td>226522</td>
<td>12000017</td>
<td>1</td>
<td>8/25/1999</td>
<td>126</td>
</tr>
<tr>
<td>351074</td>
<td>12000019</td>
<td>1</td>
<td>8/25/1999</td>
<td>310</td>
</tr>
<tr>
<td>403534</td>
<td>12000022</td>
<td>1</td>
<td>8/25/1999</td>
<td>140</td>
</tr>
<tr>
<td>415132</td>
<td>12000024</td>
<td>1</td>
<td>8/25/1999</td>
<td>623</td>
</tr>
<tr>
<td>438236</td>
<td>12000026</td>
<td>1</td>
<td>8/25/1999</td>
<td>6.9</td>
</tr>
<tr>
<td>456948</td>
<td>12000030</td>
<td>1</td>
<td>8/25/1999</td>
<td>3.4</td>
</tr>
<tr>
<td>495270</td>
<td>12000033</td>
<td>1</td>
<td>8/25/1999</td>
<td>762</td>
</tr>
<tr>
<td>503825</td>
<td>12000035</td>
<td>2</td>
<td>8/25/1999</td>
<td>4.5</td>
</tr>
<tr>
<td>504170</td>
<td>12000037</td>
<td>2</td>
<td>8/25/1999</td>
<td>6.9</td>
</tr>
<tr>
<td>504425</td>
<td>12000022</td>
<td>2</td>
<td>8/25/1999</td>
<td>5.7</td>
</tr>
</tbody>
</table>
ID-s for features

- A data table in relational database must have the **primary key** – a unique **ID**entifier of each row (feature).
- In Arc Hydro, all features are hydro features and therefore have two obligatory attributes:
  - **HydroID** – An *integer* attribute that uniquely identifies the feature in the geodatabase;
    - format for HydroID: <class number><feature number>
    - extended HydroID: <drainage area ID> <class number><feature number>
  - **Assign_HydroID** – a tool to support automatic assignment of IDs
  - **HydroCode** – A *text* attribute that is a permanent public identifier of the feature
    - to link Arc Hydro with other IS-s

![Diagram](image-url)
Relationships in data model
Relationships in data model

HydroJunction has Waterbody
Arc Hydro Tools

- description the drainage patterns of a catchment
- drainage analysis on a terrain model
- development of attributes that can be useful in hydrologic modelling
- comprehensive documentation (Overview, Tutorial, online Help) attached
Tools in this menu deal with processing of Digital Elevation Model (DEM). They are mostly used once in order to prepare spatial information for later use.
Tools in this menu deal with watershed and subwatershed delineation and basin characteristic determination. They operate on top of the spatial data prepared in the terrain preprocessing stage.
Arc Hydro Tools

- These tools provide functionality for generation of some of the key attributes (fields) in the Arc Hydro data model. Some of the tools require existence of a geometric network.
Arc Hydro Tools

- These tools generate or manipulate properties of geometric (hydro) network.
Arc Hydro Tools

- These are tools for management of Arc Hydro project properties. In general, they will be seldom used.
Arc Hydro buttons

- tracing flow path from the selected point to the outlet following the steepest descent
- delineation of watershed for a selected point:
- batch point generation (as input for watershed batch processing)
- assigning related IDentifier
- global point delineation – merges the resulting in delineation local watershed with the Catalog Units (e.g. EDNA) polygons located upstream
- tracing upstream, downstream or in both directions (e.g. to display the catchments located upstream and/or downstream from a specific junction)
Hydro Data Model

ESRI has developed models for Water Resources and has focused on surface water with input from key state, national, and international contributors. The ArcGIS Hydro model is available for review and download. We are also supporting a groundwater data model initiative and will eventually consider the full hydrologic cycle as part of the Hydro effort.

Archydro Training Classes!
The instructor-led training classes provide an introduction to the Arc Hydro data model and associated software tools supporting hydrologic and hydraulic analysis with GIS. Two courses; Archydro GIS for Water Resources, and Hydrologic and Hydraulic Analysis can be found by searching the ESRI Instructor-Led Training site.

If you are interested in downloading the most recent version of the Archydro tools please contact: Archydro@esri.com

data model user group

Join the data model user group if you are an existing ArcGIS customer and want to learn more about design and architecture of personal or enterprise Geodatabase and become a part of ESRI’s growing data model community.

We invite user group members to participate in a series of instructional web casts. Please fill out the data model survey to give us feedback on what web casts you would like to see.

User Forums
Visit the ESRI data model discussion questions with other users.

Downloads - Case Studies
These Case Studies are a good start discipline. These project examples documentation.

- San Marcos Basin Case Study
  28490kb (submitted 02/21/2003)
- Hydro Data Model Poster
  ArcGIS (submitted 06/30/2003)
- ArcHydro GIS for Water Resources
  Hydrologic and Hydraulic Analysis
  08/31/2004

Downloads - Design Templates
The Design Templates are the result of general concepts and terms for the create a template data model a

- Arc Hydro Data Model Template
  09/26/2002
- Framework Microsoft Repository
  11/19/2002
- Hydro Microsoft Repository
  11/19/2002
- Visio 2002 Update
  Visio 2002 - zip format, 19802kb (submitte
- Arc Hydro Tools version 1.1 Fina
  txt - zip format, 18819kb
- Arc Hydro Tools version 1.1 Fina
  msi, mso, txt - zip format, 18819kb
Thank you!