Geometric Transformation and Attribute Data Input

Module 3

Topics to be covered

- Geometric transformation
- RMS error and its interpretation
- Resampling of pixel values
- Attribute data in GIS
- Relational model
- Data entry
- Manipulation of fields and attribute data

Geometric Transformation

- Geometric transformation is the process of using a set of control points and transformation equations to register a digitized map, a satellite image, or an aerial photograph onto a projected coordinate system.
- As its definition suggests, geometric transformation is a common operation in GIS, remote sensing.
- Projection converts data sets from 3-D geographic coordinates to 2-D projected coordinates, whereas geometric transformation converts data sets from 2-D digitizer units or rows and columns to 2-D projected coordinates

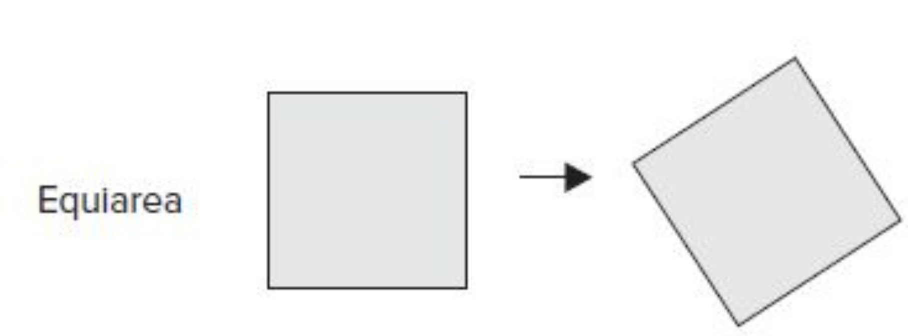
Transformation types

- A newly digitized map, either manually digitized or traced from a scanned file, is based on digitizer units.
- Digitizer units can be in inches or dots per inch.
- Geometric transformation converts the newly digitized map into projected coordinates in a process often called **map-to-map transformation**
- **Image-to-map transformation** applies to remotely sensed data, it changes the rows and columns (i.e., the image coordinates) of a satellite image into projected coordinates.

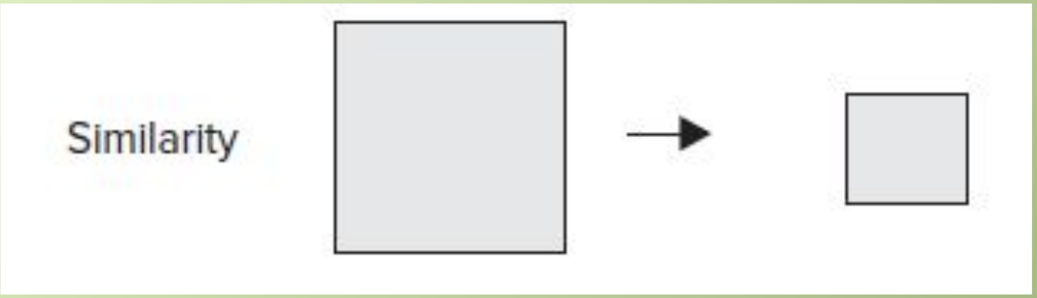
Transformation method

- Different methods have been proposed for transformation from one coordinate system to another.
- Each method is distinguished by the geometric properties it can preserve and by the changes it allows.

Equiarea transformation allows rotation of the rectangle and preserves its shape and size.

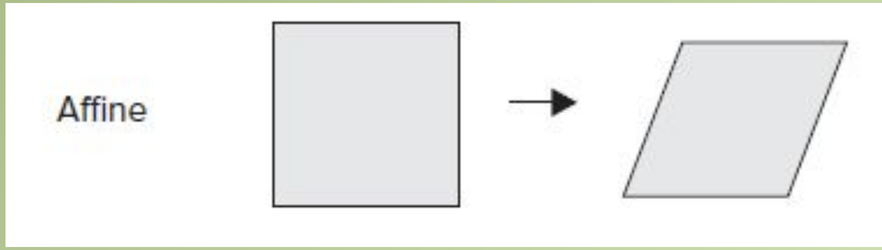


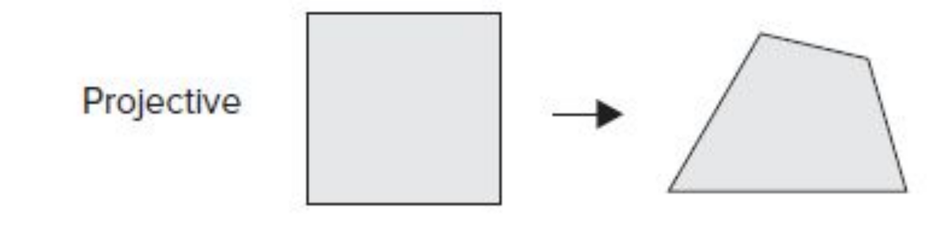
Similarity transformation allows rotation of the rectangle and preserves its shape but not size.

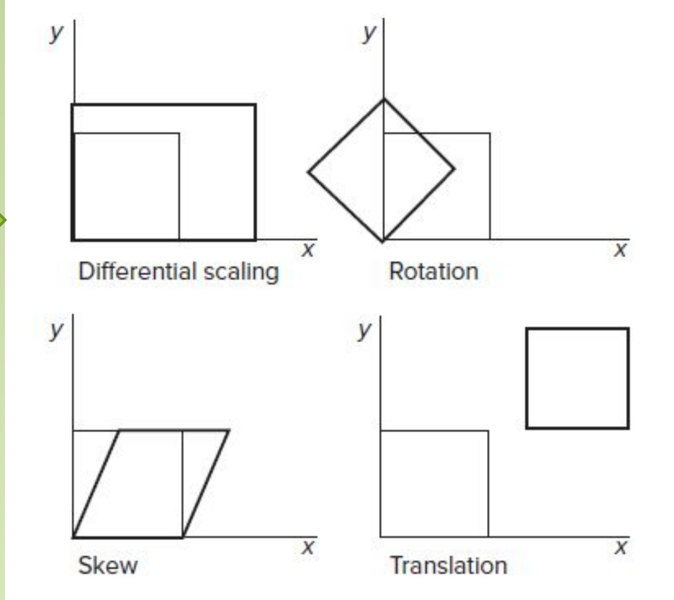


Affine transformation allows angular distortion of the rectangle but preserves the parallelism of lines (i.e., parallel lines remain as parallel lines).

Projective transformation allows both angular and length distortions, thus allowing the
rectangle to be transformed into an irregular quadrilateral







Root mean Square error

- The affine transformation uses the coefficients derived from a set of control points to transform a digitized map or a satellite image.
- The location of a control point on a digitized map or an image is an estimated location and can deviate from its actual location.
- A common measure of the goodness of the control points is the **RMS error**, which measures the deviation between the actual (true) and estimated (digitized) locations of the control points.

- RMS error for a single point is calculated by:

$$\sqrt{(x_{\text{act}} - x_{\text{est}})^2 + (y_{\text{act}} - y_{\text{est}})^2}$$

- Average RMS error is calculated by:

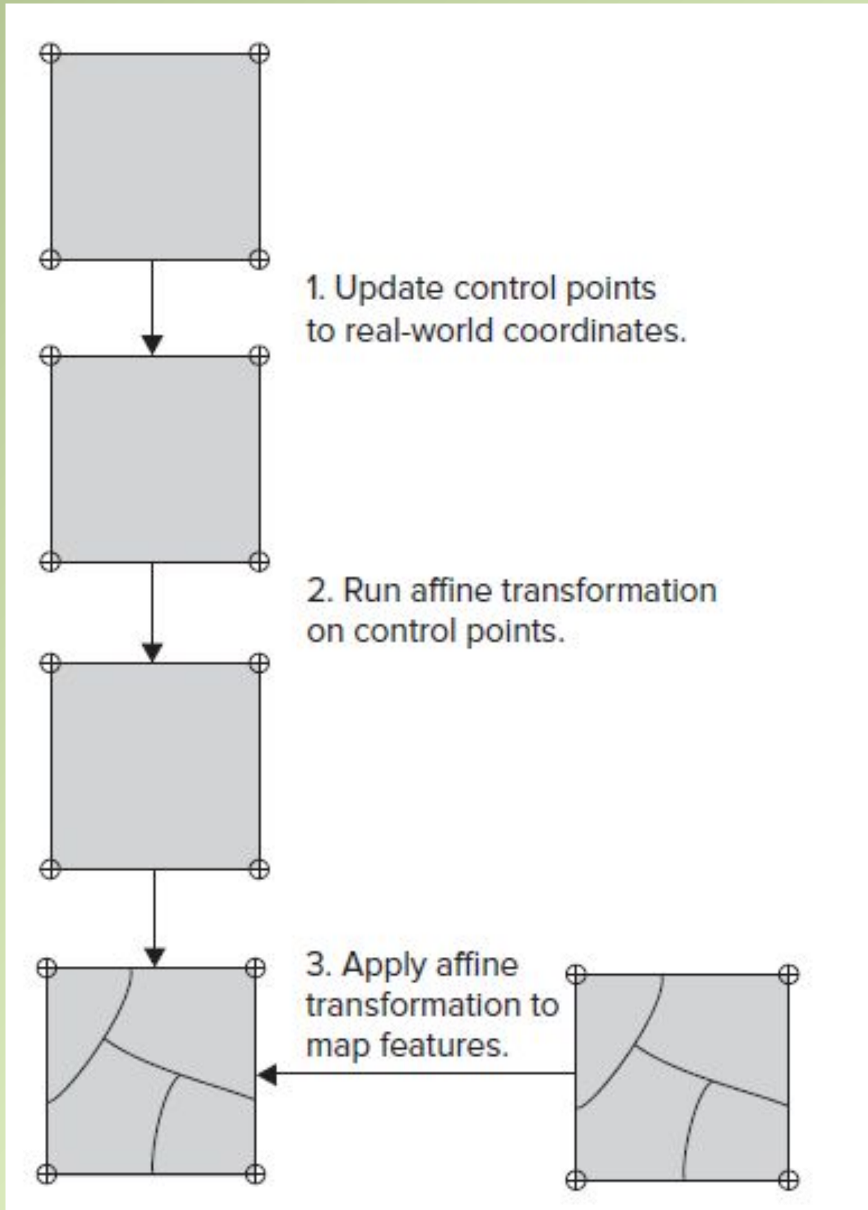
$$\sqrt{\left[\sum_{i=1}^{n}(x_{\text{act},\,i} - x_{\text{est},\,i})^2 + \sum_{i=1}^{n}(y_{\text{act},\,i} - y_{\text{est},\,i})^2\right] / n}$$

- Operationally, an affine transformation of a digitized map or image involves three steps:

1. First, update the x- and y-coordinates of selected control points to real-world (projected) coordinates. If real-world coordinates are not available, we can derive them by projecting the longitude and latitude values of the control points.

2. Second, run an affine transformation on the control points and examine the RMS error. If the RMS error is higher than the expected value, select a different set of control points and rerun the affine transformation. If the RMS error is acceptable, then the six coefficients of the affine transformation estimated from the control points are used in the next step.

3. Third, use the estimated coefficients and the transformation equations to compute the new x- and y-coordinates of map features in the digitized map or pixels in the image. The outcome from the third step is a new map or image based on a user-defined projected coordinate system



1. Update control points
to real-world coordinates.
2. Run affine transformation
on control points.
3. Apply affine
transformation to
map features.

Resampling of pixels values

- The result of geometric transformation of a satellite image is a new image based on a projected coordinate system.
- But the new image has no pixel values.
- The pixel values must be filled through resampling.
- **Resampling** in this case means filling each pixel of the new image with a value or a derived value from the original image.
- Resampling Methods:
  - nearest neighbour
  - bilinear interpolation
  - cubic convolution

- The **nearest neighbor** resampling method fills each pixel of the new image with the nearest pixel value from the original image. The nearest neighbor method does not require any numerical computation.
- The **bilinear interpolation** method uses the average of the four nearest pixel values
- The **cubic convolution** method uses the average of the 16 nearest pixel values.

Spatial Data Input

- Spatial data can be obtained from various sources.
- It can be collected from scratch, using direct spatial data acquisition techniques, or indirectly by making use of existing spatial data collected by others.

DIRECT SPATIAL DATA CAPTURE

- One way to obtain spatial data is by "direct observation" of the relevant geographic phenomena.
- This can be done through ground based field surveys, or by using remote sensors in satellites or airplanes.
- Data which is captured directly from the environment is known as **PRIMARY DATA.**

- With primary data the core concern in knowing its properties is to know the process by which it was captured, the parameters of any instruments used and the consistency with which quality requirements were observed.
- Remotely sensed imagery is usually not fit for immediate use, as various sources of error and distortion may have been present.
- An image refers to raw data produced by an electronic sensor, which are not pictorial, but arrays of digital numbers such as intensity.

INDIRECT SPATIAL DATA CAPTURE

- It includes data derived from existing paper maps through scanning, data digitized from a satellite image, processed data purchased from data capture firms or international agencies, and so on.
- Any data which is not captured directly from the environment is known as Secondary Data.
- Key sources for Indirect data capture are as follows:

1. Digitizing
2. Scanning
3. Vectorization

Digitizing

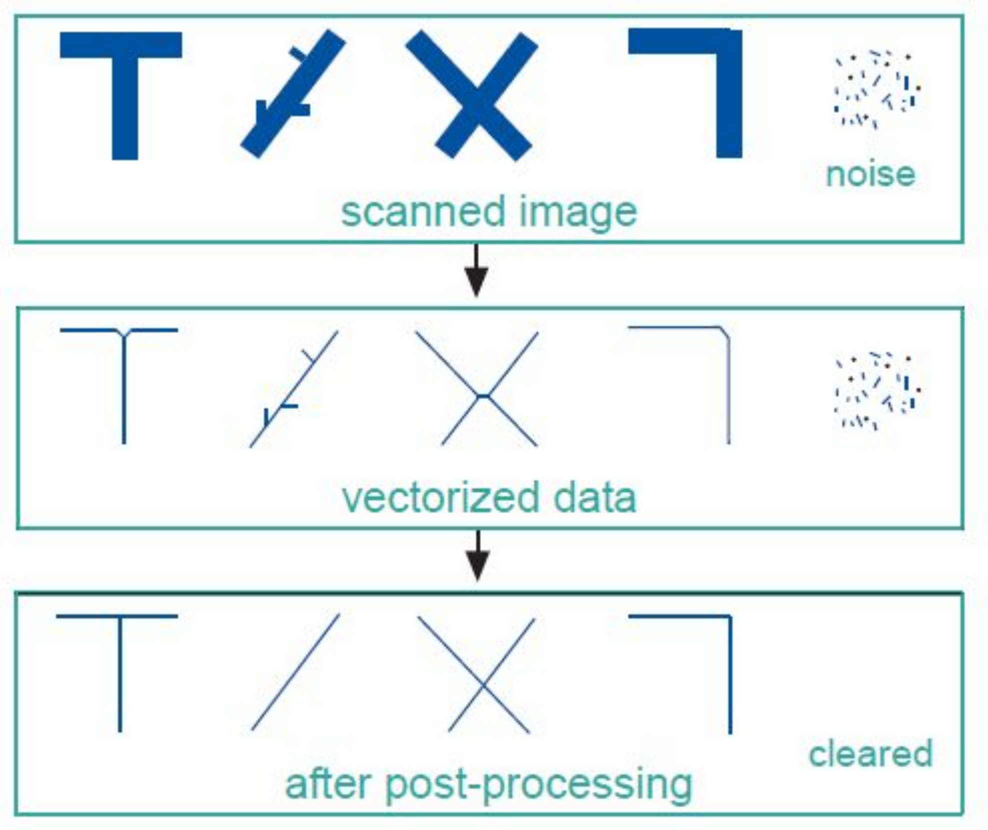
- A traditional method of obtaining spatial data is through "digitizing" existing paper maps.
- There are two forms of digitizing: **on-tablet** and **on-screen manual** digitizing.
- In on-tablet digitizing, the original map is fitted on a special surface (tablet)
- In on-screen digitizing, a scanned image of the map is shown on the computer screen.

Scanning

- The result of a scanning process is an image as a matrix of pixels, each of which holds an intensity value.
- Normal office scanners have a fixed maximum resolution, expressed as the highest number of pixels they can identify per inch; the unit is dots-per-inch. (dpi)
- For manual on screen digitizing of a paper map, a resolution of 200-300 dpi is sufficient.

Vectorization

- The process of distilling the points, lines and polygons from a scanned image is called vectorization.
- It may cause errors such as small spikes along lines, rounded corners, and so on.



Metadata

- Metadata is defined as background information that describes all necessary information about the data itself. (Data about data)
- It includes:

1. Identification information: Data sources, time of acquisition, etc.
2. Data quality information: Positional, attribute and temporal accuracy.
3. Entity and attribute information: Related attributes, units of measures, etc.

ATTRIBUTE DATA MANAGEMENT

- A geographic information system (GIS) involves both spatial and attribute data: spatial data relate to the geometries of spatial features, and attribute data describe the characteristics of the spatial features.
- The georelational data model (e.g., shapefile) stores spatial data and attribute data separately and links the two by the feature ID
- The two data sets are synchronized so that they can be queried, analyzed, and displayed in unison.
- The object-based data model (e.g., geodatabase) combines both geometries and attributes in a single system.
- Each spatial feature has a unique object ID and an attribute to store its geometry

ATTRIBUTE DATA IN GIS

- Attribute data in GIS are stored in tables.
- An attribute table is organized by row and column.
- Each row represents a spatial feature, each column describes a characteristic, and the intersection of a column and a row shows the value of a particular characteristic for a particular feature.
- A row is also called a record, and a column is also called a field.

Types of Attribute Tables

- There are two types of attribute tables for vector data in GIS.
- The first type is the **feature attribute table**, which has access to the feature geometry.
- Every vector data set has a feature attribute table.
- In the case of the georelational data model, the feature attribute table uses the feature ID to link to the feature's geometry.
- In the case of the object-based data model, the feature attribute table has a field that stores the feature's geometry

- The second type of **attribute table is nonspatial**, meaning that the table does not have direct access to the feature geometry but has a field linking the table to the feature attribute table whenever necessary.

Database Management

- The presence of feature attribute and nonspatial data tables means that a GIS requires a database management system (DBMS) to manage these tables.
- A DBMS is a software package that enables us to build and manipulate a database
- A DBMS provides tools for data input, search, retrieval, manipulation, and output. Most GIS packages include database management tools for local databases

- The use of a DBMS has other advantages beyond its GIS applications. Often a GIS is part of an enterprise wide information system, and attribute data needed for the GIS may reside in various departments of the same organization.
- Therefore, the GIS must function within the overall information system and interact with other information technologies.
- Besides database management tools for managing local databases, many GIS packages also have database connection capabilities to access remote databases.
- This is important for GIS users who routinely access data from centralized databases.

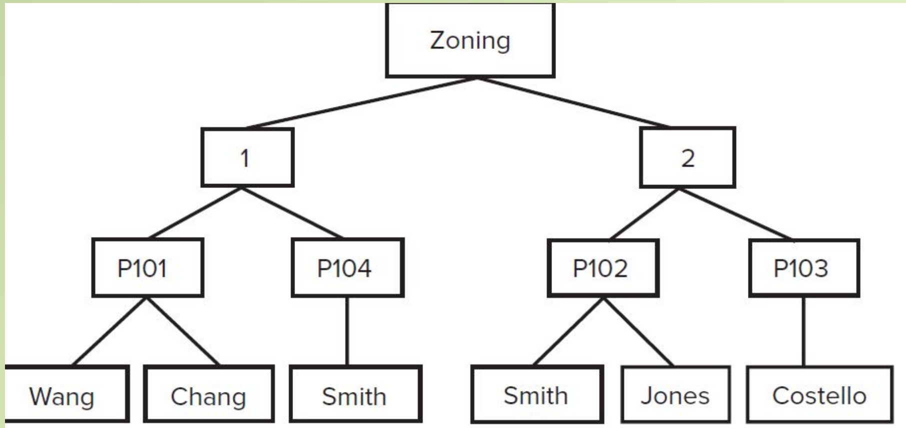
THE RELATIONAL MODEL

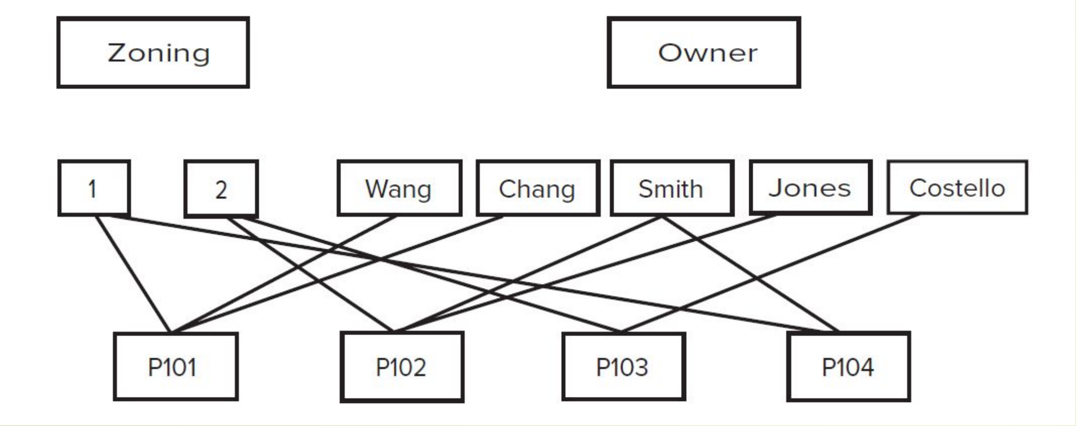
- A database is a collection of interrelated tables in digital format.
- At least four types of database designs are available: flat file, hierarchical, network, and relational
  - A **flat file** contains all data in a large table. A feature attribute table is like a flat file. Another example is a spreadsheet with attribute data only.
  - A **hierarchical database** organizes its data at different levels and uses only the one-to-many association between levels.
  - A **network database** builds connections across tables.

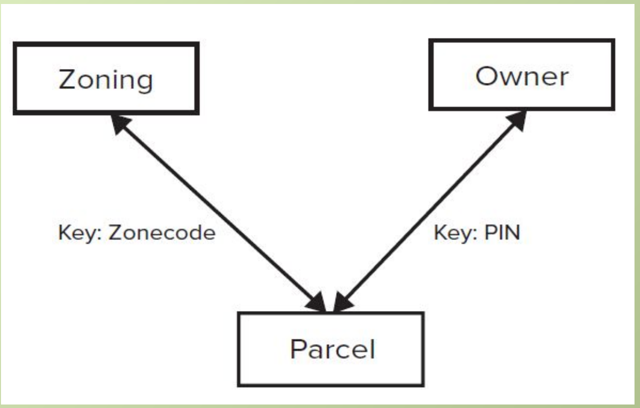
A common problem with both the hierarchical and the network database designs is that the linkages (i.e., access paths) between tables must be known in advance and built into the database at design time

- A **relational database** is a collection of tables, also called relations, that can be connected to each other by keys (Primary and Foreign).

PIN	Owner	Zoning
P101	Wang	Residential (1)
P101	Chang	Residential (1)
P102	Smith	Commercial (2)
P102	Jones	Commercial (2)
P103	Costello	Commercial (2)
P104	Smith	Residential (1)







Normalization

- Normalization is a process of decomposition, taking a table with all the attribute data and breaking it down into small tables while maintaining the necessary linkages between them
- Normalization is designed to achieve the following objectives:
  - To avoid redundant data in tables that waste space in the database and may cause data integrity problems;
  - To ensure that attribute data in separate tables can be maintained and updated separately and can be linked whenever necessary; and
  - To facilitate a distributed database.

Types of Relationships

- A relational database may contain four types of relationships or cardinalities between tables or, more precisely, between records in tables: **one-to-one, one-to-many, many-to-one, and many-to-many**
- The **one-to-one relationship** means that one and only one record in a table is related to one and only one record in another table.
- The **one-to-many relationship** means that one record in a table may be related to many records in another table.

- The **many-to-one relationship** means that many records in a table may be related to one record in another table.
- The **many-to-many relationship** means that many records in a table may be related to many records in another table.

JOINS

- A join operation brings together two tables by using a common field or a primary key and a foreign key.
- A typical example is to join attribute data from one or more nonspatial data tables to a feature attribute table for data query or analysis.
- A join operation is usually recommended for a one-to-one or many-to-one relationship.
- Given a one-to-one relationship, two tables are joined by record.
- Given a many-to-one relationship, many records in the origin have the same value from a record in the destination.
- A join operation is inappropriate with the one-to-many or many-to-many relationship because only the first matching record value from the destination is assigned to a record in the origin.

Relates

- A relate operation temporarily connects two tables but keeps the tables physically separate.
- We can connect three or more tables simultaneously by first establishing relates between tables in pairs
- One advantage of relates is that they are appropriate for all four types of relationships.
- This is important for data query because a relational database is likely to include different types of relationships

SPATIAL JOIN

- A spatial join operation uses a spatial relationship to join two sets of spatial features and their attribute data
- For example, a spatial join operation can join a school to a county in which the school is located using a topological relationship of **containment**, that is, the school is contained within a county.
- Other topological relationships can include **intersect**, such as a highway intersected by forest fire areas, and **proximity**, such as the closest distance between villages and a fault line

ATTRIBUTE DATA ENTRY

- Entering attribute data is like digitizing a paper map.
- The **<u>process</u>** requires the setup of attributes to be entered, the choice of a digitizing method, and the verification of attribute values.
  - Field Definition
  - Methods of Data Entry
  - Attribute Data Verification

Field Definition

- The first step in attribute data entry is to define each field in the table.
- A field definition usually includes the field name, field length, data type, and number of decimal digits.
- The length refers to the number of digits to be reserved for a field.
- It should be large enough for the largest number, including the sign, or the longest string in the data.

Methods of Data Entry

- The data format is important for importing.
- GIS packages can import files in delimited text, dBASE, and Excel.
- If attribute data files do not exist, then typing is the only option. But the amount of typing can vary depending on which method or tool is used

Attribute Data Verification

- Attribute data verification involves two steps.
- The first is to make sure that attribute data are properly linked to spatial data: the feature ID should be unique and should not contain null values.
- The second step is to verify the accuracy of attribute data.
- Data inaccuracies can be caused by a number of factors including observation errors, outdated data, and data entry errors.

MANIPULATION OF FIELDS AND ATTRIBUTE DATA

- Manipulation of fields and attribute data includes
  - adding or deleting fields
  - creating new attributes through classification and
  - computation of existing attribute data.

Adding or deleting fields

- Deleting unwanted fields not only reduces confusion in using the data set but also saves computer time for data processing.
- Deleting a field is straightforward. It requires specifying an attribute table and the field in the table to be deleted.
- Adding a field is required for the classification or computation of attribute data.
- The new field is designed to receive the result of classification or computation.
- To add a field, we must define the field in the same way as for attribute data entry.

Classification of Attribute Data

- Data classification can create new attributes from existing data.
- Suppose you have a data set that describes the elevations of an area. We can create new data by reclassifying these elevations into groups, such as elevations <500 meters, 500 to 1000 meters, and so on.
- Operationally, creating new attribute data by classification involves **<u>three steps</u>**:
  - defining a new field for saving the classification result,
  - selecting a data subset through query, and
  - assigning a value to the selected data subset.

Computation of Attribute Data

- New attribute data can also be created from existing data through computation.
- Operationally, it involves **two steps**:
  - defining a new field, and
  - Computing the new field values from the values of an existing attribute or attributes