Topic 1: Introduction to GIS

This topic gives introduction to Geographic Information Systems (GIS). In particular, we consider

- **Introduction to Geographic Information Systems.**
- **Geospatial data models.**
- **Map projections**
- **Coordinate systems.**

Introduction to GIS

Storage and analysis of various spatial data related Earth locations are traditionally done in Geographic Information Systems (GIS). According to the definition of Burrough and McDonnell, a GIS is '...a powerful set of tools for collecting, storing, retrieving at will, transforming, and displaying spatial data from the real world for a particular set of purposes'. Another definition mentioned in the same source refers to '...checking, manipulating, and analysing data, which are spatially referenced to the Earth'.

Service-Oriented Architectures

Today, much of the practice and research in geographic information systems is changing from toolbox-centred architectures towards service-centred architectures (such as Google Earth). In toolbox-centred architectures, the GIS application and data are situated on the users' computer or local area network. In service-centred architectures, the tools and data are situated on remote computers, typically accessed through Internet connections.

General GIS principles

Data in a GIS database provide a simplified, digital representation of Earth features for a given region. Georeferenced data can be organized within GIS using different criteria, for example, as thematic layers or spatial objects. Each thematic layer can be stored using an appropriate data model depending on the source of data and their potential use.

Geospatial data models

Georeferenced data include:

- a spatial (geometrical or graphical) component describing the location or spatial distribution of geographic phenomenon,
- an attribute component used to describe its properties.

The spatial component can be represented using one of the two basic approaches:

1. field representation, where each regularly distributed point or an area element (pixel) in the space has an assigned value (a number or no-data), leading to the raster data model;
2. geometrical objects representation, where geographic features are defined as lines, points, and areas given by their coordinates, leading to the vector data model.

Depending on scale, representation of a geographic feature can change; for example, a river can be handled as a line at small scale or as a continuous 3D field (body of water) at large scale. Similarly, a city can be represented as a point or as an area. Note that we use the terms small and large scale in the cartographic sense, for example, 1:1million is small scale, 1:1000 is large scale.

Map projections and coordinate systems

The basic property of GIS, as opposed to other types of information systems, is that the stored data are georeferenced. That means that the data have defined location on Earth using coordinates within a georeferenced coordinate system.

The fact that Earth is an irregular, approximately spherical object makes the definition of an appropriate coordinate system rather complex. The coordinate system either has to be defined on a sphere or ellipsoid, leading to a system of geographic coordinates or the sphere has to be projected on a surface that can be developed into a plane where we can define the cartesian system of coordinates (easting, northing and elevation).

Map projection

To transform the Earth surface into a plane (computer screen), a map projection is used. Direct projection of a spherical object to a plane cannot be performed without distortion.

A large number of different projections have been designed with the aim to minimize the distortion and preserve certain properties:

1. The conformal projection preserves angles (shapes for small areas) and often used in navigation and national grid systems.
2. The equidistant projection preserves certain relative distances and is used for measurement of length.
3. The equivalent(equal-area) projection preserves area and is used for measurement of areas.

Each of the properties (angle, distance, area) is preserved at the expense of the others.

Coordinate system

To accurately identify a location on Earth, a coordinate system is required. It is defined by its

1. origin (e.g., prime meridian, datum),
2. coordinate axes (e.g. x, y, z), and
3. units (angle: degree, gon, radiant; length: meter, feet).

The following coordinate systems are commonly used in GIS:

1. geographic (global) coordinate system (latitude-longitude);
2. planar (cartesian) georeferenced coordinate system (easting, northing, elevation);
3. planar non-georeferenced coordinate system, such as user's image coordinate system with origin and axes defined customary (e.g. image corner) without defining its position on Earth.