UNIVERSITÄT BAYREUTH

Lecture 1: An introduction to GIS

Meng Lu

Juniorprofessor of Geoinformatics, Bayreuth University

Introduction

Geography has always been important to humans.

- Early explorers lived or died by their knowledge of geography.
- Current societies work and play based on their understanding of who belongs where.
- Applied geography, in the form of maps and spatial information, has served discovery, planning, cooperation, and conflict for at least the past 3000 years.

Geography has always been important to humans.

- Early explorers lived or died by their knowledge of geography.
- Current societies work and play based on their understanding of who belongs where.
- Applied geography, in the form of maps and spatial information, has served discovery, planning, cooperation, and conflict for at least the past 3000 years.

Geography has always been important to humans.

- Early explorers lived or died by their knowledge of geography.
- Current societies work and play based on their understanding of who belongs where.
- Applied geography, in the form of maps and spatial information, has served discovery, planning, cooperation, and conflict for at least the past 3000 years.

Spatial information has a greater impact on our lives than we realize by helping us produce the food we eat, the energy we burn, the clothes we wear, and the diversions we enjoy.

For the above, there are tools called geographic information systems (GIS) to aid us with geographic knowledge.

Spatial information has a greater impact on our lives than we realize by helping us produce the food we eat, the energy we burn, the clothes we wear, and the diversions we enjoy.

For the above, there are tools called geographic information systems (GIS) to aid us with geographic knowledge.

In the “big data" era

The capture and treatment of spatial data has accelerated over the past three decades, and continues to evolve.

Thus, the key to all definitions of a GIS are “where" and “what".

- “Where": absolute and relative location of features
- “What": properties and attributes of those features

In the “big data" era

The capture and treatment of spatial data has accelerated over the past three decades, and continues to evolve.

Thus, the key to all definitions of a GIS are “where" and “what".

- “Where": absolute and relative location of features
- “What": properties and attributes of those features

What is GIS?

GIS is a tool for making and using spatial information. A more detailed definition could be:

GIS is a computer-based system to aid in the **collection, maintenance, storage, analysis, output, and distribution** of spatial data and information.

Therefore, GIS and spatial analyses are concerned with features and their spatial information.

Figure 1: The satellite image at the center shows a forested area in western Oregon, United States, with a patchwork of lakes (dark area, upper left and middle right), forest and clearings (middle), and mountains and desert (right), (Bolstad (2016)

GIS is essential in:

- Business
- Government
- Education
- Nonprofit organizations

besides, has been used to:

- Fight crime
- Protect endangered species
- Reduce pollution
- Treat epidemics
- Improve public health

Example: human populations and consumption have reached levels such that many resources, including air and land, are already being limited (Figure 2).

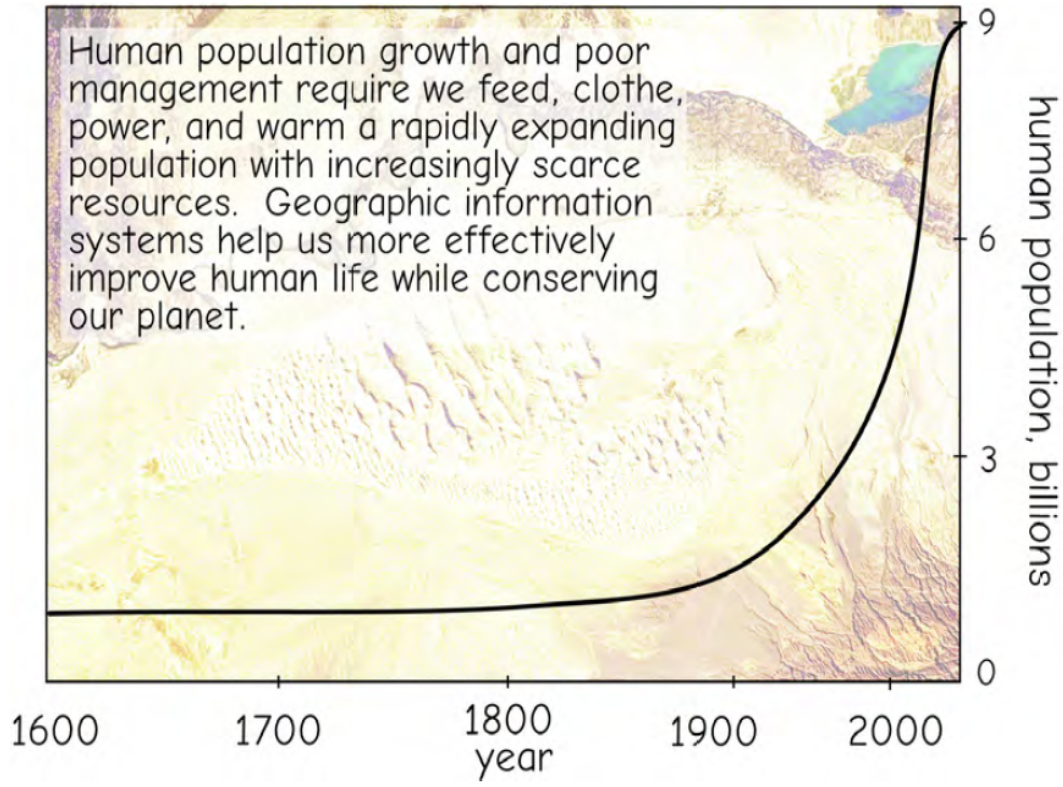

Figure 2: Human population growth during the past 400 years has increased the need for efficient resource use (Bolstad (2016)).

Example: Hazard monitoring, evacuation planning, and damage mapping. (Figure 3).

Figure 3: The Sarychev volcano, in the Kuril Islands of Russia, erupted in June, 2009. Advanced satellite imaging allows us to track the eruptions and plumes, new space-based surveying aids in planning evacuation and mapping damage, and repeated observation allows us to overlay observations, measure impacts, and plan for recovery (Bolstad (2016)).

Example: conflicts in resource use, concerns about pollution, and precautions to protect public health have led to legislative mandates that explicitly or implicitly require the consideration of geography (Figure 4).

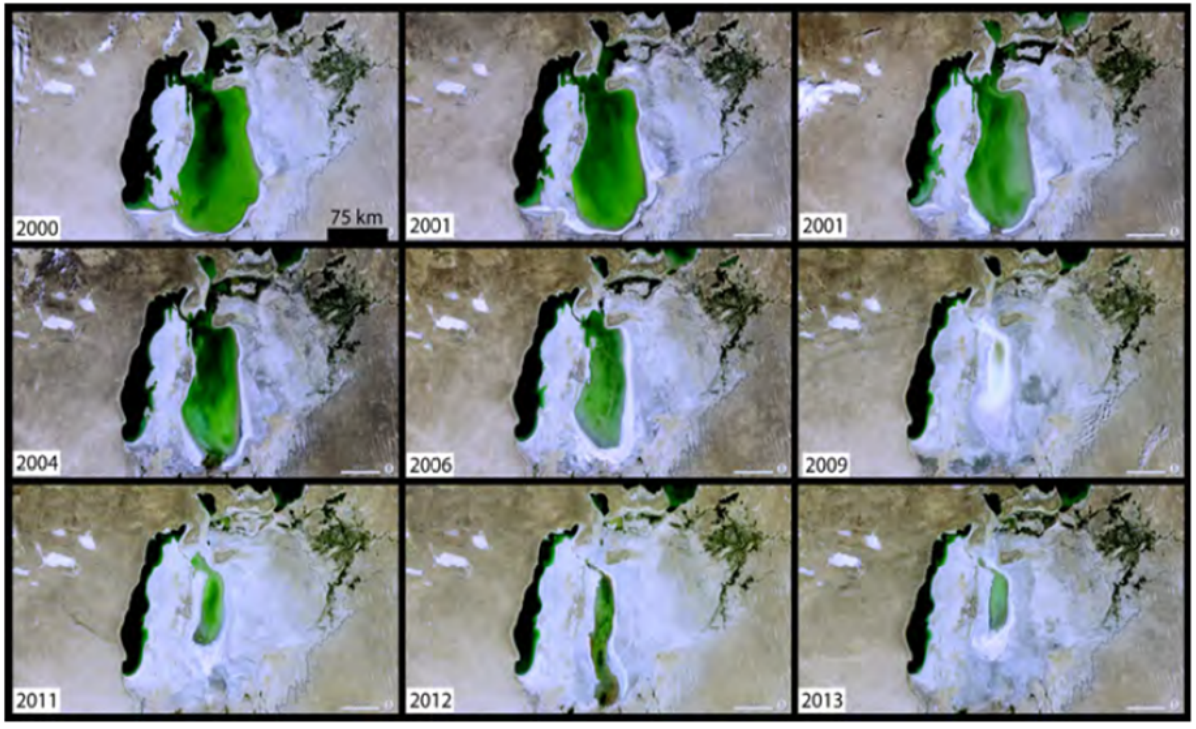

Figure 4: These satellite images from 2000 (upper left) to 2013 (lower right) show a shrunken Aral Sea due to the overuse of water. Diversion for irrigation has destroyed a rich fishery, the economic base for many seaside communities. GIS could be used to document change, mitigate damage, and effectively manage our natural resources (Bolstad (2016)). More about Aral Sea

GIS in action

1. Environmental protection

Oneida County is located in northern Wisconsin, a forested area characterized by exceptional scenic beauty.

Problem?

- The region has experienced a rapid expansion in the permanent and seasonal human populations. Retirees, urban exiles, and vacationers are increasingly drawn to the scenic and recreational amenities available in Oneida County.

1. Environmental protection

Oneida County is located in northern Wisconsin, a forested area characterized by exceptional scenic beauty.

Problem?

- The region has experienced a rapid expansion in the permanent and seasonal human populations. Retirees, urban exiles, and vacationers are increasingly drawn to the scenic and recreational amenities available in Oneida County.

1. Environmental protection

Oneida County is located in northern Wisconsin, a forested area characterized by exceptional scenic beauty.

Problem?

- The region has experienced a rapid expansion in the permanent and seasonal human populations. Retirees, urban exiles, and vacationers are increasingly drawn to the scenic and recreational amenities available in Oneida County.

Solution using GIS?

Sea Grant Institute of the University of Wisconsin, and the Land Information and Computer Graphics Facility of the University of Wisconsin have developed a Shoreland Management GIS Project. This project helps protect valuable nearshore and lake resources, and provides an example of how GIS tools are used for water resource management (Figure 5).

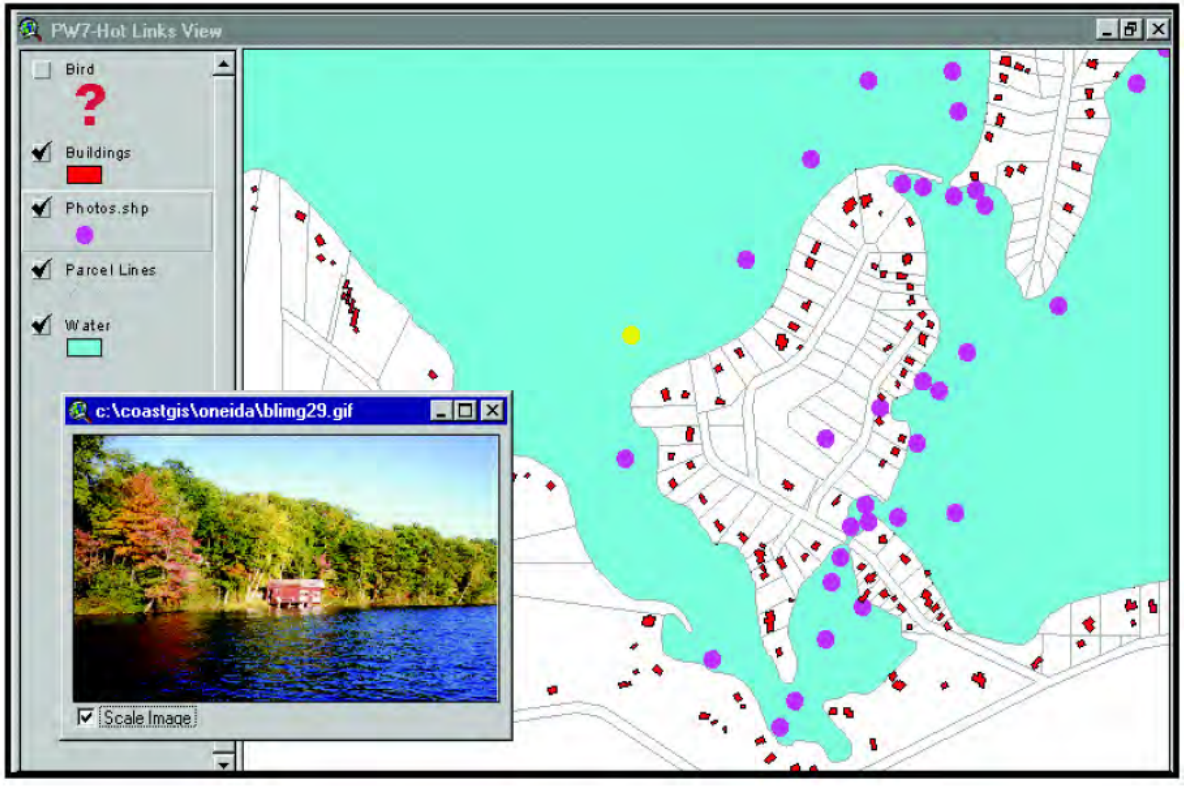

Figure 5: Parcel information entered in a GIS may substantially improve government services. Here, images of the shoreline taken from lake vantage points are combined with digital maps of the shoreline, buildings, and parcel boundaries. The image in the lower left was obtained from the location shown as a light dot near the center of the figure (Bolstad (2016)).

2. Save endangered species.

The blackfooted ferret is a small carnivore of western North America, and is one of the most endangered mammals on the continent.

Problem?

- The blackfooted ferret has become endangered because of declines in the range and number of prairie dog colonies, coupled with ferret sensitivity to canine distemper and other diseases.

2. Save endangered species.

The blackfooted ferret is a small carnivore of western North America, and is one of the most endangered mammals on the continent.

Problem?

- The blackfooted ferret has become endangered because of declines in the range and number of prairie dog colonies, coupled with ferret sensitivity to canine distemper and other diseases.

2. Save endangered species.

The blackfooted ferret is a small carnivore of western North America, and is one of the most endangered mammals on the continent.

Problem?

- The blackfooted ferret has become endangered because of declines in the range and number of prairie dog colonies, coupled with ferret sensitivity to canine distemper and other diseases.

Solution using GIS?

Ferrets are tracked in nighttime spotlighting surveys, often in combination with radiotracking. Ferret location and movement are combined with detailed data on prairie dog colony boundaries, burrow locations, surrounding vegetation, and other spatial data (Figure 6).

Figure 6: Specialized equipment is used to collect spatial data. Here a burrow location is recorded using a GPS receiver, as an interested black footed ferret looks on (Bolstad (2016)).

3. Improve public health.

Air pollution is a major cause of sickness and death, primarily from nitrogen and sulfur dioxides, carbon monoxide, ozone, and small particles from oil, gas, coal, and wood combustion.

Problem?

- Reducing sickness and death requires identifying areas of high exposure, particularly for vulnerable populations.

3. Improve public health.

Air pollution is a major cause of sickness and death, primarily from nitrogen and sulfur dioxides, carbon monoxide, ozone, and small particles from oil, gas, coal, and wood combustion.

Problem?

- Reducing sickness and death requires identifying areas of high exposure, particularly for vulnerable populations.

3. Improve public health.

Air pollution is a major cause of sickness and death, primarily from nitrogen and sulfur dioxides, carbon monoxide, ozone, and small particles from oil, gas, coal, and wood combustion.

Problem?

- Reducing sickness and death requires identifying areas of high exposure, particularly for vulnerable populations.

Solution using GIS?

- GIS has been used to map concentrations, identify sources, and plan improvements (Figure 7)
- A number of satellite instruments, culminating in the Ozone Mapping and Profiling Suite (OMPS) have been launched over the past 30 years to record air quality. This has led to a long-term record of pollutant concentrations, and improved understanding of the sources and dynamics of pollutants across regional through global geographies. These data allow measurement of peak and chronic exposure to pollutants for different populations (Figure 8).

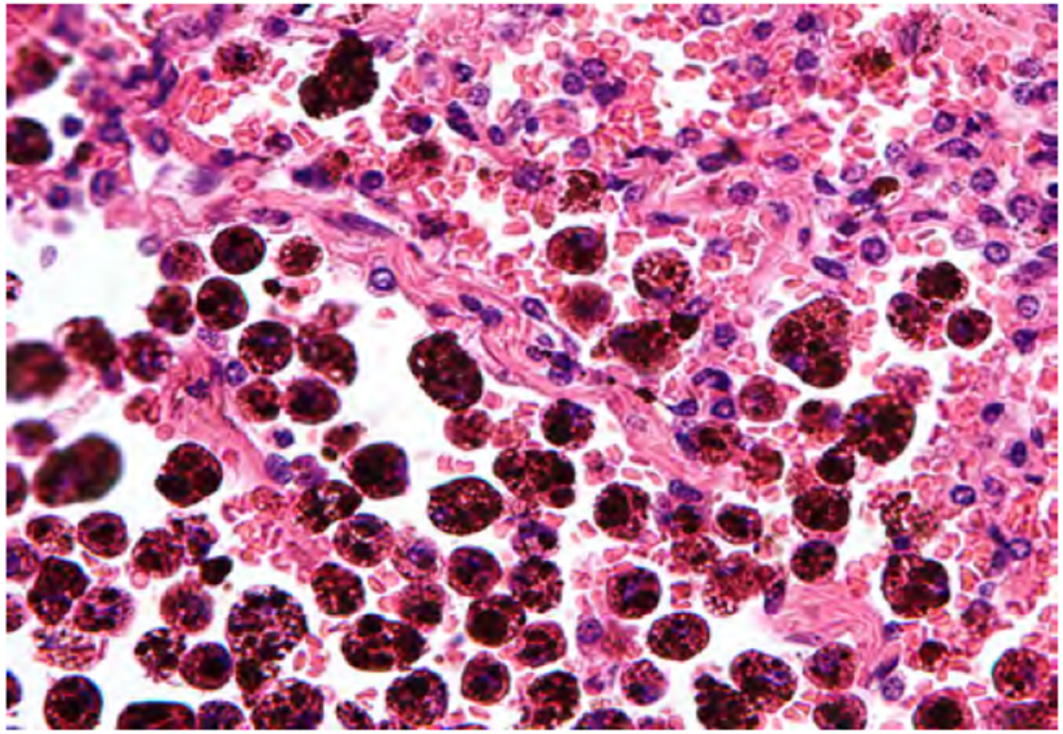

Figure 7: Small particles lodge in the lungs, cause inflammation and reducing lung function. Alveolar macrophages attempt to isolate this material, but air pollution levels commonly exceed the lungs capacity for self-cleaning. Excessive exposure often shows as concentrations of dark particles on lung micrographs, as seen above (Bolstad (2016)).

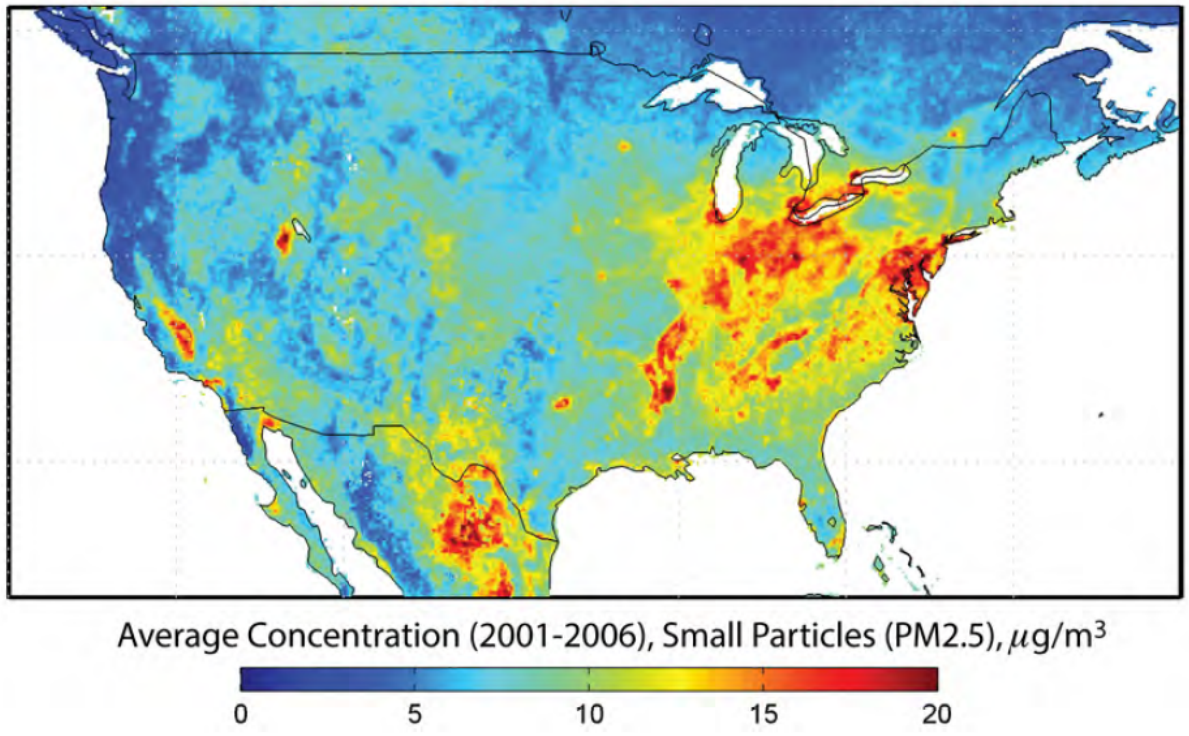

Figure 8: Scientists at NASA have developed methods to map air pollution across continents on a daily basis, which may be averaged to estimate chronic exposure (Bolstad (2016)).

GIS Components

A GIS is composed of hardware, software, data, humans, and a set of organizational protocols. These components must be well integrated for effective use of GIS, and the development and integration of these components is an iterative, ongoing process.

1. Hardware for GIS: A fast computer, large data storage capacities, and a high-quality, large display form the hardware foundation of most GIS (Figure 9).

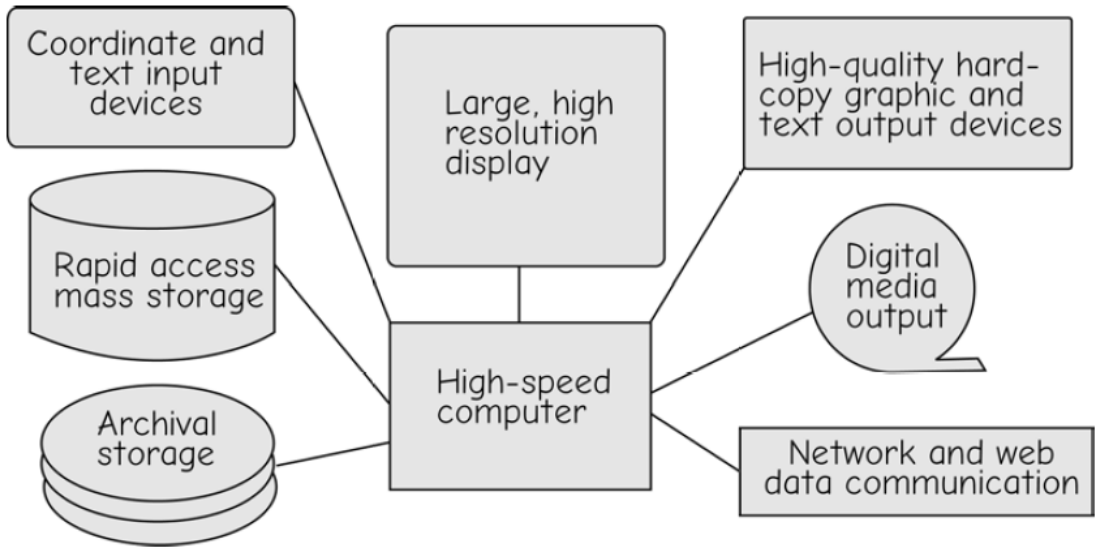

Figure 9: GIS are typically used with a number of general-purpose and specialized hardware components (Bolstad (2016)).

A fast computer is required because:

- Spatial analyses are often applied over large areas and/or at high spatial resolutions.
- Calculations often have to be repeated over tens of millions of times, corresponding to each space we are analyzing in our geographical analysis.
- Operations may take substantial time on general-purpose computers when run over large areas, and complex operations can be unbearably long-running.

2. GIS Software: GIS software provides the tools to manage, analyze, and effectively display and disseminate spatial information.

GIS by necessity involves the collection and manipulation of coordinates. We also collect qualitative or quantitative information on the nonspatial attributes of geographic features.

- Data entry
  - Coordinates
  - Attributes
  - Data import
- Editing
  - Point, line and area editing
  - Attributes editing
  - Automated error detection and editing
- Data management
  - Copy, subset and merge data
  - Versioning
  - Data registration and projection
  - Summarization and data reduction
  - Documentation
  - Compression
  - Indexing

- Analysis
  - Spatial query
  - Attribute query
  - Interpolation, connectivity, proximity, buffering, terrain analysis, boundary dissolve, spatial data overlay, moving window analyses, map algebra, etc.
- Output
  - Map design and layout
  - Hardcopy map printing
  - Digital graphic production
  - Export format generation
  - Metadata output
  - Digital map serving

3 Common GIS softwares:

- **ArcGIS**
- QGIS
- GRASS GIS
- SAGA GIS
- R
- Python
- MapInfo
- AUTOCAD MAP 3D

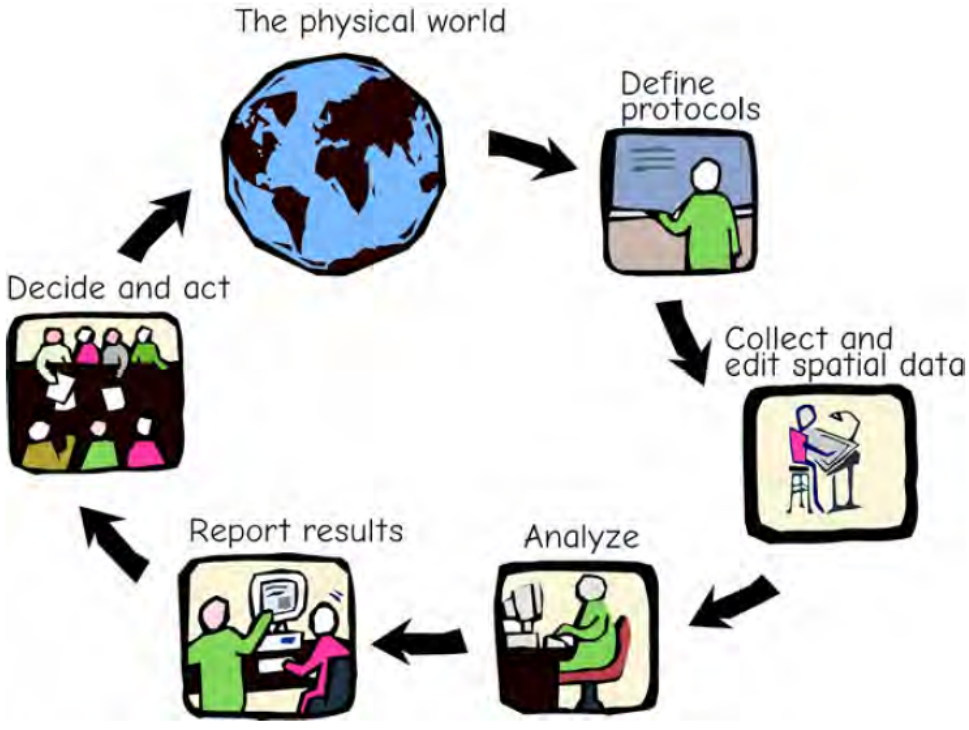

Figure 10: Effective use of GIS in a loop (Bolstad (2016)).

Conclusions

- GIS is a computer-based systems for the collection, management, analysis, output and distribute spatial data.
- GIS is supported by the disciplines of geography, surveying, engineering, space science, computer science, cartography, statistics, and a number of others.
- GIS hardware often have large storage capacities, fast computing speed, and ability to capture coordinates.
- Software for GIS are unique in their ability to manipulate coordinates and associated attribute data. A number of software tools and packages are available.
- GIS is one of the most important tools in understanding the spatial phenomena, planning, and decision making.

Thank You

References I

Bolstad, P. (2016). *GIS fundamentals: A first text on geographic information systems*. Eider (PressMinnesota).