

DEPARTMENT OF GEOMATICS



FACULTY OF CIVIL
ENGINEERING
CTU IN PRAGUE

CARTOGRAPHY

Subject:
Geomatics

Language:
English

Difficulty:
Introductory

Resources
and study materials

DECEMBER 2022



155CART

COURSES FOR
INTERNATIONAL
STUDENTS

WHAT YOU'LL LEARN

Concepts fundamental to make maps

Create, manage, visualize, analyze, and interpret geospatial data

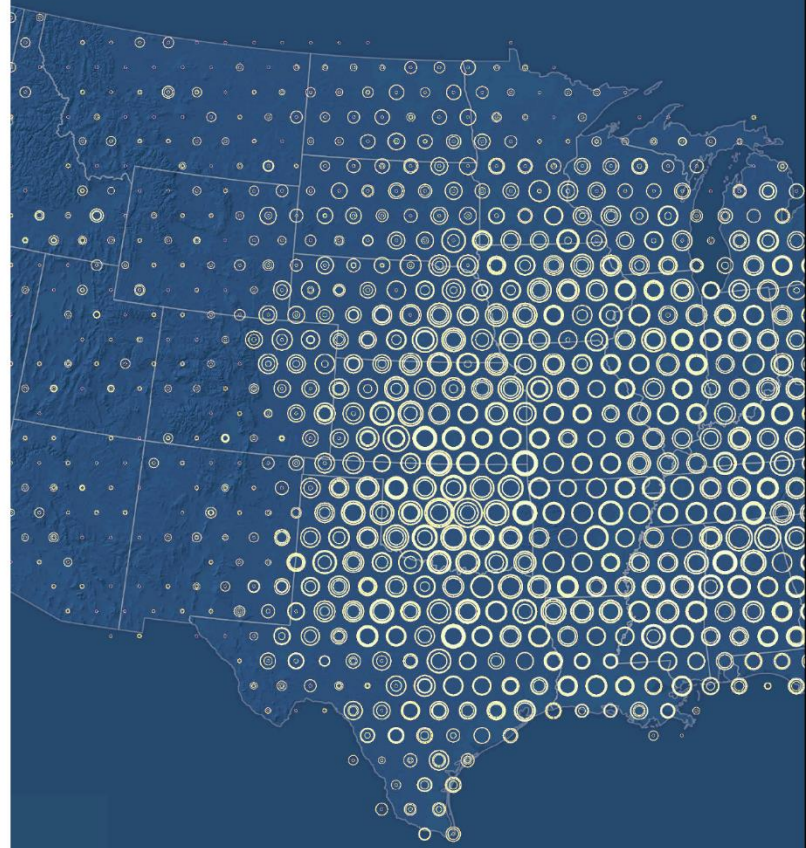
Work with vector data, explore its attribute and spatial relationships, use various powerful geoprocessing tools

Discover common thematic map types

Mapping and design principles for cartography

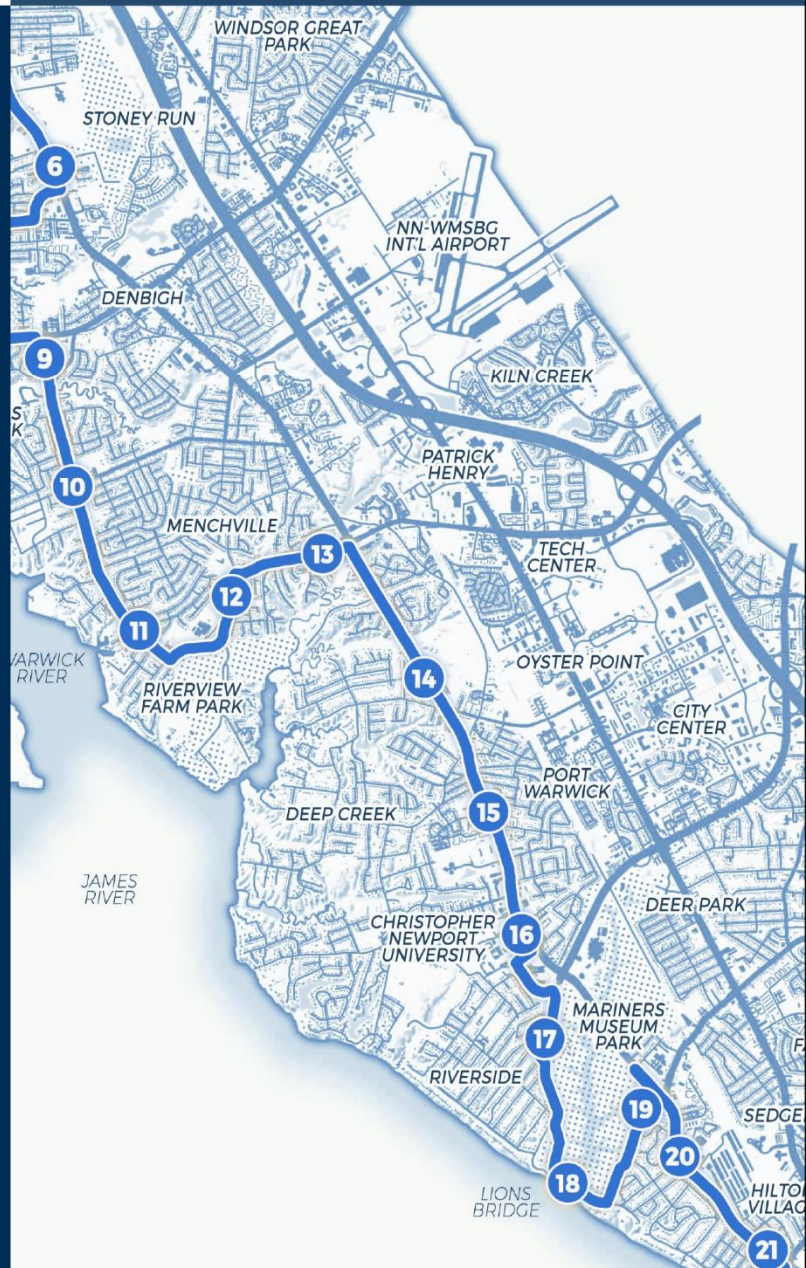
Get general overview of data sources and ways of getting the right data for your next project

Easily share your maps to web environment for everyone to use



COURSE DESCRIPTION

Application of digital methods in the creation of cartographic outputs. Data sources and their availability, geographic databases in the Czech Republic and in the European and international context. Principles of creating topographic and thematic maps using GIS software. Cartographic outputs from GIS with a focus on modern methods of visualizing spatial phenomena. Web cartography, cloud technologies, web services and applications. The main goal of the course is to employ habits in making of own cartographic outputs and to avoid inaccuracies and errors in the creation and interpretation of maps.



COVERED TOPICS

Course introduction

Geographic vs. Projected Coordinate System

Map Projections in Detail

Georeferencing

Geocoding

Principles of Map Design

Data Resource Overview

Thematic Mapping

Choropleth Maps

Diagram Maps

Grid Maps, Data Bining

Cartograms

Multivariate Mapping

ArcGIS Online

Course Introduction

What is cartography?

"The art and science of expressing graphically, usually through maps, the natural and social features of the earth." (support.esri.com)

"The International Cartographic Association defines cartography as the discipline dealing with the conception, production, dissemination and study of maps. Cartography is also about representation – the map. This means that cartography is the whole process of mapping.

Cartography is a complex, an ever-changing field, but at the center of it is the map-making process. Viewed in the broadest sense, this process includes everything from the gathering, evaluation and processing of source data, through the intellectual and graphical design of the map, to the drawing and reproduction of the final document. As such, it is a unique mixture of science, art and technology and calls for a variety of in-depth knowledge and skills on the part of the cartographer. Sometimes one person directs this entire sequence of cartographic activities, but this occurs only in relatively simple cases. In the creation of a map, it is much more common for the various tasks to be split up and accomplished by several individuals."

(Canadian Cartographic Association)

resources

What is Cartography?

cca-acc.org

britannica.com

MOOC Esri

resources

ArcGIS Pro Online Tutorials

Introduction to
ArcGIS Pro

pro.arcgis.com

ArcGIS Pro Quick-start
Tutorials

pro.arcgis.com

ArcGIS Pro Basics

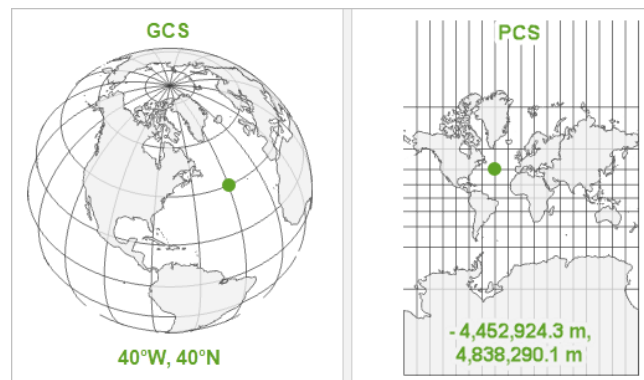
esri.com

Geographic vs. Projected Coordinate System

“What is the difference between a geographic coordinate system (GCS) and a projected coordinate system (PCS)? Here’s the short answer:

- A GCS defines where the data is located on the earth’s surface.
- A PCS tells the data how to draw on a flat surface, like on a paper map or a computer screen.
- A GCS is round, and so records locations in angular units (usually degrees). A PCS is flat, so it records locations in linear units (usually meters).

A geographic coordinate system (GCS) is used to define locations on a model of the surface of the earth. The GCS uses a network of imaginary lines (longitude and latitude) to define locations. This network is called a graticule.



There are many different models of the earth’s surface, and therefore many different GCS! World Geodetic System 1984 (WGS 1984) is designed as a one-size-fits-all GCS, good for mapping global data. Australian Geodetic Datum 1984 is designed to fit the earth snugly around Australia, giving you good precision for this continent but poor accuracy anywhere else.

Once your data knows where to draw, it needs to know how. The earth’s surface—and your GCS—are round, but your map—and your computer screen—are flat. That’s a problem. You can’t draw the round earth on a flat surface without deforming it. Imagine peeling an orange and trying to lay the peel flat on a table. You can get close, but only if you start tearing the peel apart. This is where map projections come in. They tell you how to distort the earth—how to tear and stretch that orange peel—so the parts that are most important to your map get the least distorted and are displayed best on the flat surface of the map.” (pro.arcgis.com)

resources

Coordinate Systems

Coordinate Systems, Projections,
and Transformations

pro.arcgis.com

Coordinate Systems: What’s the
Difference?

esri.com

Coordinate Reference Systems

docs.ggis.org

GCS vs. PCS

pro.arcgis.com

resources

Supporting online tutorials/courses

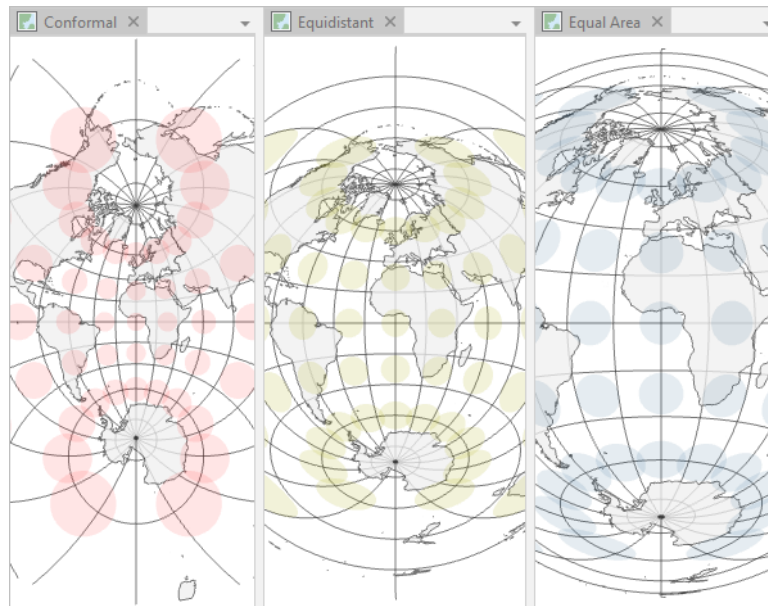
Fix data when it appears in the
wrong place

learn.arcgis.com

Map Projections in Detail

"You will not find a projection that is suitable for all maps. All projections distort the earth in some way. Each one seeks to preserve some geometric property at the expense of others.

Conformal projections preserve angles locally, so the shapes of features appear true. But the cost of this quality is the distortion of areas and distances. Equal area projections preserve area, at the expense of angles, so the shapes of some places appear skewed. Equidistant projections preserve distances, although only from certain points or along certain lines on the map.



Three maps drawn with examples of conformal, equal area, and equidistant projections, overlaid with geodesic circles that demonstrate geometric distortions.

Compromise projections provide a representation of the earth that is not perfectly correct in any way but not badly distorted in any way either. They are usually used for maps of the entire world.

There are dozens of projections available in ArcGIS that can be configured into countless projected coordinate systems. Your choice of a projected coordinate system depends on many factors, including the part of the world you are mapping, the scale of your map, and the purpose of your map. You want to choose a projected coordinate system in which the places and properties that are most important to your map are the least distorted." (pro.arcgis.com)

resources

Map Projections

Quick Notes on Map Projections
in ArcGIS Pro
pro.arcgis.com

Choose the Right Projection
pro.arcgis.com

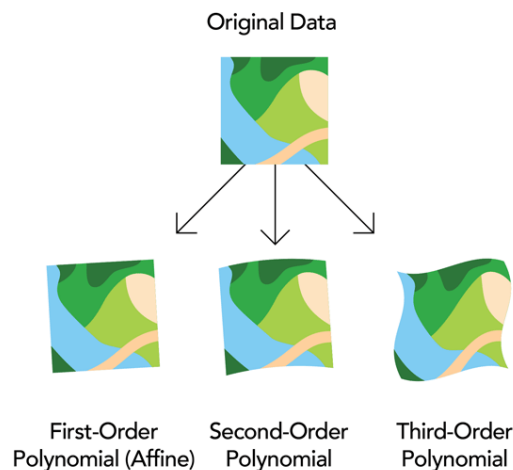
Georeferencing

"Raster data is obtained from many sources, such as satellite images, aerial cameras, and scanned maps. Modern satellite images and aerial cameras tend to have relatively accurate location information, but might need slight adjustments to line up all your GIS data. Scanned maps and historical data usually do not contain spatial reference information. In these cases you will need to use accurate location data to align or georeference your raster data to a map coordinate system. A map coordinate system is defined using a map projection – a method by which the curved surface of the earth is portrayed on a flat surface.

When you georeference your raster data, you define its location using map coordinates and assign the coordinate system of the map frame. Georeferencing raster data allows it to be viewed, queried, and analyzed with your other geographic data. The georeferencing tools on the Georeference tab allows you to georeference any raster dataset.

In general, there are four steps to georeference your data:

1. Add the raster dataset that you want to align with your projected data.
2. Use the Georeference tab to create control points, to connect your raster to known positions in the map
3. Review the control points and the errors
4. Save the georeferencing result, when you are satisfied with the alignment."



(pro.arcgis.com)

resources

Georeferencing

[Overview of Georeferencing](#)

pro.arcgis.com

[Understanding Raster Georeferencing](#)

pro.arcgis.com

[Georeferencing tools](#)

pro.arcgis.com

[Georeference a raster to a referenced layer](#)

pro.arcgis.com

resources

Video tutorials

[Georeferencing in ArcGIS Pro in 5 Minutes: Rubbersheeting](#)

pro.arcgis.com

[Georeferencing in ArcGIS Pro in 5 Minutes: Control Points](#)

pro.arcgis.com

Geocoding

Very briefly **geocoding** is a process that converts location names to map coordinates.

(learn.arcgis.com)

“Geocoding is the process of transforming a description of a location—such as a pair of coordinates, an address, or a name of a place—to a location on the earth's surface. You can geocode by entering one location description at a time or by providing many of them at once in a table. The resulting locations are output as geographic features with attributes, which can be used for mapping or spatial analysis.

You can quickly find various kinds of locations through geocoding. The types of locations that you can search for include points of interest or names from a gazetteer, like mountains, bridges, and stores; coordinates based on latitude and longitude or other reference systems, such as the Military Grid Reference System (MGRS) or the U.S. National Grid system; and addresses, which can come in a variety of styles and formats, including street intersections, house numbers with street names, and postal codes.

From simple data analysis to business and customer management to distribution techniques, there is a wide range of applications for which geocoding can be used. With geocoded addresses, you can spatially display the address locations and recognize patterns within the information. This can be done by simply looking at the information or using some of the analysis tools available with ArcGIS. You can also display your address information based on certain parameters, allowing you to further analyze the information. A few of these applications are described in the sections that follow.”

(desktop.arcgis.com)

resources

Supporting online tutorials/courses

Convert a list of historic places
into a map
Learn.esri.com

Principles of Map Design

"The good cartographer is both a scientist and an artist. He/she must have a thorough knowledge of his/her subject and model, the Earth...the ability to generalize intelligently and to make a right selection of the features to show. These are represented by means of lines or colors; and the effective use of lines or colors requires more than knowledge of the subject – it requires artistic judgement." (Erwin J. Raisz)

Map Design is a process, the cartographer has to think carefully about audience, medium, and design elements:

- What to exclude from a map can be as important as what to include.
- How to symbolize potentially abstract topics.
- Ensure that the design, layout, colors, and intended patterns are communicated.
- Provided useful labels, scale, and direction/orientation without distracting.

Follow these steps when authoring a map:

1. Consider what the real-world distribution of the phenomenon might look like
2. Determine the purpose of the map and its intended audience
3. Collect data appropriate for the map's purpose
4. Design and construct the map
5. Determine whether users find the map useful and informative

If you see a particularly eye-grabbing map, take a careful look and see what "map essentials" are included. Almost all maps will have some or all of these: **title**, **legend**, **scale**, **directional indicator** (North arrow, or a graticule of latitude/longitude lines, for instance), **neat line** (border to frame the map), **source** (where did the map data come from?), **citations** (be authoritative, plagiarism applies to maps, too), **cartographer's name**, **map projection** (optional), **date**.

Choice of color is a huge factor in cartography since color can:

- imply importance or value (higher vs. lower)
- communicate an emotion
- indicate clustering
- use different color ramps or combination of hues
- signify a type of nature feature through the use of a specific color, e.g., green for vegetation"

(esri.com)

resources

Mapping principles

[Principles of Map Design](#)

storymaps.arcgis.com

[Mapping with Purpose](#)

esri.com

[Design Principles for Cartography](#)

esri.com

[Map-making, step by step](#)

esri.com

[Carto checklist](#)

esri.com

[How to smart map](#)

esri.com

resources

Supporting online tutorials/courses

[Introduction to a Cartography](#)

esri.com

[Make a River Map](#)

esri.com

Data Resource Overview

Some useful vector/raster data resources, web data services, and geoportals are described below.

"*Natural Earth* is a public domain map dataset available at 1:10m, 1:50m, and 1:110 million scales. Featuring tightly integrated vector and raster data, with Natural Earth you can make a variety of visually pleasing, well-crafted maps with cartography or GIS software.

Data themes are available in three levels of detail mentioned above. For each scale, themes are listed on Cultural, Physical, and Raster category pages.

- Large scale data (1:10m) – The most detailed. Suitable for making zoomed-in maps of countries and regions. Show the world on a large wall poster.
- Medium scale data (1:50m) – Suitable for making zoomed-out maps of countries and regions. Show the world on a tabloid size page.
- Small scale data (1:100m) – Suitable for schematic maps of the world on a postcard or as a small locator globe."

(naturalearthdata.com)

"*ArcGIS Living Atlas of the World* is the foremost collection of geographic information from around the globe. It includes maps, apps, and data layers to support your work. There are multiple ways how to use ArcGIS Living Atlas of the World:

- Explore maps, apps, and data layers from Esri and thousands of other organizations.
- Combine content with your own data to create new maps and applications.
- Get inspired. See how others are visualizing data and solving problems."

(livingatlas.arcgis.com)

resources

Global spatial data

Natural Earth data

naturalearth.com

ArcGIS Living Atlas of the World

livingatlas.arcgis.com

Esri Demographics

[Learn.esri.com](http://learn.esri.com)

Eurostat

ec.europa.eu

resources

Czech spatial data

Prague geographic data

geoportalpraha.cz

Czechia spatial data

arcdata.cz

Nature conservation agency of the Czech Republic

data.nature.cz

Thematic Mapping

"Thematic maps cover a wide variety of mapping solutions, and include choropleth, proportional symbol, isoline, dot density, dasymetric, and flow maps as well as cartograms, among others. Each thematic map type requires a different data processing method and employs different visual variables, resulting in representations that are either continuous or discrete and smooth or abrupt. As a result, each solution highlights different aspects of the mapped phenomena and shapes the message for the map readers differently. Thematic maps are tools for understanding spatial patterns, and the choice of thematic map type should support this understanding. Therefore, the main consideration when selecting a thematic map type is the purpose of the map and the nature of the underlying spatial patterns.

This entry reviews the common types of thematic maps, describes the visual variables that are applied in them, and provides design considerations for each thematic map type, including their legends. It also provides an overview of the relative strengths and limitations of each thematic map type." (gistbok.ucgis.org)

"Thematic maps depict information on a particular topic or theme. The detail portrayed on a thematic map may be physical, statistical, measured, or interpreted, and sometimes requires specialist knowledge by the map user. Weather, population density and geology maps are examples of thematic maps." (icsm.gov.au)

"While a topographic or reference map mostly depicts things that are visible on the ground, such as lakes, roads, or forests, a thematic map often visualizes phenomena that are not, such as election results, habitat ranges, and agricultural suitability. As a result, thematic symbology is more abstract. The color, size, and shape of symbols are varied so the most important map features are the most obvious, and the quantitative and qualitative relationships between the data are clear. The map designer is less concerned with making the map resemble the place and more concerned with presenting a clear communication of the data, its patterns, and the message they want to convey with it." (learn.arcgis.com)

resources

Supporting online tutorials/courses

Common Thematic Map Types gistbok.ucgis.org	Design symbology for a thematic map in ArcGIS Pro Learn.esri.com	Adventures in Mapping esri.com
Design a layout for a thematic map in ArcGIS Pro learn.arcgis.com	How-to videos by John Nelson John Nelson	Cartographic creations in ArcGIS Pro Learn.esri.com

resources

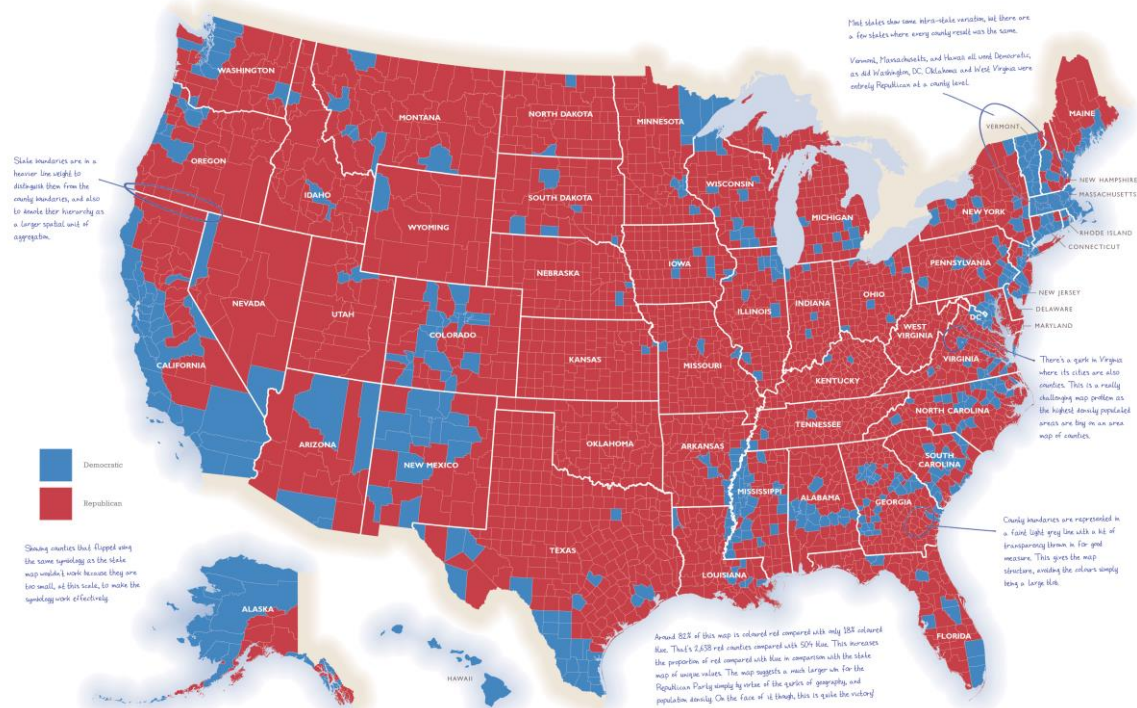
Recommended literature

Thematic Mapping: 101 Inspiring Ways to Visualise Empirical Data Ken Field
--

Choropleth Maps

"First developed by Baron Pierre Charles Dupin for his 1826 map showing levels of illiteracy in France, the map used an unclassed technique with shadings from black to white. As well as being the first choropleth map, it often is regarded as the first modern statistical map. It wasn't until 1938 that the actual term choropleth map was introduced by the geographer John Kirtland Wright."

(Ken Field, Themating Mapping: 101 Inspiring Ways to Visualise Empirical Data)



"A choropleth map is a thematic map that uniformly colors each non-overlapping enumeration unit according to the represented value. Choropleth maps typically receive sequential color schemes varying color value as a primary visual variable, using a "dark-is-more" order for light backgrounds and the reverse "light-is-more" order for dark backgrounds. Apart from color value, choropleth maps also may employ color hue and color saturation in multihued spectral schemes and in diverging schemes. Diverging schemes are used to emphasize a critical value. Qualitative or "rainbow" color schemes are generally not recommended due to the numerical enumerated values represented in choropleth maps. Choropleth maps only represent enumerated data, often enumerated to political boundaries or a tessellation of regular shapes, with coloring of regions based on nominal differences (e.g., different soil types, etc.) not considered as choropleth maps." (gistbok.ucgis.org)

resources

Symbology settings for a choropleth map in ArcGIS Pro

Graduated colors

pro.arcgis.com

Unclassed colors

pro.arcgis.com

Bivariate colors

pro.arcgis.com

resources

Video tutorials

Normalizing and Classifying Choropleth Maps

esri.com

Diagram Maps

Proportional point symbols

"The first use of proportional symbols was made by Scottish engineer and political economist William Playfair in his book *Statistical Breviary*, published in 1801. He laid out an array of circles of different sizes, each representing the population of different cities through scaling the area of the circle to the data value. French engineer Charles Joseph Minard made numerous maps, graphs, and charts, but he was notable for merging the two and creating maps with charts and diagrams that sat on top. Published in 1858, his map of proportional symbols to show coal mine production was the first map to incorporate statistical diagrams with circles proportional to a data variable. A variation of the proportional symbol is the graduated symbol, in which data values are represented by range-graded symbols of fixed sizes. Each data value in a certain class is depicted using the same-sized symbol. Symbols also may be designed to have a pseudo-3D appearance in which the volume of then symbol is proportional to the data value being mapped. Hungarian-born American cartographer Erwin Raisz made use of 3D symbology in his 1944 *Atlas of Global Geography*.

Proportional line symbols

"The same concept as previous was applied to lines in 1837 by Henry Drury Harness on his map showing transportation in Ireland, in which the value of data was represented by a line whose thickness was proportional to the number of passengers. French engineer Charles Joseph Minard made excellent use of proportional line symbology in his many flow maps in the mid-19th century, and on his famous map of Napoleon's 1812 march on Moscow, published in 1869. That map was, in fact, originally the bottom map on a sheet that contained another flow map, that of the campaign by military commander Hannibal some 2,000 years before that of Napoleon. Curiously, not all the lines on Minard's map of Napoleon's march were proportional. Although the legend says that 1 millimetre in line width is equivalent to 10,000 troops, at the point in which the map label indicates there are 10,000 troops, the line is 2 millimetres in width. Sometimes range-grading of symbols is used to symbolise extreme values on a proportional symbol map, and this is possibly what Minard did here to ensure overall clarity."

(Ken Field, *Themating Mapping: 101 Inspiring Ways to Visualise Empirical Data*)

resources

Symbology settings for a diagram map in ArcGIS Pro

Proportional symbols

pro.arcgis.com

Graduated symbols

pro.arcgis.com

The many ways to symbolize
by size

esri.com

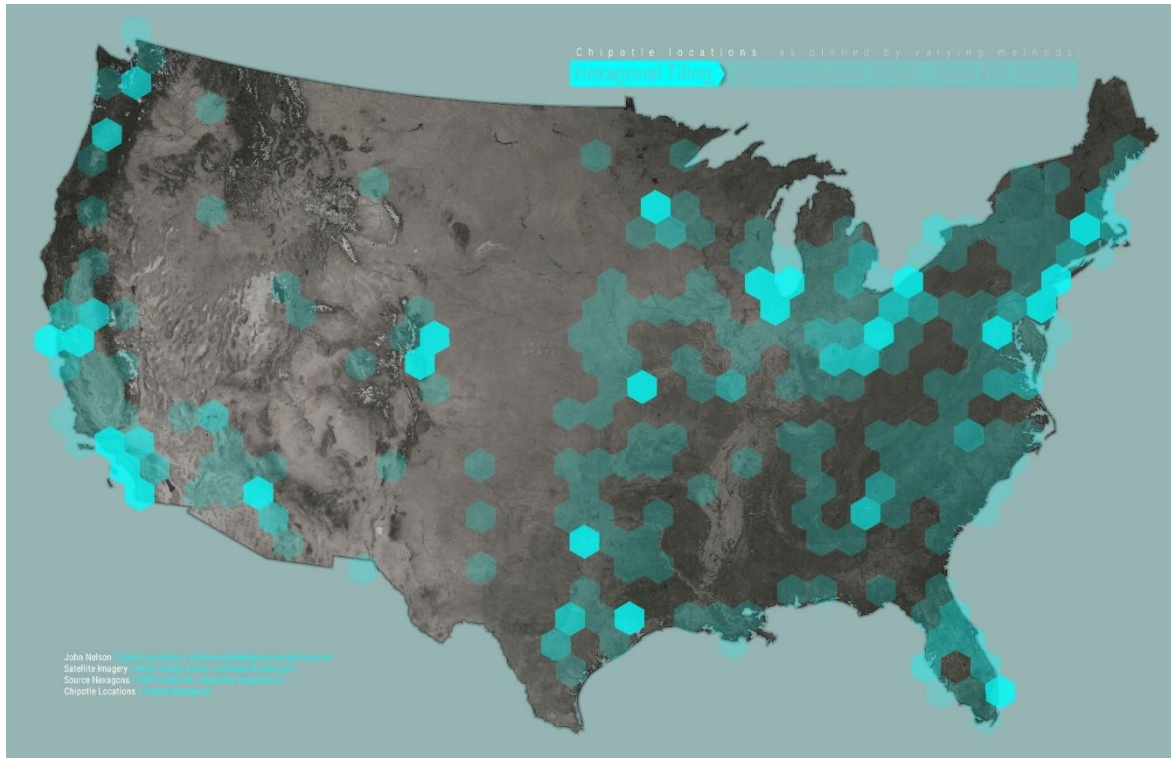
Data classification methods

pro.arcgis.com

Grid Maps, Data Binning

"Binning data into boundaries on thematic maps is as old as the choropleth map, which can be traced to Baron Pierre Charles Dupin in his 1826 map showing levels of illiteracy in France. In a contemporary sense, binning more commonly refers to aggregation of data variable occurrences within regular grids such as hexagons (hex-binning). Original data values are aggregated and replaced by a value representing some measure of their combined occurrence such as total or mean. It's effectively a spatial histogram."

(Ken Field, Themating Mapping: 101 Inspiring Ways to Visualise Empirical Data)



resources

Supporting online courses/tutorials

Hexperiment

adventuresinmapping.com

Six Months of Drought in the American Southeast

esri.com

How to turn a ton of overlapping data into a hexagon map

esri.com

Cartograms

Cartogram (compromise)

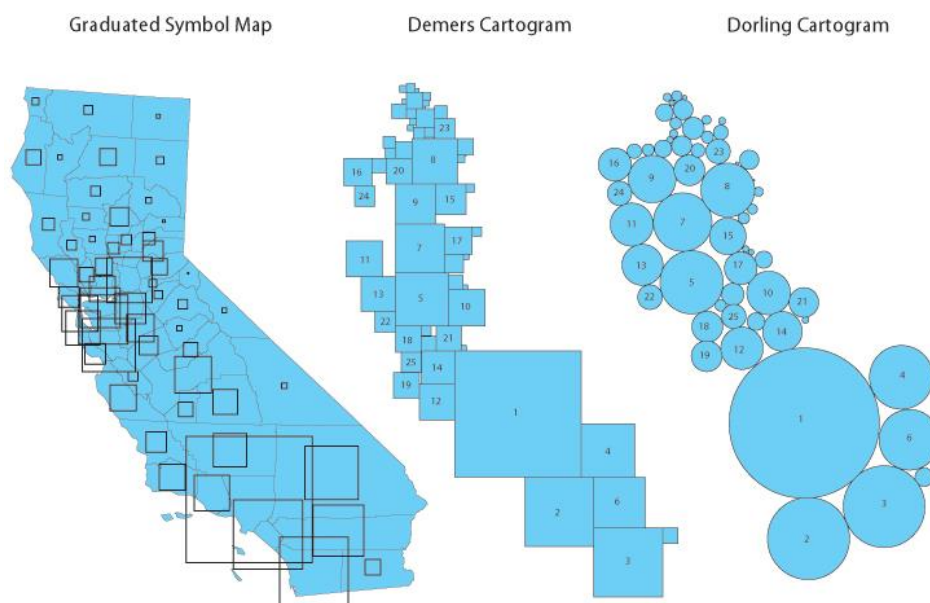
"A compromise cartogram uses a geographical map as the background framework, and repeated symbols are positioned on top to represent the data variable. Without the geographical map, it would be a noncontiguous mosaic cartogram. Gabriel Dance and Nick Evershed of The Guardian developed the technique for the 2013 Australian election.

Cartogram (Demers)

The Demers cartogram is a technique for representing data for areas that eschews geography in preference for a geometric shape that represents the unit areas. It is ostensibly the same as a Dorling cartogram except it uses squares instead of circles to reduce the gaps between mapped objects. The Demers sacrifices distance to maintain contiguity. It was created by undergraduate student Steve Demers during his Bachelor of Arts in geography studies at the University of California, Santa Barbara, under the direction of research cartographer and Professor of Geography Keith Clarke in 2002. Demers also created a 20-foot span population cartogram of human figures on one of the campus walls. Each figure represented 10 million people.

Cartogram (Dorling)

Developed by British geographer Danny Dorling in 1996, the Dorling cartogram is a technique for representing data for areas that replaces geographical shapes with a circle to represent the unit areas, sized by the data variable. A Dorling cartogram does not maintain shape, topology, or object centroids and is an abstract representation of the spatial pattern of the phenomenon being mapped. It can be likened to a proportional symbol map in which the symbols have been repositioned in a selforganising manner using cellular-automata methods to overcome the problems of overlaps caused by some non-contiguous cartogram techniques." (Ken Field, Themating Mapping: 101 Inspiring Ways to Visualise Empirical Data)



resources

Cartogram Maps

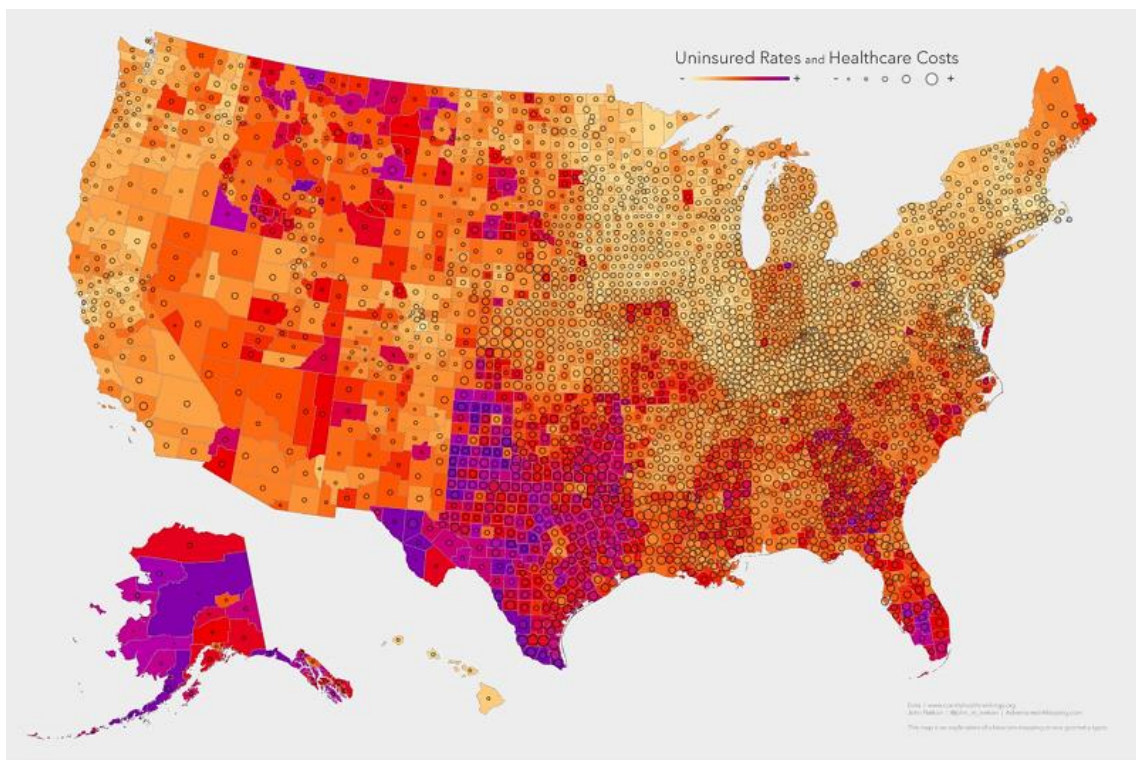
Cartogram maps: Data
visualization with exaggeration

gisgeography.com

Multivariate Mapping

"Bivariate and multivariate maps encode two or more data variables concurrently into a single symbolization mechanism. Their purpose is to reveal and communicate relationships between the variables that might not otherwise be apparent via a standard single-variable technique. These maps are inherently more complex, though offer a novel means of visualizing the nuances that may exist between the mapped variables. As information-dense visual products, they can require considerable effort on behalf of the map reader, though a thoughtfully-designed map and legend can be an interesting opportunity to effectively convey a comparative dimension.

This chapter describes some of the key types of bivariate and multivariate maps, walks through some of the rationale for various techniques, and encourages the reader to take an informed, balanced approach to map design weighing information density and visual complexity. Some alternatives to bivariate and multivariate mapping are provided, and their relative merits are discussed." (John Nelson)



resources

Multivariate Mapping

Multivariate Mapping Overview

gistbok.ucgis.org

Create web maps

pro.arcgis.com

Get started with creating
3D web scenes

pro.arcgis.com

Create apps from maps

pro.arcgis.com

Perform analysis

pro.arcgis.com

Publish hosted layers

pro.arcgis.com

Share items

pro.arcgis.com

ArcGIS Online, sharing data from ArcGIS Pro

"ArcGIS Online is a cloud-based mapping and analysis solution. Use it to make maps, analyze data, and to share and collaborate. Get access to workflow-specific apps, maps and data from around the globe, and tools for being mobile in the field. Your data and maps are stored in a secure and private infrastructure and can be configured to meet your mapping and IT requirements.

Work with smart, data-driven styles to explore and visualize 2D and 3D data. Share your maps with anyone, anywhere or keep them private. Work collaboratively with your colleagues to build maps, scenes, apps and notebooks. Access intuitive analysis tools that help you better understand data."

(doc.arcgis.com)

resources

What you can do with ArcGIS Online

What is ArcGIS Online

pro.arcgis.com

Create web maps

pro.arcgis.com

Get started with creating
3D web scenes

pro.arcgis.com

Create apps from maps

pro.arcgis.com

Perform analysis

pro.arcgis.com

Publish hosted layers

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Share items

pro.arcgis.com



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ENGINEERING
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Feel free to contact

prof. Ing. Jiří Cajthaml, Ph.D.



Maps are more than diagrams that help you navigate from point A to point B. They are windows into information that allows you to explore the world, visualize data, and see trends to engage more productively. Maps can spark curiosity, provide insight, spur people to action, and help build solutions toward a better future.

esri.com
GIS software developer