METHODS
OF SPATIAL DATA VISUALIZATION
in the Context of Suburbanization

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About me

- PhD student of Geoinformatics and Cartography
- digital cartography, geovisualization, 3D, tactile cartography
- doctoral thesis visual analysis of thematic 3D data

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Outline

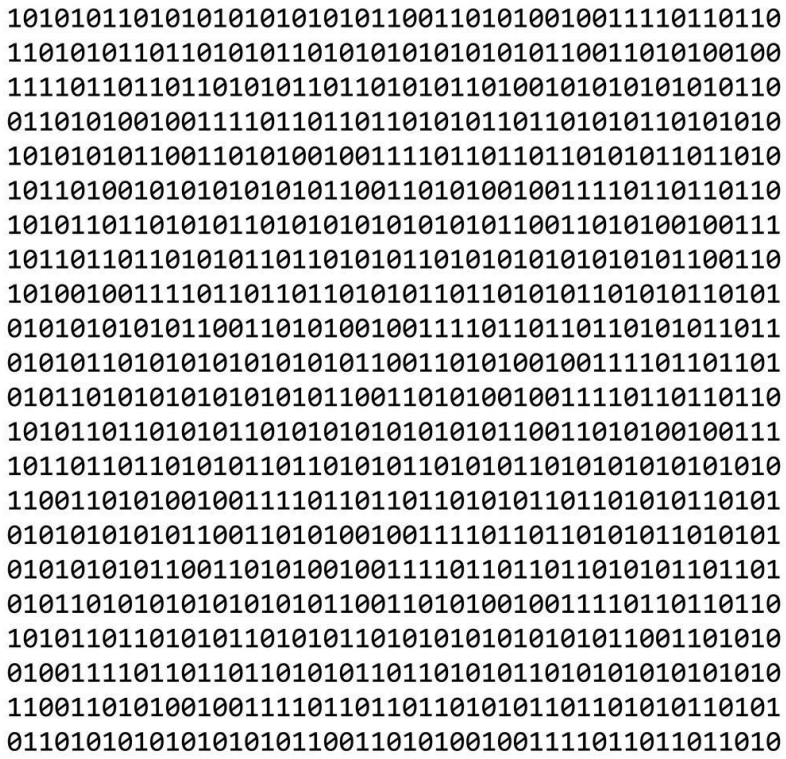
- Introduction
  - Spatial Data Visualization
  - Cartography
  - Sources of Spatial Data
- Methods
- Conclusion

Introduction

Spatial Data Visualization | Cartography
Sources of Spatial Data

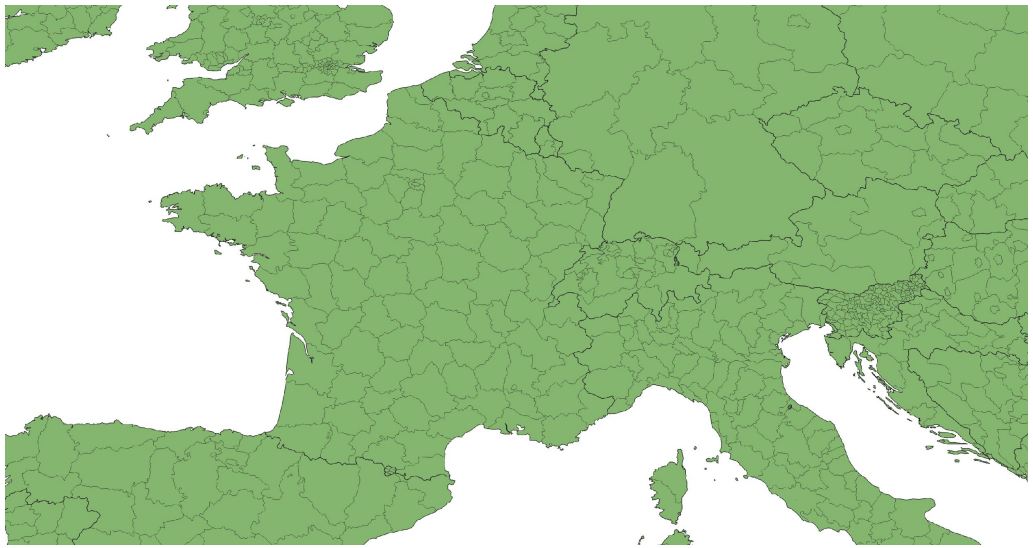
Spatial Data (Geodata)

- data that have a **geographical (spatial) component**
- linked with a specific location on the earth's surface
- point, line or area
- spatial analysis
- base for map making



Spatial Data

- two components
  - **geometric × attribute**



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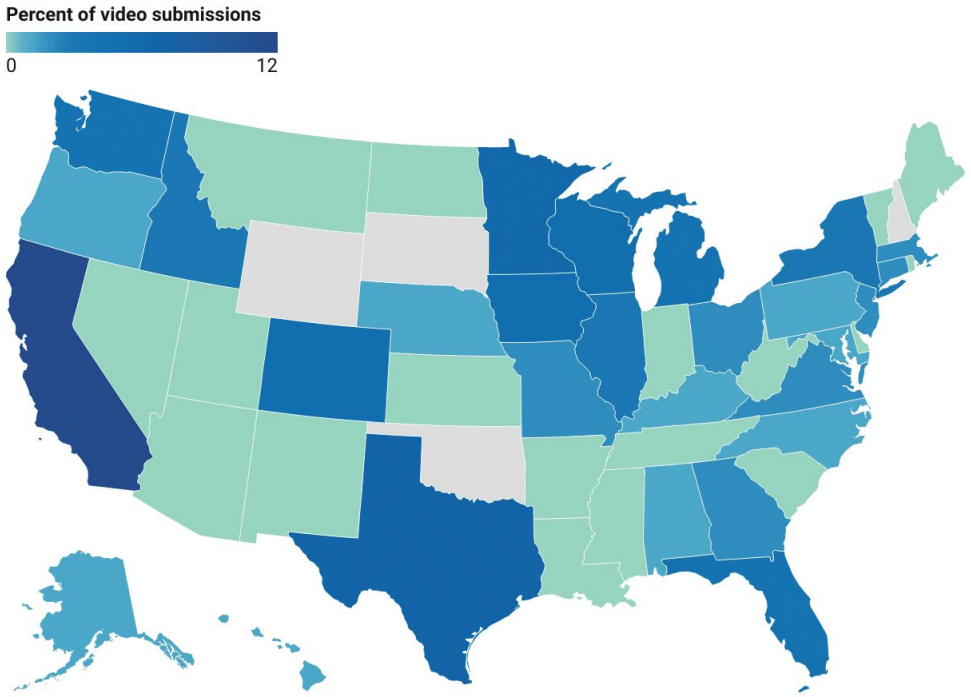
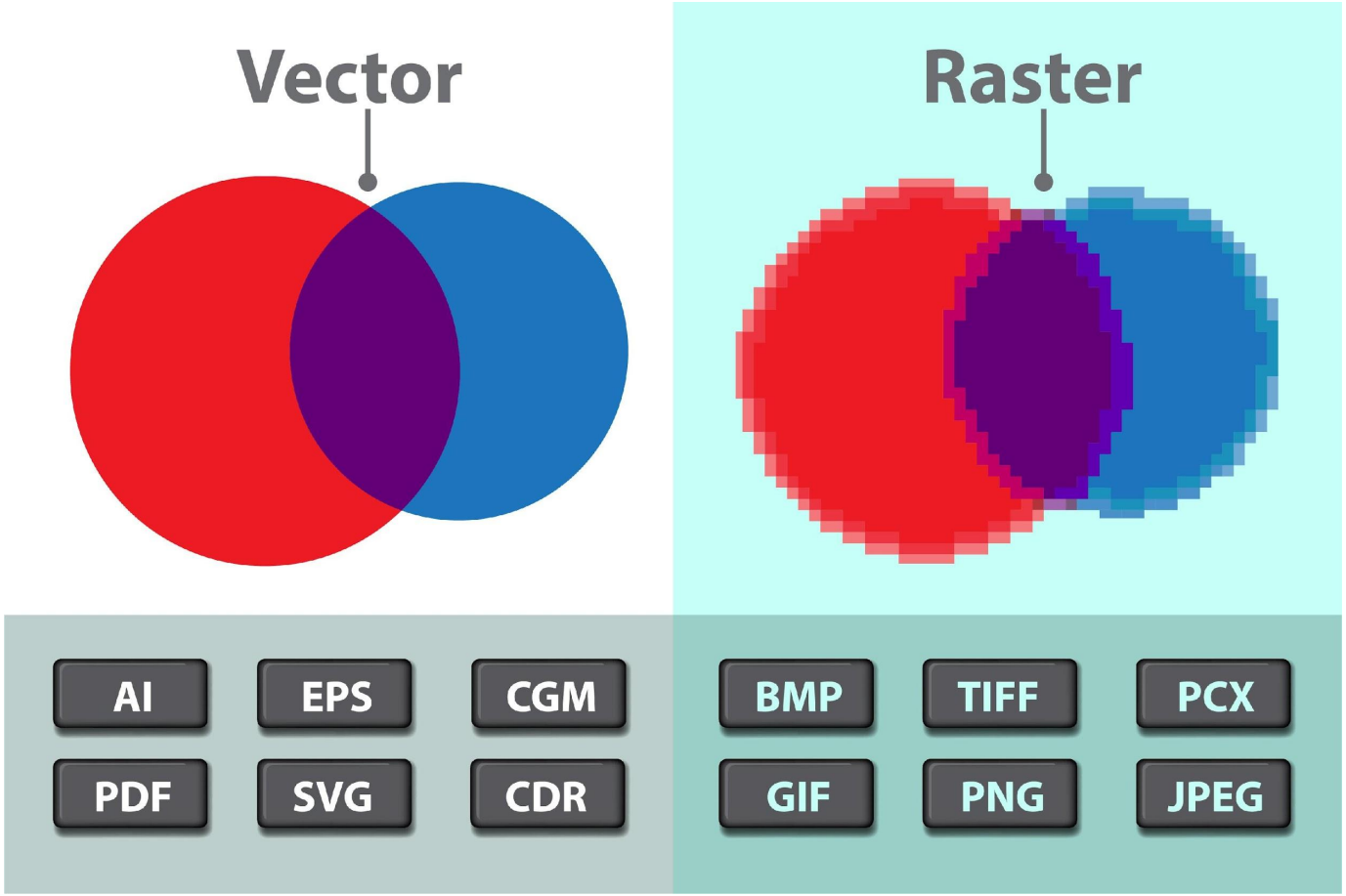
Spatial Data Visualization

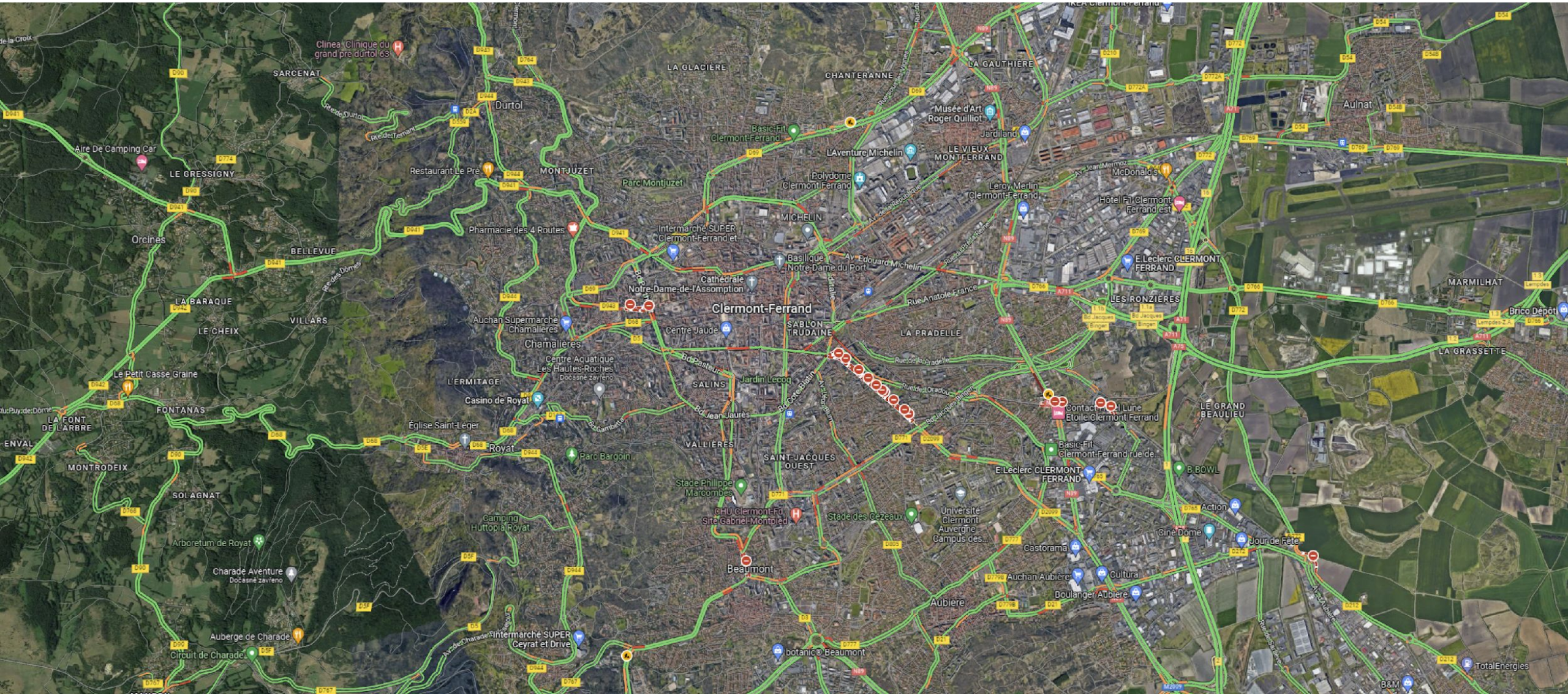
- quantitative × qualitative



Spatial Data Visualization

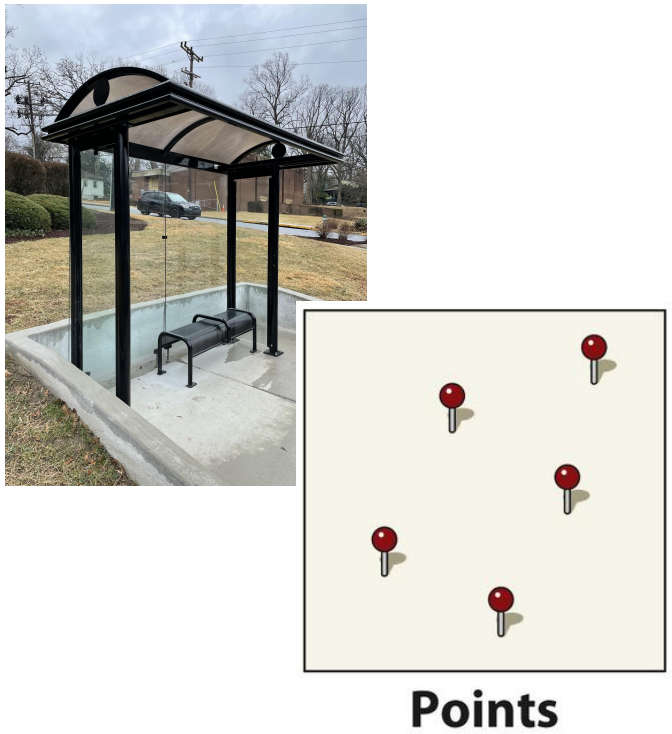
- vector × raster



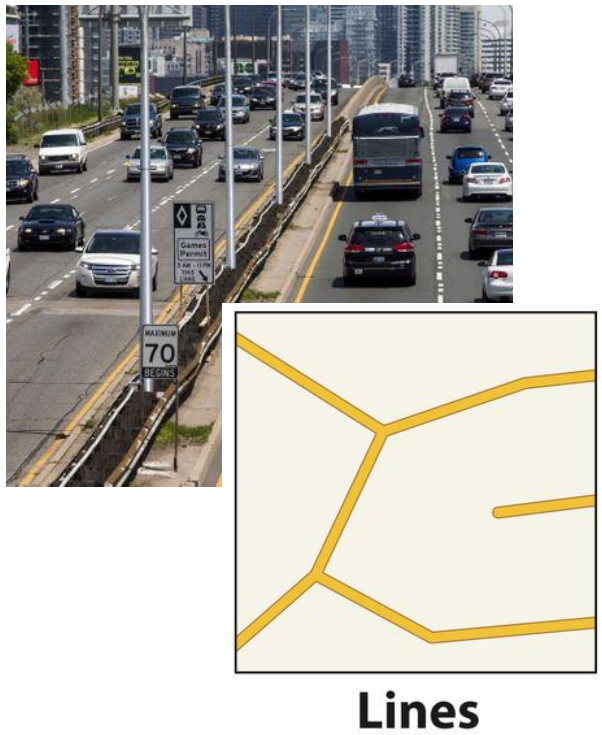

Clinea Clinique du grand pre durtol 63
SARCENAT
Durtol
LA GLACIÈRE
CHANTERANNE
LA GAUTHIÈRE
Aulnat
Aire De Camping Car
LE GRESSIGNY
Restaurant Le Pré
MONTJUZET
Parc Montjuzet
Basic-Fit Clermont-Ferrand...
L'Aventure Michelin
LE VIEUX MONTFERRAND
Musée d'Art Roger Quilliot
Jardiland
Polydome Clermont Ferrand
Leroy Merlin Clermont-Ferrand
McDonald's
Hôtel Fi Clermont Ferrand est
Orcines
BELLEVUE
Pharmacie des 4 Routes
Intermarché SUPER Clermont-Ferrand et...
MICHELIN
Basilique Notre-Dame du Port
E.Leclerc CLERMONT FERRAND
LA BARAQUE
LE CHEIX
VILLARS
Cathédrale Notre-Dame-de-l'Assomption
Clermont-Ferrand
Auchan Supermarché Chamalières
Chamalières
Centre Jaude
SABLON TRUDAINE
LA PRADELLE
LES RONZIÈRES
MARMILHAT
Brico Dépôt
LA GRASSETTE
Centre Aquatique Les Hautes-Roches
Docasné zavřeno
Le Petit Casse Graine
L'ERMITAGE
SALINS
Jardin Lecoq
Casino de Royat
FONTANAS
LA FONT DE L'ARBRE
Église Saint-Léger
Royat
Parc Bargoin
VALLIÈRES
SAINT JACQUES OUEST
LE GRAND BEAULIEU
Contact Hôtel Lune Etoile Clermont Ferrand
Basic-Fit Clermont-Ferrand rue de...
E.Leclerc CLERMONT FERRAND
B BOWL
ENVAL
MONTRODEIX
SOLAGNAT
Stade Philippe Marcombes
CHU Clermont-Fd Site Gabriel-Montpied
Stade des Gézeaux
Université Clermont Auvergne - Campus des...
Action
Ciné Dôme
Jour de Fête
Camping Huttopia Royat
Arboretum de Royat
Castorama
Charade Aventure
Docasné zavřeno
Beaumont
Auchan Aubière
Cultura
Boulanger Aubière
Aubière
Auberge de Charade
Circuit de Charade
Intermarché SUPER Ceyrat et Drive
botanic® Beaumont
TotalEnergies
B&M

Spatial Data Visualization

- point × line × area (polygon)



Points

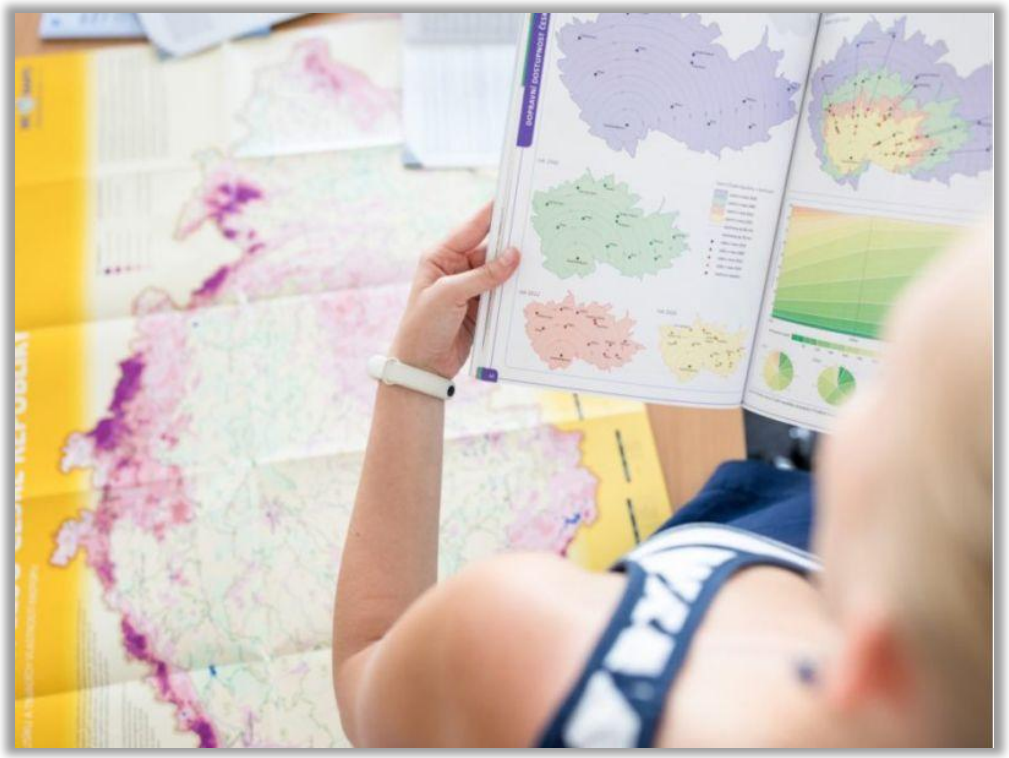


Lines

Polygons

Cartography

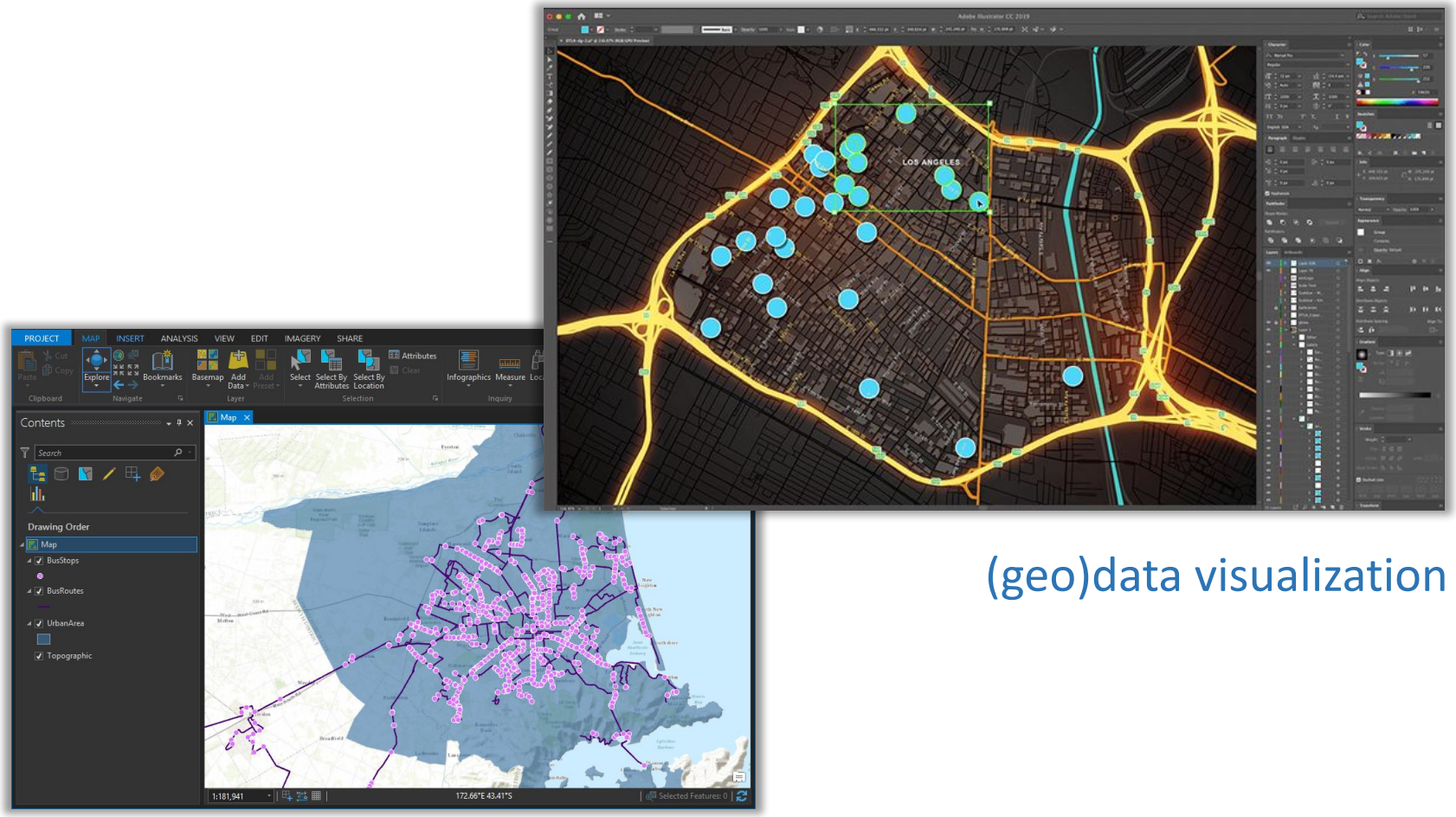
- science, technology and art of **maps (making & use)**
- a map can represent a large amount of spatial information
  - fast
  - understandable
  - engaging
- **digital (GIS based) cartography**



Cartography – process

(geo)data collection

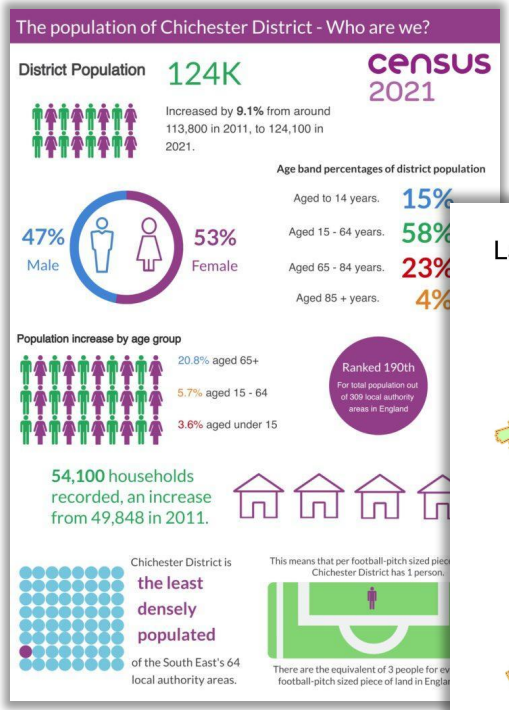
(geo)data management & analysis

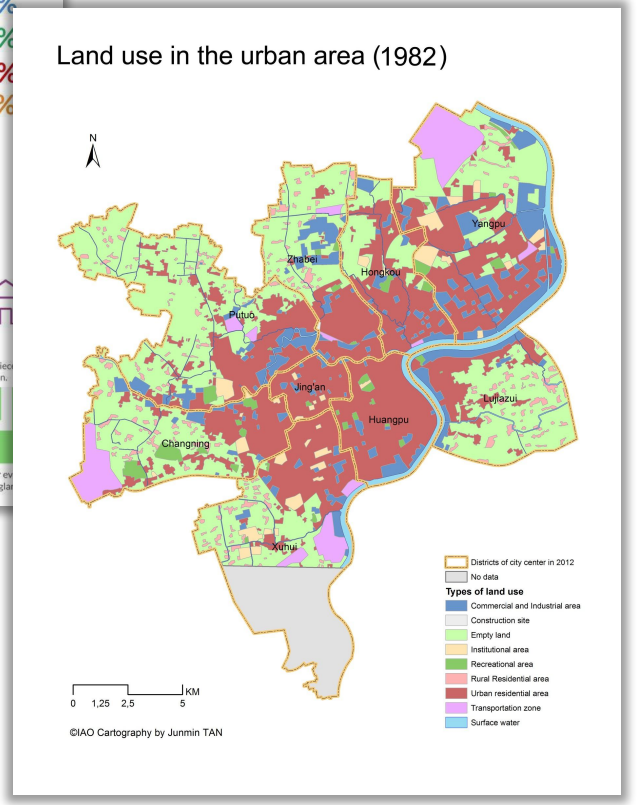


(geo)data visualization

Sources of Spatial Data – Suburbanization

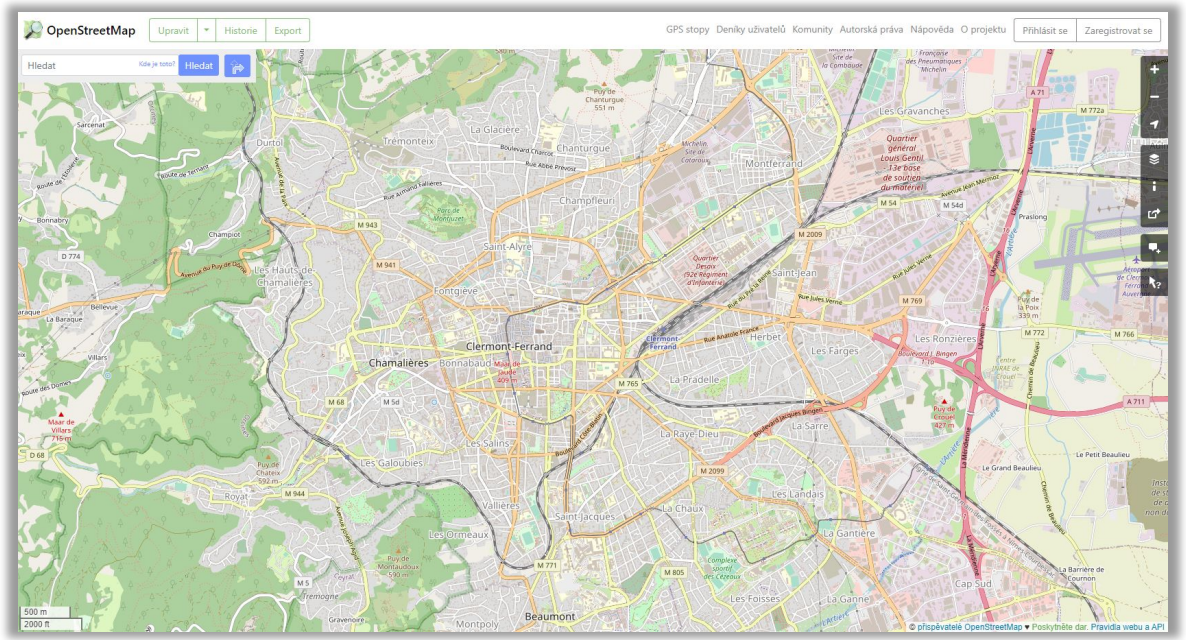
- census/statistical data
  - migration
  - new houses/flats
  - commuting to work or school
- land use/land cover data
- satellite imagery
- mobile operator data
- field data collection

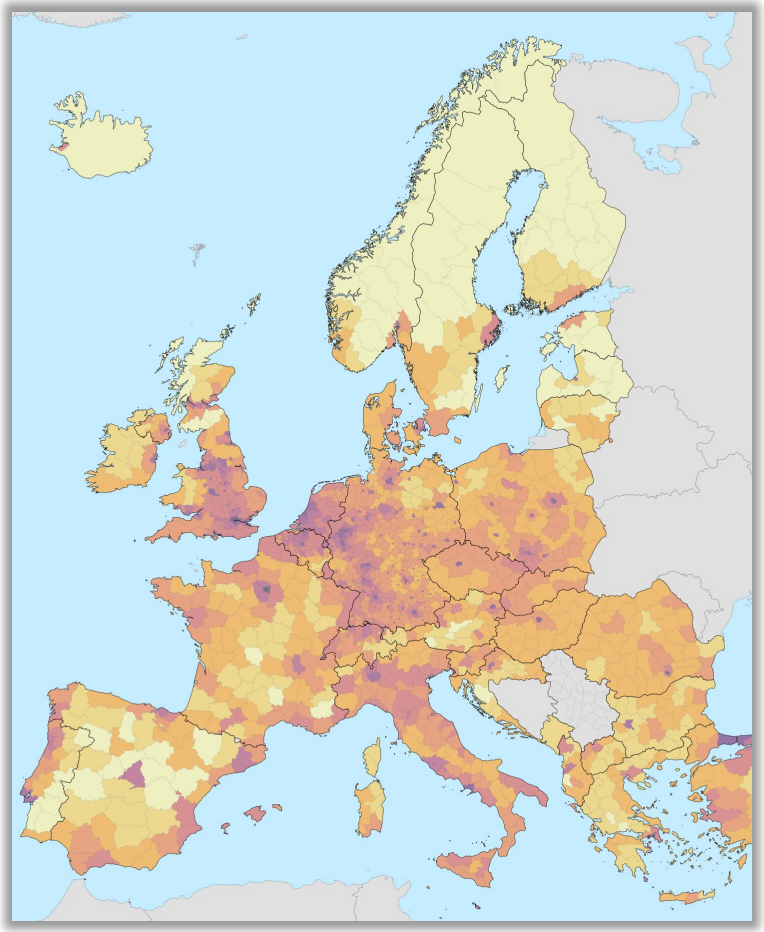




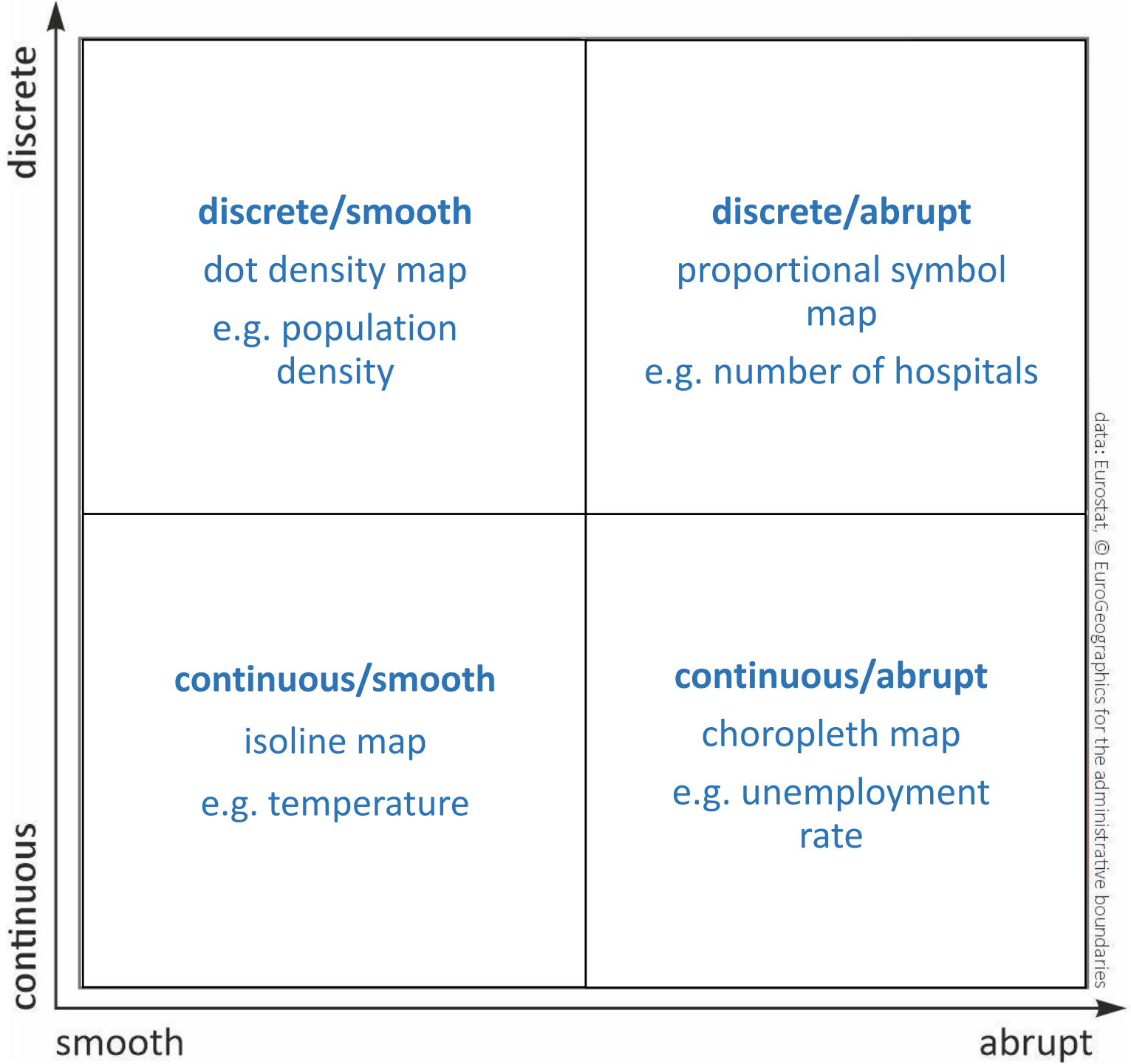
Sources of Spatial Data – Additional

- administrative units
- topographic data





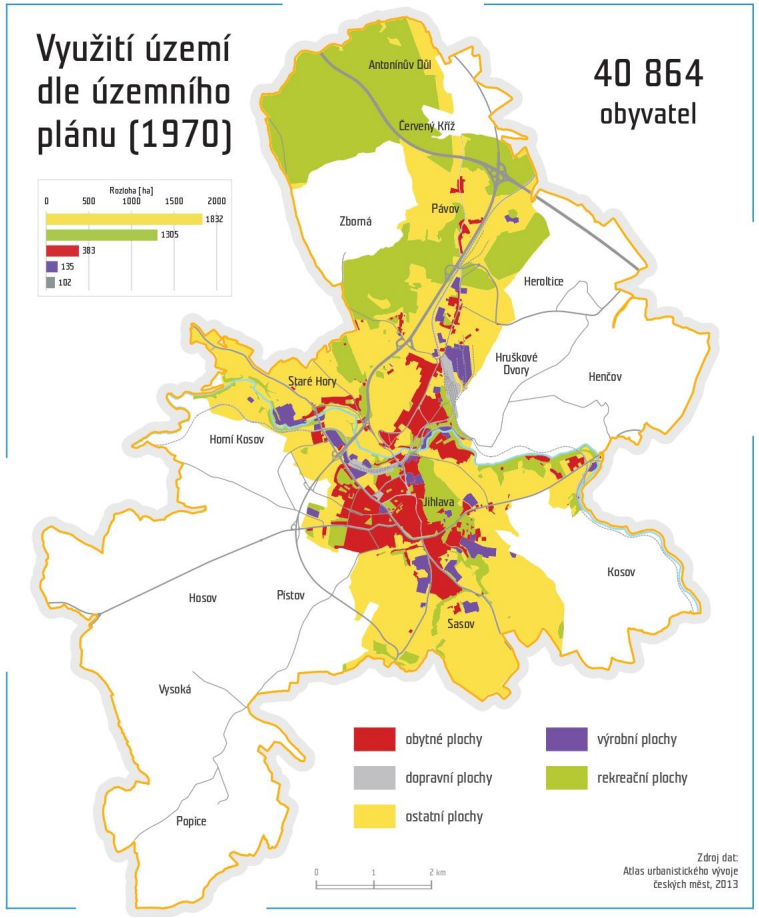
Methods
of Spatial Data Visualization

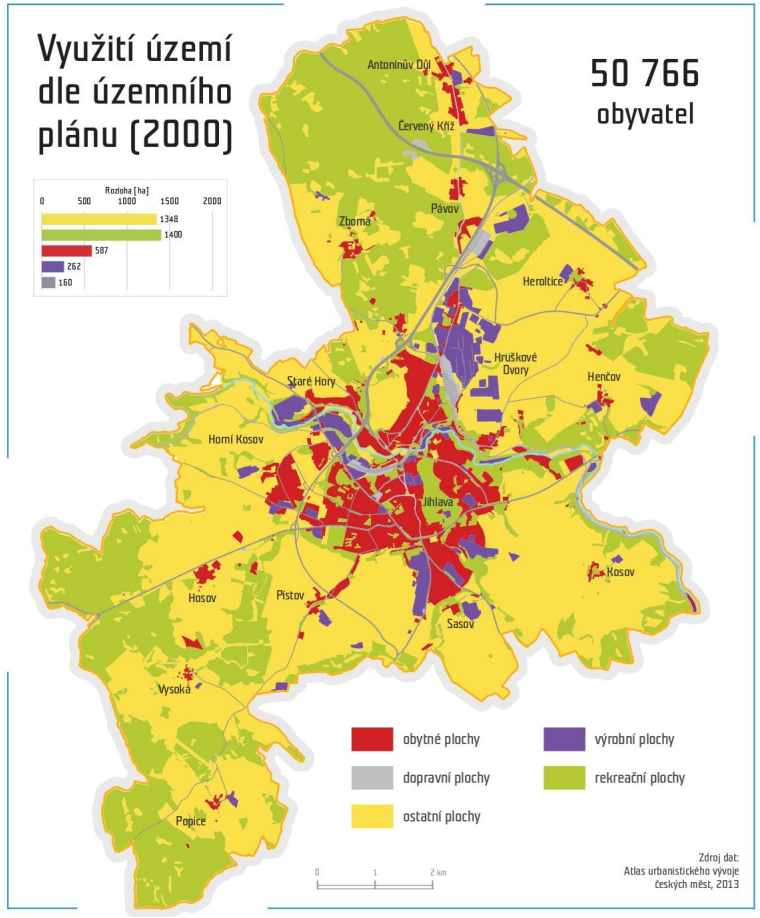

discrete
continuous
smooth
abrupt
discrete/smooth
dot density map
e.g. population density
discrete/abrupt
proportional symbol map
e.g. number of hospitals
continuous/smooth
isoline map
e.g. temperature
continuous/abrupt
choropleth map
e.g. unemployment rate
data: Eurostat, © EuroGeographics for the administrative boundaries

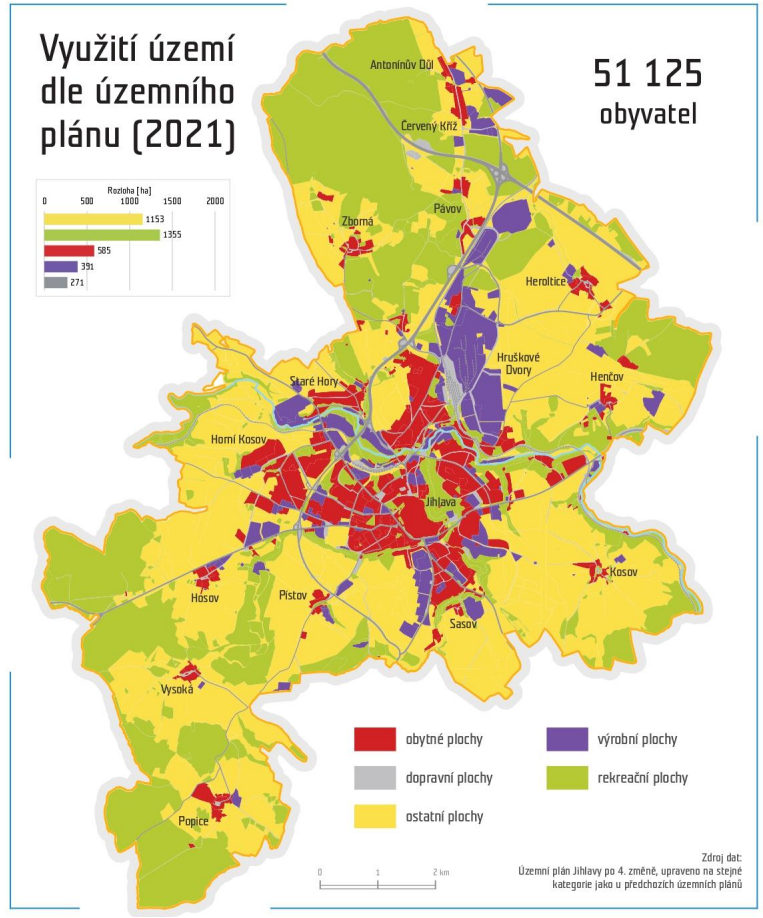
Areal Symbols Method

- **qualitative data**
- differentiation of areas
- easy to create and interpret
- coloured or hatched fill

Areal Symbols Method – Suburbanization

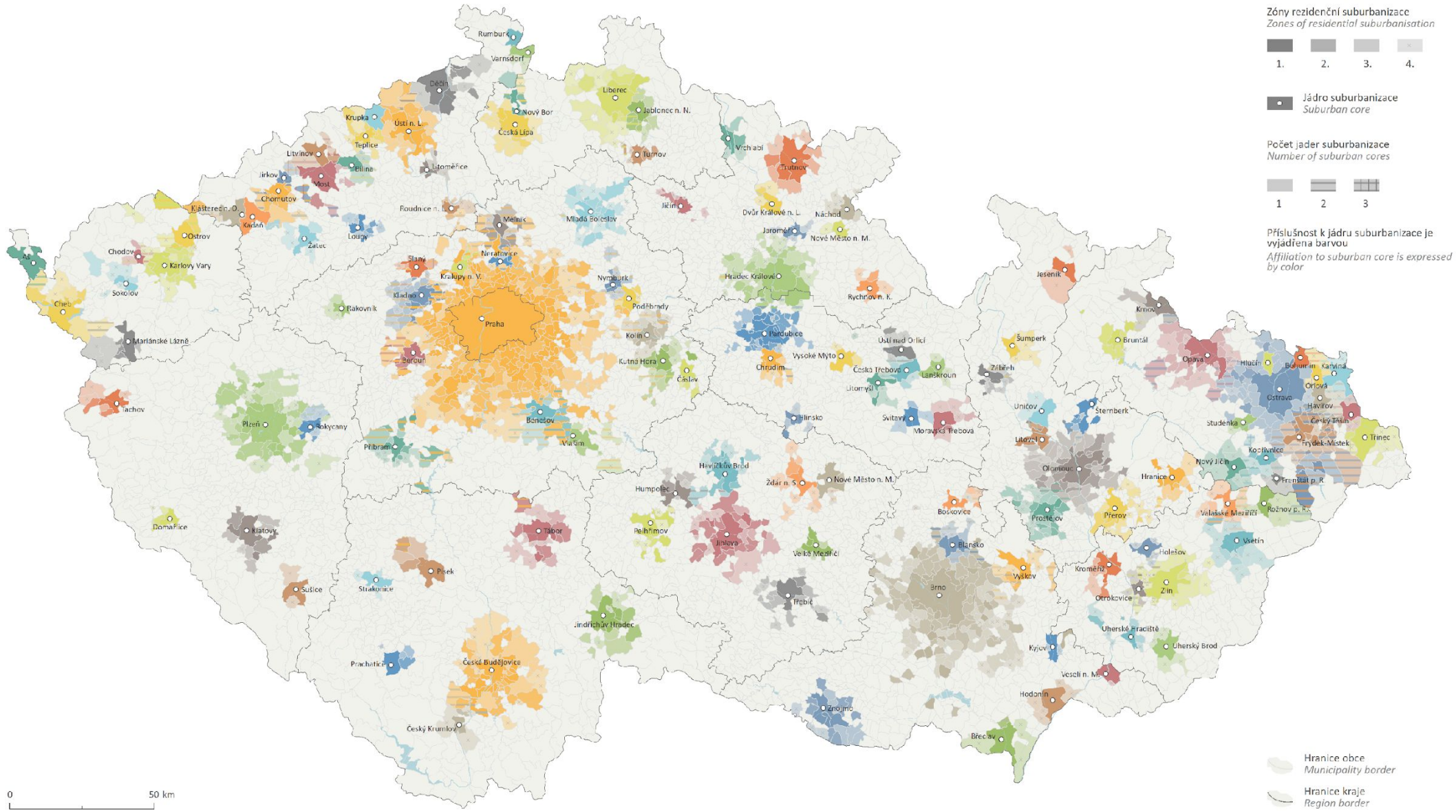






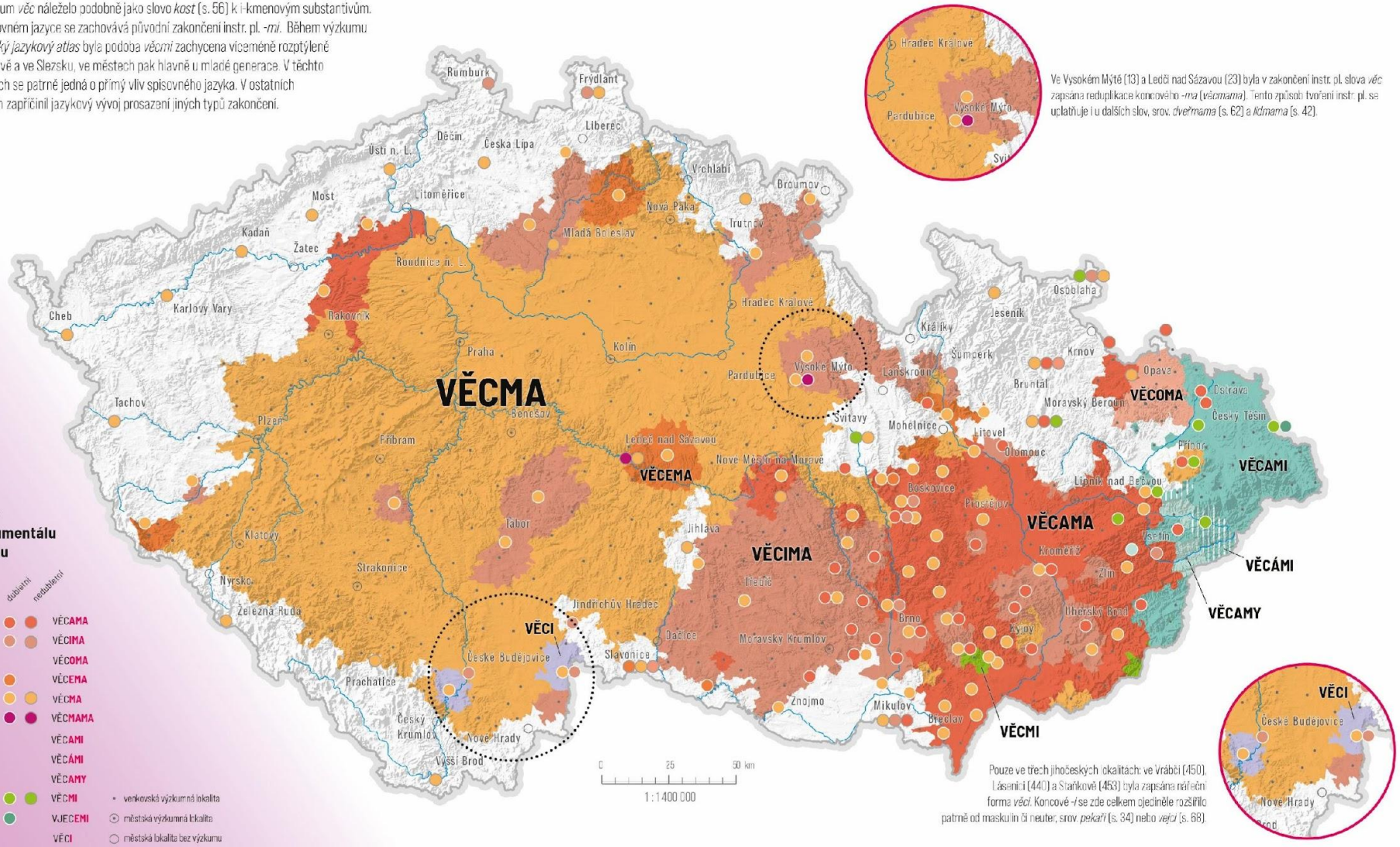
Zóny rezidenční suburbanizace v obcích Česka 2016

Zones of residential suburbanization in Czech municipalities 2016



VĚC *instr. pl.* ***věcmi***

Femininum *věc* náleželo podobně jako slovo *kost* (s. 56) k i-kmenovým substantivům. Ve spisovném jazyce se zachovává původní zakončení instr. pl. *-mi*. Během výzkumu pro *Český jazykový atlas* byla podoba *věcmi* zachycena víceméně rozptýlené na Moravě a ve Slezsku, ve městech pak hlavně u mladé generace. V těchto případech se patrně jedná o přímý vliv spisovného jazyka. V ostatních nářečích zapříčinil jazykový vývoj prosazení jiných typů zakončení.



Tvary instrumentálu plurálu

v areálu / dubletní / nedubletní

- VĚCAMA
- VĚCIMA
- VĚCOMA
- VĚCEMA
- VĚCMA
- VĚCMAMA
- VĚCAMI
- VĚCÁMI
- VĚCAMY
- VĚCMI
- VJECEMI
- VĚCI

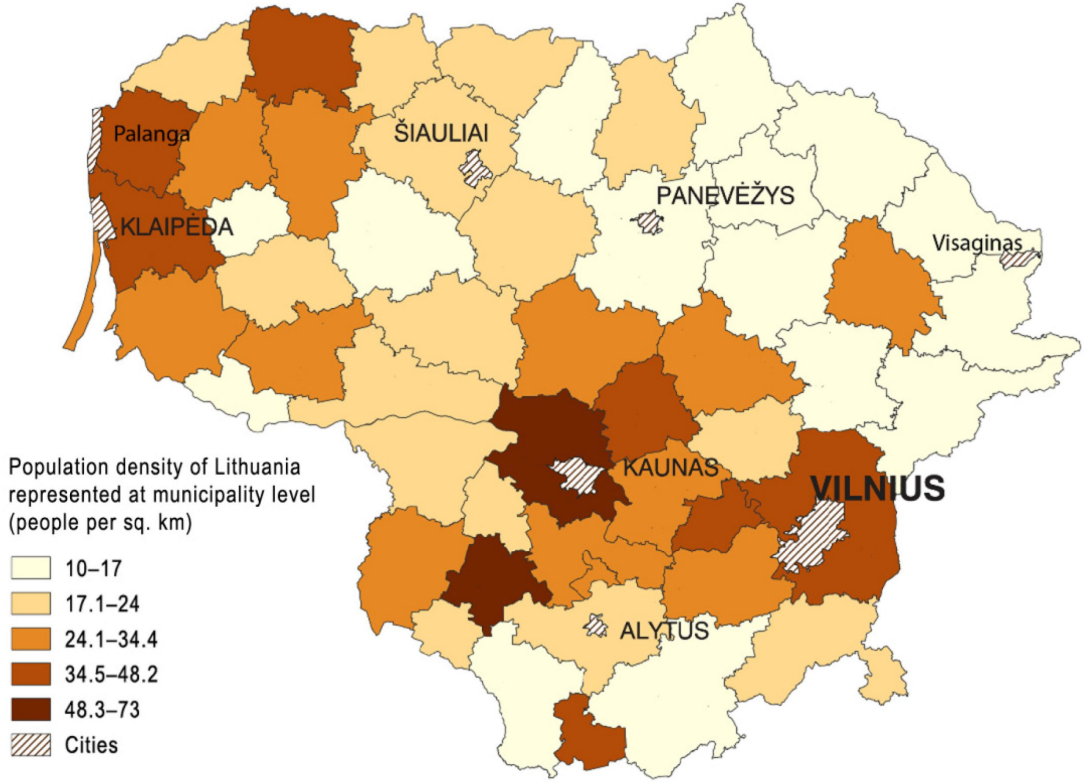
- venkovská výzkumná lokalita
- městská výzkumná lokalita
- městská lokalita bez výzkumu

Ve Vysokém Mýtě (13) a Ledči nad Sázavou (23) byla v zakončení instr. pl. slova *věc* zapsána reduplikace koncového *-ma* (*věcmama*). Tento způsob tvoření instr. pl. se uplatňuje i u dalších slov, srov. *dveřmama* (s. 62) a *lidmama* (s. 42).

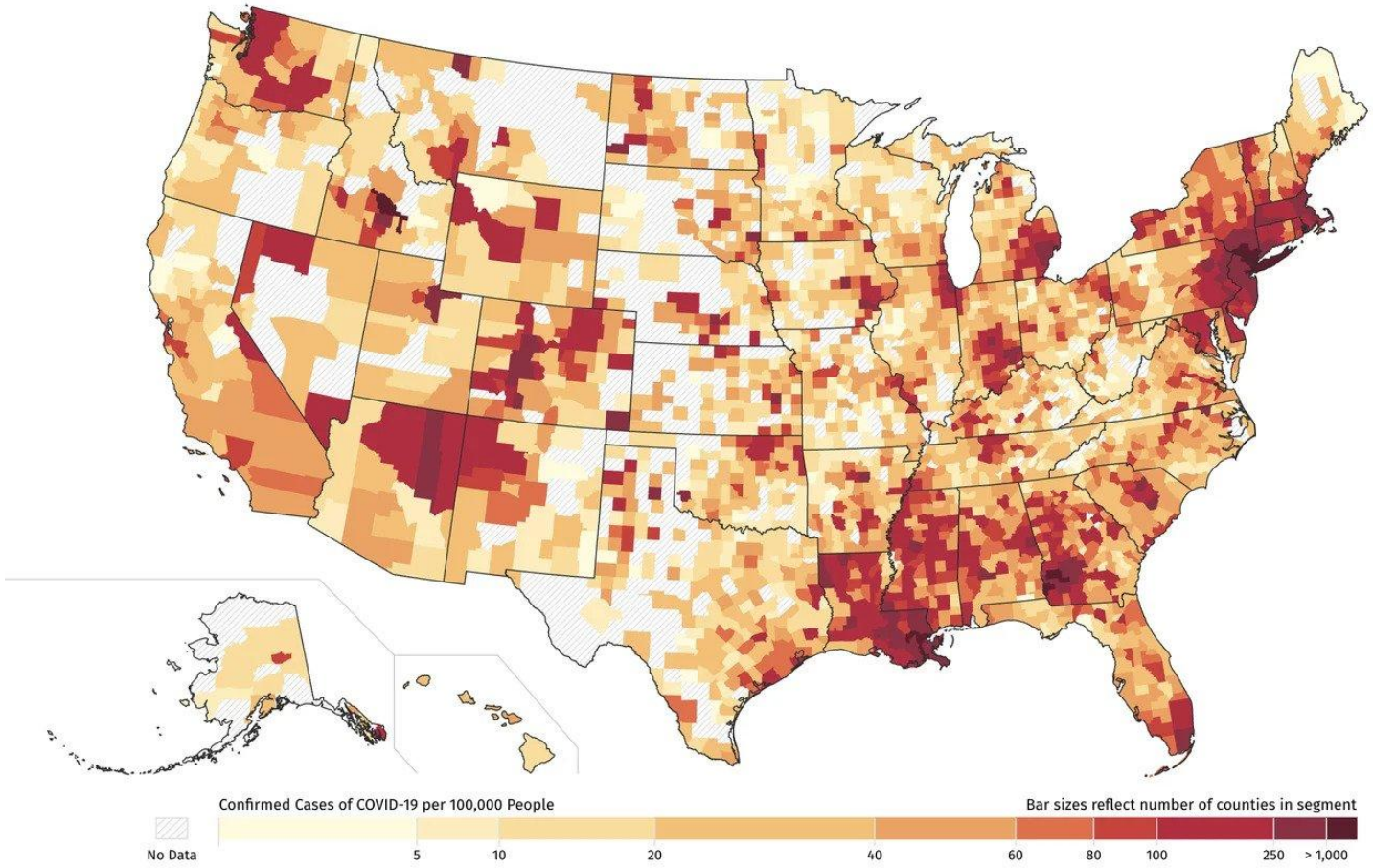
Pouze ve třech jihočeských lokalitách: ve Vrábči (450), Lásenici (440) a Staňkově (453) byla zapsána nářeční forma *věcí*. Koncové *-í* se zde celkem ojediněle rozšířilo patrně od maskulin či neuter, srov. *pekaří* (s. 34) nebo *vejcí* (s. 88).

Choropleth Maps

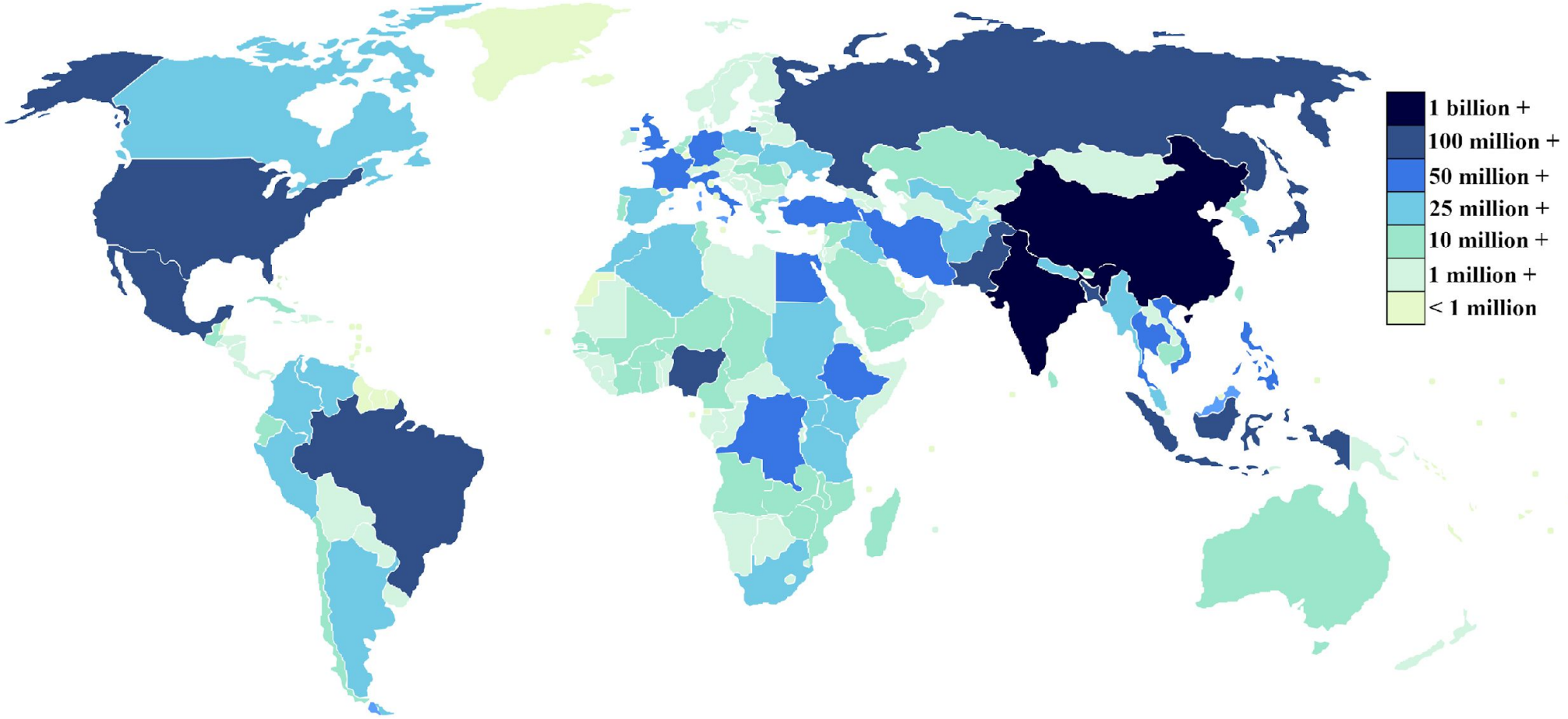
- very common method
- **relative quantitative data**
- data must be recalculated
  - **to area** (e.g. population per sq. km) → true choropleth maps
  - **to other units** (e.g. %, 1 000 people) → false choropleth maps



False Choropleth Map



Wrong Choropleth Map



RURAL AND URBAN MUNICIPALITIES

delimitation with fuzzy inference system (Czech Republic at 2010)

Vít PÁSZTO, Alžběta BRYCHTOVÁ, Pavel TUČEK, Lukáš MAREK, Jaroslav BURIAN

Department of Geoinformatics, Faculty of Science, Palacky University in Olomouc, Czech Republic

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Presented map is the result of the original approach of rural and urban area delimitation with the application of the fuzzy logic. Most of existing classifications of municipalities is the issue of Boolean logic, where the municipality is strictly designated as either rural or urban. This abrupt and strict classification does not reflect real situation and is driven on simple rule (usually according to the total population in a region). This problem can be solved using fuzzy sets and -ogic theory, which allows to smooth the transition between two adjacent classes via fuzzy degrees of membership. Aim of this map is to visualize in an illustrative way what is the fuzzy degree of membership of each municipality in Czech republic. Seven indicators were applied for the computation of the final degree of membership, which describes each municipality in the zone of its urbanity and rurality according to the principles of fuzzy sets and -ogic theory.

selection of indicators

correlation analysis or/and principal component analysis

Czech Statistical Office database

limit values and weights

indicators

- total population
- total population per built-up area
- flats in family houses per total number of flats
- number of completed flats per 1000 inhabitants
- change of population
- driving distance from county seat
- urbanized area per overall municipality area

determination of municipality degree of membership to the rural or urban area in the interval ⟨0; 1⟩

fuzzy inference system

cartographic visualization

AREA OF INTEREST
localization of The Czech Republic within Europe

SPATIAL DATA SOURCES:

The National Topographic Database DataZABAGED® - Administrative areas (POLIGONY) and Seat represented by built-up area expressed by point (BLOCTUPP)
© Czech Office for Surveying, Mapping and Cadastre, 31/12/2010

Administrative Units - Countries 2010 1 : 60 000 000
© EuroGeographics, 2010

MAPS OF THE CZECH REPUBLIC:

Projection: UTM zone 33N
Datum: WGS84
Coordinate System: WGS84
Scale of the main map: 1 : 500 000
Scale of the secondary maps: 1 : 7 500 000

MAP OF THE EUROPE:

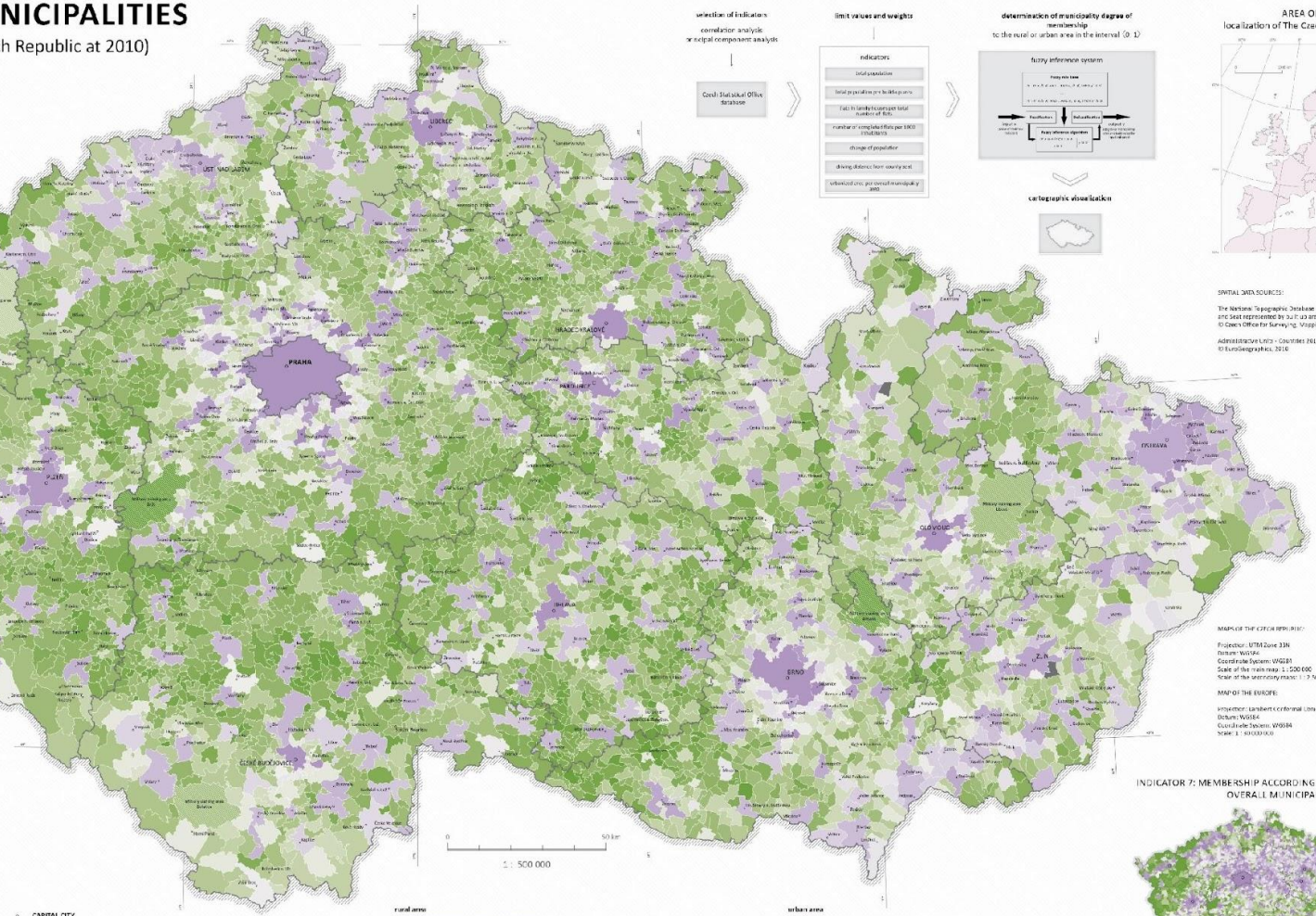
Projection: Lambert conformal conic, central meridian 10°
Datum: WGS84
Coordinate System: WGS84
Scale: 1 : 40 000 000

Table 1: Municipalities with the highest membership to the urban area.

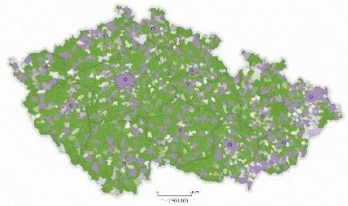
municipality	membership to the urban area
1. Brandýs nad Labem-Stará Boleslav	1.00
2. Ostrov	1.00
3. Čelákovice	0.99
4. Odolena Voda	0.99
5. Hradec	0.98
6. Bucovly	0.98
7. Šlapanice	0.97
8. Jirny u Prahy	0.96
9. Vrapenice	0.96
10. Praha	0.95
11. Vestec	0.95
12. Ústí nad Orlicí	0.94
13. Hlučín	0.94
14. Hradec Králové	0.94
15. Kolovec	0.94
16. Liberec	0.94
17. Olomouc	0.94
18. Ústí nad	0.94
19. Brno	0.93
20. Jihlava	0.93

Table 2: Weights of indicators.

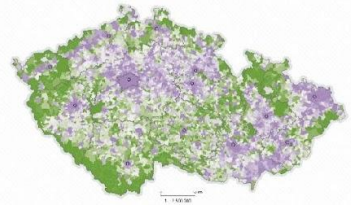
indicator	weight
1. Total population	0.15
2. Total population per built-up area	0.20
3. Flats in family houses per total number of permanently occupied flats	0.20
4. Number of completed flats per 1000 inhabitants	0.10
5. Population change	0.05
6. Driving distance to the county seat	0.10
7. Urbanized area per overall municipality area	0.20
Sum of weights	1.00



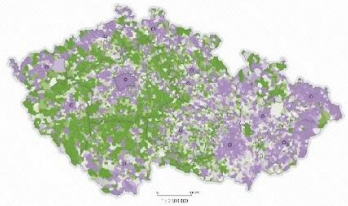
INDICATOR 1: MEMBERSHIP ACCORDING TO THE TOTAL POPULATION



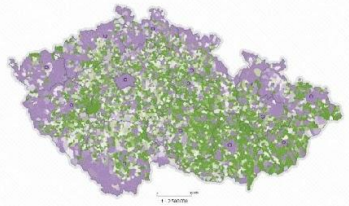
INDICATOR 7: MEMBERSHIP ACCORDING TO THE URBANIZED AREA PER OVERALL MUNICIPALITY AREA



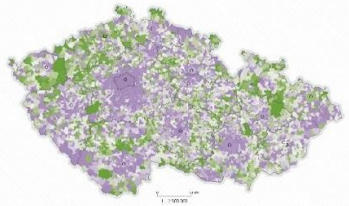
INDICATOR 2: MEMBERSHIP ACCORDING TO THE TOTAL POPULATION PER BUILT-UP AREA



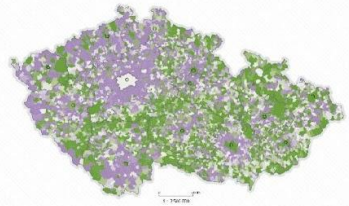
INDICATOR 3: MEMBERSHIP ACCORDING TO FLATS IN FAMILY HOUSES PER TOTAL NUMBER OF PERMANENTLY OCCUPIED FLATS



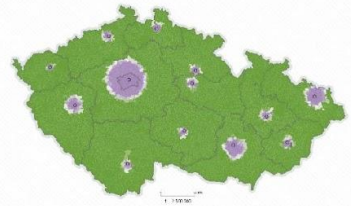
INDICATOR 4: MEMBERSHIP ACCORDING TO THE NUMBER OF COMPLETED FLATS PER 1.000 INHABITANTS



INDICATOR 5: MEMBERSHIP ACCORDING TO THE POPULATION CHANGE

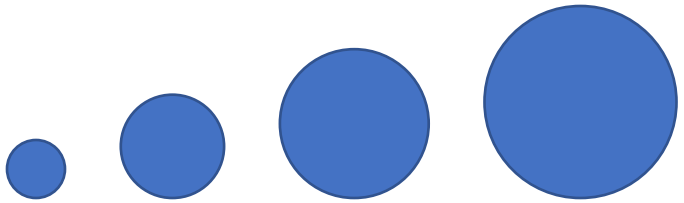


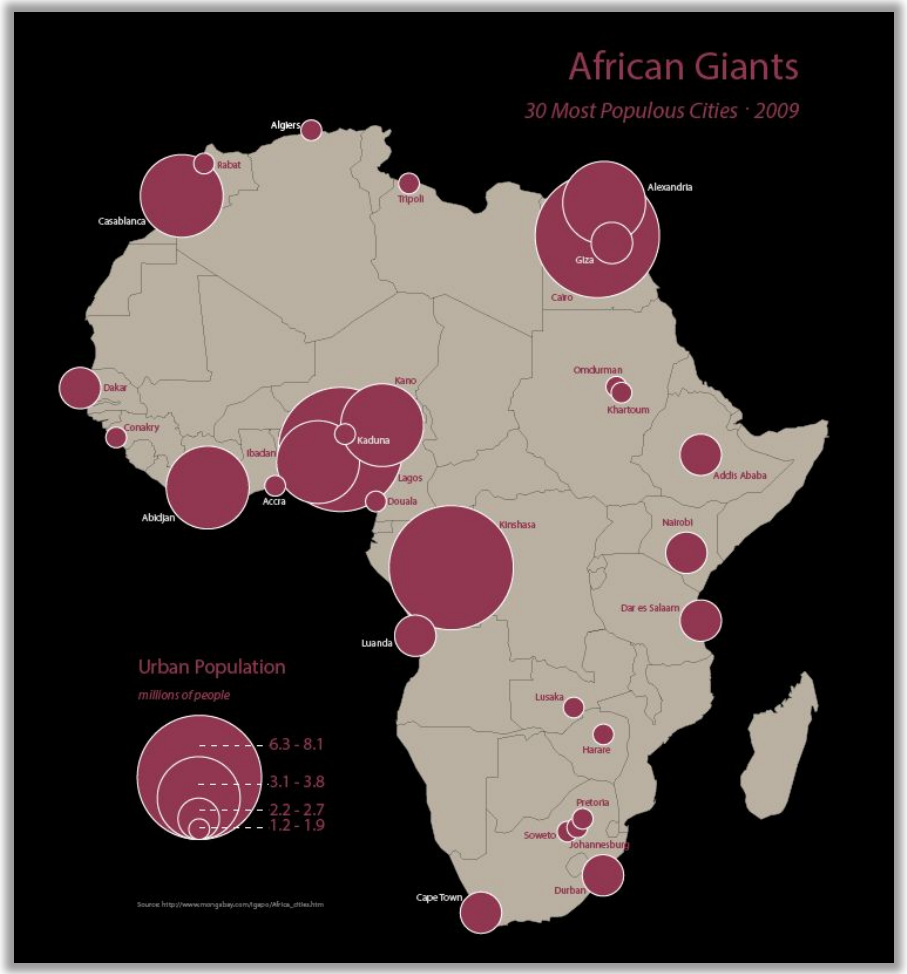
INDICATOR 6: MEMBERSHIP ACCORDING TO THE DRIVING DISTANCE TO THE COUNTY SEAT



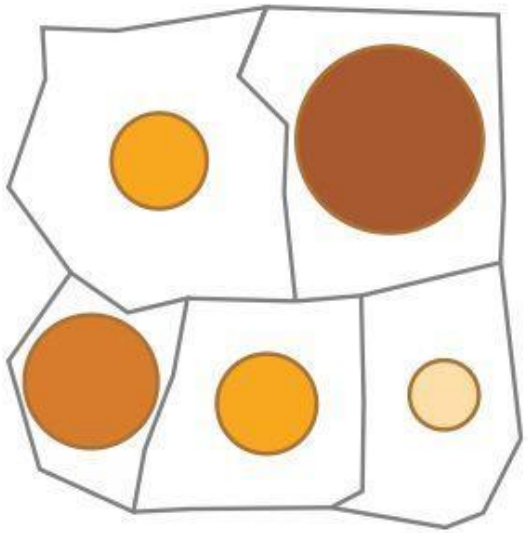
Proportional Symbols Method

- **quantitative data**
- map symbols vary in size
- charts or diagrams
  - pie charts, bar charts, …

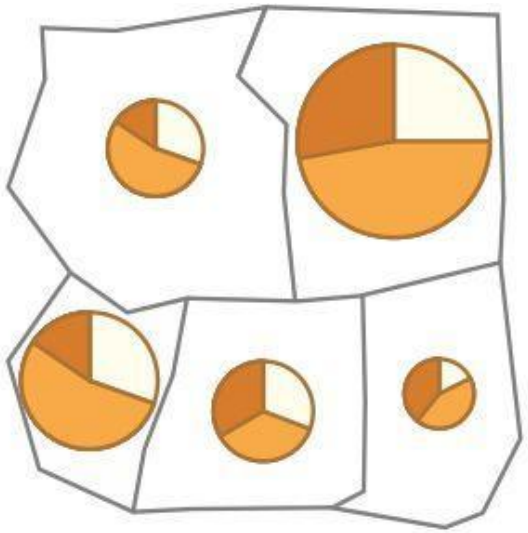




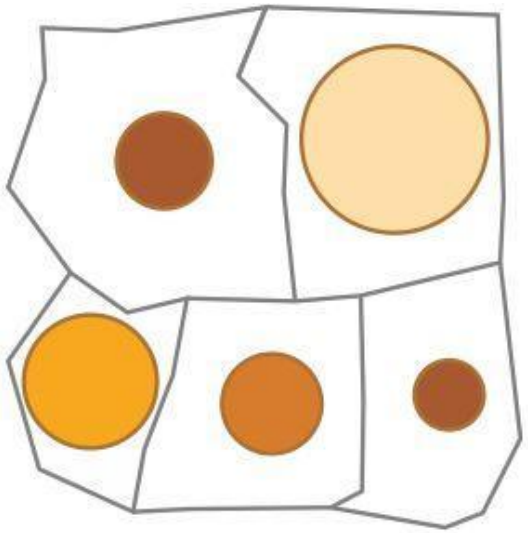
Proportional Symbols Method



POPULATION
SHOWN TWICE
using two visual variables (size and hue) for the same data of total population

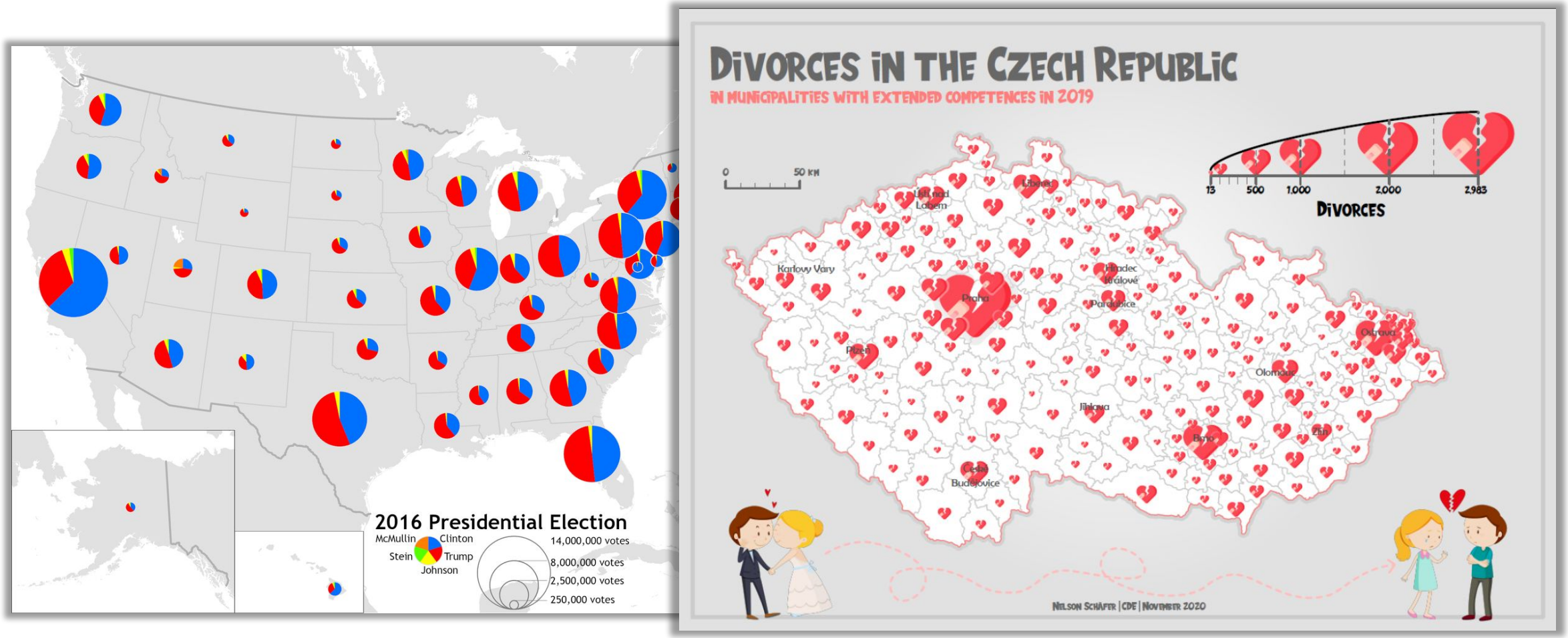


POPULATION
& POPULATION STRUCTURE
with the additional attribute (share of pre-workers, workers and post-workers)



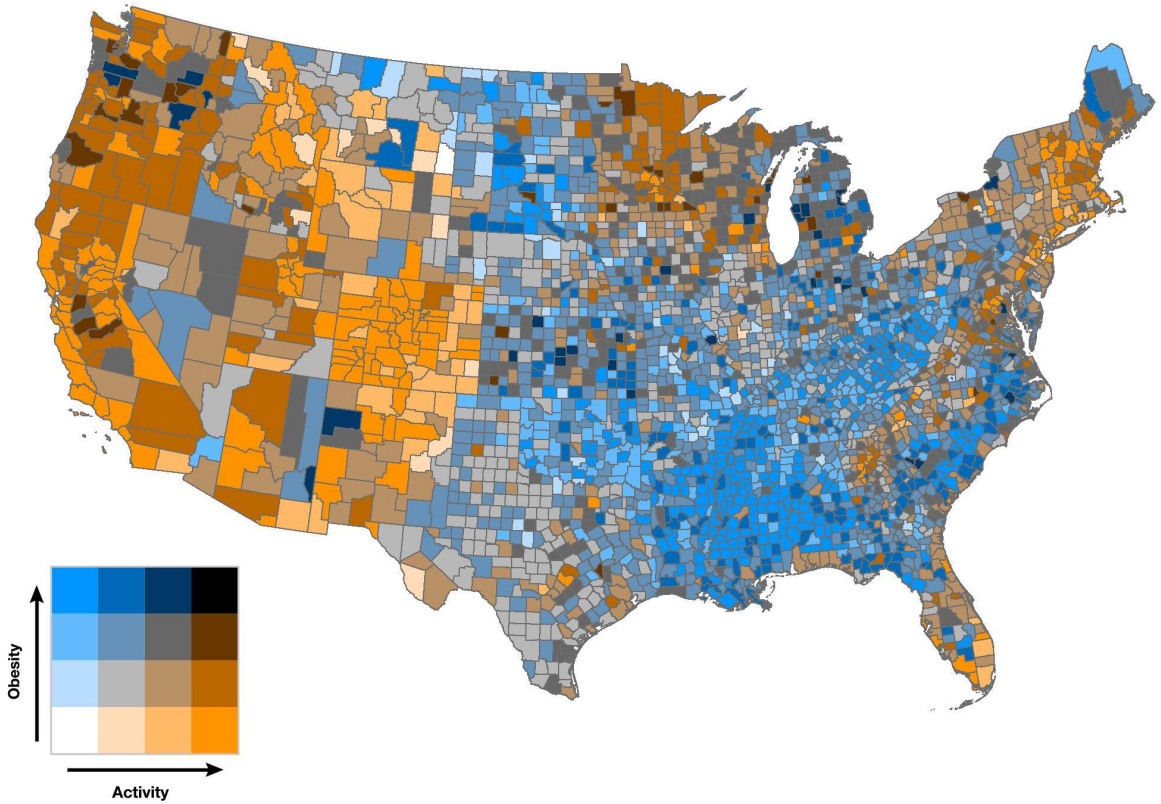
POPULATION
& UNEMPLOYMENT RATE
multivariable map, using two visual variables (size and hue) to show two different but related phenomenons

Proportional Symbols

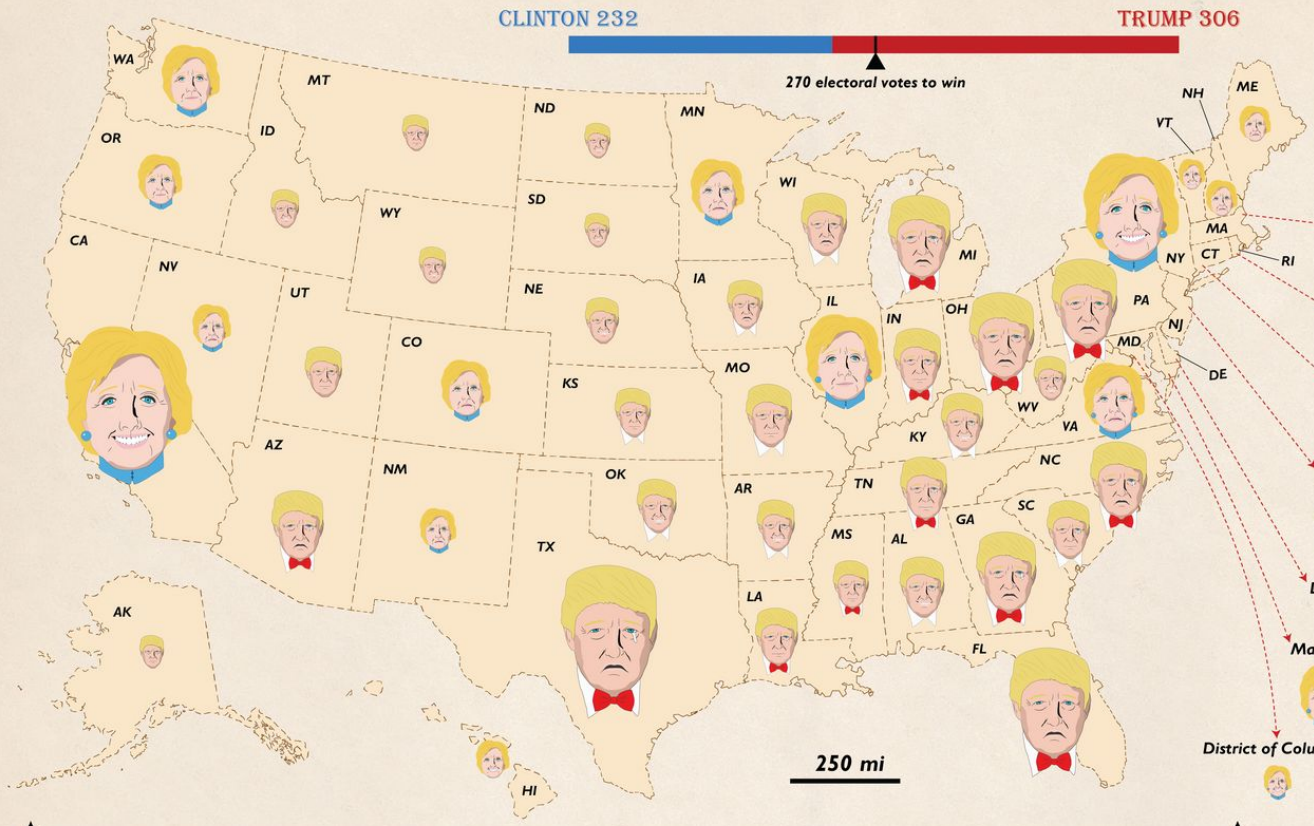


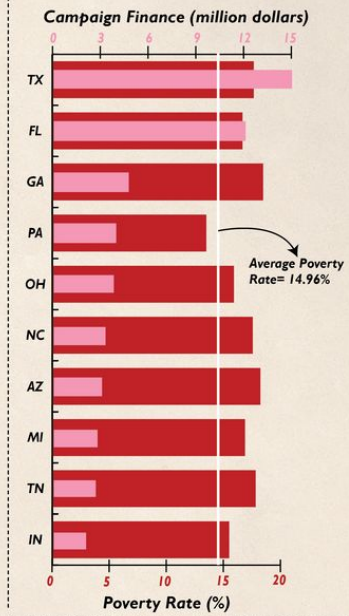
Multivariate Maps

- **quantitative data**
- combining two or more variables
- visualisation of **relationships** between variables
- harder to read and interpret



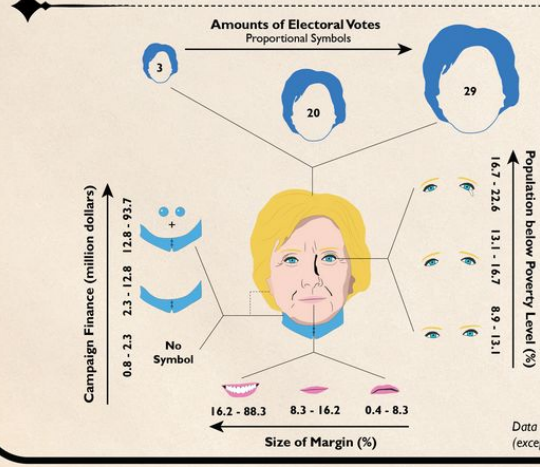
FACING THE YEAR 2016 PRESIDENTIAL ELECTION

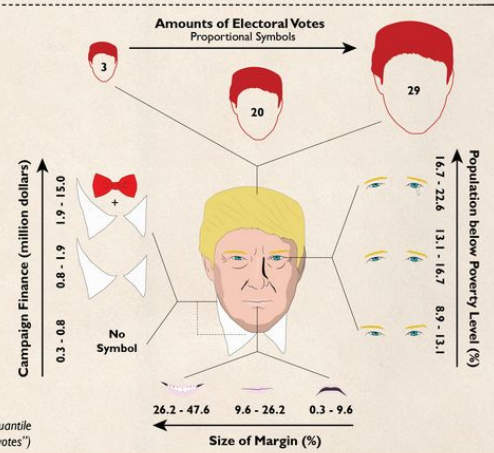




Trump's Tears

*Among the **top 10 states** that provided **the highest campaign donations** for Trump, **9** of the states' poverty rates (population percentage below 1.0 income-poverty ratio) are **higher than the nation's average**. **6 out of the 9** states are in the **southern** or in **southeastern** part of the nation.*
As the President-elect, Trump may need to consider and design policies to solve the economic issues within those regions.

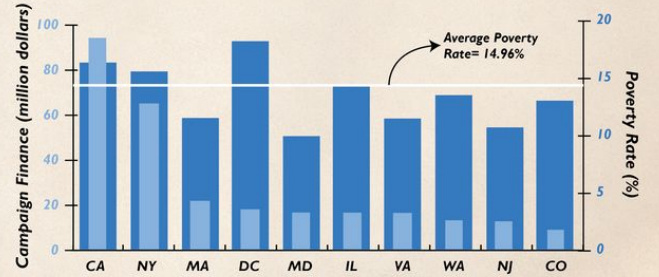




Data Classification Method: Quantile (except "Amount of Electoral votes")

Clinton's Smiles

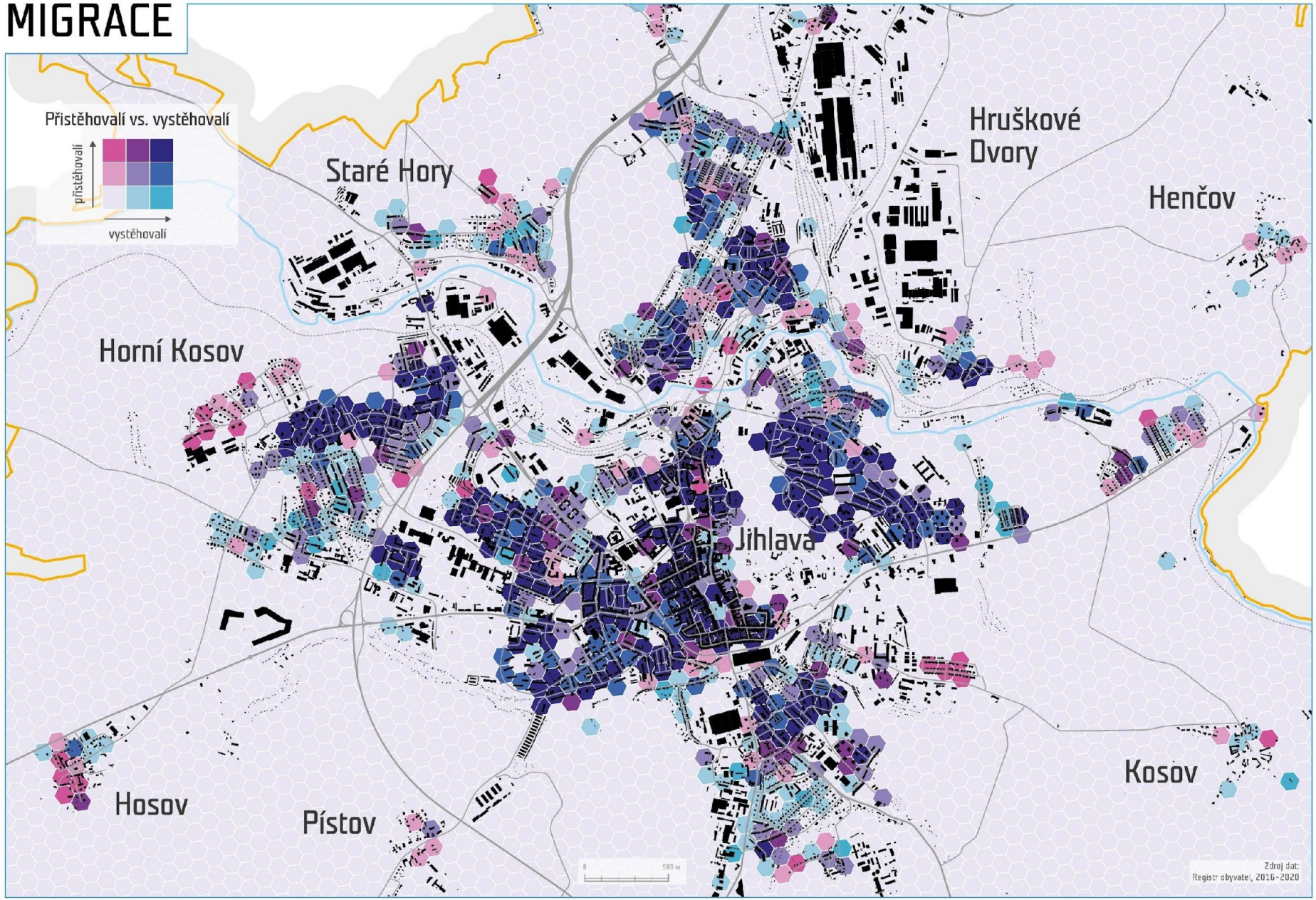
*Within the **top 10 states** that provided for Clinton **the most campaign finances**, **7** of the states's poverty rates are **lower than the nation's average**. **4 out of the 7** states are in **west coast** or in **northeastern** part of the nation, which usually are the regions with relatively higher levels of education and developed tertiary and quarternary sector economy.*



Cartographer: Beichen Tian

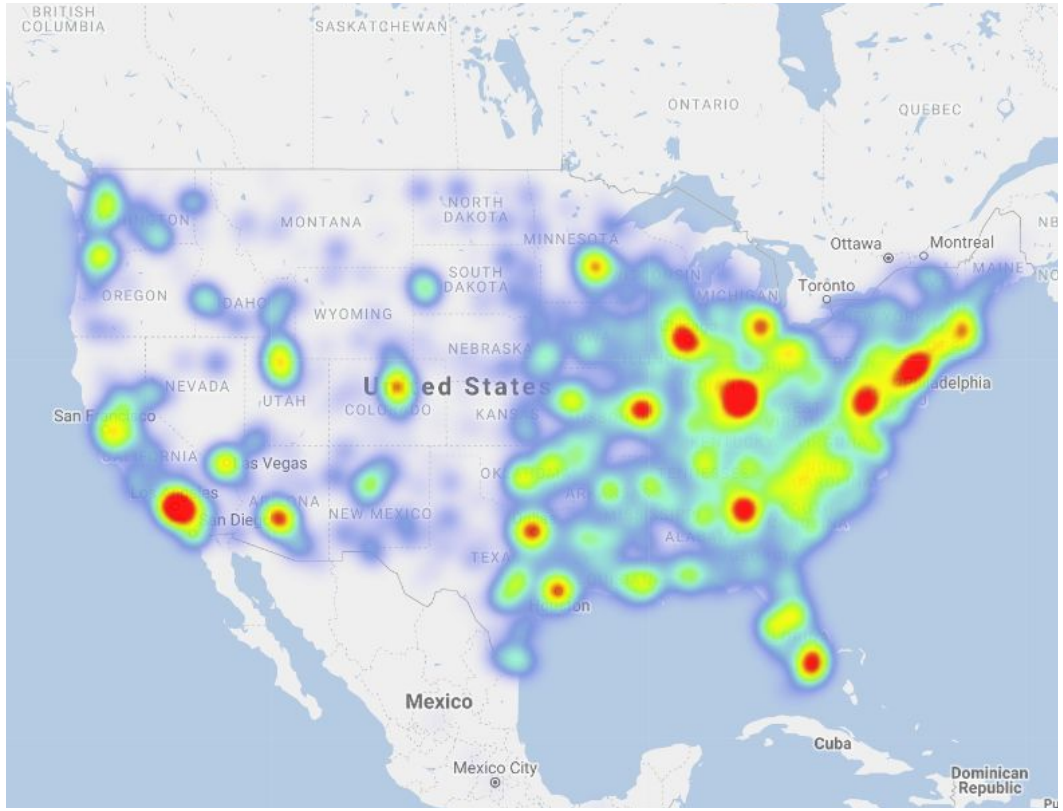
Data Sources: CNN, Federal Election Commission, NHGIS

MIGRACE

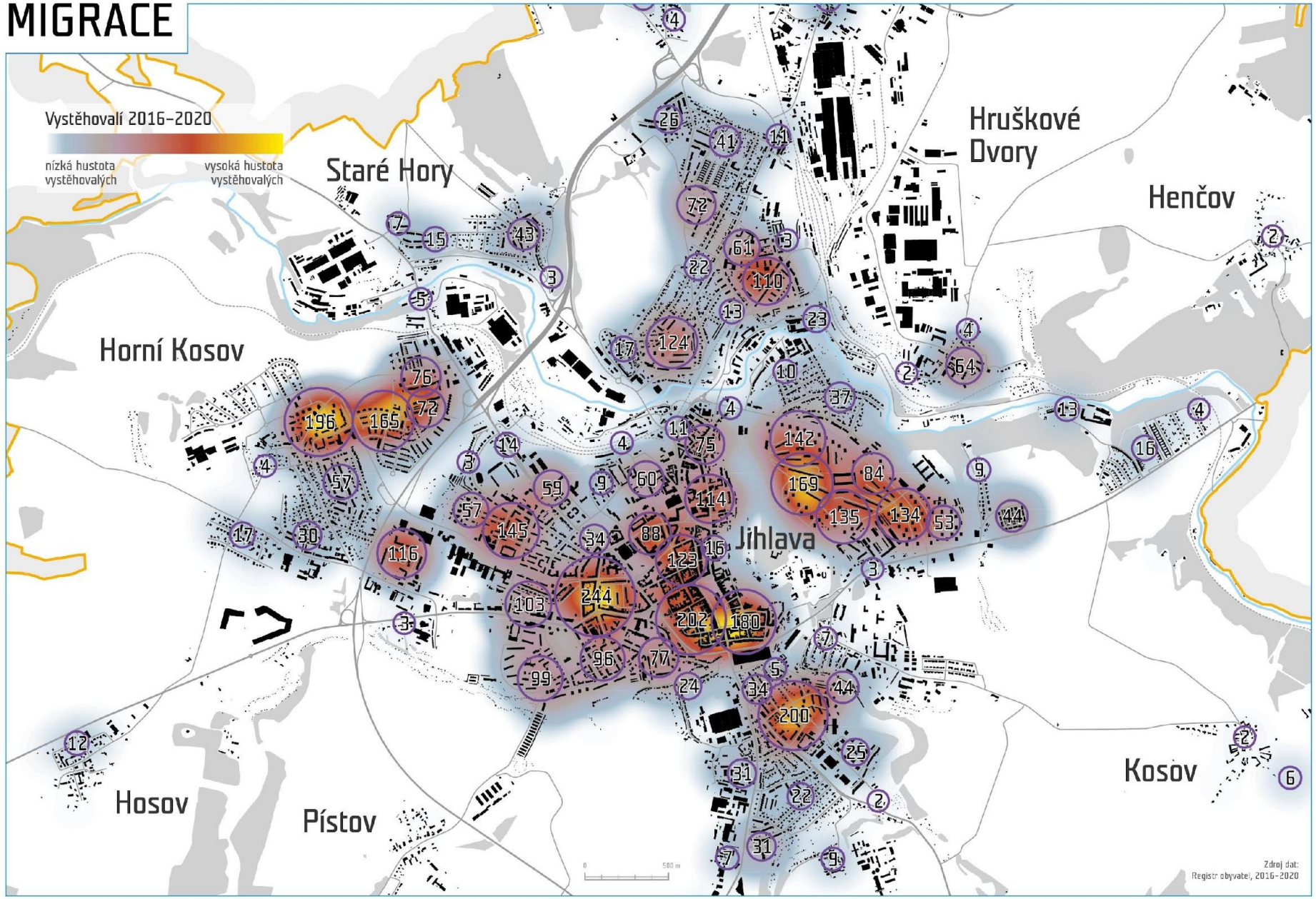

Přistěhovalí vs. vystěhovalí
přistěhovalí
vystěhovalí
Staré Hory
Hruškové Dvory
Henčov
Horní Kosov
Jihlava
Hosov
Pístov
Kosov
0
500 m
Zdroj dat:
Registr obyvatel, 2016–2020

Heat Maps

- **quantitative data**
- visualization of the **density** of the phenomenon
- values expressed by **colour gradient**
- for quick data preview
- clusters

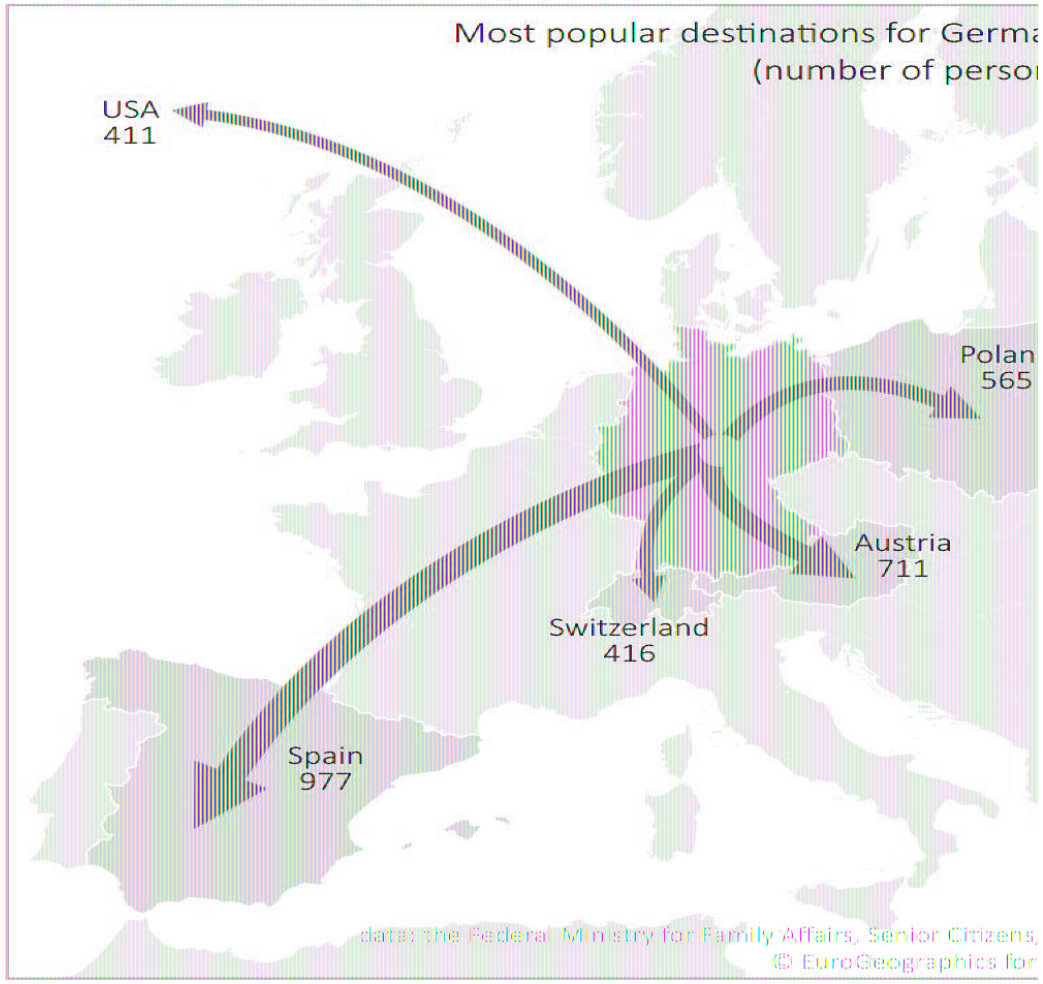


MIGRACE

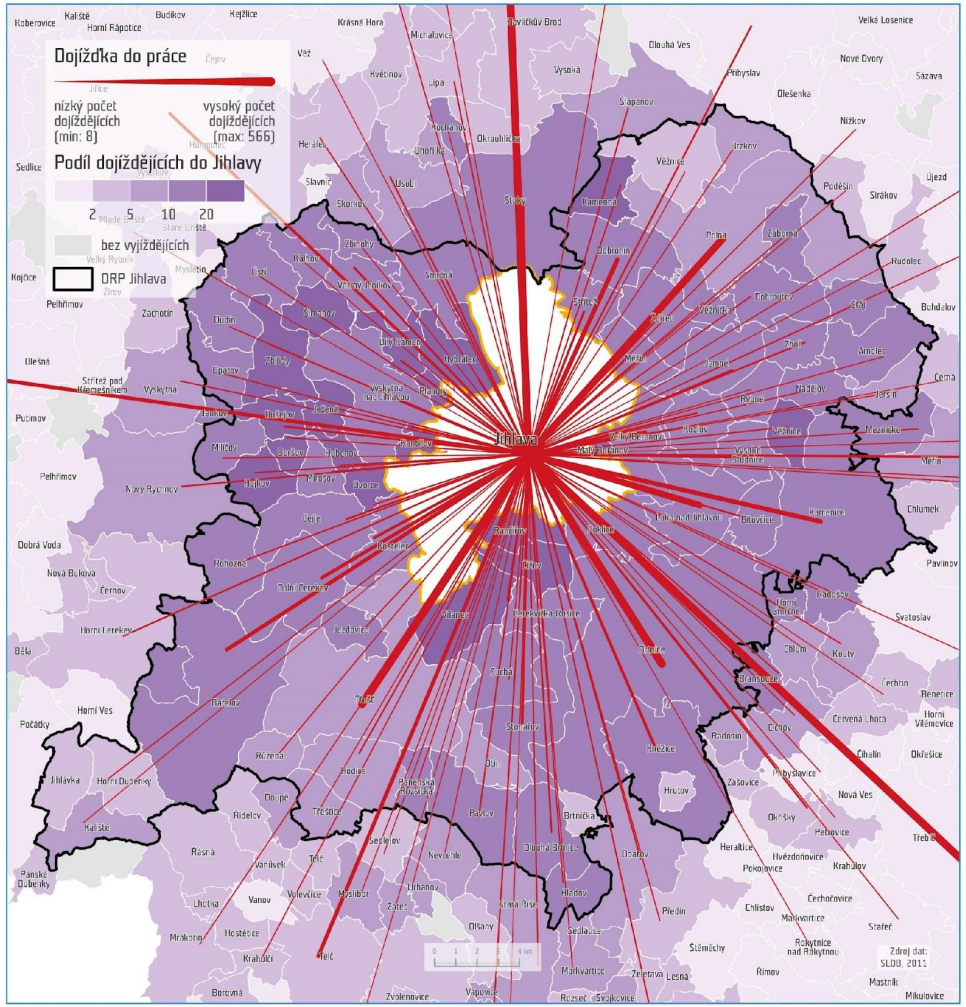

Vystěhovalí 2016–2020
nízká hustota vystěhovalých
vysoká hustota vystěhovalých
Staré Hory
Hruškové Dvory
Henčov
Horní Kosov
Jihlava
Hosov
Pístov
Kosov
0
500 m
Zdroj dat:
Registr obyvatel, 2016–2020

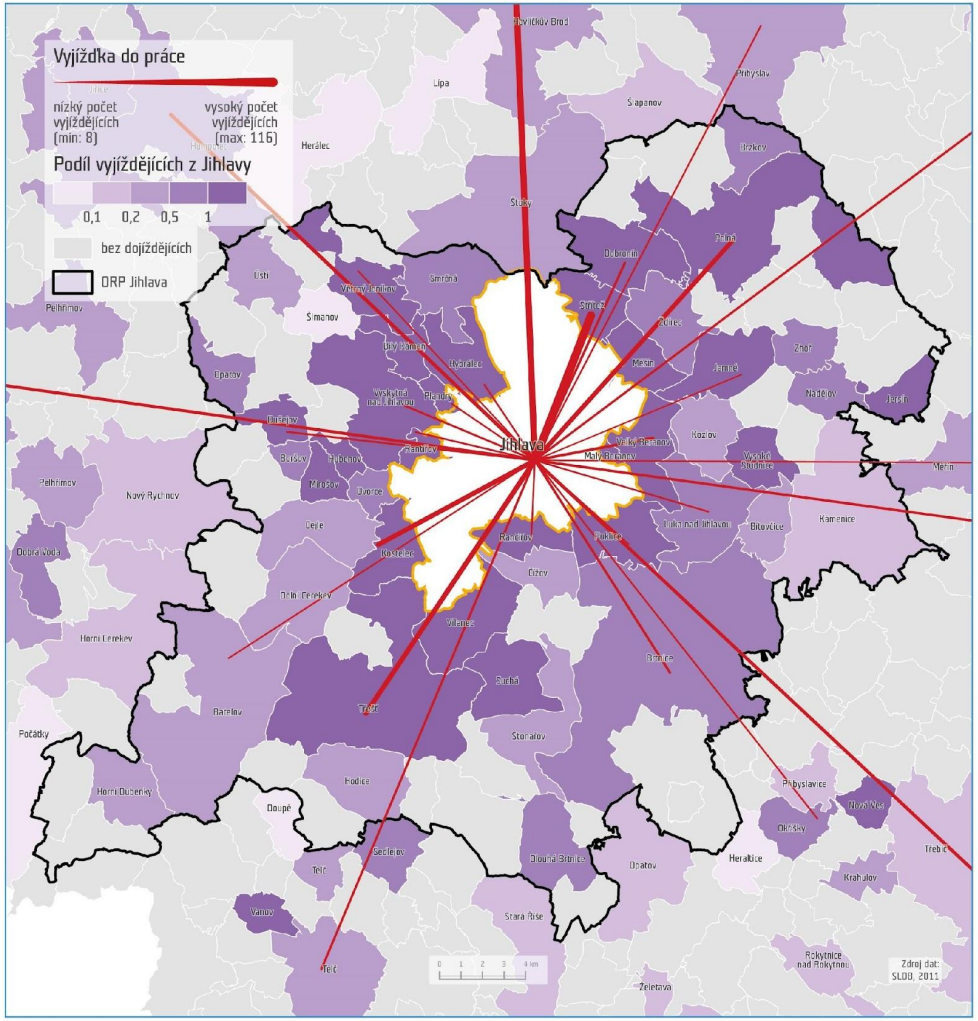
Flow Maps

- **quantitative data**
- represents the direction and/or magnitude of a phenomenon
- lines can represent a real course or a generalized schematic connection

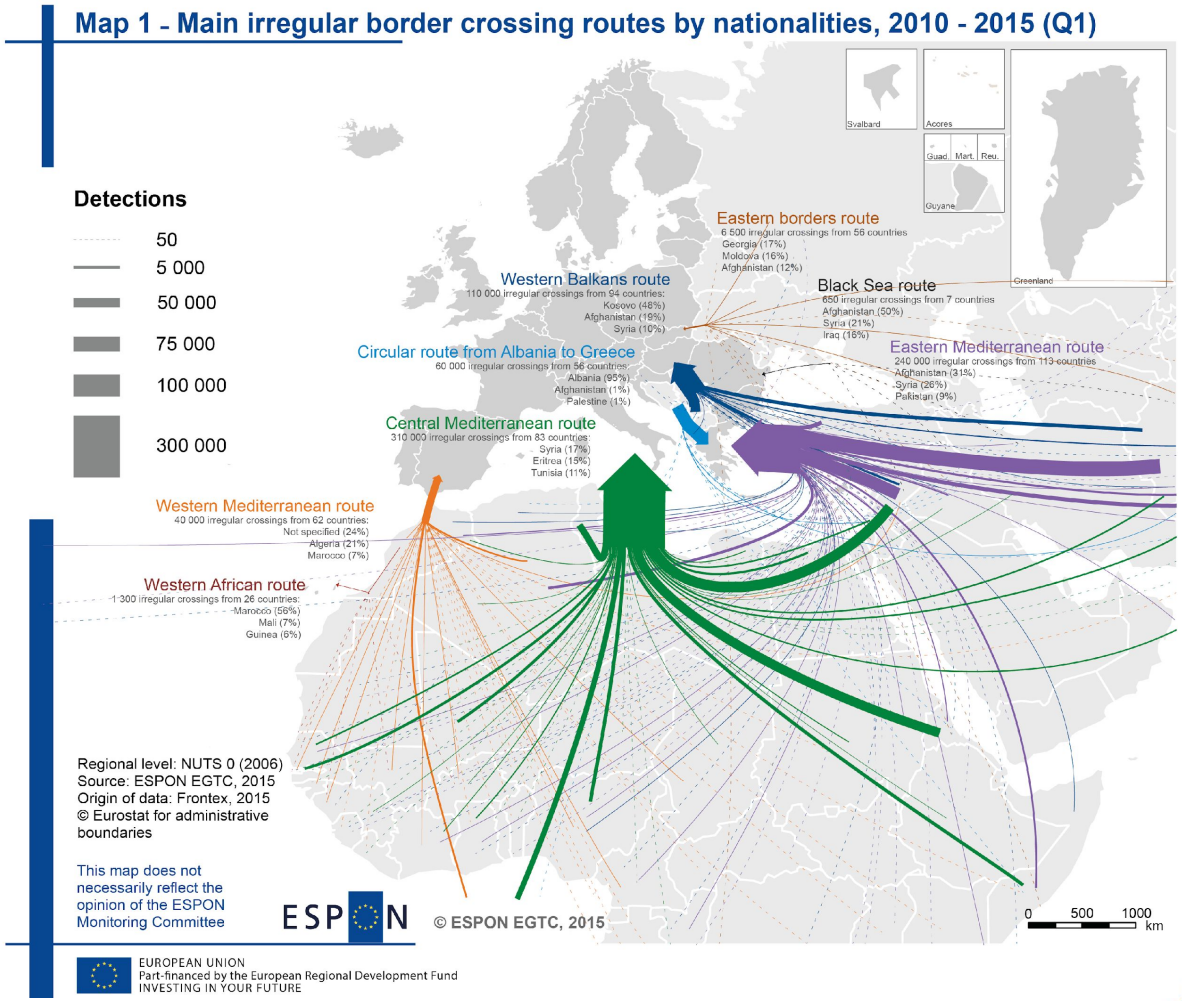


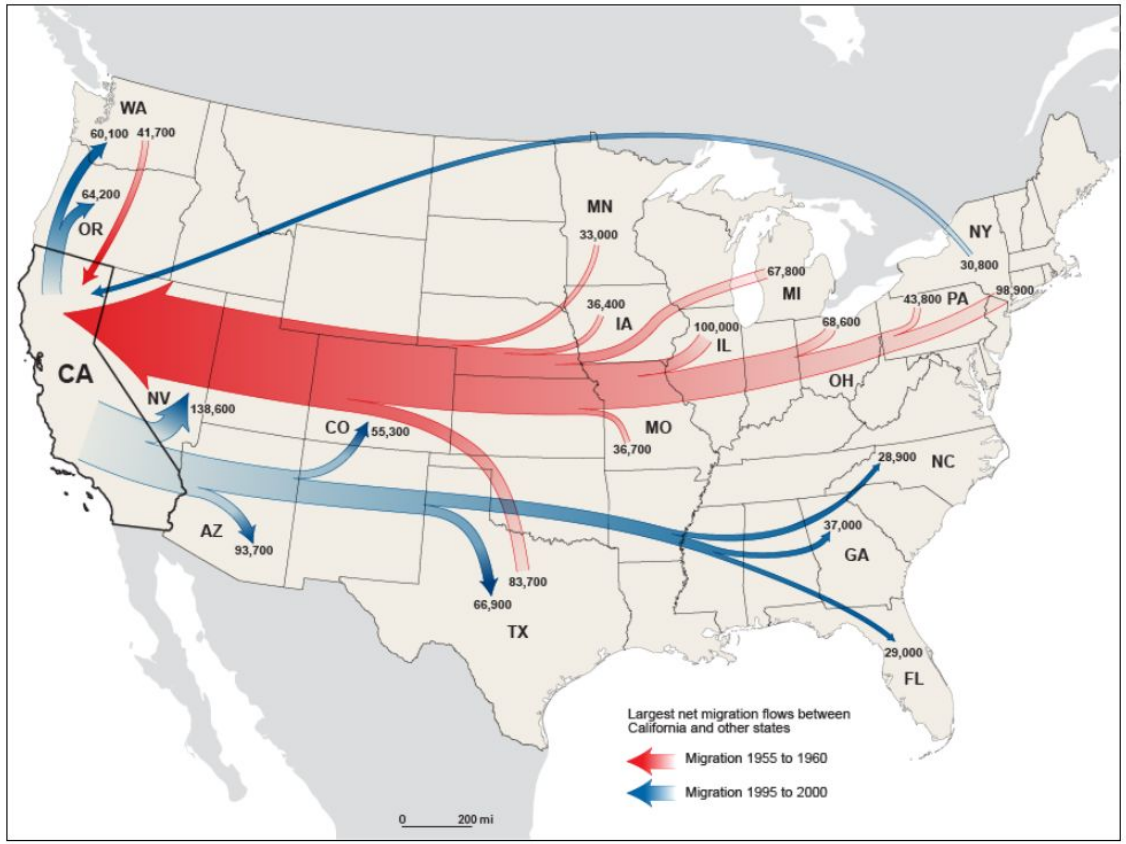
Flow Maps – Suburbanization





Flow Maps – Migration

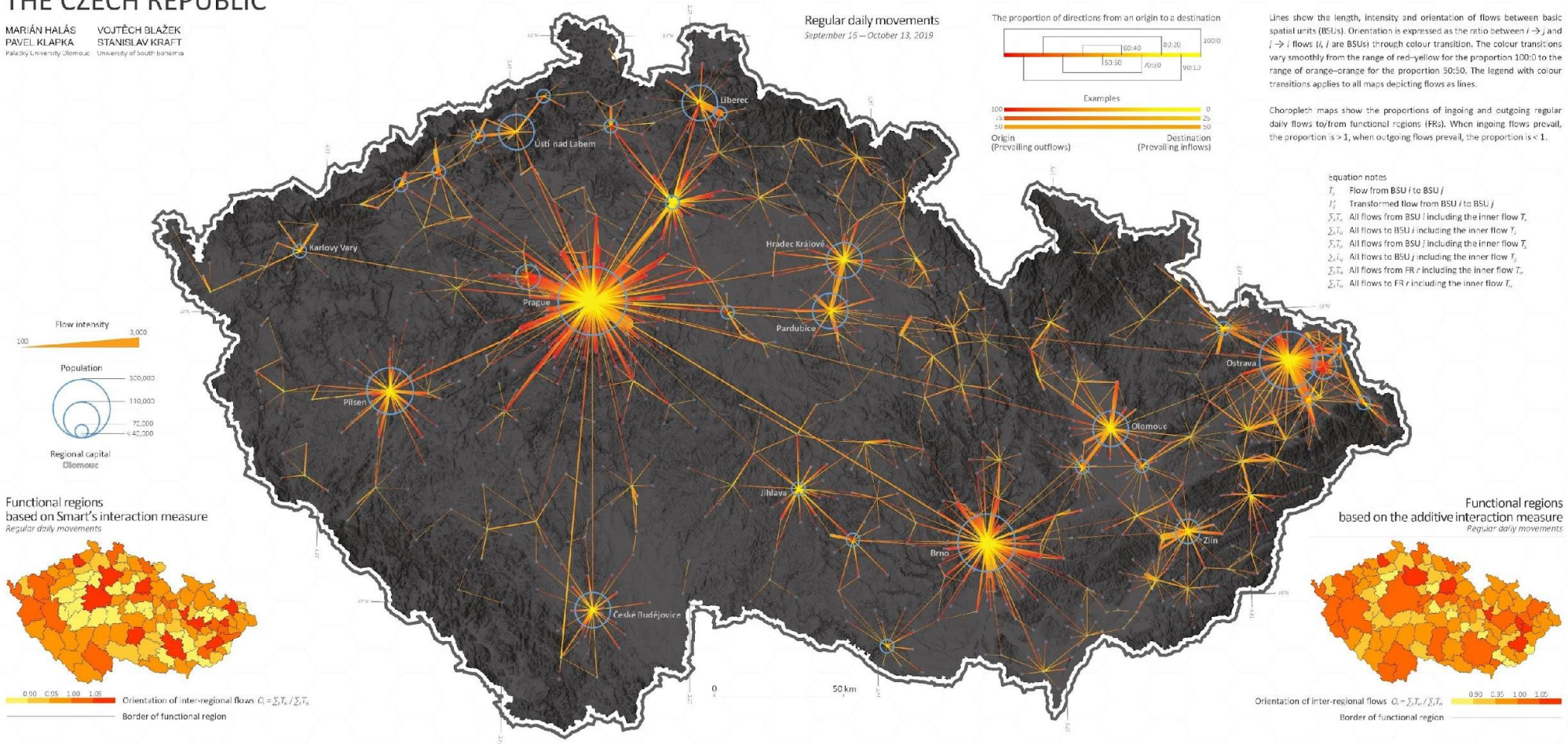




POPULATION MOVEMENTS BASED ON MOBILE PHONE LOCATION DATA

THE CZECH REPUBLIC

MARIÁN HALÁS, PAVEL KLAPKA — Palacký University Olomouc
VOJTĚCH BLAŽEK, STANISLAV KRAFT — University of South Bohemia



Lines show the length, intensity and orientation of flows between basic spatial units (BSUs). Orientation is expressed as the ratio between $i \rightarrow j$ and $j \rightarrow i$ flows (i, j are BSUs) through colour transition. The colour transitions vary smoothly from the range of red–yellow for the proportion 100:0 to the range of orange–orange for the proportion 50:50. The legend with colour transitions applies to all maps depicting flows as lines.

Choropleth maps show the proportions of ingoing and outgoing regular daily flows to/from functional regions (FRs). When ingoing flows prevail, the proportion is > 1, when outgoing flows prevail, the proportion is < 1.

Equation notes

- T_{ij} Flow from BSU i to BSU j
- T'_{ij} Transformed flow from BSU i to BSU j
- $\sum_j T_{ij}$ All flows from BSU i including the inner flow T_{ii}
- $\sum_i T_{ij}$ All flows to BSU i including the inner flow T_{ii}
- $\sum_j T_{ij}$ All flows from BSU j including the inner flow T_{jj}
- $\sum_i T_{ij}$ All flows to BSU j including the inner flow T_{jj}
- $\sum_r T_{rs}$ All flows from FR r including the inner flow T_{rr}
- $\sum_s T_{rs}$ All flows to FR r including the inner flow T_{rr}

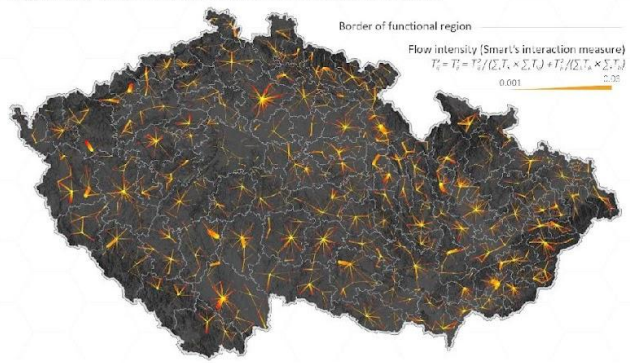
Functional regions based on Smart's interaction measure

Regular daily movements

Functional regions based on the additive interaction measure

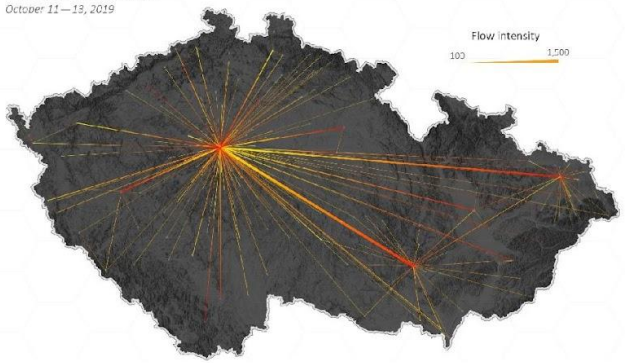
Regular daily movements

Regular daily movements based on Smart's interaction measure

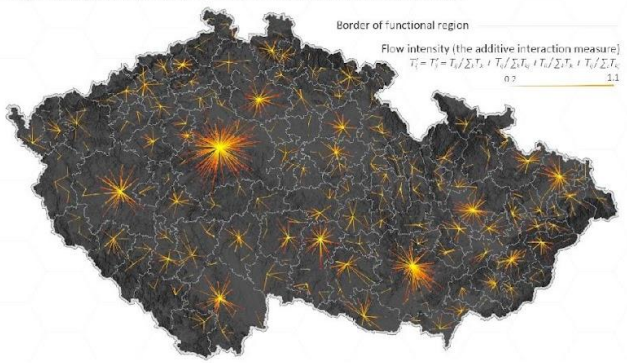


Weekend movements

October 11 — 13, 2019

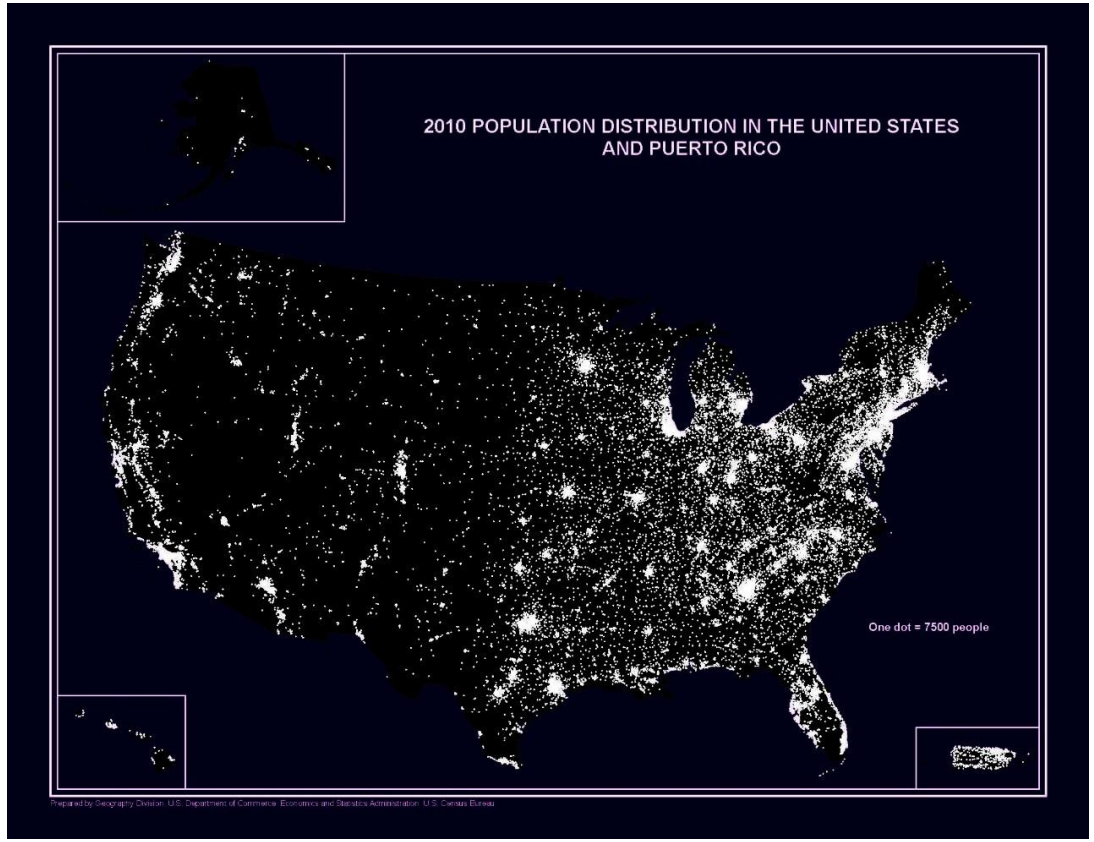


Regular daily movements based on the additive interaction measure

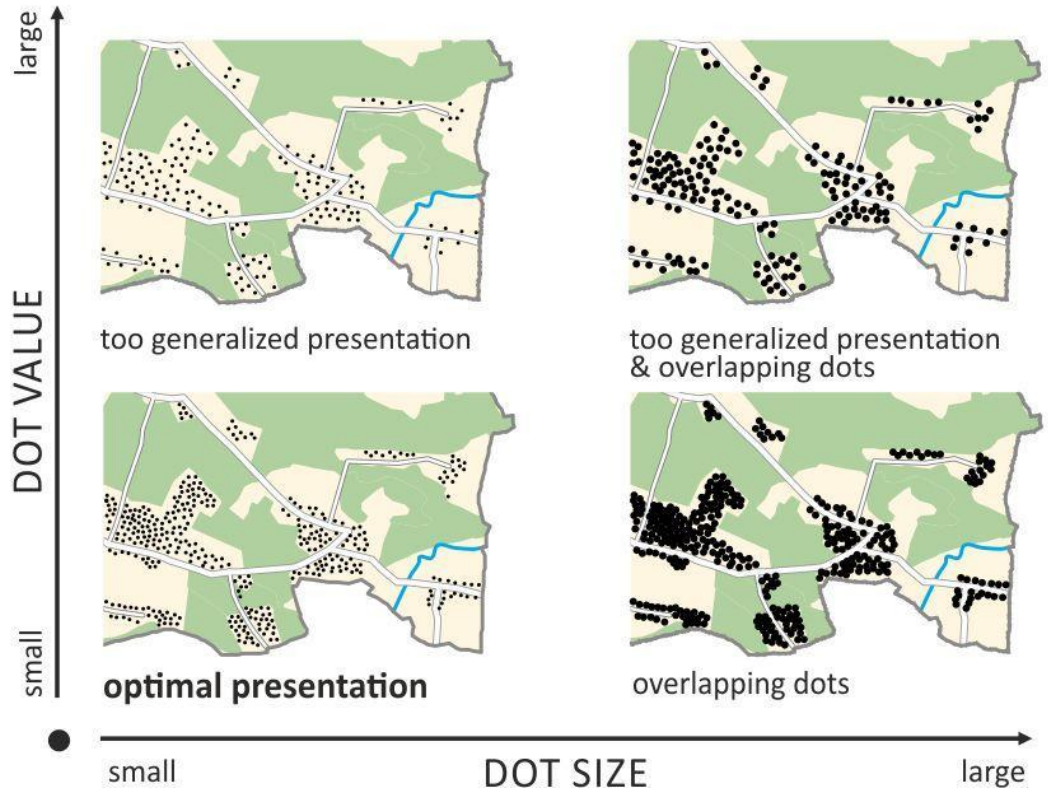


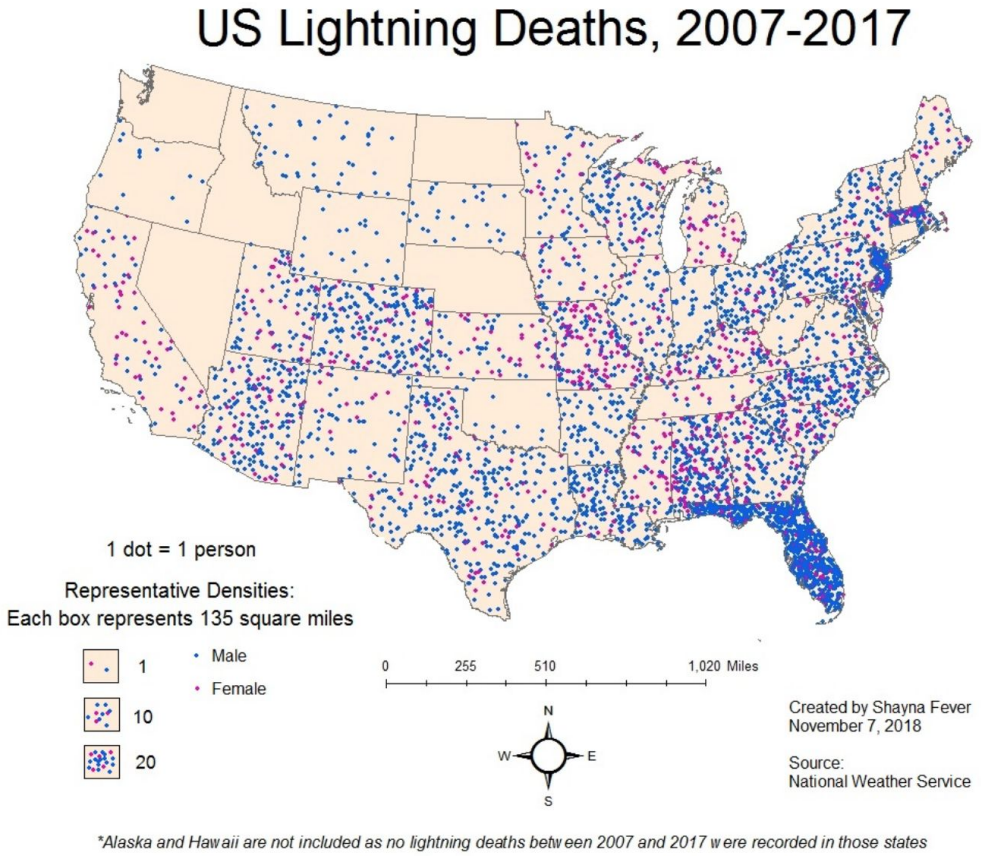
Dot (Density) Maps

- **quantitative data**
- each dot represents an amount of the mapped attribute
- visualizing distribution of density of a phenomenon
- dot value × dot size



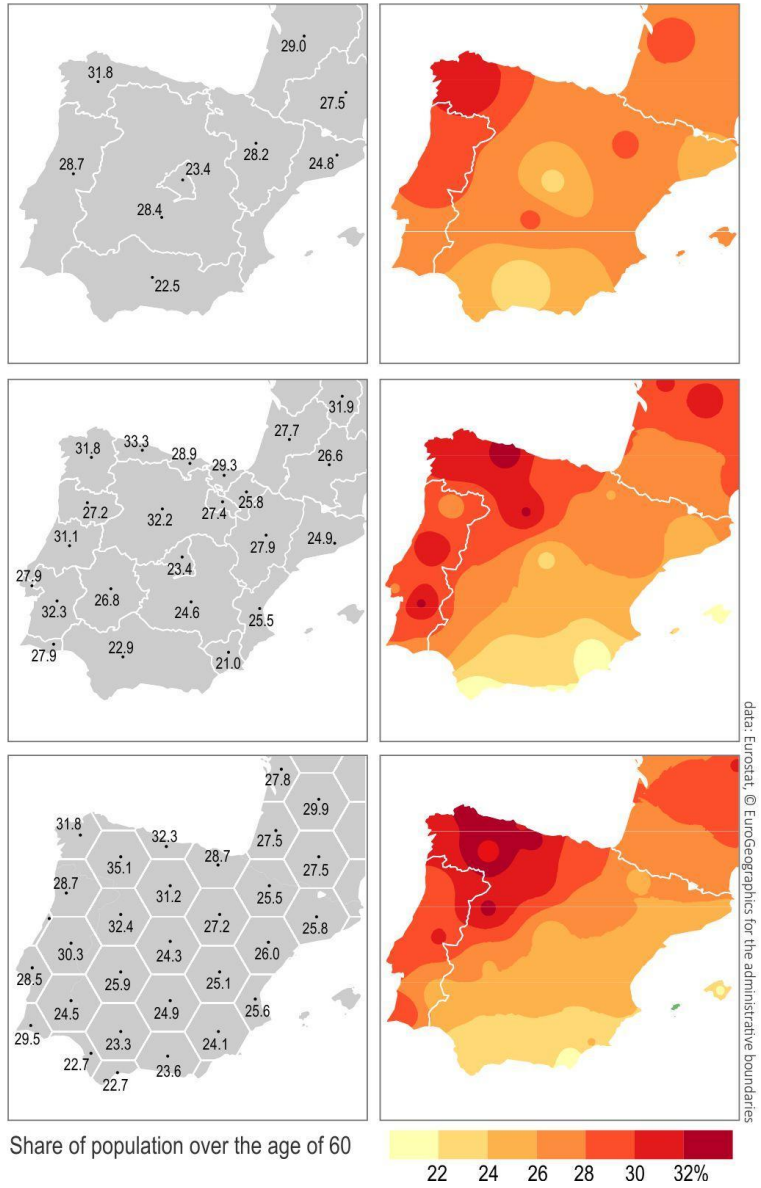
Dot (Density) Maps





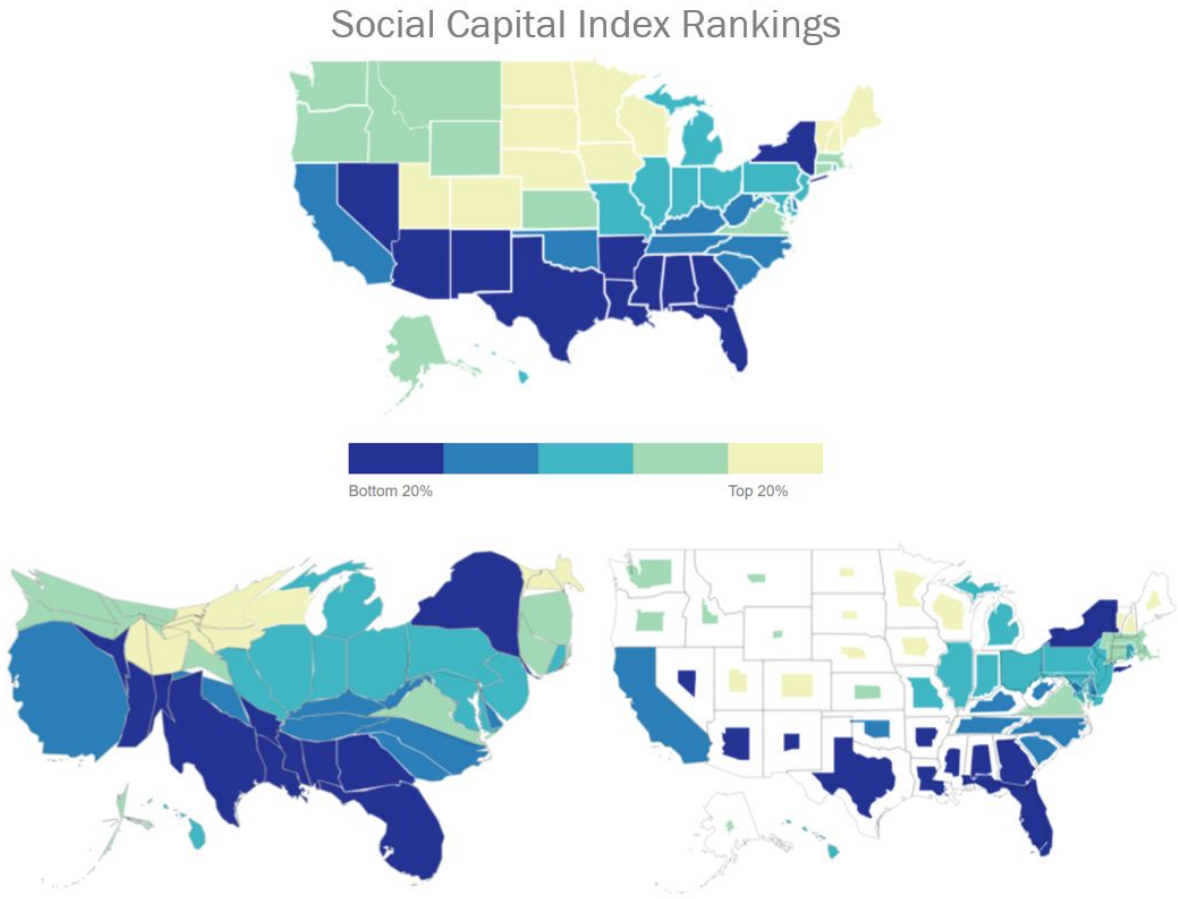
Isoline Maps

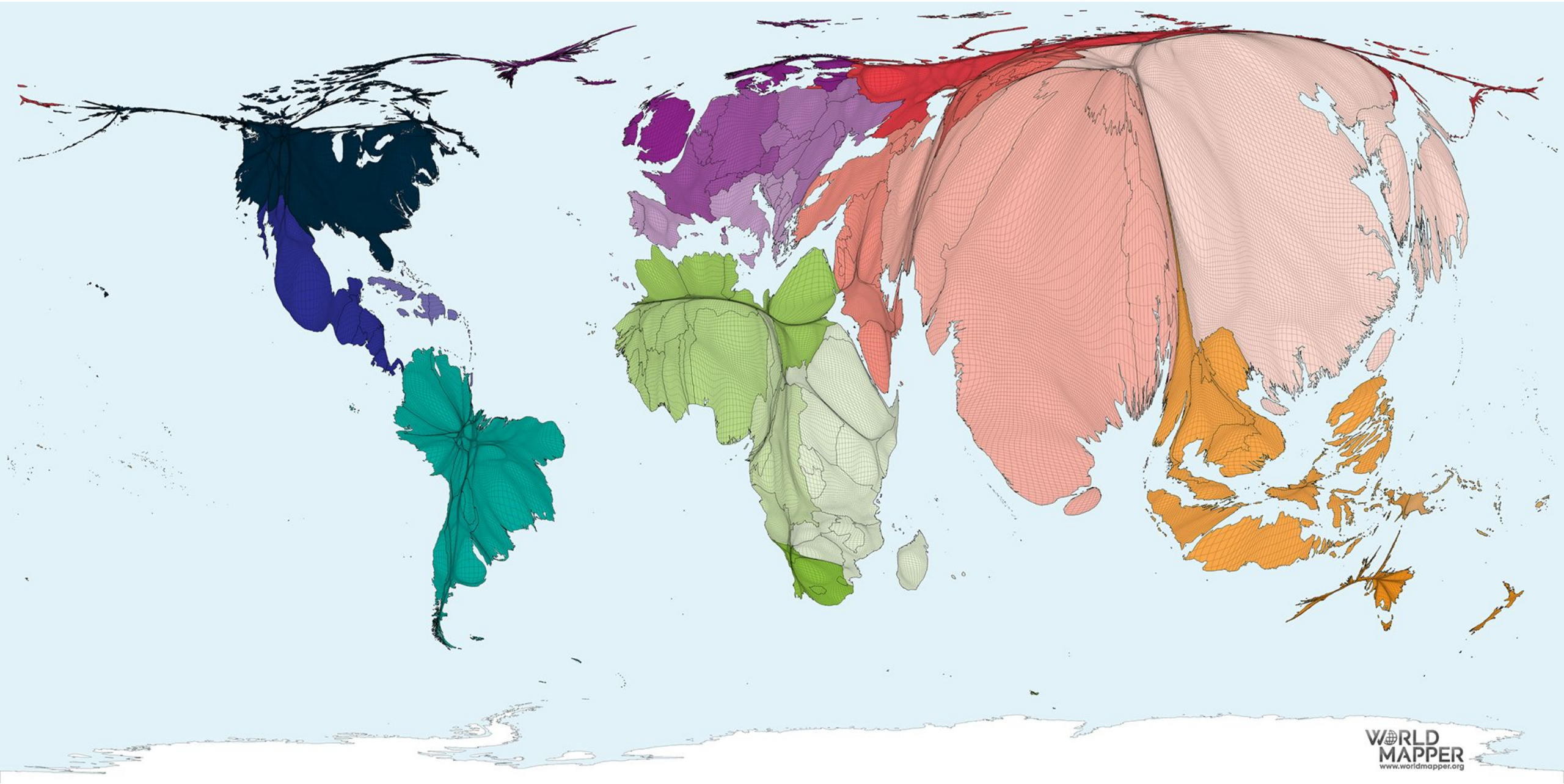
- **quantitative data**
- represents data with **lines** derived through **interpolation**
- connects points of equal attribute value on a map
- more use in physical geography (terrain, meteorological variables)



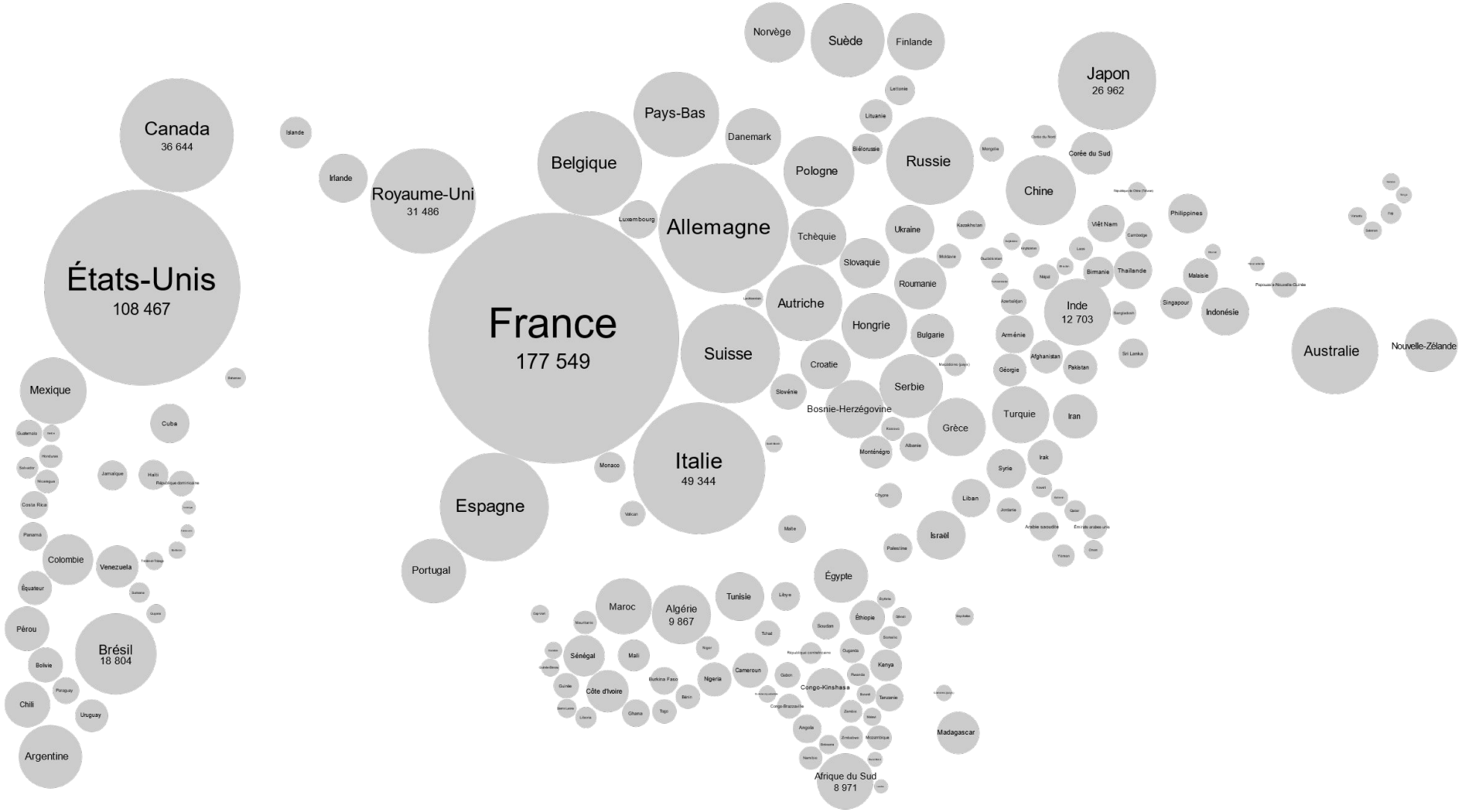
Cartogram Method

- **quantitative data**
- **geographic size is altered** to be directly proportional to a selected variable
- unlike other methods, it **changes shape** instead of map symbols
- abstract




WORLD
MAPPER
www.worldmapper.org

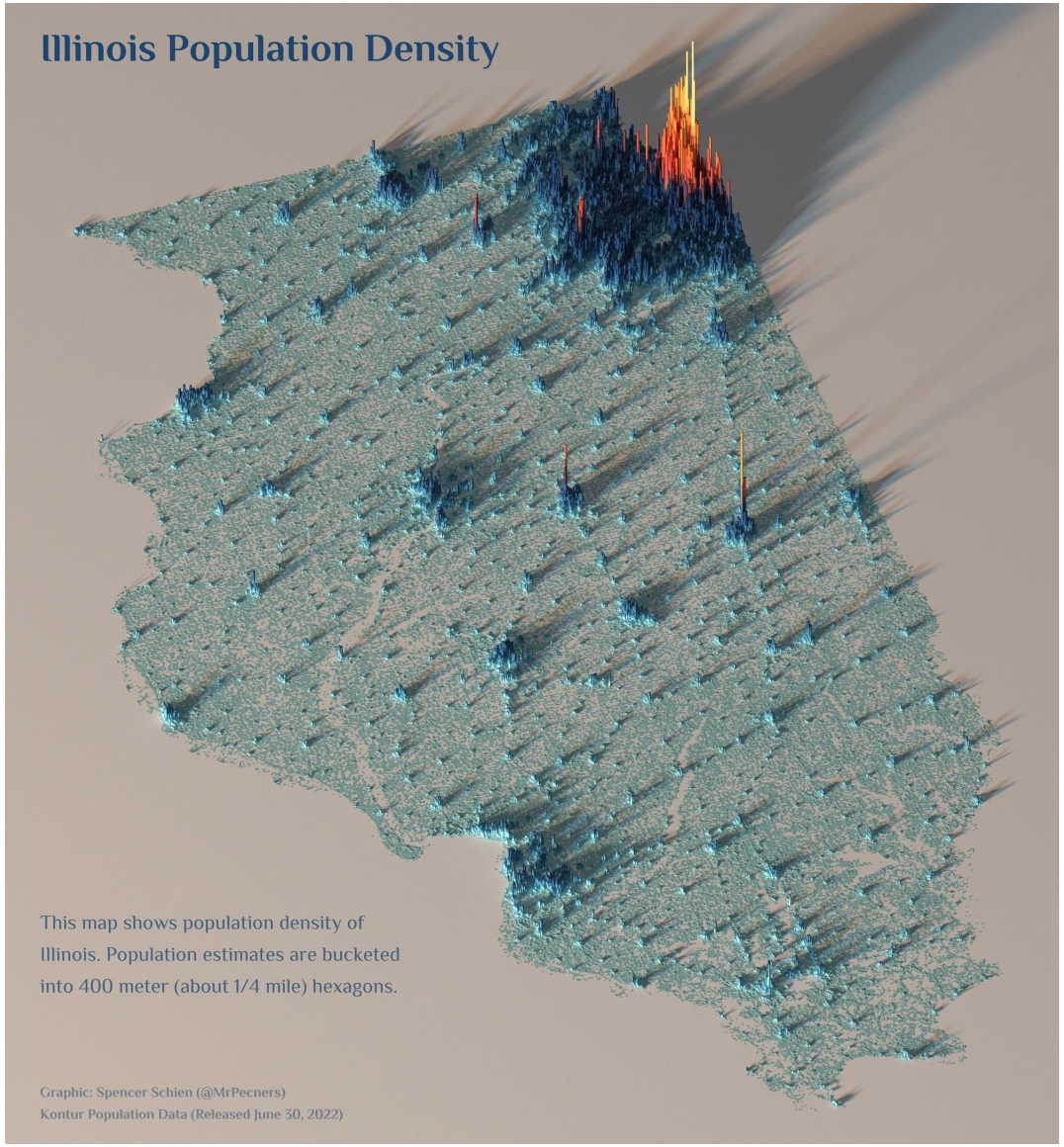
Carte proportionnelle au nombre de liens vers les articles de pays (2011-07)



Comparatif avec le nombre de liens vers les quelques articles de villes

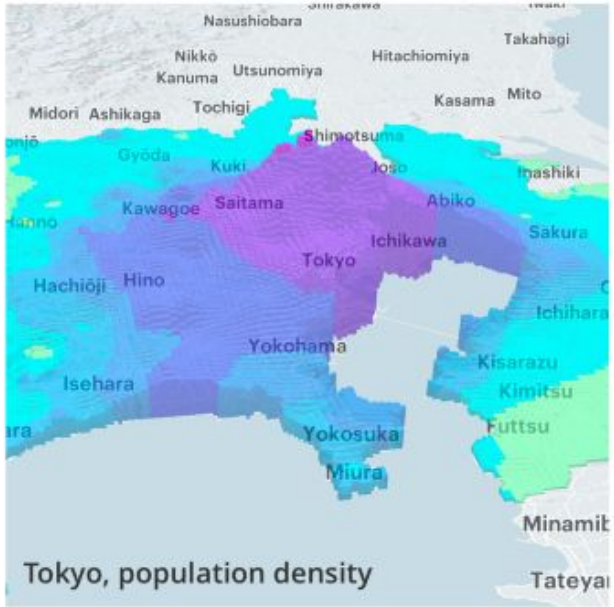
3D Visualizations

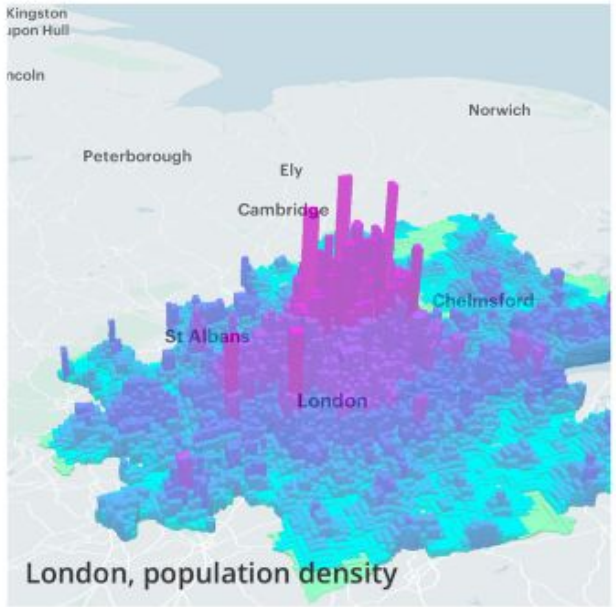
- **qualitative and quantitative data**
- unconventional visualizations
- interactivity and animations
- analog × digital
- 3D printing

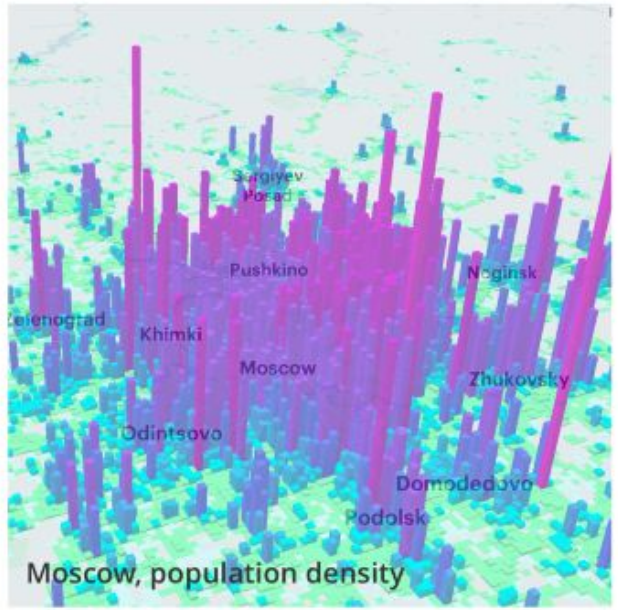


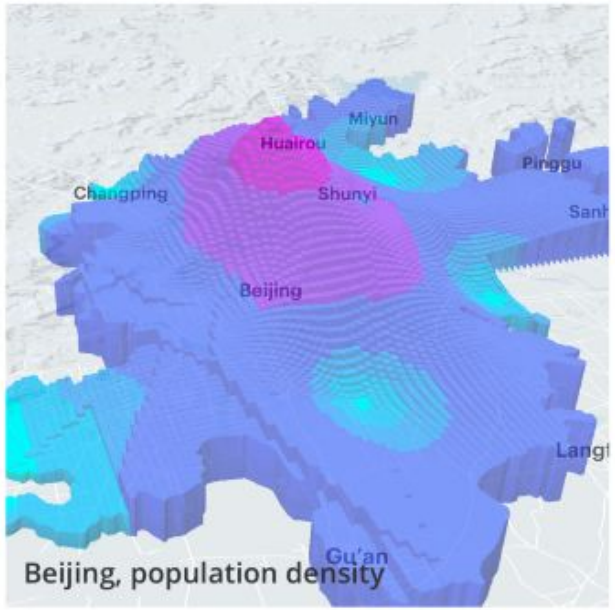

IPR PRAHA
3D model Prahy
MALÁ STRANA
JOSEFOV
NOVÉ MĚSTO
VINOHRADY
VYŠEHRAD


IPR Praha
3D model Prahy
NOVE MĚSTO
VINOHRADY
VYŠEHRAD
NUSLE

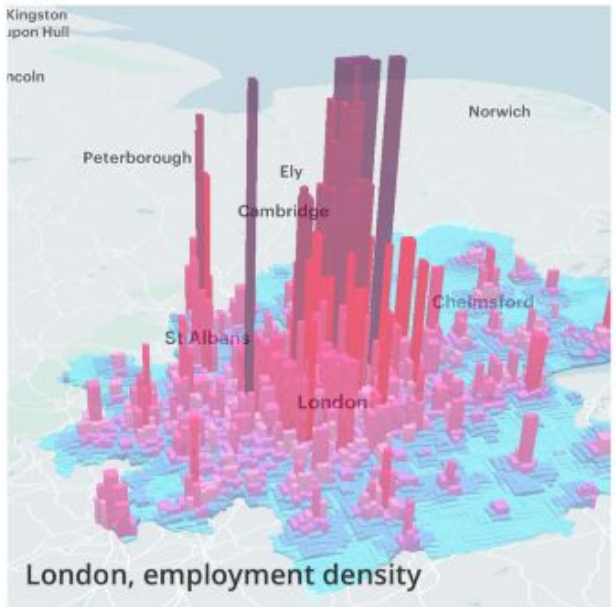

Nasushiobara
Takahagi
Nikkō
Hitachiomiya
Kanuma
Utsunomiya
Midori
Ashikaga
Tochigi
Kasama
Mito
Shimotsuma
Gyōda
Kuki
Joso
Inashiki
Kawagoe
Saitama
Abiko
Sakura
Ichikawa
Tokyo
Hachiōji
Hino
Ichihara
Yokohama
Kisarazu
Isehara
Kimitsu
Futtsu
Yokosuka
Miura
Minamib
Tateya
Tokyo, population density

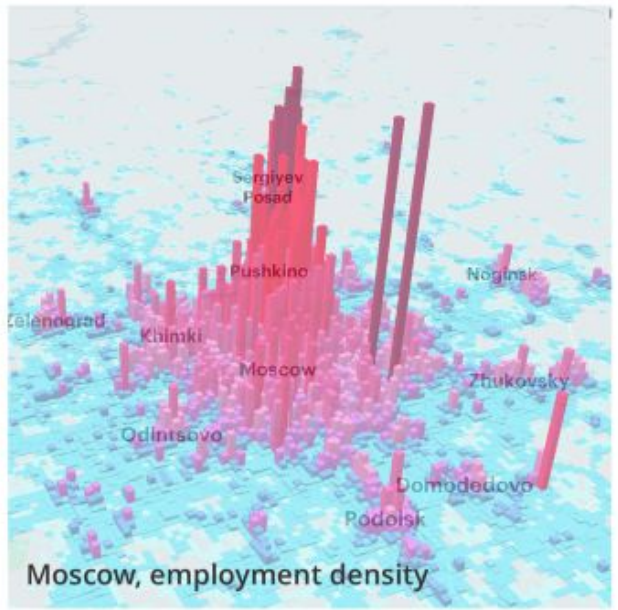

Kingston upon Hull
Norwich
Peterborough
Ely
Cambridge
Chelmsford
St Albans
London
London, population density


Sergiyev Posad
Pushkino
Noginsk
Zelenograd
Khimki
Moscow
Zhukovsky
Odintsovo
Domodedovo
Podolsk
Moscow, population density


Miyun
Huairou
Pinggu
Changping
Shunyi
Beijing
Gu'an
Beijing, population density


Nasushiobara
Takahagi
Nikkō
Hitachiomiya
Kanuma
Utsunomiya
Midori
Ashikaga
Tochigi
Kasama
Mito
Shimotsuma
Gyōda
Kuki
Joso
Inashiki
Kawagoe
Saitama
Abiko
Sakura
Ichikawa
Tokyo
Hachiōji
Hino
Ichihara
Yokohama
Kisarazu
Isehara
Kimitsu
Futtsu
Yokosuka
Miura
Minamib
Tateya
Tokyo, employment density

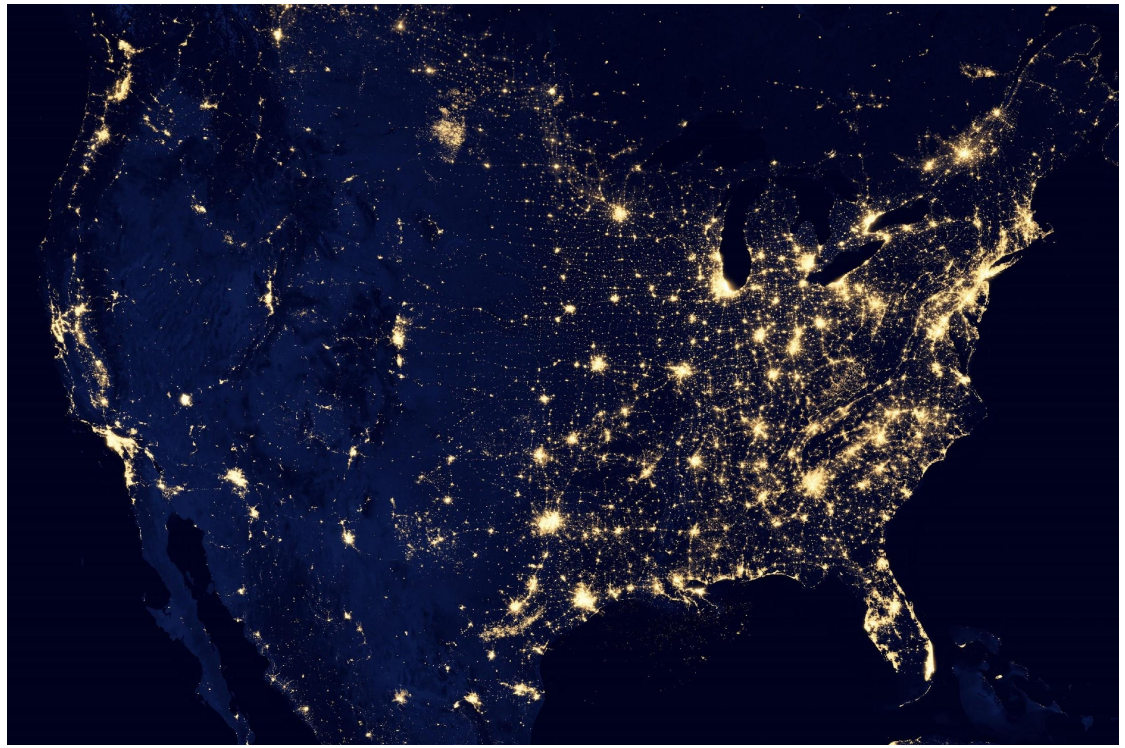

Kingston upon Hull
Norwich
Peterborough
Ely
Cambridge
Chelmsford
St Albans
London
London, employment density


Sergiyev Posad
Pushkino
Noginsk
Zelenograd
Khimki
Moscow
Zhukovsky
Odintsovo
Domodedovo
Podolsk
Moscow, employment density


Miyun
Huairou
Pinggu
Changping
Shunyi
Beijing
Gu'an
Beijing, employment density

Aerial Imagery

- taken by satellite, plane, (drone)
- **remote sensing**
  - obtaining information about an object or phenomenon **without making physical contact**
  - **passive** (photography, infrared)
  - **active** (RADAR, LiDAR)



2003

369 residents

2006

504 residents

2015

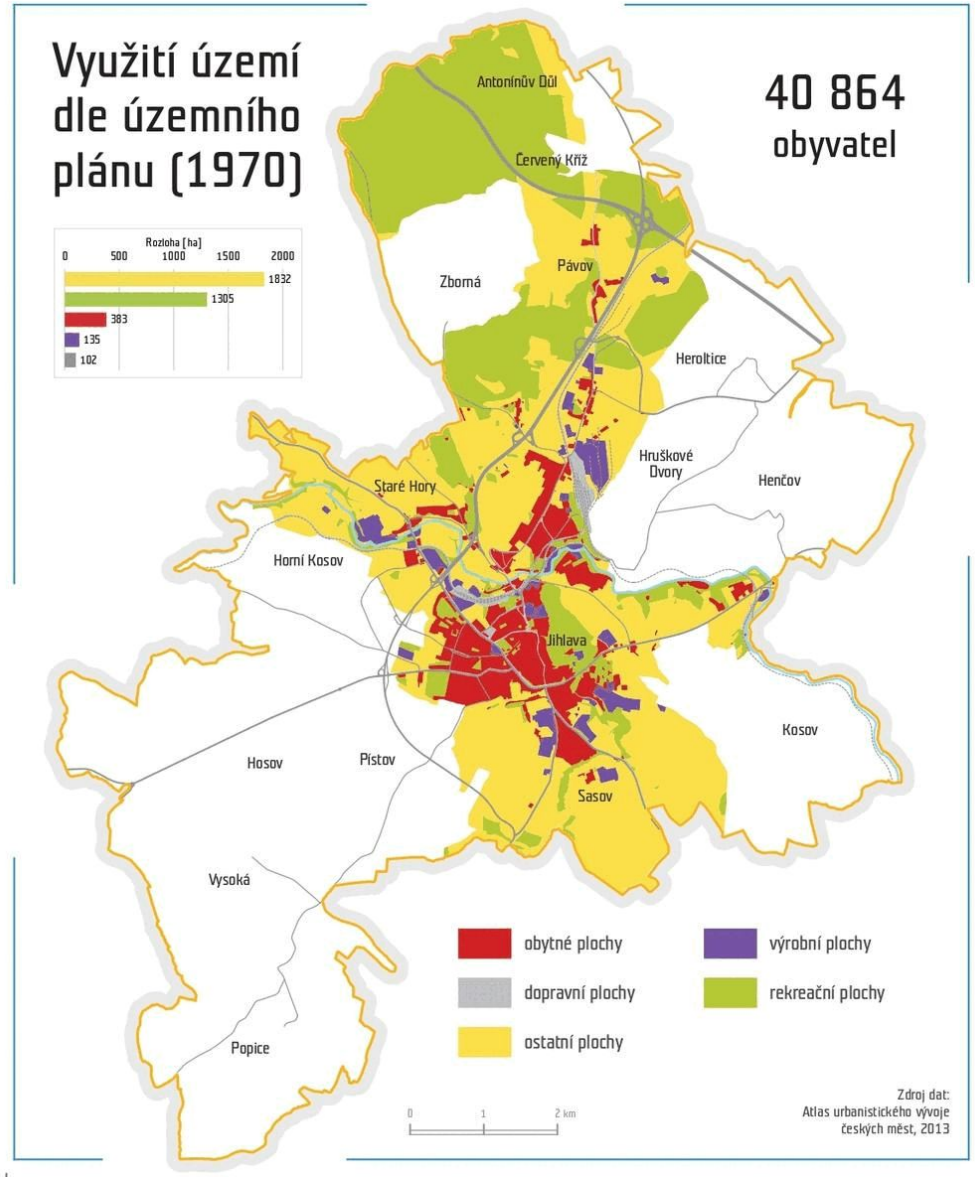
853 residents

2021

1028 residents

Animations


08:02:00


Využití území dle územního plánu (1970)
40 864 obyvatel
Rozloha [ha]
0
500
1000
1500
2000
1832
1305
383
135
102
Antonínův Důl
Červený Kříž
Pávov
Zborná
Heroltice
Hruškové Dvory
Henčov
Staré Hory
Horní Kosov
Jihlava
Kosov
Hosov
Pístov
Sasov
Vysoká
Popice
obytné plochy
výrobní plochy
dopravní plochy
rekreační plochy
ostatní plochy
0
1
2 km
Zdroj dat:
Atlas urbanistického vývoje českých měst, 2013

Conclusion

Conclusion

- there are **many ways** to visualize spatial data
- the choice of the method depends on the **type of data** and the **purpose of the visualization**
- maps help us better understand **spatial relationships and spatial patterns**

			Areal Symbols	Choropleth maps	Proportional Symbols	Multivariate Maps	Heat Maps	Flow Maps	Dot Maps	Isoline Maps	Cartogram Method	3D Visualisations	Animations
quantitative data	absolute	point	✗	✗	✓	✓	✓	✗	✓	✗	✗	✓	✓
		line	✗	✗	✗	✓	✗	✓	✗	✓	✗	✓	✓
		area	✗	✗	✓	✓	✗	✗	✗	✓	✓	✓	✓
	relative	point	✗	✗	✓	✓	✓	✗	✓	✗	✗	✓	✓
		line	✗	✗	✗	✓	✗	✓	✗	✓	✗	✓	✓
		area	✗	✓	✓	✓	✗	✗	✗	✓	✓	✓	✓
qualitative data	point		✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓
	line		✗	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓
	area		✓	✗	✗	✗	✗	✗	✗	✗	✗	✓	✓

Thank you for your attention!

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