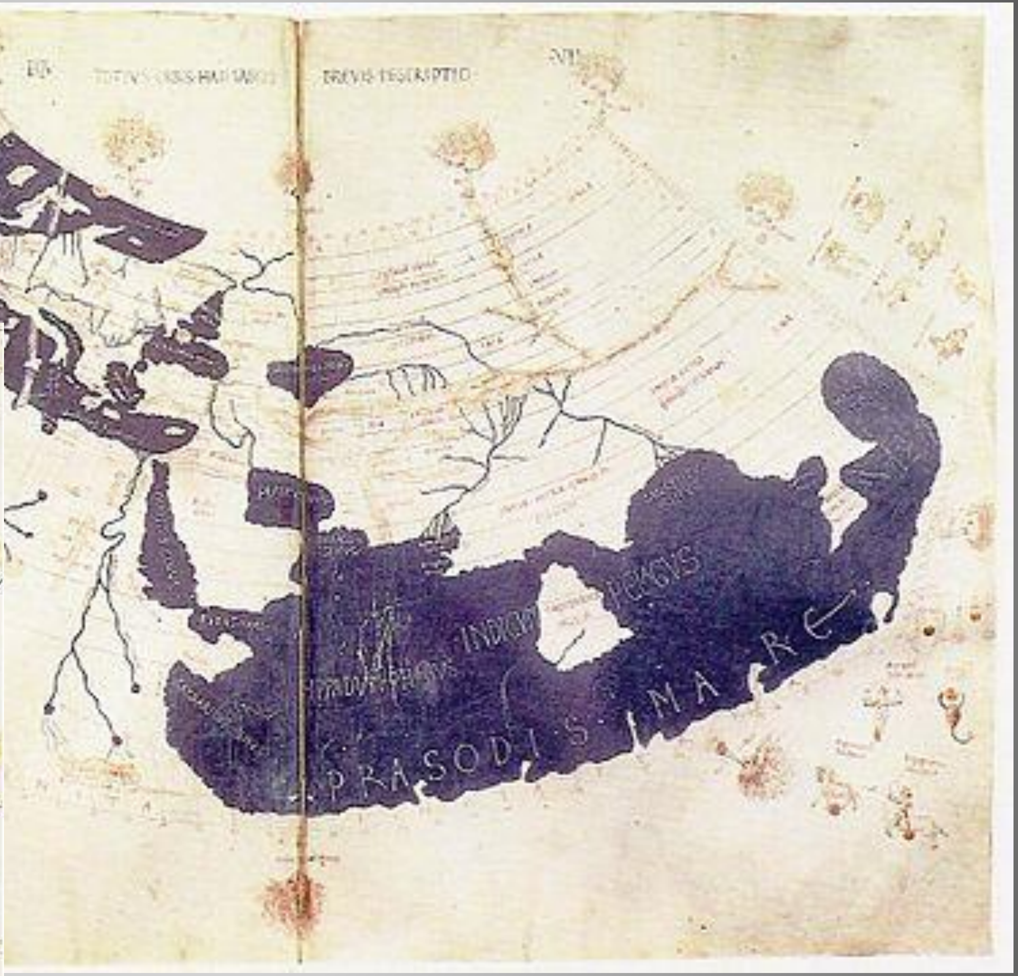
CS225: Spatial Computing

Introduction to Spatial Computing

Amr Magdy
Computer Science and Engineering
www.cs.ucr.edu/~amr/

Once upon a time...

Claudius Ptolemy (AD 90 – AD 168)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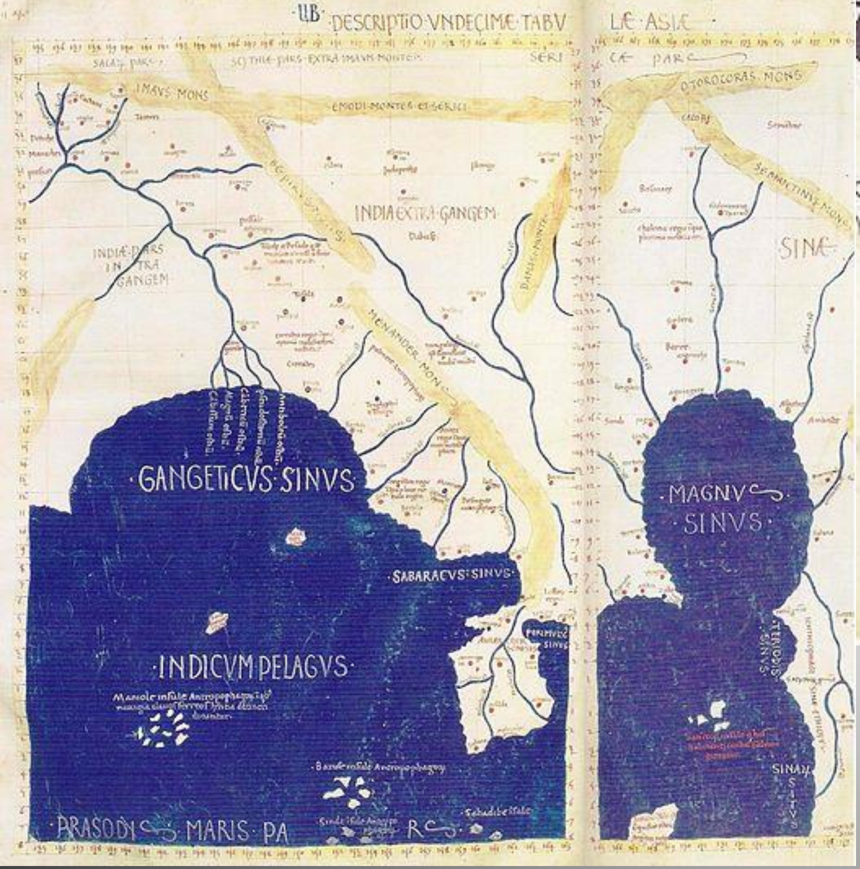
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SCYTHIÆ PARS EXTRA IMAVM MONTEM
SERICÆ PARS
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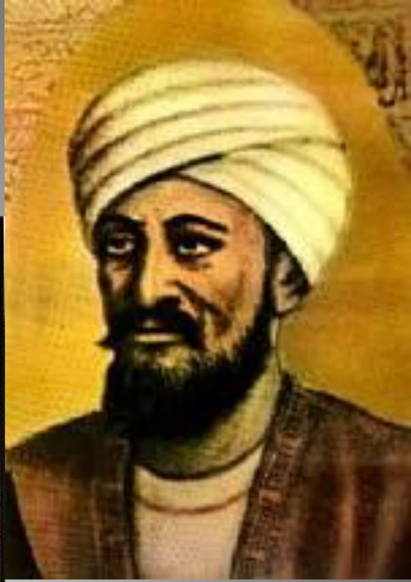
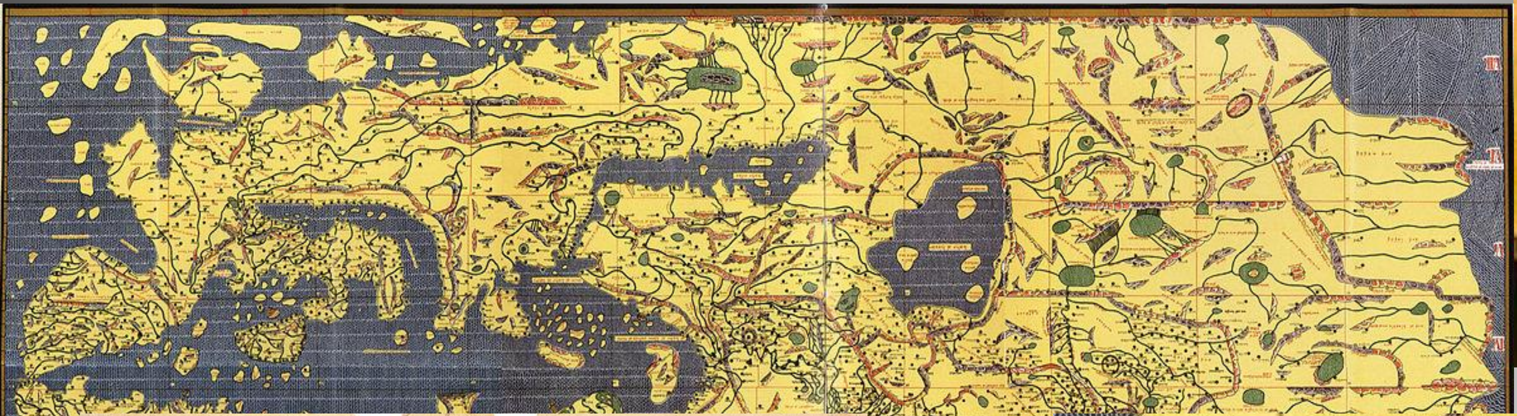
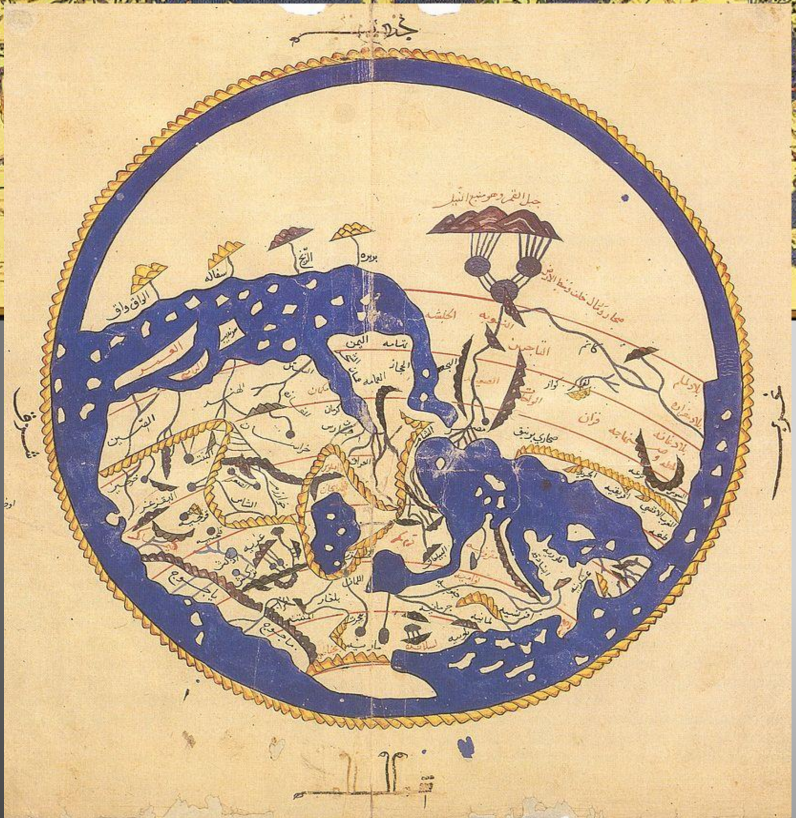
EMODI MONTES ET SERICI
OTOROCORAS MONS
SEMANTINVS MONS
INDIA EXTRA GANGEM
INDIÆ PARS INTRA GANGEM
MENANDER MON
SINÆ
GANGETICVS SINVS
MAGNVS SINVS
SABARACVS SINVS
INDICVM PELAGVS
PRASODIS MARIS PARS
SINÆ SINVS

Al Idrisi (1099–1165)

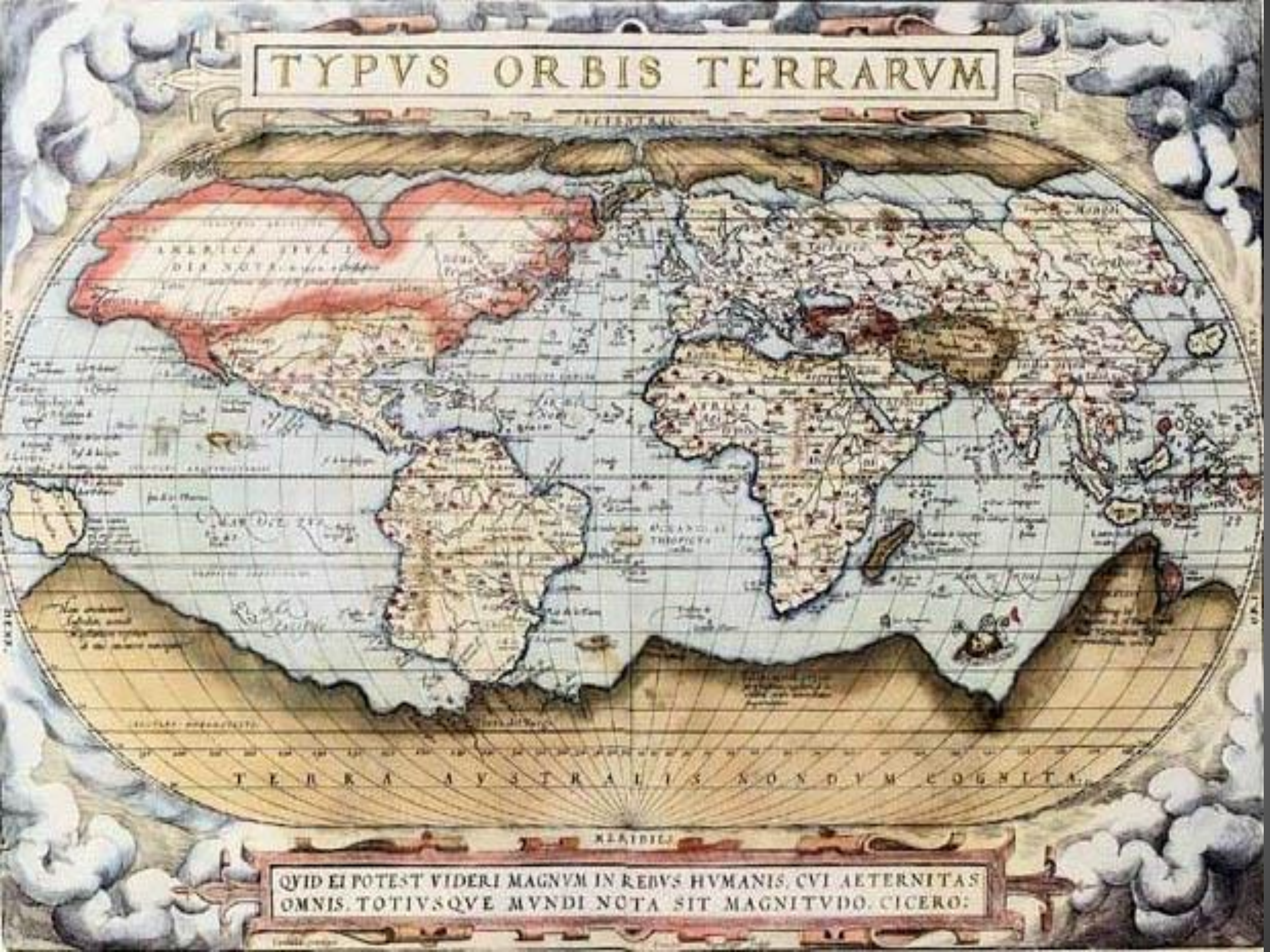






bahr al hazar

Zona frigida
Rusia
EVROPA
Mar Atlantico
AFRICA
INDIA
Regno de China
Tropicus Cancri
Tropicus Cancri
Mar do Sul
Equinocialis
Equinocialis
Brasil
Tropicus Capricorni
Tropicus Capricorni
Mar Indico
Mar Pacifico
Mar Meridional


TYPVS ORBIS TERRARVM
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MERIDIES
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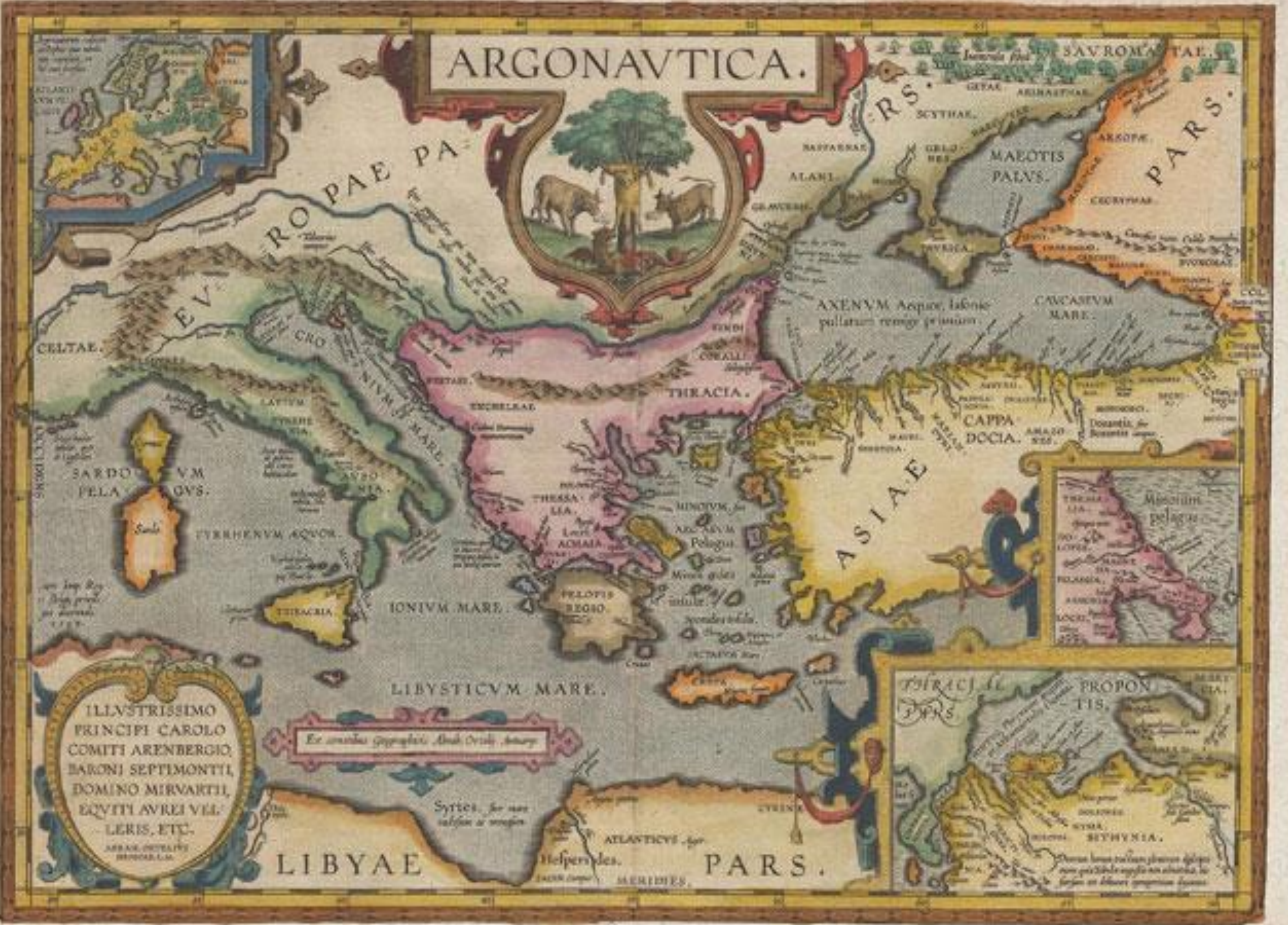
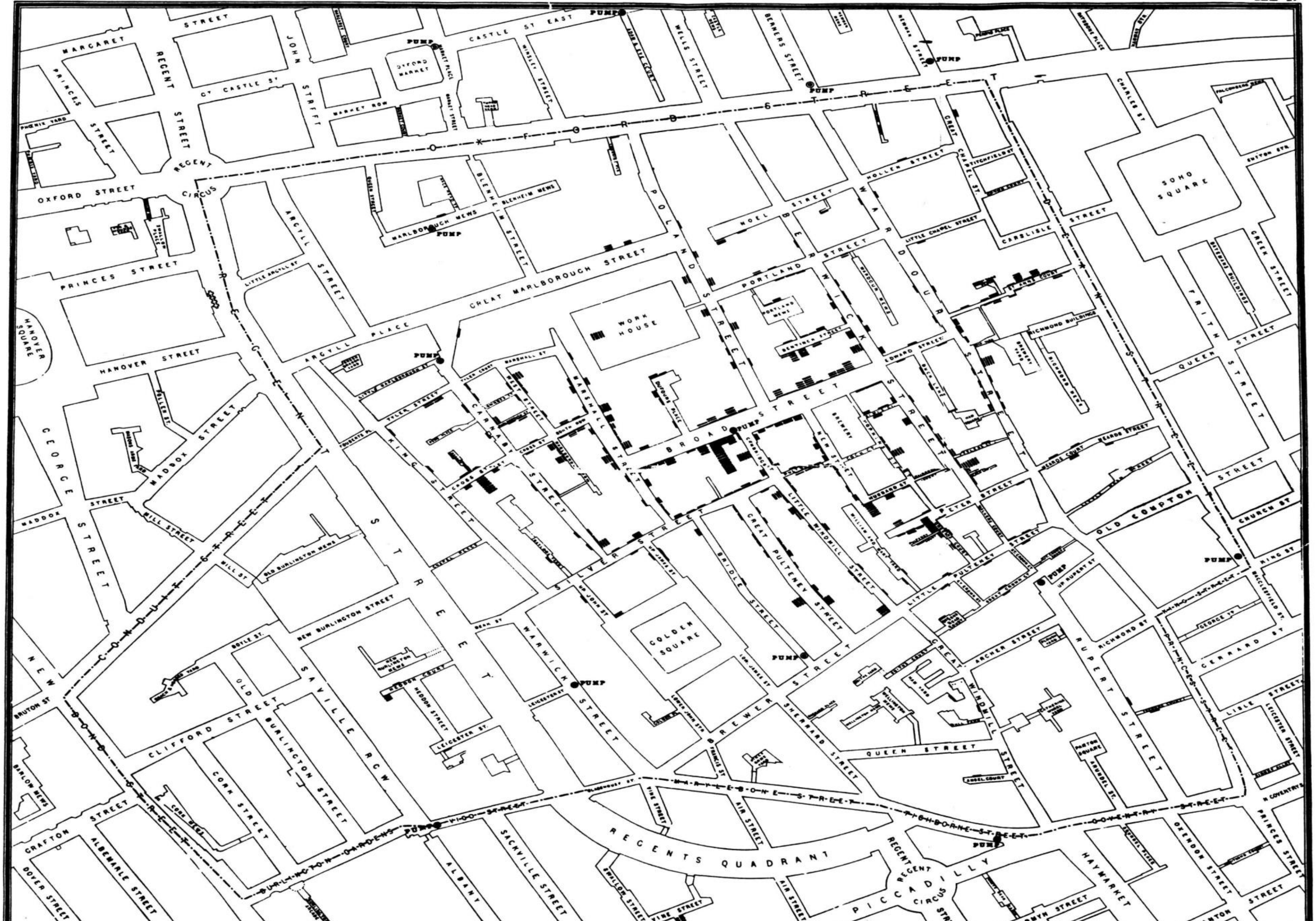

ARGONAVTICA.
EVROPAE PARS.
SAVROMATAE.
SCYTHAE.
GETAE.
ARIMASPHAE.
BASTARNAE.
ALANI.
GELONES.
MAEOTIS PALVS.
ARSOPAE.
CECRYPHAE.
TAVRICA.
PARS.
AXENVM Aequor, Iasoniae pulsatum remige primum.
CAVCASEVM MARE.
CELTAE.
CRO
NIVM MARE.
THRACIA.
LATIVM.
TYRRHENIA.
AVSONIA.
SARDOVM PELAGVS.
Sardo
TYRRHENVM AEQVOR.
TRINACRIA.
IONIVM MARE.
THESSALIA.
ACHAIA.
PELOPIS REGIO.
MINOIVM, sive ARCADIVM Pelagus.
Minoae siue insulae.
Sporades insulae.
CRETA.
CAPPADOCIA.
AMAZONES.
ASIAE.
Doeantis, siue Doeantis campus.
Myrtoum pelagus.
THRACIAE PARS.
PROPONTIS.
BITHYNIA.
LIBYSTICVM MARE.
Syrtes, siue mare vadosum et vorago.
ATLANTICVS Ager.
Hesperides.
CYRENE.
LIBYAE PARS.
MERIDIES.
OCCIDENS.

ILLVSTRISSIMO
PRINCIPI CAROLO
COMITI ARENBERGIO,
BARONI SEPTIMONTII,
DOMINO MIRVARTII,
EQVITI AVREI VEL-
LERIS, ETC.
ABRAH. ORTELIVS
DEDICAB. L.M.

Ex conatibus Geographicis Abrah. Ortelij Antuerp.

Cholera cases in the London epidemic of 1854

MAP 1.


OXFORD STREET
BROAD STREET
GOLDEN SQUARE
SOHO SQUARE
WORK HOUSE
REGENT STREET
REGENT CIRCUS
REGENTS QUADRANT
PICCADILLY
REGENT CIRCUS
GREAT MARLBOROUGH STREET
POLAND STREET
BERWICK STREET
WARDOUR STREET
DEAN STREET
FRITH STREET
GREEK STREET
CHARLES ST
QUEEN STREET
OLD COMPTON STREET
PRINCES STREET
GERRARD ST
RUPERT STREET
GREAT WINDMILL ST
MARYLEBONE STREET
TICHBORNE STREET
COVENTRY STREET
HAYMARKET
SAVILLE ROW
BURLINGTON STREET
CORK STREET
OLD BURLINGTON STREET
NEW BURLINGTON STREET
CLIFFORD STREET
CONDUIT STREET
NEW BOND STREET
MADDOX STREET
GEORGE STREET
HANOVER STREET
HANOVER SQUARE
PRINCES STREET
MARGARET STREET
JOHN STREET
CASTLE ST EAST
GT CASTLE ST
OXFORD MARKET
ARGYLL STREET
ARGYLL PLACE
KING STREET
CARNABY STREET
MARSHALL STREET
SILVER STREET
WARWICK STREET
SWALLOW STREET
VIGO STREET
BURLINGTON GARDENS
SACKVILLE STREET
ALBANY
ALBEMARLE STREET
DOVER STREET
GRAFTON STREET
AIR STREET
BREWER STREET
SHERRARD STREET
BRIDLE STREET
GREAT PULTENEY STREET
LITTLE WINDMILL STREET
PORTLAND STREET
NOEL STREET
HOLLEN STREET
GREAT CHAPEL ST
BLENHEIM STREET
MARLBOROUGH MEWS
CHURCH ST
LISLE STREET
LEICESTER STREET
OXENDON STREET
PUMP

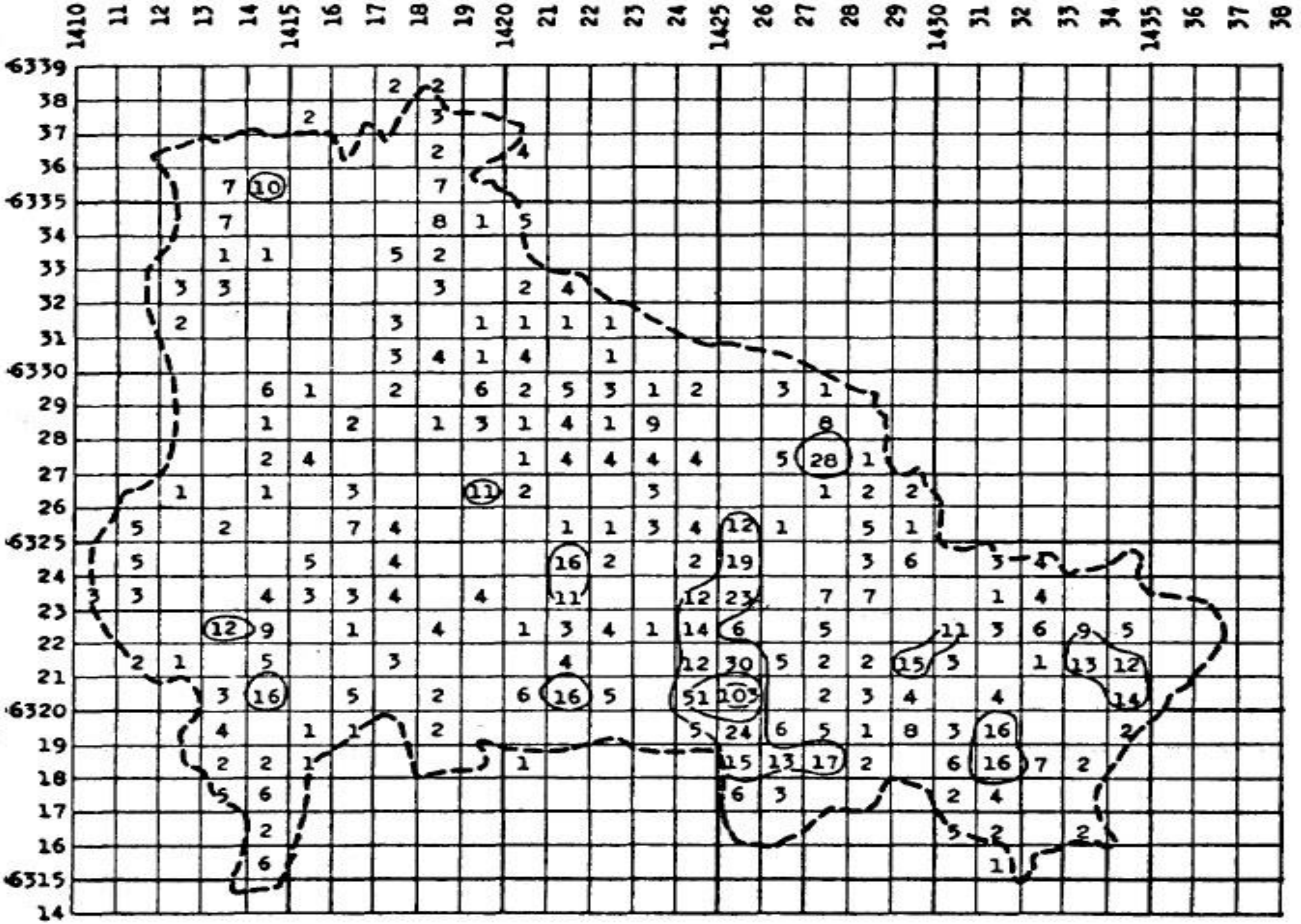

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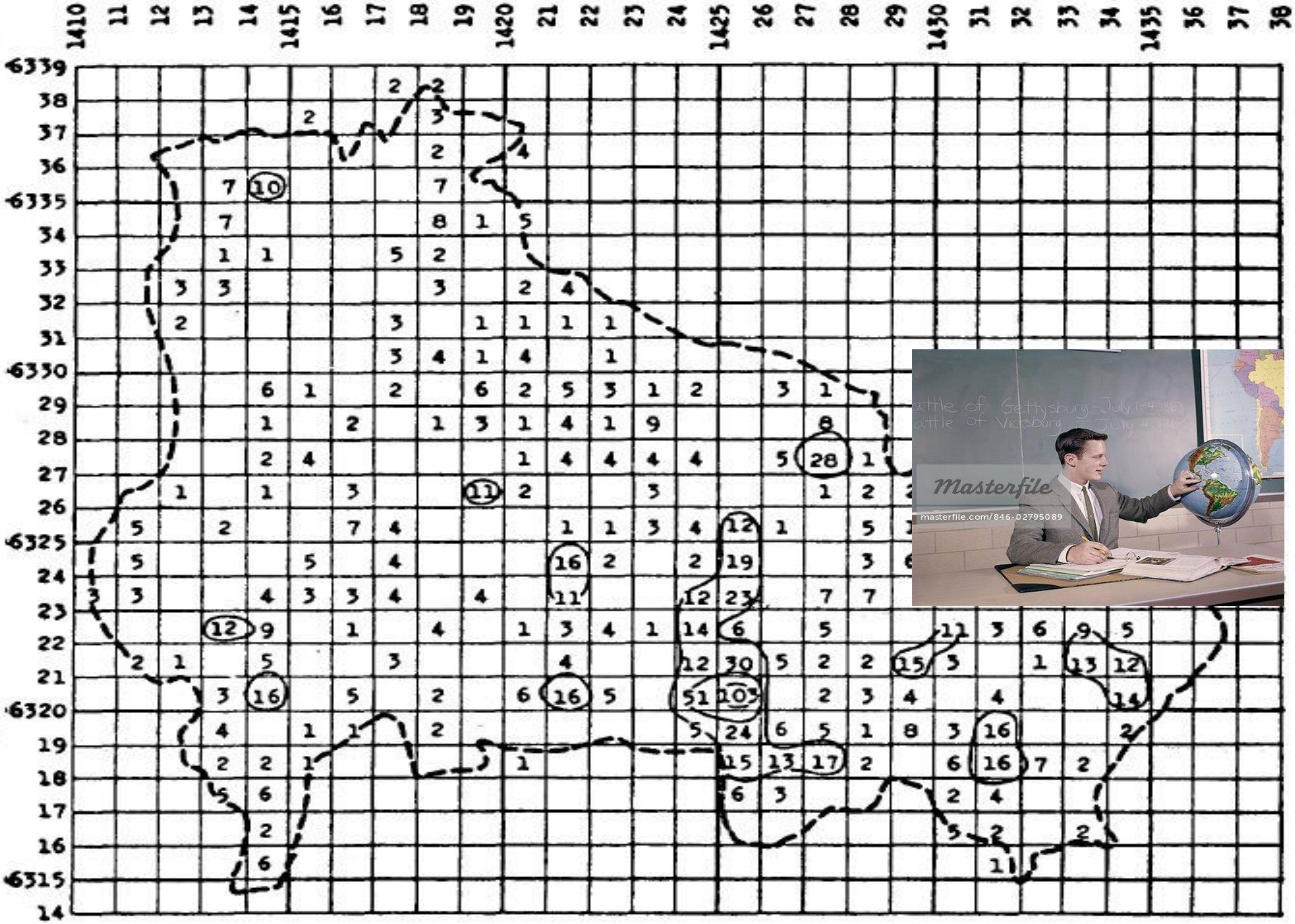
FIGURE 3—Children under 15 years of age in 1940.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6325
6320
6315
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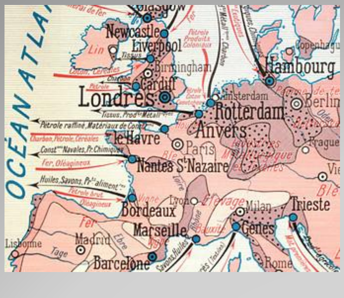
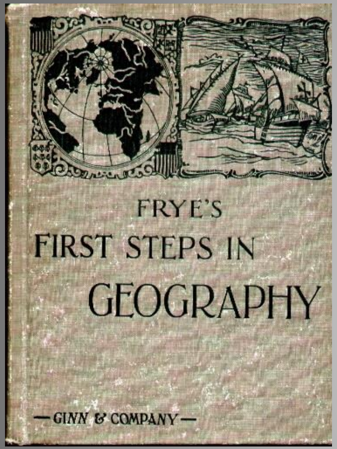
Masterfile
masterfile.com/846-02795089

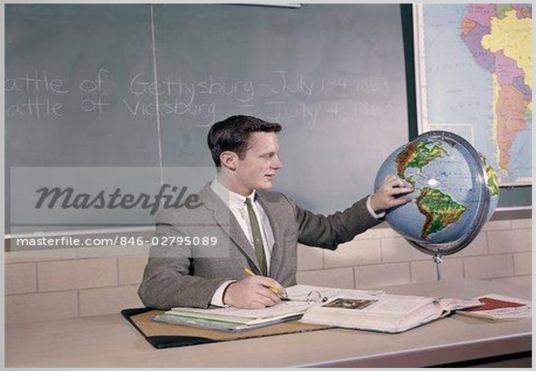
FIGURE 3—Children under 15 years of age in 1940.


OCÉAN ATLA
Glasgow
Newcastle
Liverpool
Birmingham
Cardiff
Londres
Hambourg
Amsterdam
Rotterdam
Anvers
Berlin
Paris
le Havre
Nantes
S.t Nazaire
Prague
Bordeaux
Lyon
Milan
Trieste
Marseille
Gênes
Madrid
Lisbonne
Barcelone
Rome



FRYE'S
FIRST STEPS IN
GEOGRAPHY

—GINN & COMPANY—


attle of Gettysburg - July 1-4, 1863
attle of Vicksburg - July 4, 1863
Masterfile
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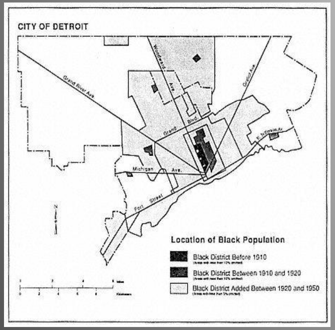
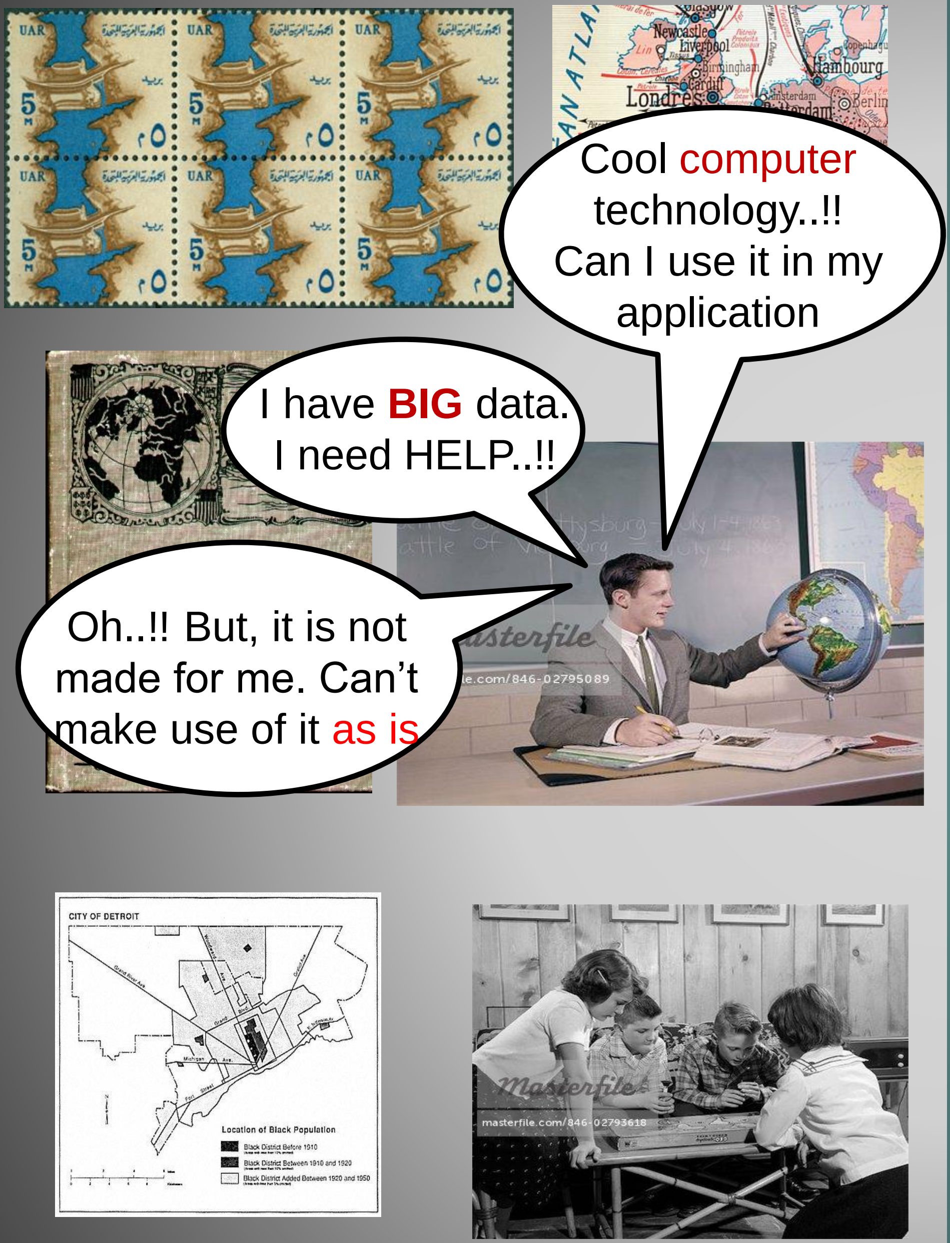
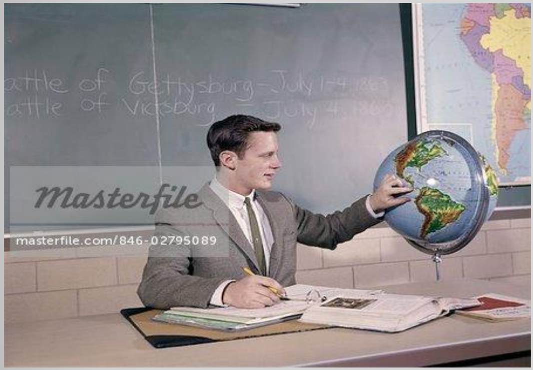

CITY OF DETROIT
Grand River Ave.
Woodward Ave.
Gratiot Ave.
E. Jefferson Av.
Michigan Ave.
Fort Street
Grand Blvd.
Location of Black Population
Black District Before 1910
Black District Between 1910 and 1920
Black District Added Between 1920 and 1950

Masterfile
masterfile.com/846-02793618

IBM
SYSTEM/360


Cool computer technology..!! Can I use it in my application
I have BIG data. I need HELP..!!
Oh..!! But, it is not made for me. Can't make use of it as is
CITY OF DETROIT
Location of Black Population

My pleasure. Here it is.
UNIVAC
IBM

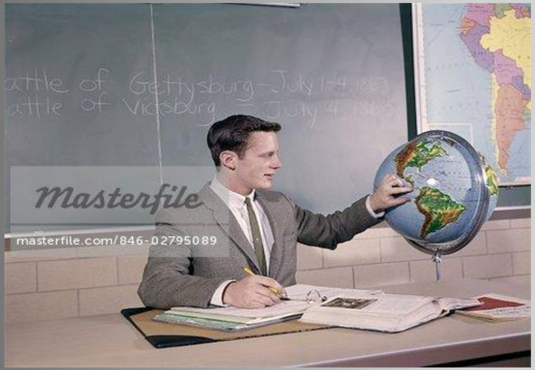

attle of Gettysburg – July 1-4, 1863
attle of Vicksburg – July 4, 1863
Masterfile
masterfile.com/846-02795089

IBM
SYSTEM 360

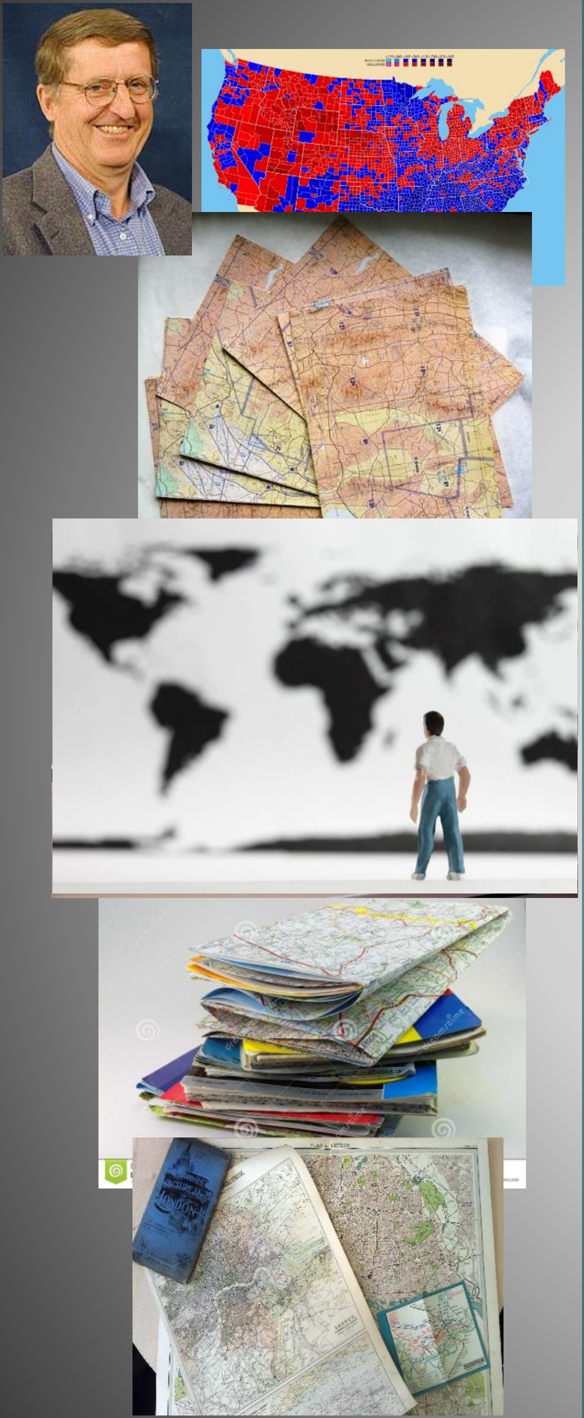
1969

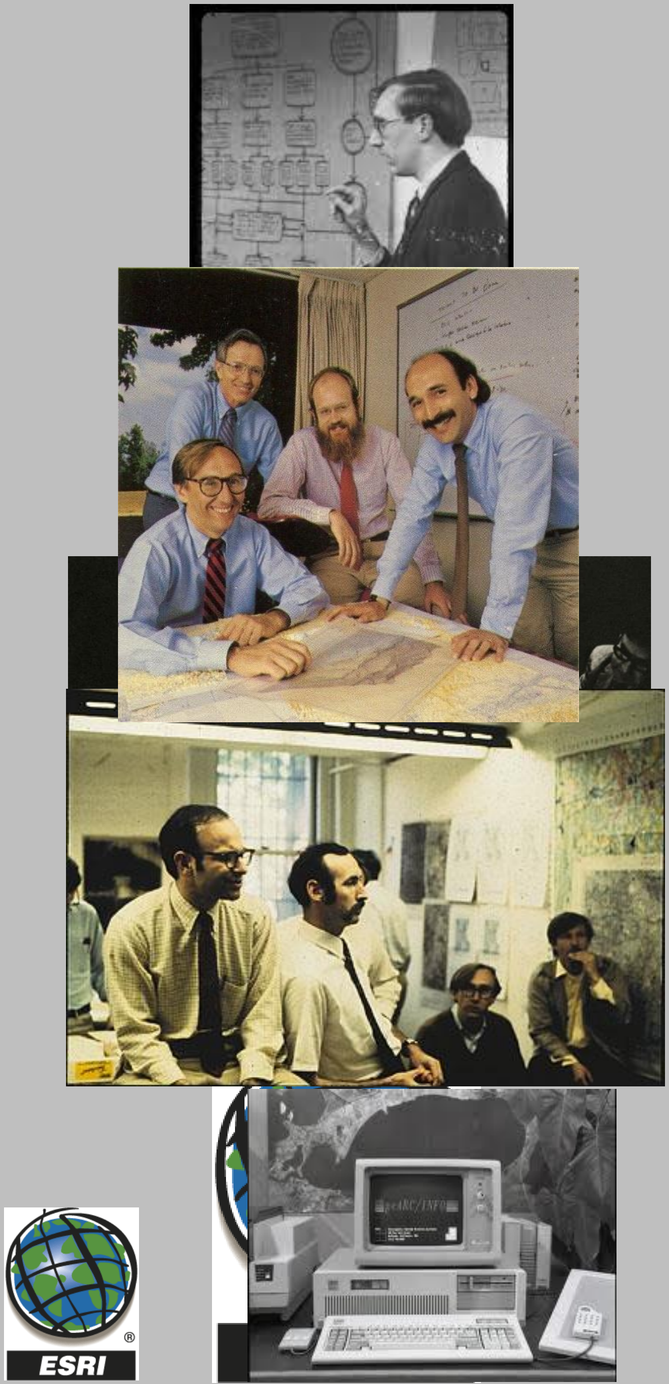
Kindly let me understand your needs

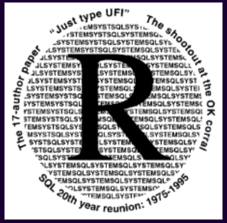
Kindly let me get the technology you have


attle of Gettysburg – July 1-4 1863
attle of Vicksburg – July 4 1863
Masterfile
masterfile.com/846-02795089

ESRI






"Just type UFI"
The shootout at the OK corral
SQL 20th year reunion: 1975-1995
The 17-author paper
R

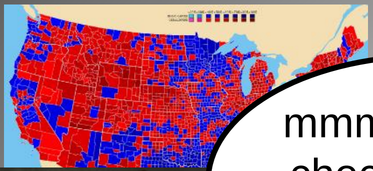
DATABASE MANAGEMENT SYSTEMS

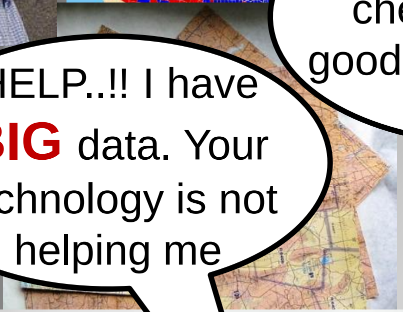
PostgreSQL

Informix

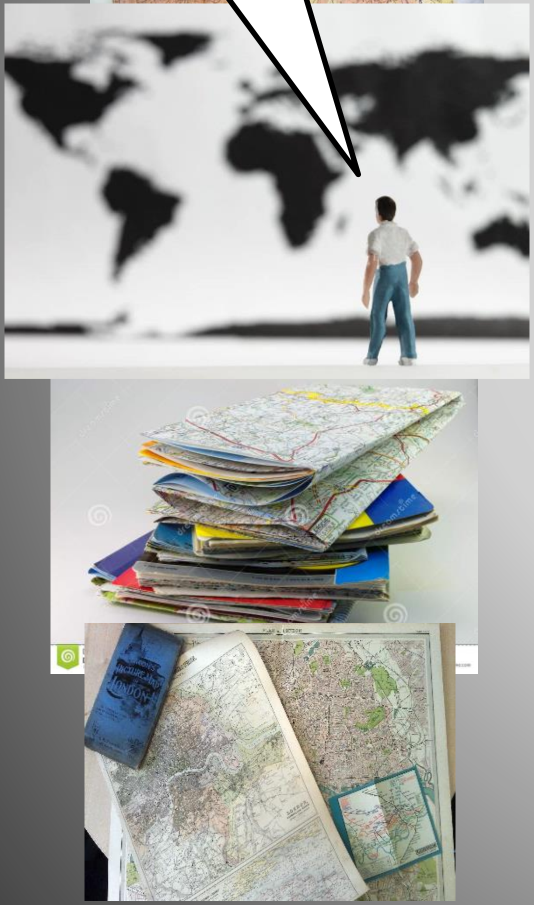
ORACLE
DATABASE
ORACLE

AIRLINE BOOKING





HELP..!! I have **BIG** data. Your technology is not helping me



mmm…Let me check with my good friends there.

Cool Database technology..!! Can I use it in my application?

Oh..!! But, it is not made for me. Can't make use of it as is

ESRI

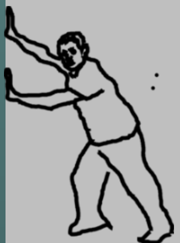
My pleasure. Here it is.

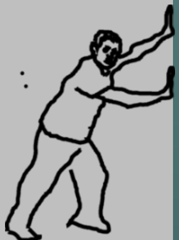
PostgreSQL

Informix

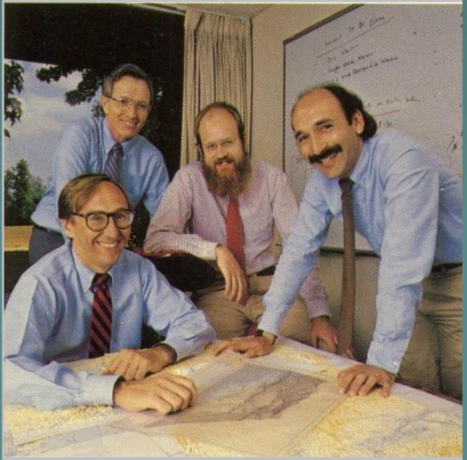
ORACLE

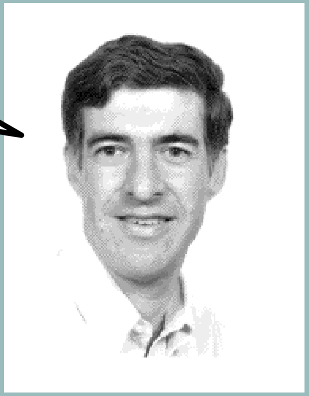
AIRLINE BOOKING

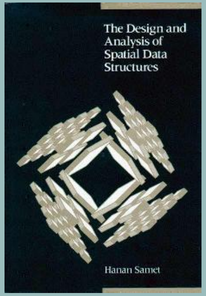


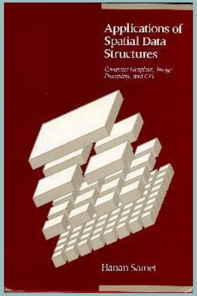


Kindly let me understand your needs

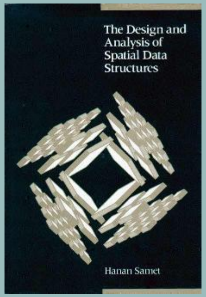


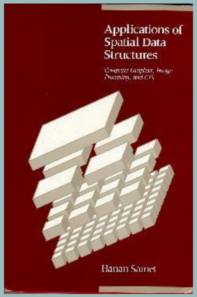



The Design and Analysis of Spatial Data Structures
Hanan Samet


Applications of Spatial Data Structures
Computer Graphics, Image Processing, and GIS
Hanan Samet

Kindly let me get the technology you have


The Design and Analysis of Spatial Data Structures
Hanan Samet


Applications of Spatial Data Structures
Computer Graphics, Image Processing, and GIS
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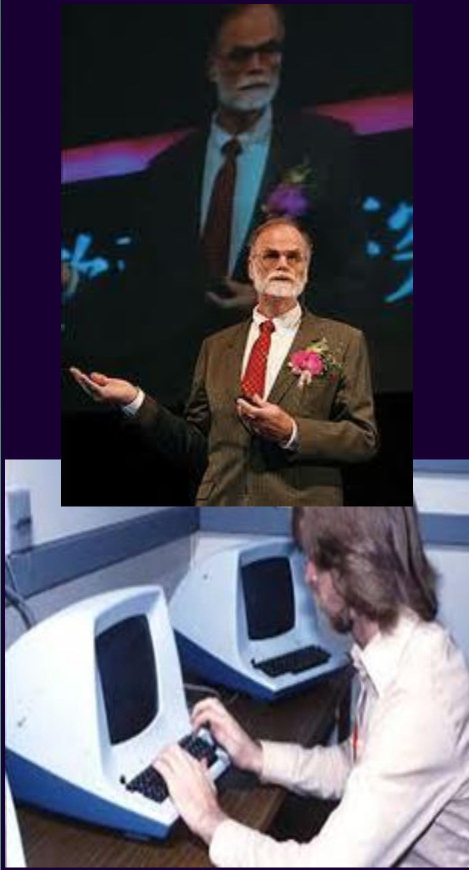
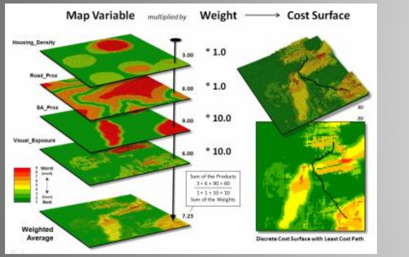
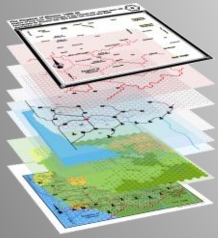
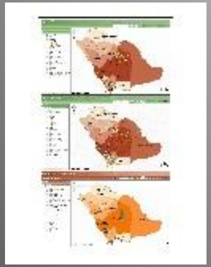


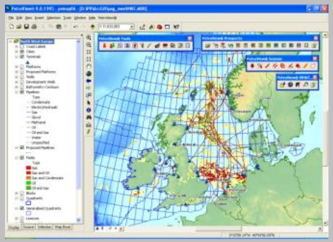

Map Variable
multiplied by
Weight
Cost Surface
Housing_Density
Road_Prox
SA_Prox
Visual_Exposure
* 1.0
* 1.0
* 10.0
* 10.0
Weighted Average
Discrete Cost Surface with Least Cost Path

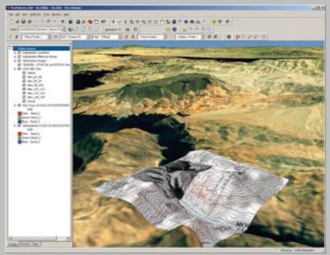
IRAN
Arabian Gulf
BAHRAIN
Manama
SAUDI ARABIA
QATAR
Doha
Riyadh
N





ESRI ArcGIS

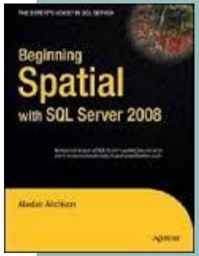




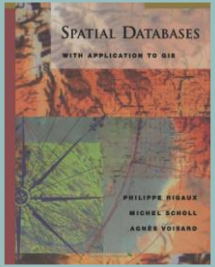
idrisi

PostGIS
Geospatial Objects for PostgreSQL

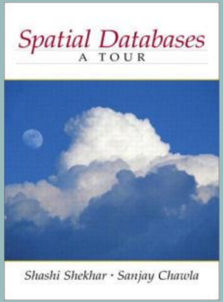
ORACLE 11g
DATABASE
Oracle Spatial and Graph
ORACLE



Beginning Spatial with SQL Server 2008



SPATIAL DATABASES
WITH APPLICATION TO GIS
PHILIPPE RIGAUX
MICHEL SCHOLL
AGNÈS VOISARD



Spatial Databases
A TOUR
Shashi Shekhar · Sanjay Chawla

ORACLE

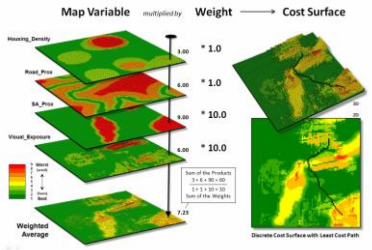
IBM DB2

Microsoft SQL Server

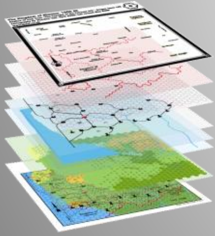
PostgreSQL
the world's most advanced open source database

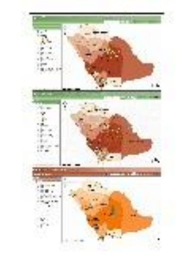
MySQL

SYBASE | An SAP Company

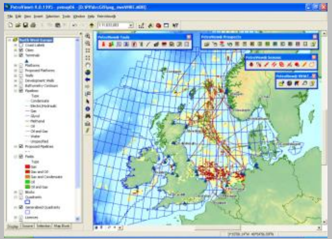

Map Variable
multiplied by
Weight
Cost Surface
Housing_Density
Road_Prox
SA_Prox
Visual_Exposure
* 1.0
* 1.0
* 10.0
* 10.0
Weighted Average
Discrete Cost Surface with Least Cost Path

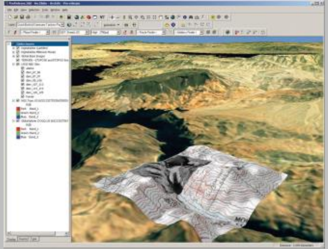
IRAN
Arabian Gulf
BAHRAIN
Manama
SAUDI ARABIA
QATAR
Doha
Riyadh
N





ESRI ArcGIS

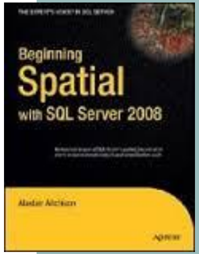




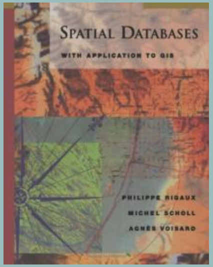
idrisi

PostGIS
Geospatial Objects for PostgreSQL

ORACLE 11g DATABASE
Oracle Spatial and Graph
ORACLE



Beginning Spatial with SQL Server 2008
Alastair Aitchison
Apress



SPATIAL DATABASES
WITH APPLICATION TO GIS
PHILIPPE RIGAUX
MICHEL SCHOLL
AGNÈS VOISARD

Spatial Databases
A TOUR
Shashi Shekhar · Sanjay Chawla

ORACLE

IBM DB2

Microsoft SQL Server

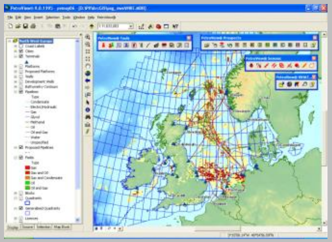
PostgreSQL
the world's most advanced open source database

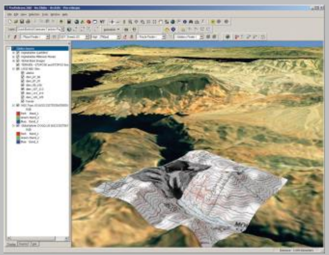
MySQL

SYBASE | An SAP Company

Weight
Cost Surface
Weighted Average

ESRI ArcGIS

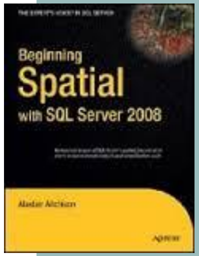




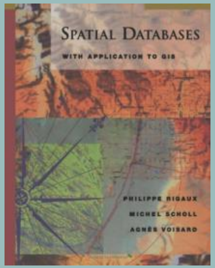
idrisi

PostGIS
Geospatial Objects for PostgreSQL

ORACLE 11g
DATABASE
Oracle
Spatial and Graph
ORACLE



Beginning
Spatial
with SQL Server 2008
Alastair Aitchison
Apress



SPATIAL DATABASES
WITH APPLICATION TO GIS
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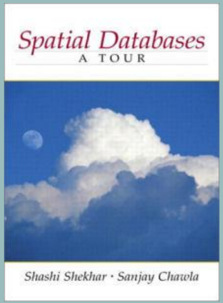
AGNÈS VOISARD



Spatial Databases
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Google
bing
twitter
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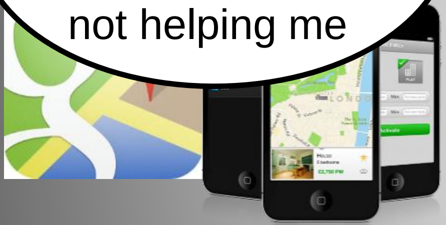
MapReduce
amazon web services EC2
hadoop
cloudera IMPALA
Spark

ORACLE
IBM DB2
Microsoft SQL Server
PostgreSQL
MySQL
SYBASE | An SAP Company

HELP..!! Again, I have **BIG** data. Your technology is not helping me

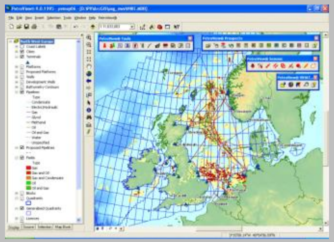


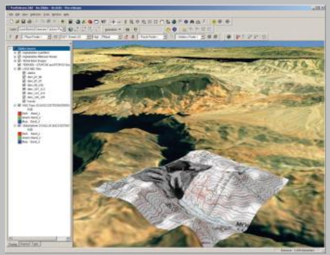
NASA

Sorry, seems like the DBMS technology cannot scale more

Let me check with my other good friends there.

ESRI GIS





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Cool Big Data technology..!! Can I use it in my application?

Oh..!! But, it is not made for me. Can't make use of it as is

PostGIS
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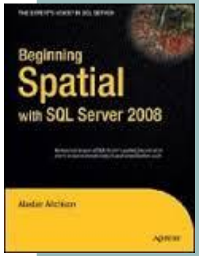
Oracle Spatial and Graph
ORACLE



Beginning Spatial with SQL Server 2008
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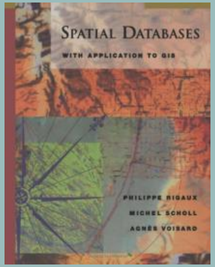

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PHILIPPE RIGAUX
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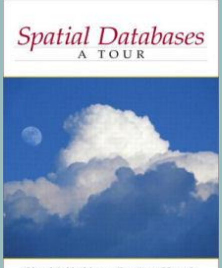

Spatial Databases
A TOUR
Shashi Shekhar · Sanjay Chawla

Google
bing

My pleasure. Here it is.

facebook
MapReduce
amazon web services
EC2
hadoop
cloudera IMPALA
Spark

ORACLE
IBM DB2
Microsoft SQL Server
PostgreSQL
MySQL
SYBASE | An SAP Company

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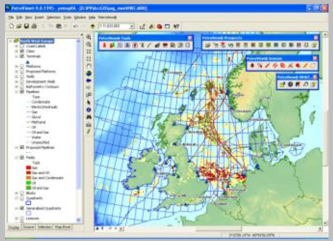
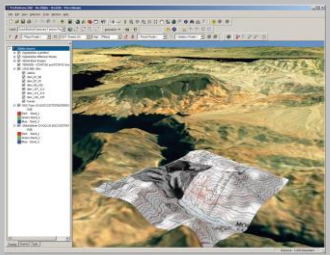
ESRI ArcGIS





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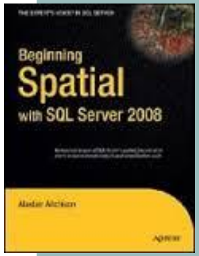

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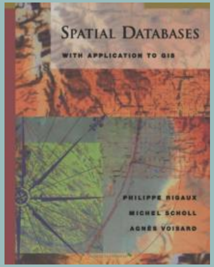

Spatial Databases
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Spatial Databases
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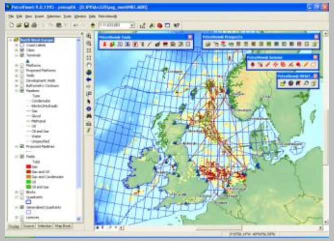
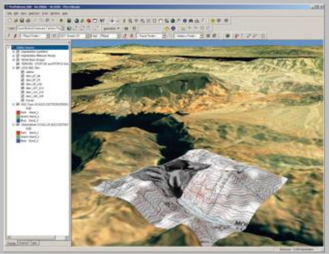
Kindly let me understand your needs

ArcGIS
ESRI





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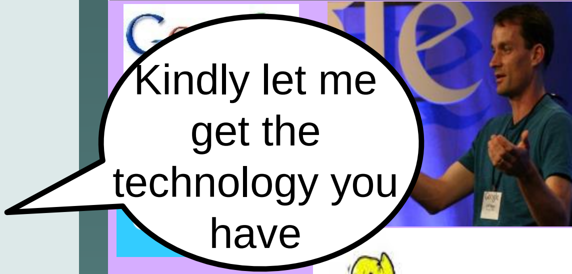
Kindly let me get the technology you have

facebook
MapReduce
amazon web services™ EC2
hadoop
cloudera IMPALA
Spark

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ORACLE 11g DATABASE
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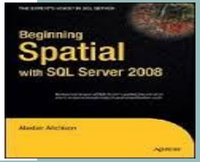
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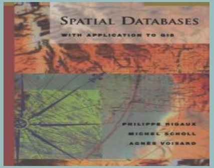
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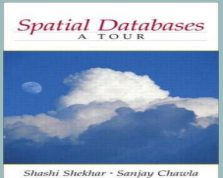
Spatial Databases A TOUR
Shashi Shekhar · Sanjay Chawla

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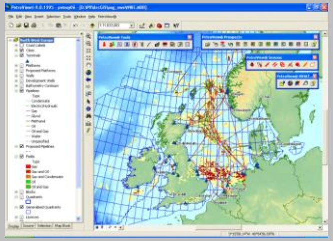
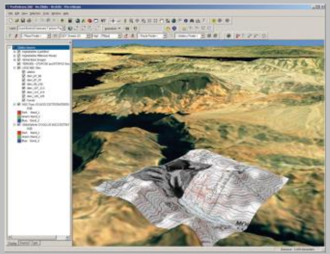
The Era of Big Spatial Data

NASA

ESRI ArcGIS





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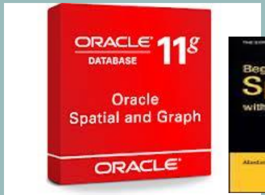
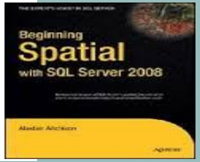


ORACLE 11g DATABASE

Oracle Spatial and Graph

ORACLE



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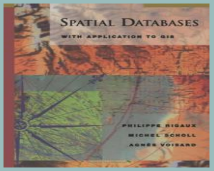
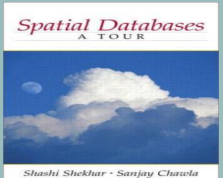


Spatial Databases with application to GIS

Philippe Rigaux · Michel Scholl · Agnès Voisard



Spatial Databases A Tour

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IBM DB2

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PostgreSQL
the world's most advanced open source database

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The Era of Big Spatial Data

Recent products are there….

Simba

GeoSpark

rasdaman
raster data manager

Hadoop-GIS
Spatial Big Data Solutions

Spatial Hadoop
I can play with your spatial data

geomesa

GeoTrellis

SpaceCurve

SPHINX

What is Spatial Computing?

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- A field that innovates a set of technologies and techniques to combine spatial information with computing technologies

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  - Technologies could be software, hardware, or both

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  - What is around me?
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  - What is in or around certain area(s)? (Spatial Analysis)
    - Situation after a natural disaster, changes over time, etc
    - Science, e.g., vegetation analysis, environment, ecology,…etc
    - Enterprise, e.g., agriculture, ride sharing, market research,…etc

Who use Spatial Computing?

- Hundreds of millions of people (if not billions)

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  - Estimated value by 2020: $600B
    (McKinsey Global Institute, 2011 report on Big Data)

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OGC
Open Geospatial Consortium, Inc.

ESRI ArcGIS

Google Earth

OpenStreetMap

SaTScan™
Software for the spatial, temporal, and space-time scan statistics

Ushahidi

ORACLE®
SPATIAL

bing™ maps

6.1 miles
101

Broadway
Church St
W Broadway
TRIBEC
Chambers St
0.20
14.9
3:53
31
4:18
TOMTOM

here

LUCIDYA
Lucid Insights

waze
Outsmarting Traffic, Together.

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- The governments

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May 18th, 2011

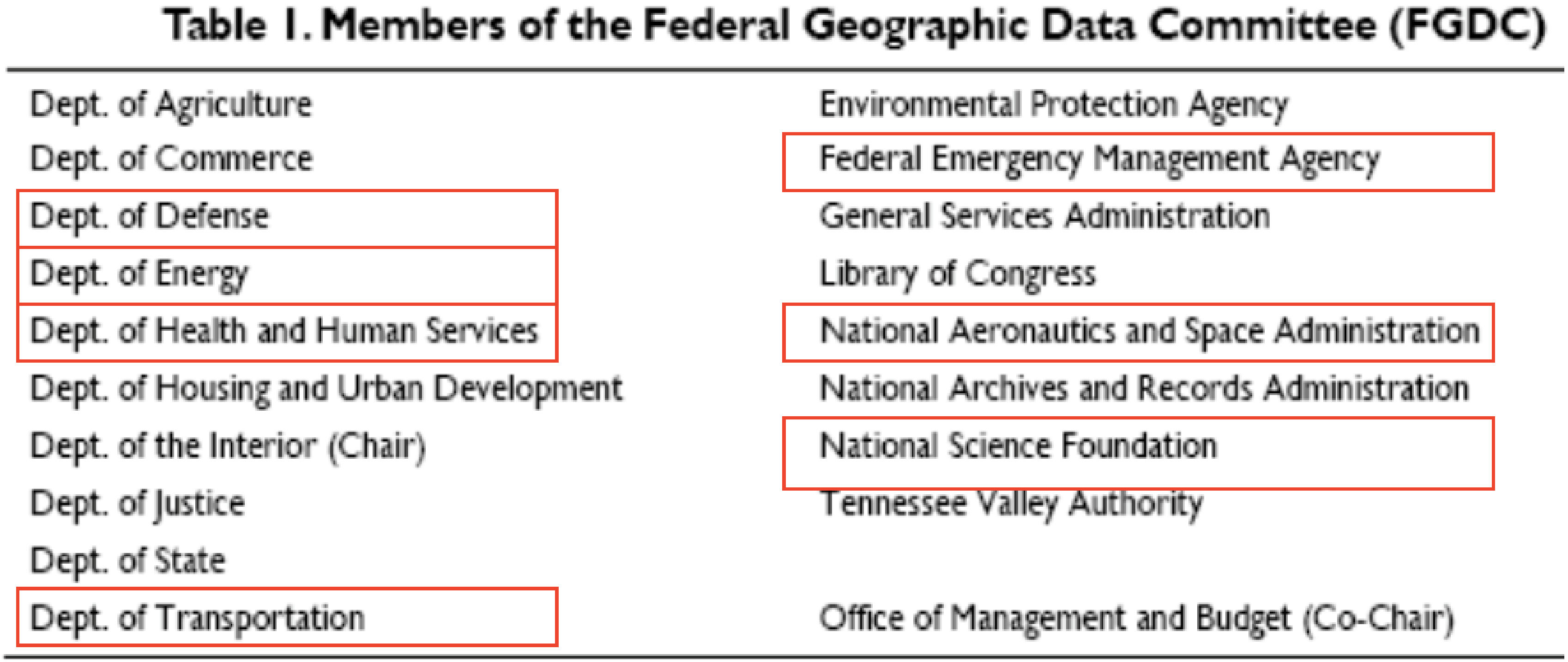

Table 1. Members of the Federal Geographic Data Committee (FGDC)

Dept. of Agriculture	Environmental Protection Agency
Dept. of Commerce	Federal Emergency Management Agency
Dept. of Defense	General Services Administration
Dept. of Energy	Library of Congress
Dept. of Health and Human Services	National Aeronautics and Space Administration
Dept. of Housing and Urban Development	National Archives and Records Administration
Dept. of the Interior (Chair)	National Science Foundation
Dept. of Justice	Tennessee Valley Authority
Dept. of State	
Dept. of Transportation	Office of Management and Budget (Co-Chair)

Folger, Peter. Geospatial Information and Geographic Information Systems (GIS): Current Issues and Future Challenges. Congressional Research Service. June 8th, 2009.

Who use Spatial Computing?

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- The governments
- The public

Who use Spatial Computing?

UCR

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Pokémon GO

waze

Outsmarting Traffic, Together.

Google Earth

Ushahidi

OpenStreetMap

bing maps

Broadway
Church St
W Broadway
TRIBECA
Chambers St
0.20
14.9
3:53
31
4:18
TOMTOM

Major technologies and areas (past, present, & future)

- GPS
- Location Based Services
- Spatial Data Management Systems
- Geographic Information Systems
- Spatial Predictive Analysis (Spatial Statistics, or Spatial Data Mining)
- Virtual Globes and VGI (or CGI)

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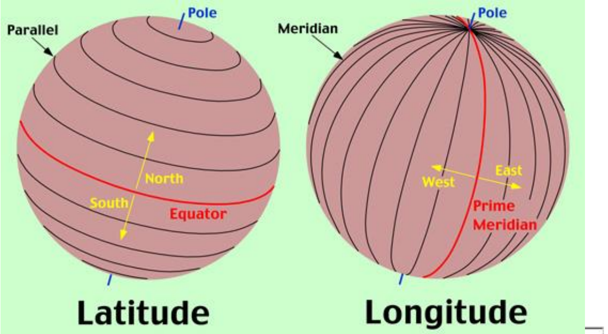
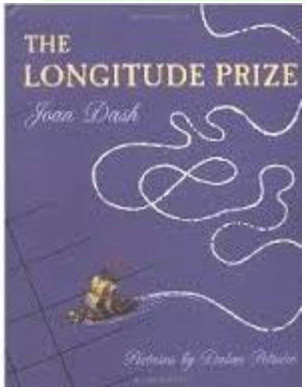
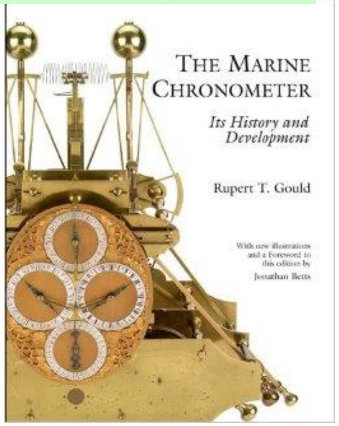
Global Positioning Systems (GPS)

- Positioning ships
  - Latitude f(compass, star positions) → ancient and medieval civilizations
  - Longitude Prize (1714) → marine chronometer


Parallel
Pole
North
South
Equator
Latitude
Meridian
Pole
East
West
Prime Meridian
Longitude


THE LONGITUDE PRIZE

Joan Dash

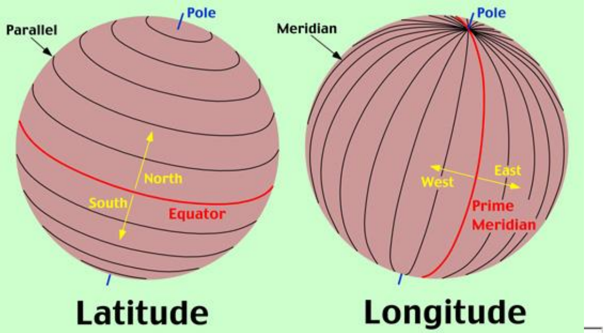

THE MARINE CHRONOMETER

Its History and Development

Rupert T. Gould

With new illustrations and a Foreword to this edition by Jonathan Betts

Global Positioning Systems (GPS)


Parallel
Pole
Meridian
Pole
North
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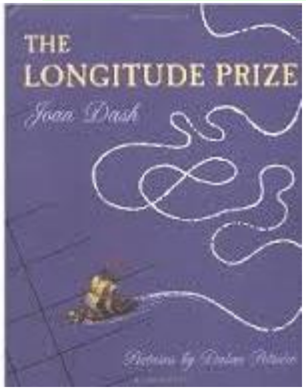
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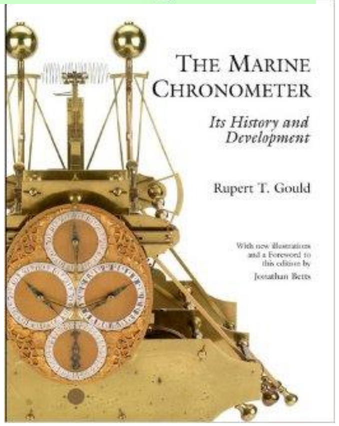
Pictures by Dusan Petricic


THE MARINE CHRONOMETER
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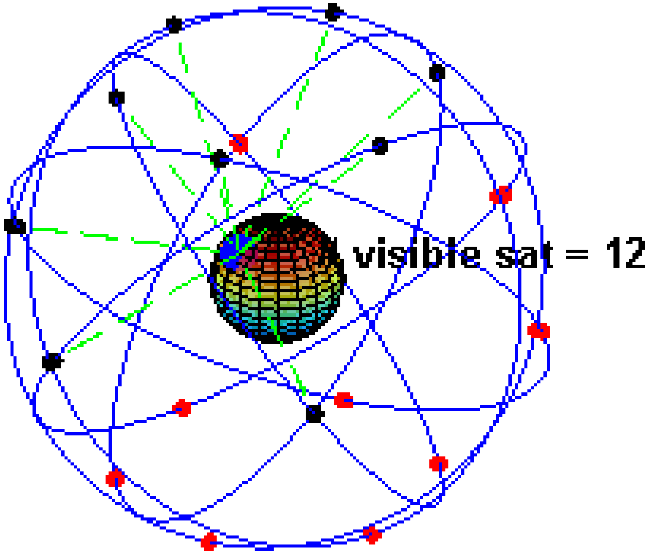
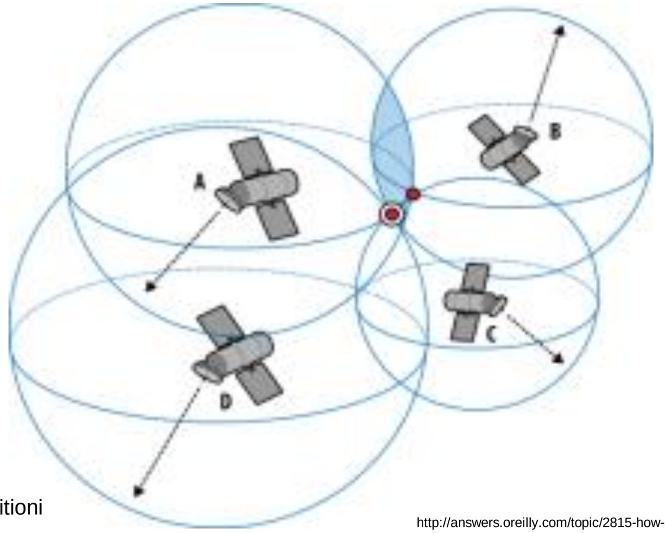
With new illustrations and a Foreword to this edition by Jonathan Betts

- Global Navigation Satellite Systems
  - Infrastructure: satellites, ground stations, receivers, …
  - Use: Positioning (sub-centimeter), Clock synchronization

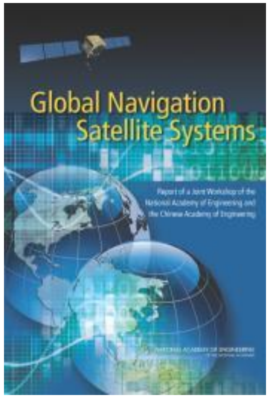

visible sat = 12

http://en.wikipedia.org/wiki/Global_Positioning_System

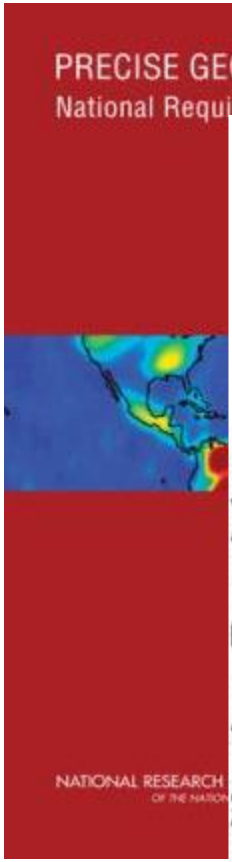
Trilateration



http://answers.oreilly.com/topic/2815-how-devices-gather-location-information/

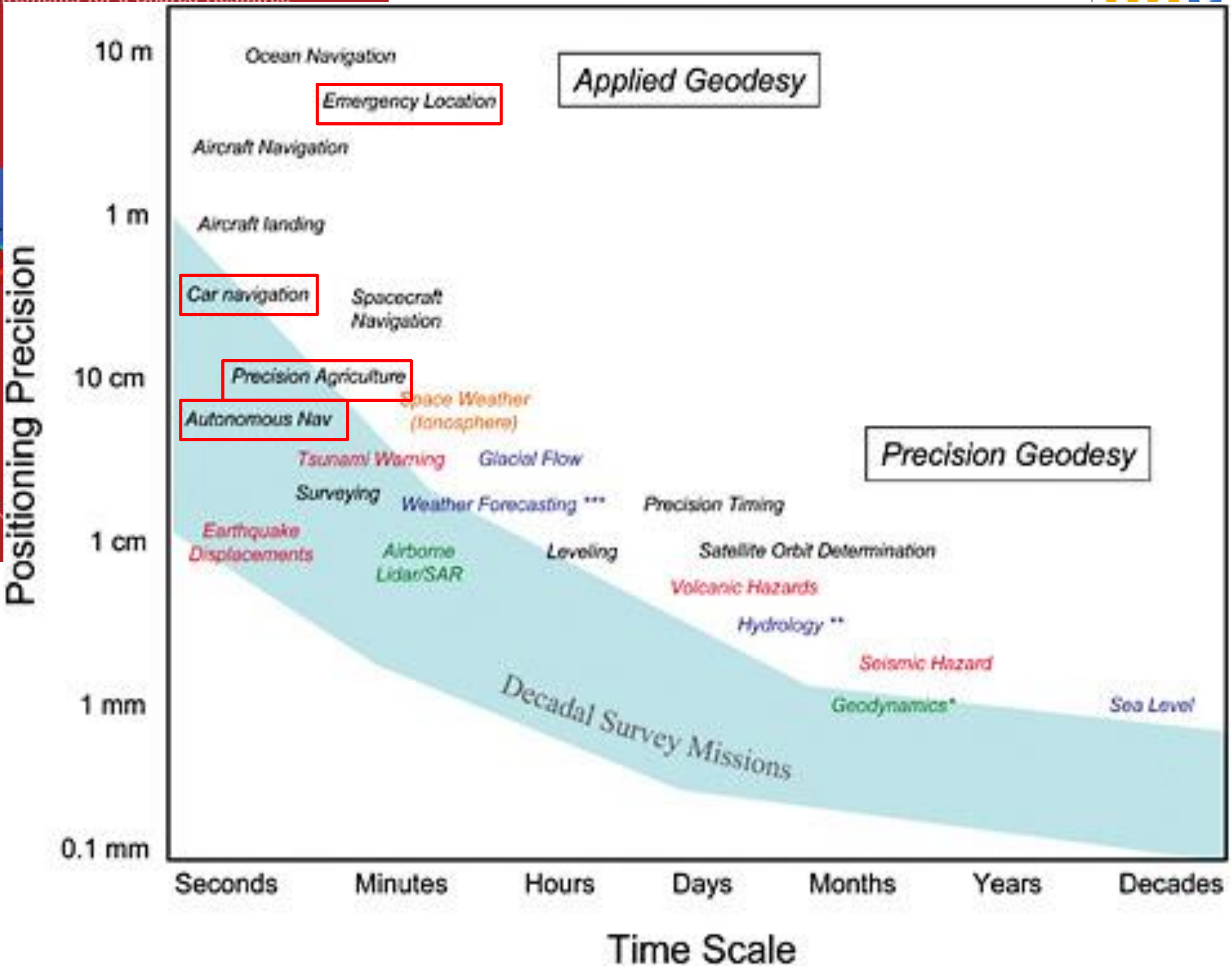

Global Navigation Satellite Systems
Report of a Joint Workshop of the National Academy of Engineering and the Chinese Academy of Engineering

Positioning Precision



PRECISE GEODETIC INFRASTRUCTURE
National Requirements for a Shared Resource

NATIONAL RESEARCH



Future & Trends: Localization Indoors, Underground, & Underwater

- GPS works outdoors, but,
  - We are indoors 90% of time!
  - Ex. malls, hospitals, airports, …

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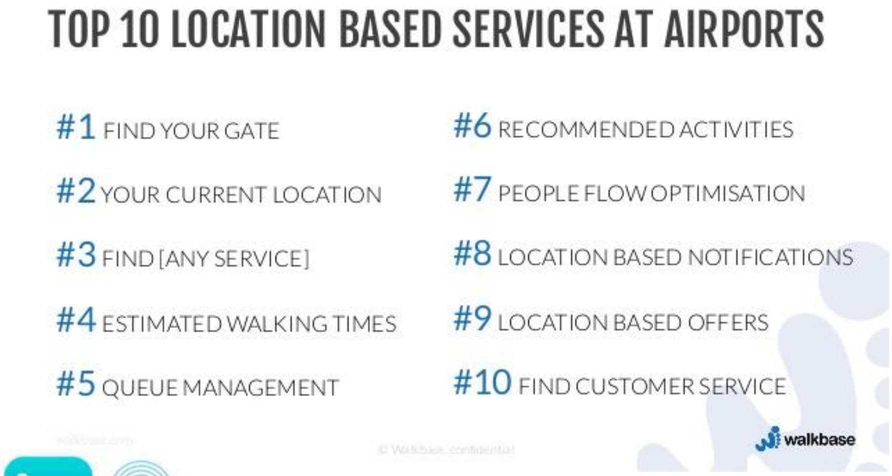
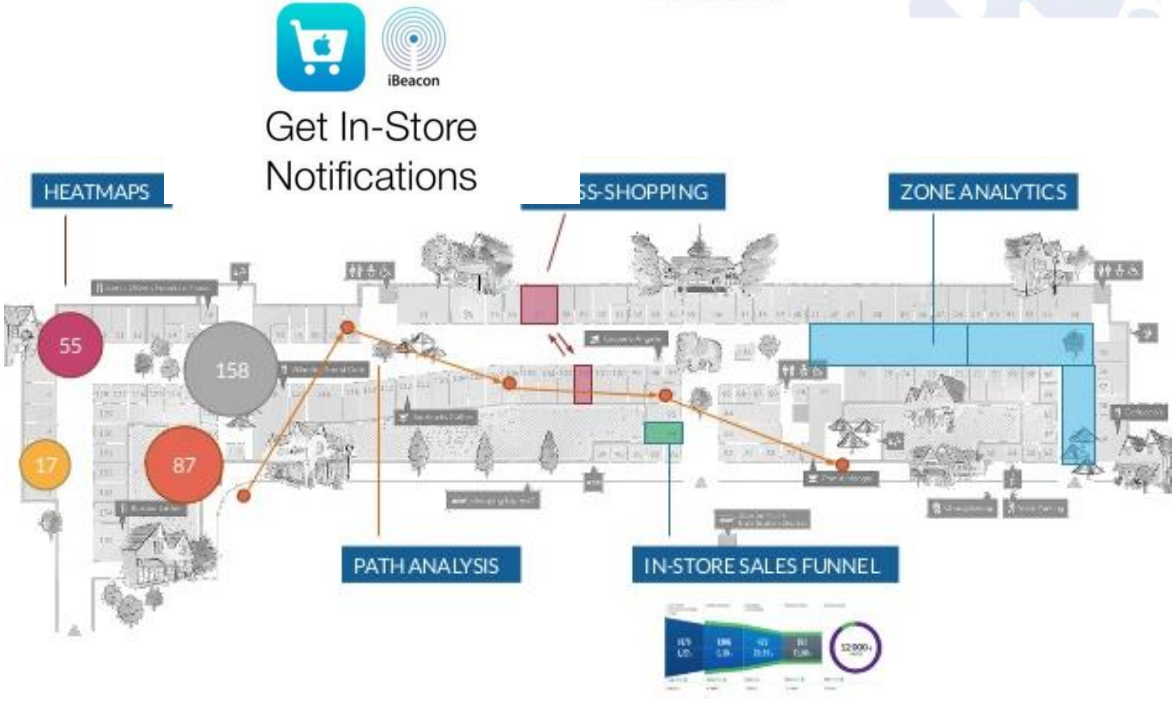


TOP 10 LOCATION BASED SERVICES AT AIRPORTS

#1 FIND YOUR GATE	#6 RECOMMENDED ACTIVITIES
#2 YOUR CURRENT LOCATION	#7 PEOPLE FLOW OPTIMISATION
#3 FIND [ANY SERVICE]	#8 LOCATION BASED NOTIFICATIONS
#4 ESTIMATED WALKING TIMES	#9 LOCATION BASED OFFERS
#5 QUEUE MANAGEMENT	#10 FIND CUSTOMER SERVICE

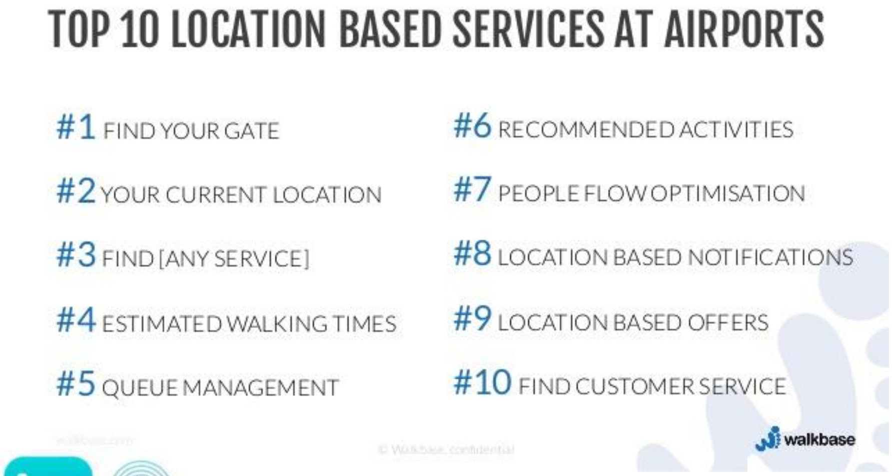
walkbase


iBeacon
Get In-Store Notifications
HEATMAPS
SS-SHOPPING
ZONE ANALYTICS
55
158
17
87
PATH ANALYSIS
IN-STORE SALES FUNNEL

Future & Trends: Localization Indoors, Underground, & Underwater

- GPS works outdoors, but,
  - We are indoors 90% of time!
  - Ex. malls, hospitals, airports, …

- Leveraging existing indoor infrastructure
  - Blue Tooth, Wi-Fi, …



TOP 10 LOCATION BASED SERVICES AT AIRPORTS

#1 FIND YOUR GATE

#2 YOUR CURRENT LOCATION

#3 FIND [ANY SERVICE]

#4 ESTIMATED WALKING TIMES

#5 QUEUE MANAGEMENT

#6 RECOMMENDED ACTIVITIES

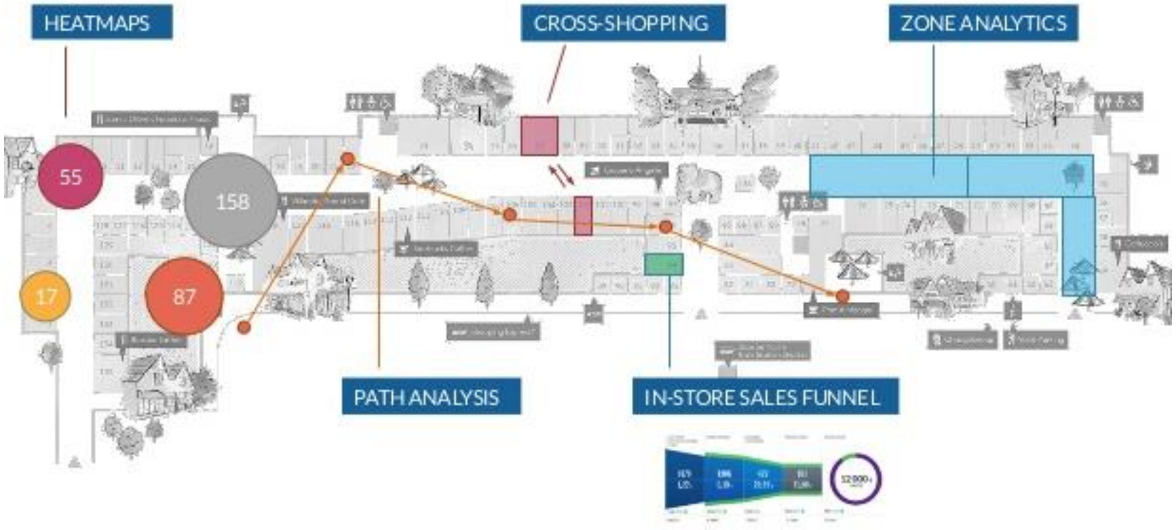
#7 PEOPLE FLOW OPTIMISATION

#8 LOCATION BASED NOTIFICATIONS

#9 LOCATION BASED OFFERS

#10 FIND CUSTOMER SERVICE

Get In-Store Notifications



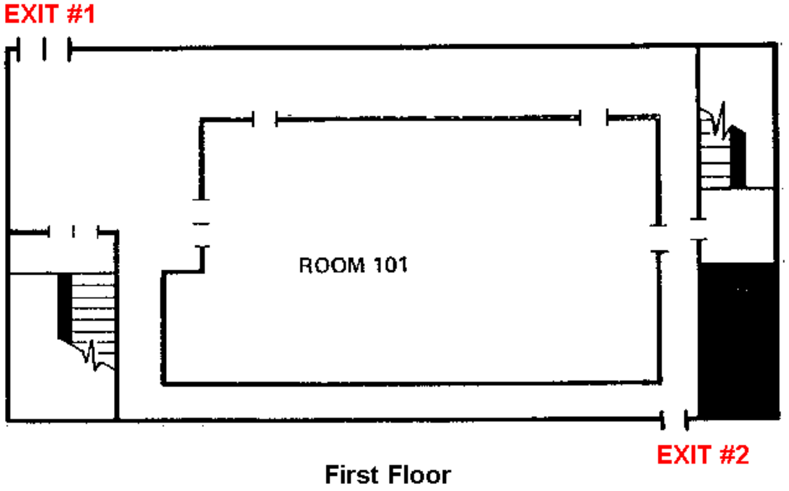
HEATMAPS
CROSS-SHOPPING
ZONE ANALYTICS
55
158
17
87
PATH ANALYSIS
IN-STORE SALES FUNNEL

Future & Trends: Localization Indoors, Underground, & Underwater

http://www.mobilefringe.com/products/square-one-shopping-center-app-for-iphone-and-android/

- GPS works outdoors, but,
  - We are indoors 90% of time!
  - Ex. malls, hospitals, airports, etc.
  - Indoor asset tracking, exposure hotposts, …
- Leveraging existing indoor infrastructure
  - Blue Tooth, WiFi, Cell-towers, cameras, Other people?
- How to model indoors for navigation, tracking, hotspots, …?
  - What are nodes and edges ?

iBeacon
Get In-Store Notifications


EXIT #1
ROOM 101
EXIT #2
First Floor

WiFi Localization

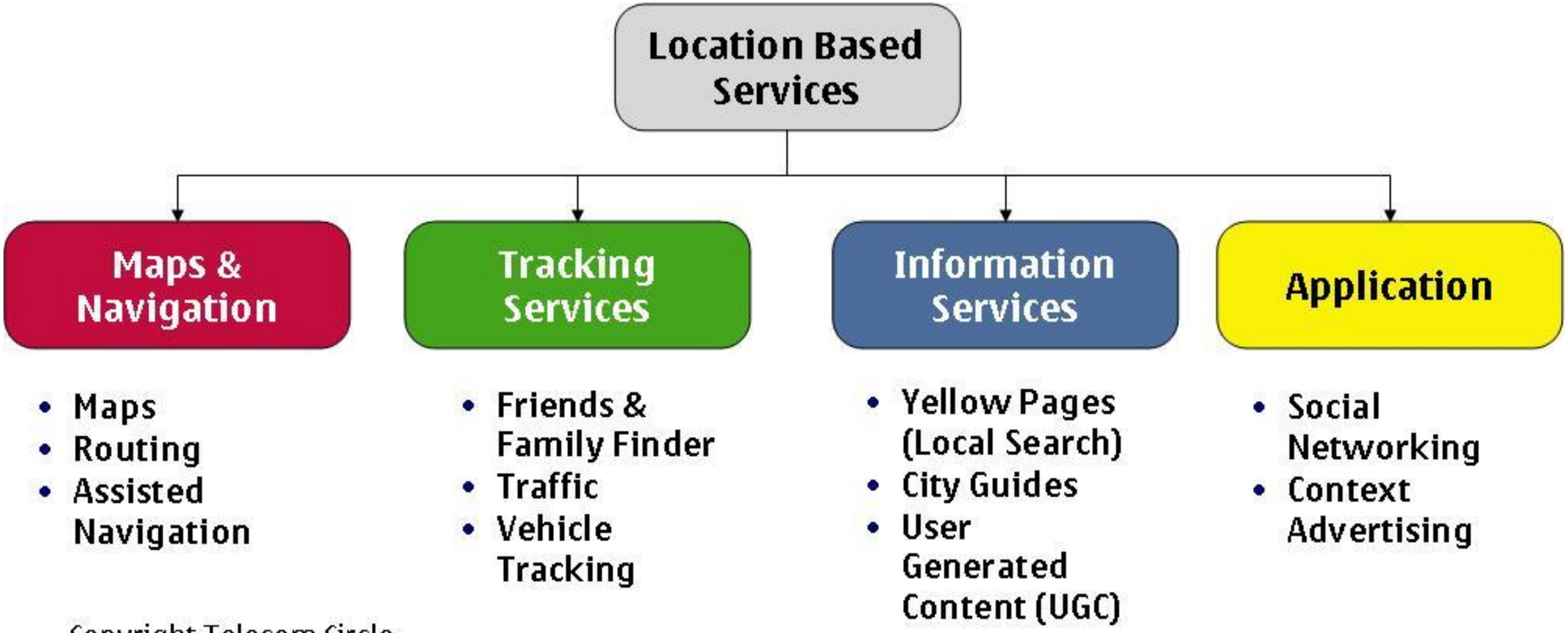
http://rfid.net/basics/rtls/123-wi-fi-how-it-works

Major technologies and areas (past, present, & future)

- GPS
- Location Based Services
- Spatial Data Management Systems
- Geographic Information Systems
- Spatial Predictive Analysis (Spatial Statistics, or Spatial Data Mining)
- Virtual Globes and VGI (or CGI)

Location Based Services

- Services based on your location
  - Location Sharing: Where am I? (street address, <latitude, longitude>)
  - Directory: Where is the nearest gas station?
  - Routes: What is the shortest path to reach there?



Location Based Services

Maps & Navigation

- Maps
- Routing
- Assisted Navigation

Tracking Services

- Friends & Family Finder
- Traffic
- Vehicle Tracking

Information Services

- Yellow Pages (Local Search)
- City Guides
- User Generated Content (UGC)

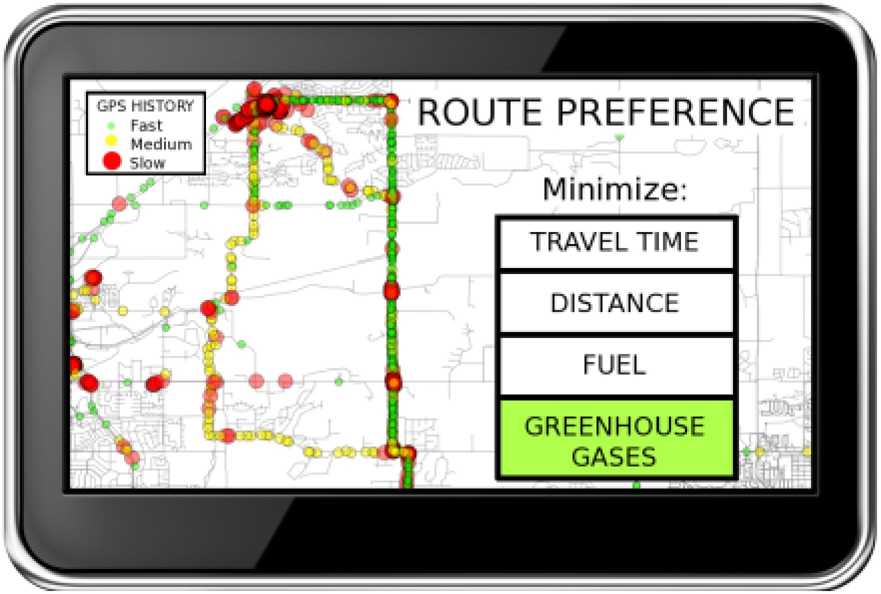
Application

- Social Networking
- Context Advertising

Copyright Telecom Circle

Trends: Next Generation Navigation

- Eco-Routing
- Best start time
- Road-capacity aware


GPS HISTORY
● Fast
● Medium
● Slow
ROUTE PREFERENCE
Minimize:
TRAVEL TIME
DISTANCE
FUEL
GREENHOUSE GASES

NO LEFT TURN

Trends: Persistent Geo-Hazard Monitoring

- Environmental influences on our health & safety
  - air we breathe, water we drink, food we eat

Air Quality
69

Traffic Density and NYCCAS Monitoring Locations

Trends: Persistent Geo-Hazard Monitoring

- Environmental influences on our health & safety
  - air we breathe, water we drink, food we eat
- Surveillance
  - Passive > Active > Persistent
  - How to economically cover all locations all the time ?
  - Crowd-sourcing, e.g., smartphones, tweets, ...etc

Air Quality
69

Traffic Density and NYCCAS Monitoring Locations

American Red Cross
twitter

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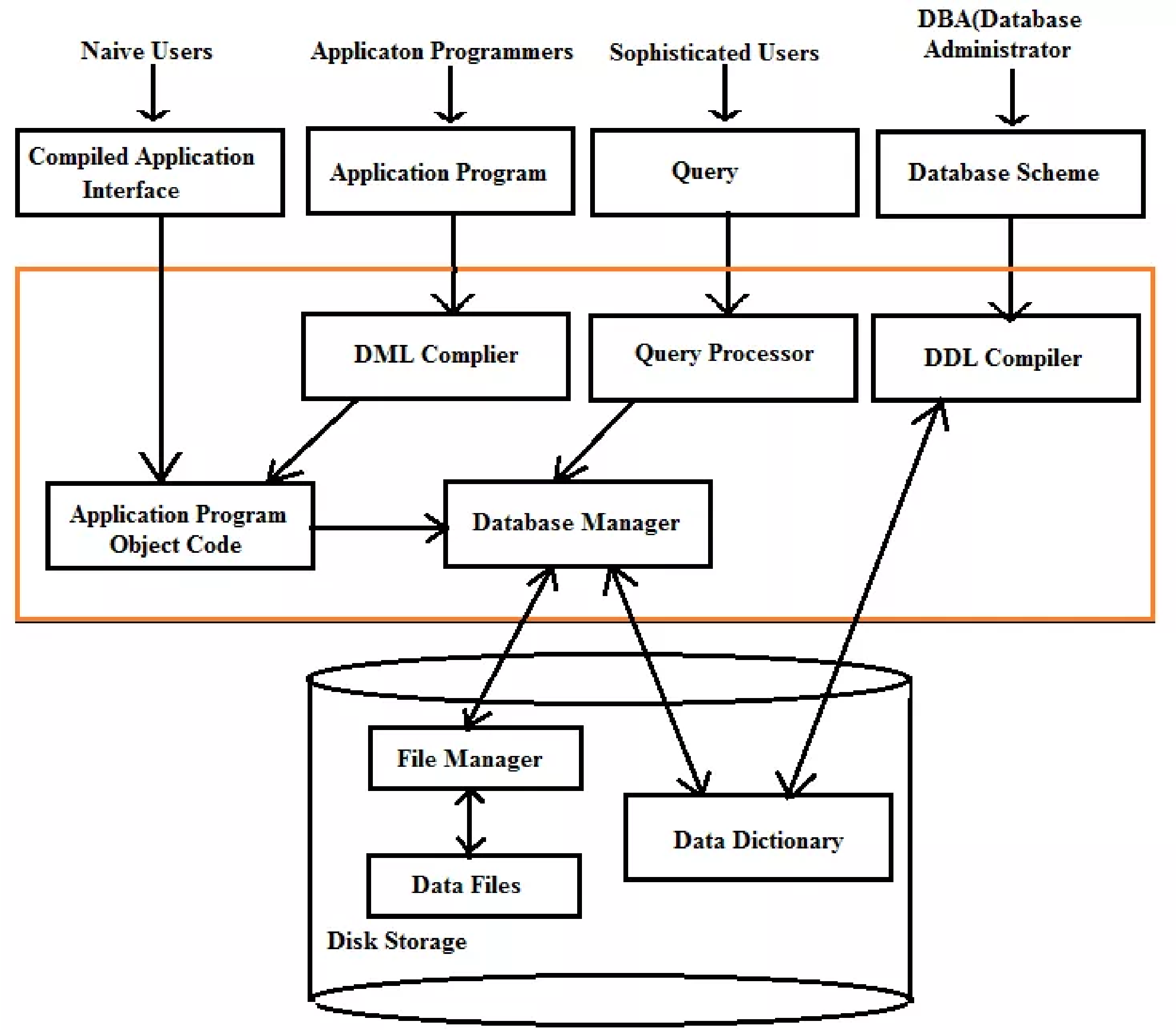
Database Management Systems (DBMSs)


Naive Users
Applicaton Programmers
Sophisticated Users
DBA(Database Administrator
Compiled Application Interface
Application Program
Query
Database Scheme
DML Complier
Query Processor
DDL Compiler
Application Program Object Code
Database Manager
File Manager
Data Dictionary
Data Files
Disk Storage

Spatial Database Management Systems (SDBMS)

- An SDBMS is a software module that:
  - Can work with an underlying database management system (DBMS)
  - Supports spatial data models, spatial abstract data types (ADTs) and a query language from which these ADTs are callable

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  - Supports spatial indexing, efficient algorithms for processing spatial operations, and domain specific rules for query optimization

SDBMS: Spatial Data Examples

- Examples of non-spatial data
  - Names, phone numbers, email addresses of people

- Examples of spatial data
  - Census Data
  - NASA satellites imagery - terabytes of data per day
  - Weather and climate data
  - Rivers, farms, ecological impact
  - Medical imaging

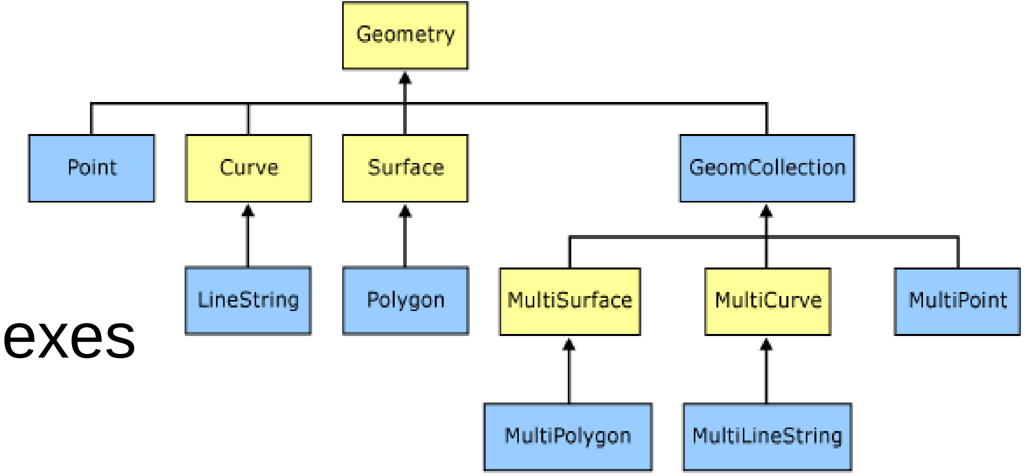
SDBMS: Non-Spatial vs. Spatial Queries

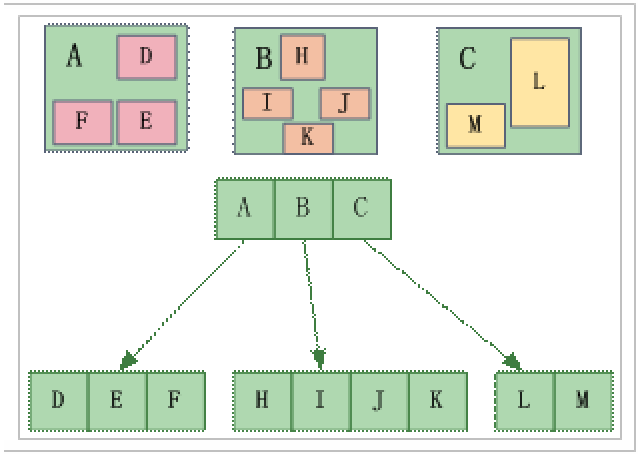
- Non-spatial queries
  - List the names of all bookstore with more than ten thousand titles
  - List the names of ten customers, in terms of sales, in the year 2001

- Spatial Queries
  - List the names of all bookstores with ten miles of Minneapolis
  - List all customers who live in Tennessee and its adjoining states

Components of an SDBMS

- Spatial data model
- Query language
- Query processing
- File organization and indexes
- Query optimization, etc.


Geometry
Point
Curve
Surface
GeomCollection
LineString
Polygon
MultiSurface
MultiCurve
MultiPoint
MultiPolygon
MultiLineString


A
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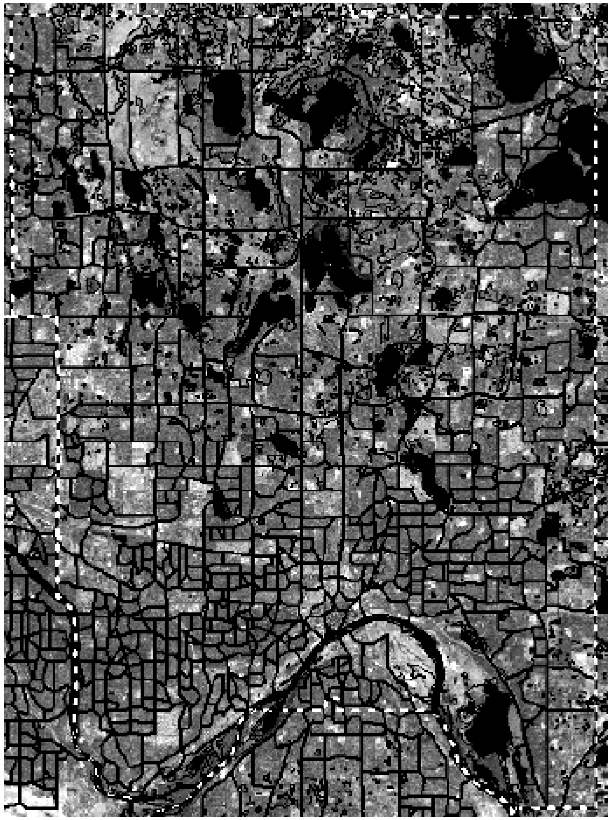
K
L
M

SDBMS Example

- Consider a spatial dataset with:
  - County boundary (dashed white line)
  - Census block - name, area, population, boundary (dark line)
  - Water bodies (dark polygons)
  - Satellite Imagery (gray scale pixels)



SDBMS Example

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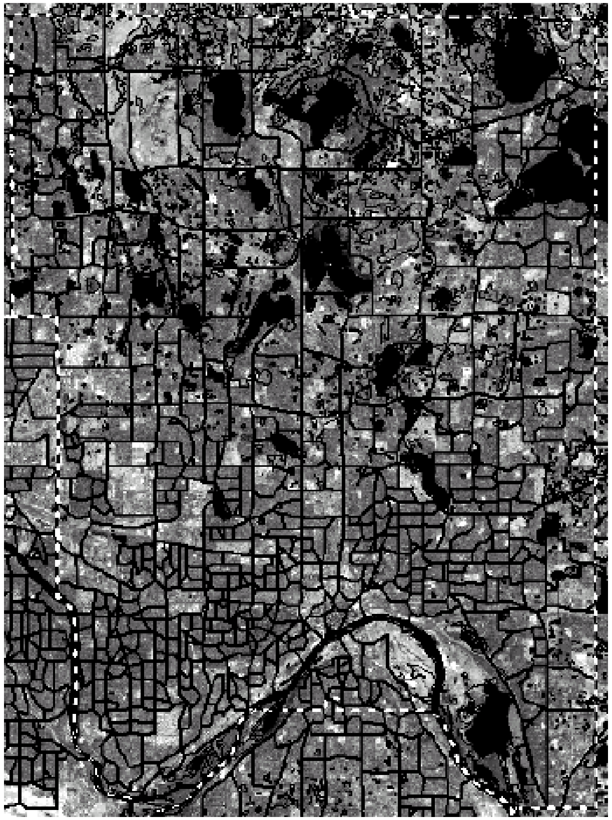
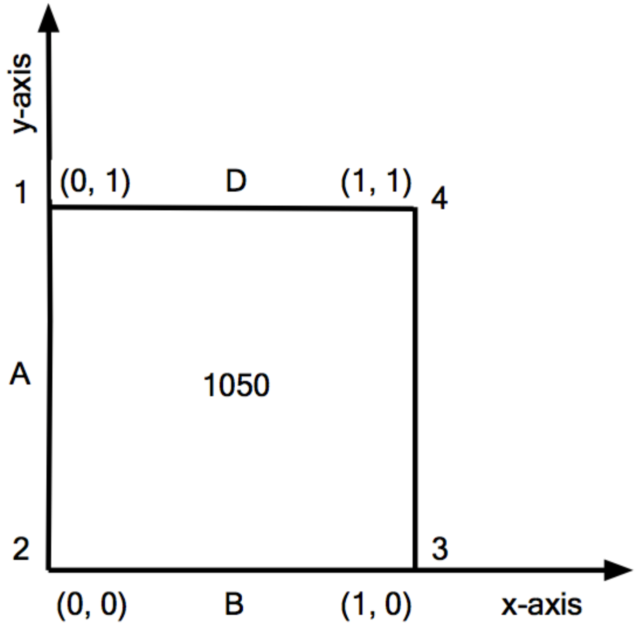
  - County boundary (dashed white line)
  - Census block - name, area, population, boundary (dark line)
  - Water bodies (dark polygons)
  - Satellite Imagery (gray scale pixels)
- Storage in a SDBMS table:

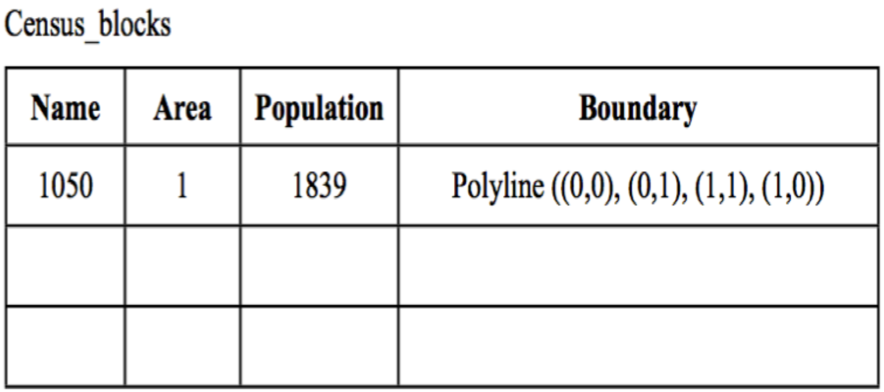
```
create table census_blocks (
name          string,
area          float,
population    number,
boundary      polygon );
```



SDBMS Example

- A row in the table **census_blocks**
- Boundary has a spatial data type that can be manipulated by the query language, query processor, indexes, etc

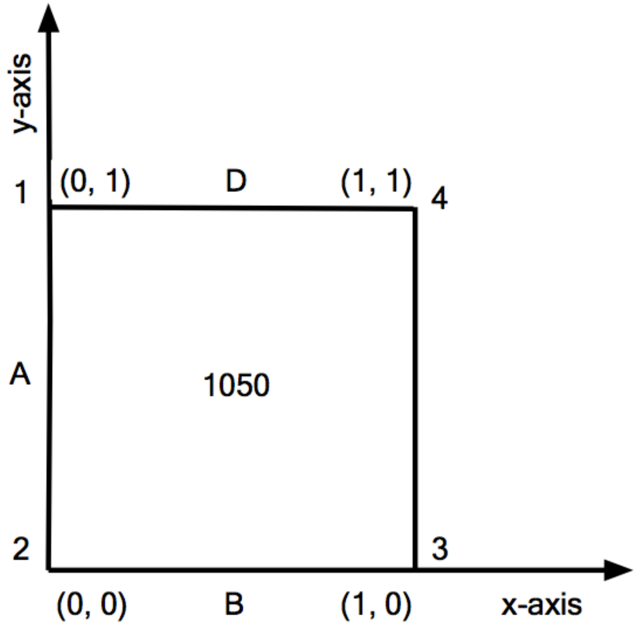

y-axis
1
(0, 1)
D
(1, 1)
4
A
1050
2
3
(0, 0)
B
(1, 0)
x-axis


Census_blocks

Name	Area	Population	Boundary
1050	1	1839	Polyline ((0,0), (0,1), (1,1), (1,0))

SDBMS Example

- A row in the table **census_blocks**
- Boundary has a spatial data type that can be manipulated by the query language, query processor, indexes, etc
- Query: Select * FROM census_blocks C, factory F WHERE Overlap(C.boundary, F. boundary)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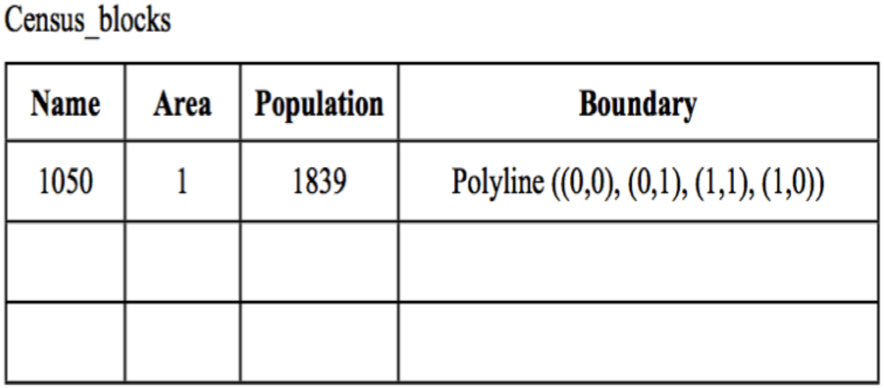

Census_blocks

Name	Area	Population	Boundary
1050	1	1839	Polyline ((0,0), (0,1), (1,1), (1,0))

Spatial beyond Databases

- Distributed systems
  - Hadoop, Spark, Impala, …etc

Spatial beyond Databases

Simba

GeoSpark

rasdaman
raster data manager

Spatial Hadoop
I can play with your spatial data

Hadoop-GIS
Spatial Big Data Solutions

geomesa

GeoTrellis

SpaceCurve

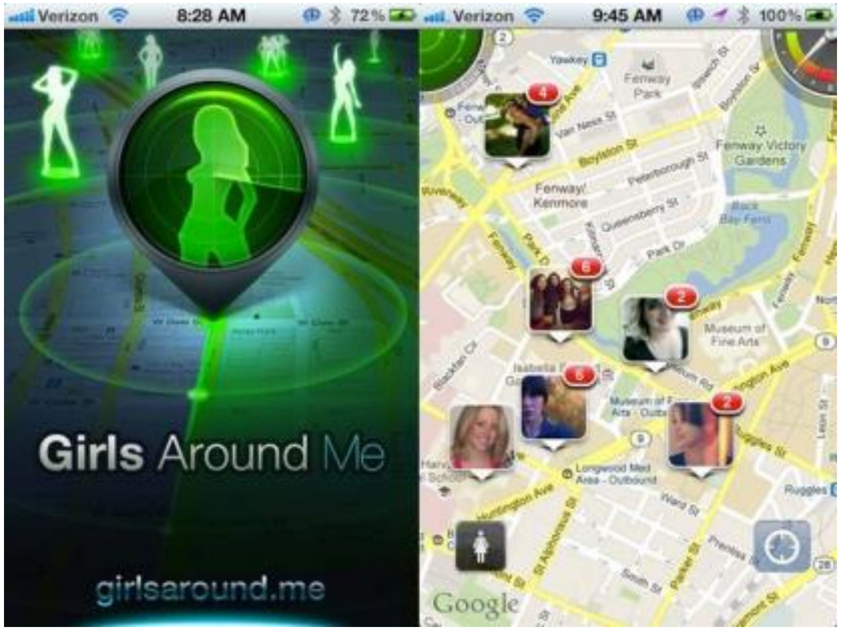
SPHINX

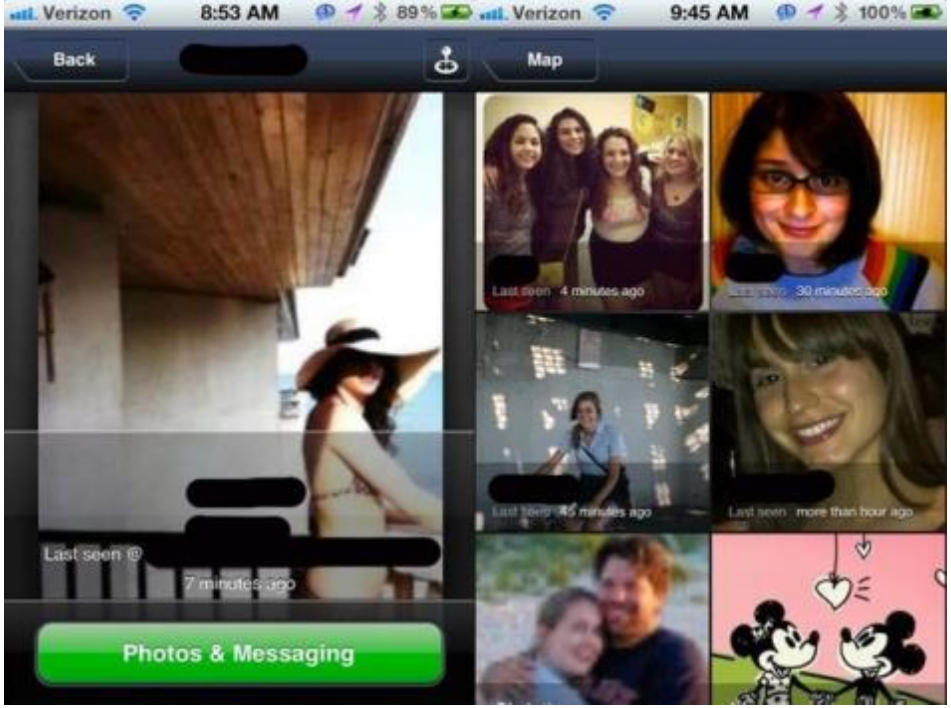
Challenges: Privacy vs. Utility

- Check-in risks: Stalking, GeoSlavery, Others know that you are not home, etc

Challenges: Privacy vs. Utility

- Check-in risks: Stalking, GeoSlavery, Others know that you are not home, etc
- Ex: Girls Around me App (3/2012)


Verizon 8:28 AM 72%
Girls Around Me
girlsaround.me
Verizon 9:45 AM 100%
Fenway Park
Boylston St
Fenway/Kenmore
Museum of Fine Arts
Google


Verizon 8:53 AM 89%
Back
[redacted]
Map
Verizon 9:45 AM 100%
Photos & Messaging

Last seen @ [redacted] 7 minutes ago

Last seen 4 minutes ago

Last seen 30 minutes ago

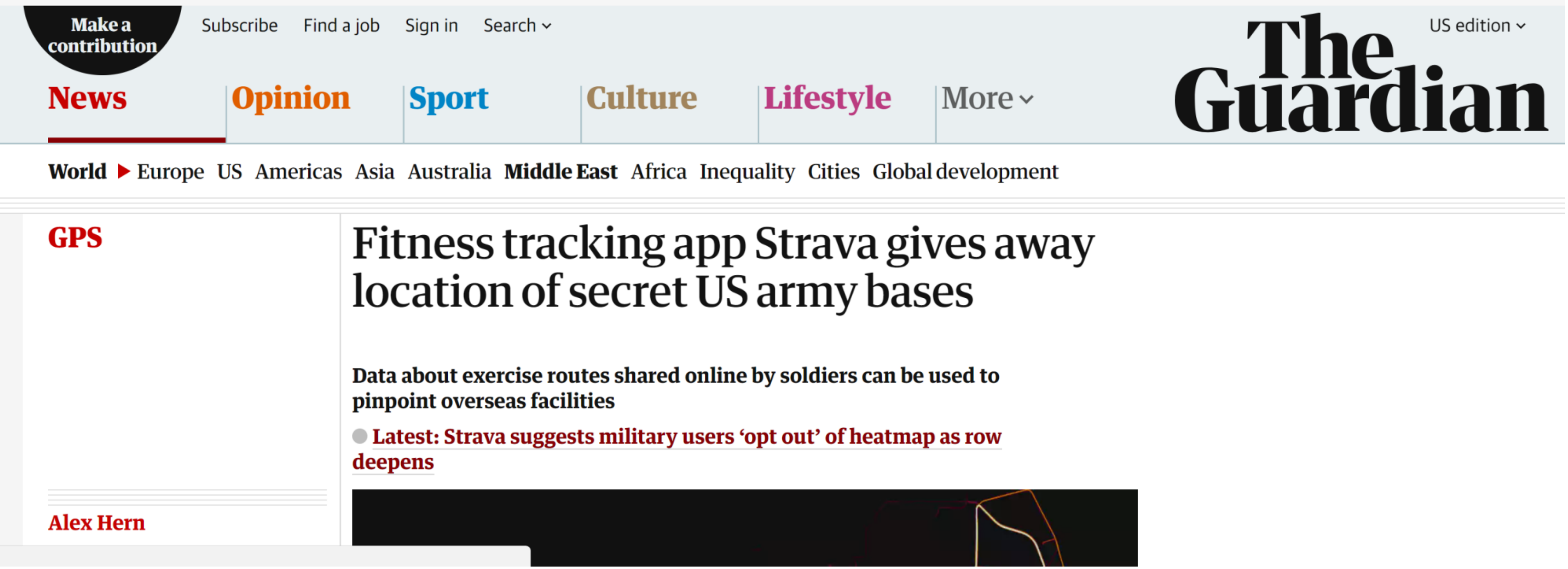
Last seen 45 minutes ago

Last seen more than hour ago

The Girls of Girls Around Me. It's doubtful any of these girls even know they are being tracked. Their names and locations have been obscured for privacy reasons. (Source: Cult of Mac, March 30, 2012)

JANUARY IS NATIONAL STALKING AWARENESS MONTH
StalkingAwarenessMonth.org

Challenges: Security vs. Utility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Middle East
Africa
Inequality
Cities
Global development

GPS

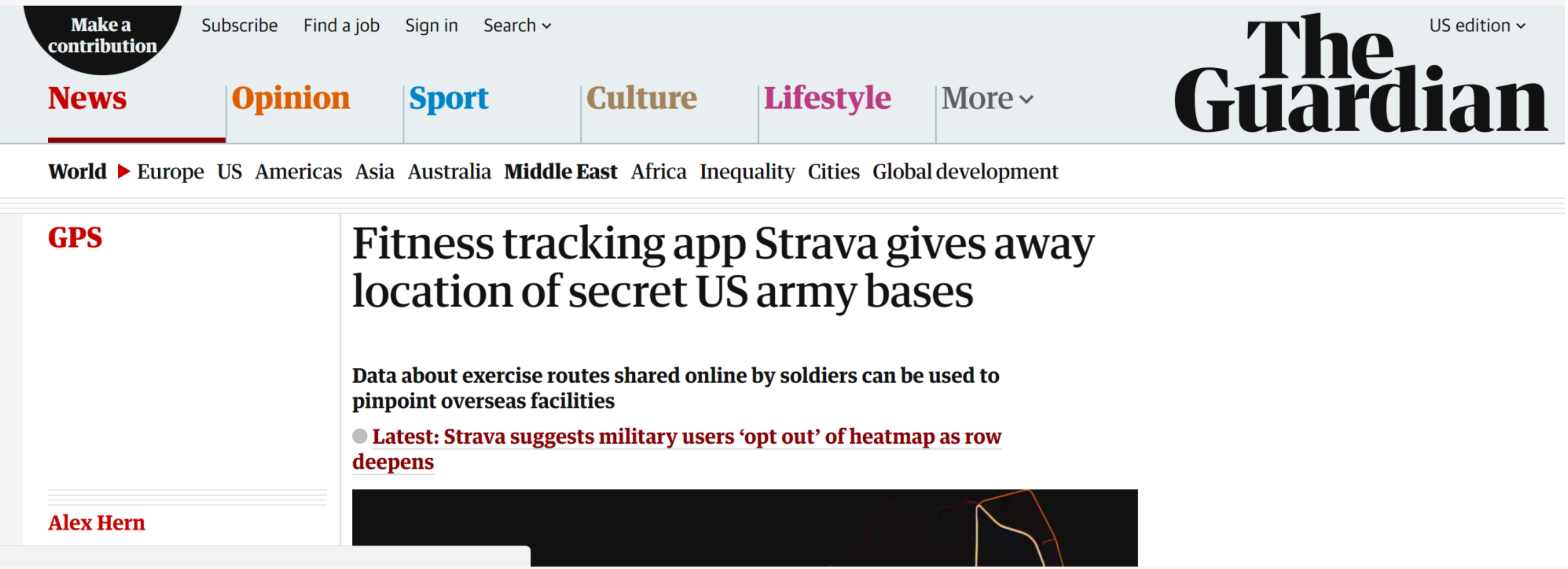
Fitness tracking app Strava gives away location of secret US army bases

Data about exercise routes shared online by soldiers can be used to pinpoint overseas facilities

Latest: Strava suggests military users 'opt out' of heatmap as row deepens

Alex Hern

Challenges: Security vs. Utility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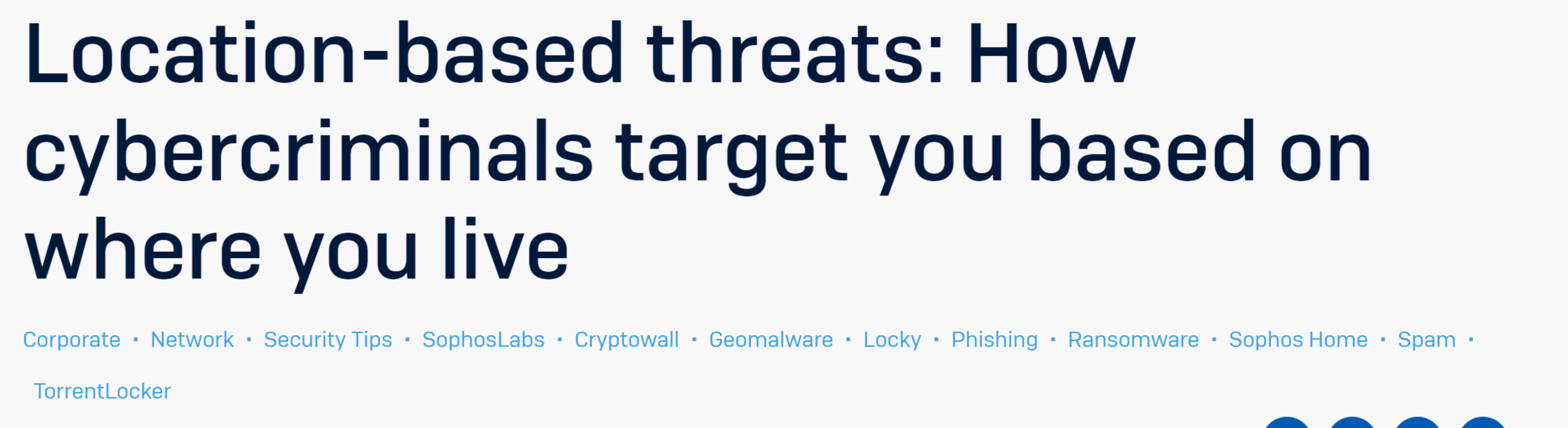

Location-based threats: How cybercriminals target you based on where you live

Corporate · Network · Security Tips · SophosLabs · Cryptowall · Geomalware · Locky · Phishing · Ransomware · Sophos Home · Spam · TorrentLocker

Challenges: Security vs. Utility

- Important questions:
  - Who gets my data?
  - Who do they give it to?
  - What promises do I get?

Challenges: Security vs. Utility

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  - Economic Entities
  - Public Safety
  - Policy Makers

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  - What promises do I get?
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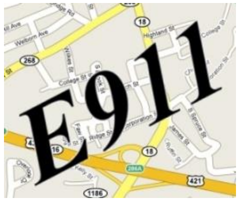
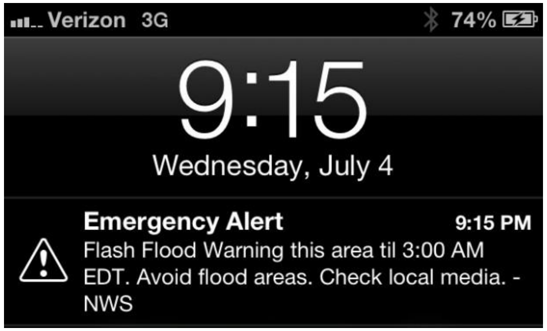
  - Civil Society
  - Economic Entities
  - Public Safety
  - Policy Makers
- Agreements and disagreements
  - Agreements: E911, emergency alerts
  - Controversial: traffic monitoring




Verizon 3G 74%

9:15

Wednesday, July 4

Emergency Alert 9:15 PM

Flash Flood Warning this area til 3:00 AM EDT. Avoid flood areas. Check local media. - NWS

Spatial beyond GeoSpatial

- Examples:
  - Human bodies
  - VLSI
  - Universe

Spatial beyond GeoSpatial

- Examples:
  - Human bodies
  - VLSI chips and boards
  - Universe
  - Indoor and virtual spaces
- Challenges:
  - What are the reference system?
    - On Mars? Outside Milkyway galaxy? In augmented reality spaces?
    - Is it one for all humans? Or personalized?
  - Accuracy
  - 3D+ scalability

Major technologies and areas (past, present, & future)

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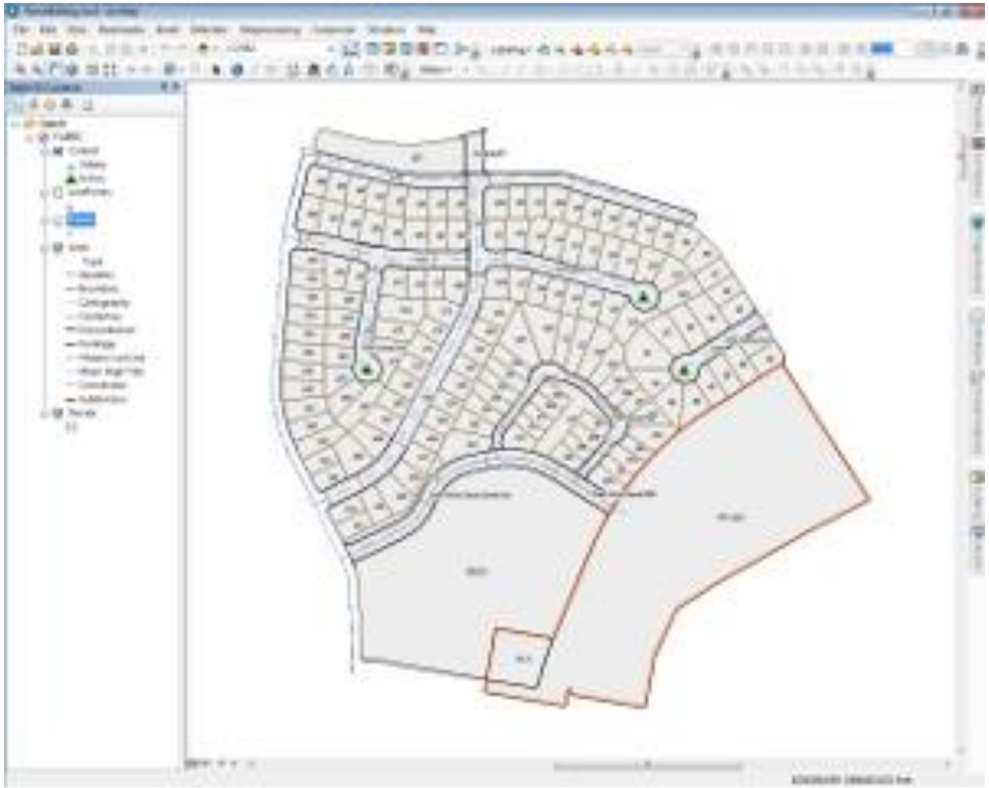
Geographic Information Systems (GIS)

- Software packages for working with maps and geographic information.
  - Creating and using maps
  - Compiling geographic data
  - Analyzing mapped info
  - Sharing and discovering geographic information



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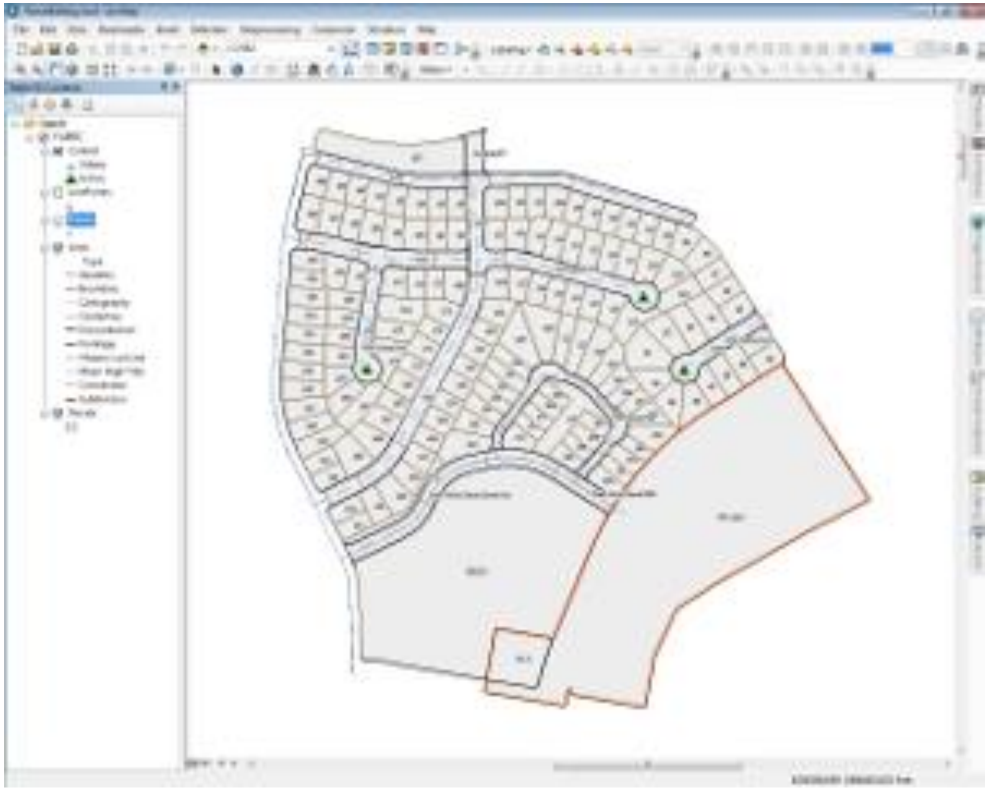
esri
ArcGIS®



How different GIS from SDBMS?

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- GIS uses SDBMS to store, search, and query spatial data

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- GIS used to visualize and analyze spatial data
  - Rich high-level analysis
- SDBMS used to store, index, and query spatial data efficiently
  - Efficient and scalable fundamental querying and data management operations

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- GIS is a software application, SDBMS is a data management system
- GIS used to visualize and analyze spatial data
  - Rich high-level analysis
- SDBMS used to store, index, and query spatial data efficiently
  - Efficient and scalable fundamental querying and data management operations
- SDBMS can be used by applications other than GIS
  - Astronomy, location-based services, brain informatics, etc

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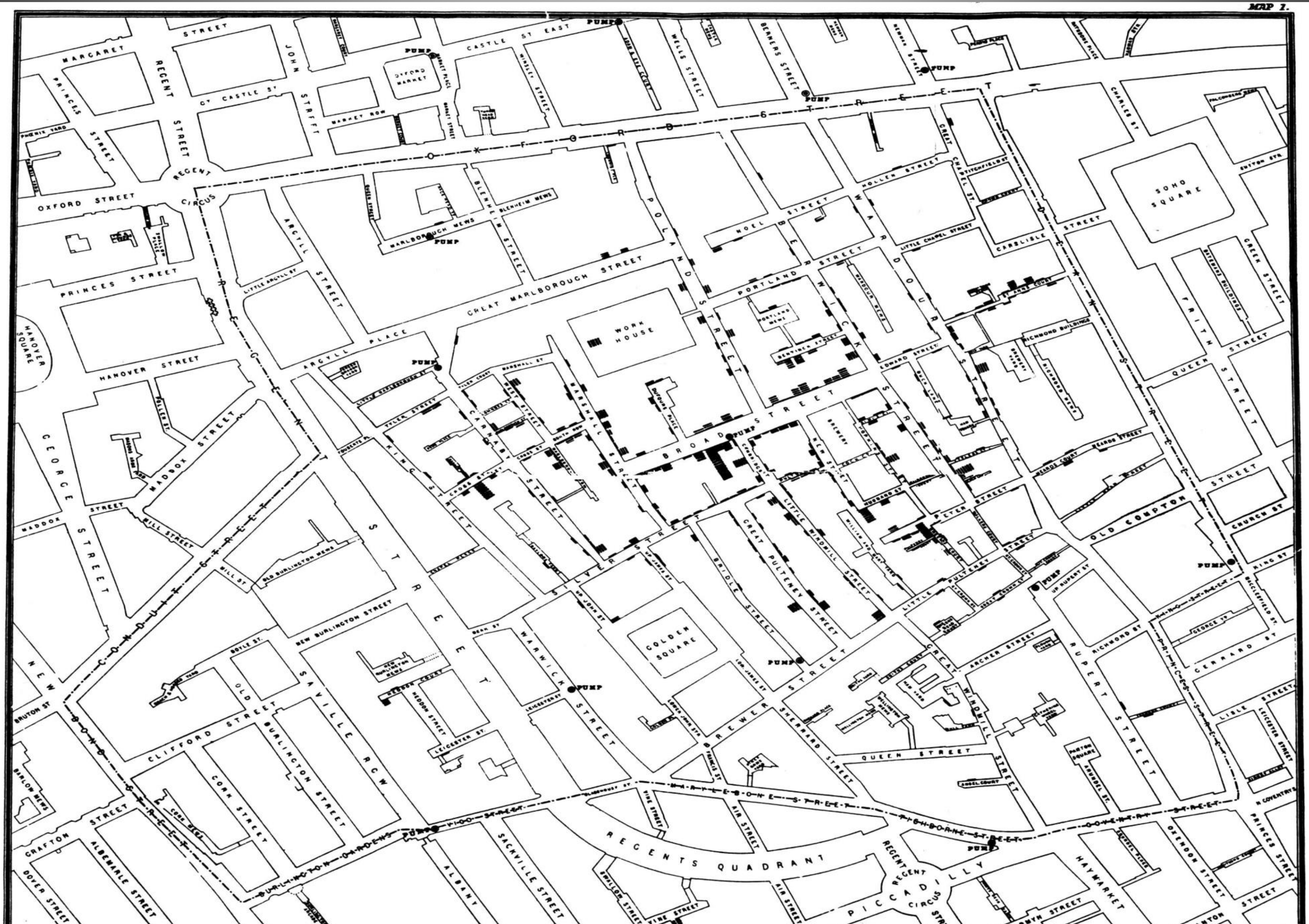
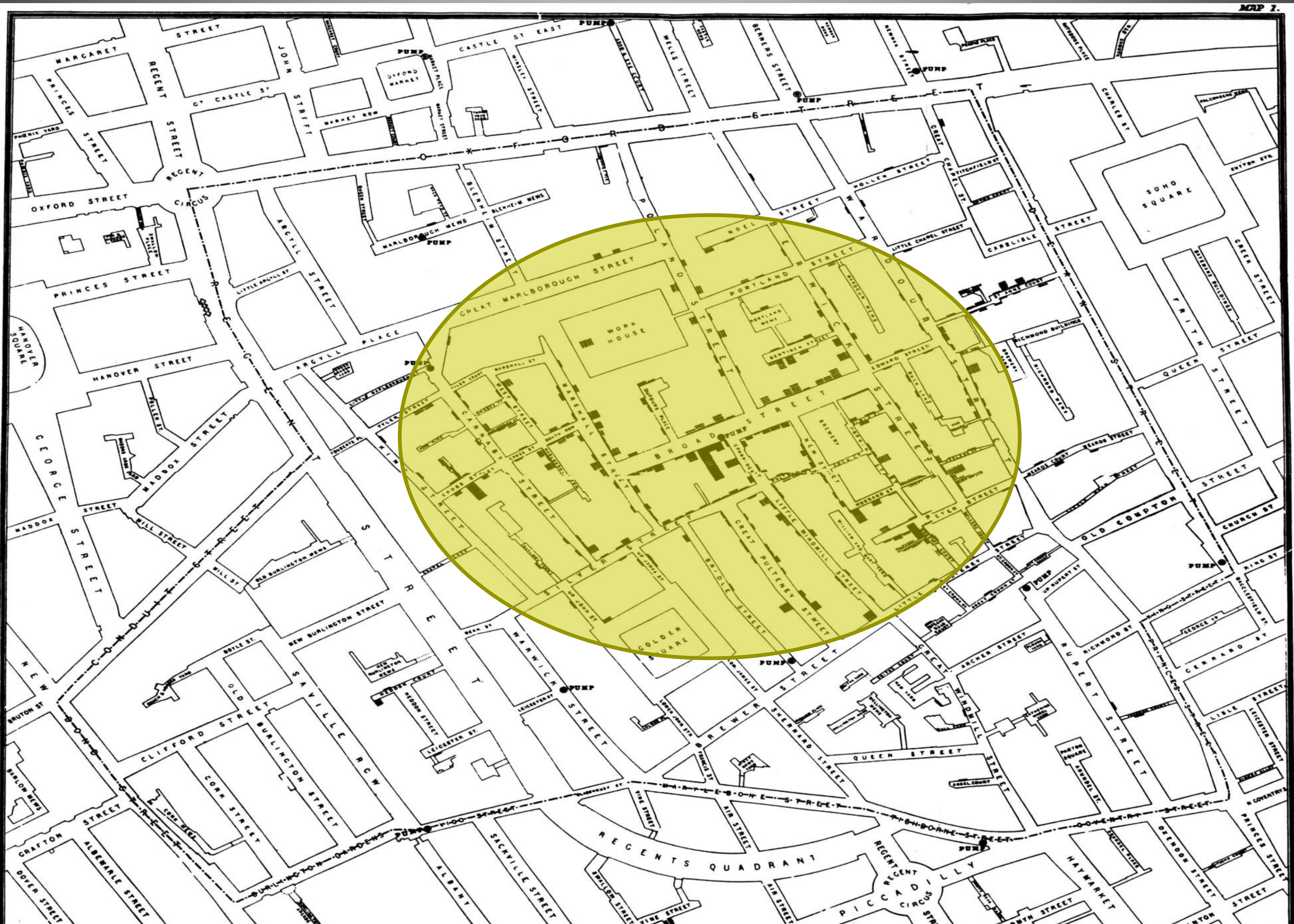
Cholera cases in the London epidemic of 1854


MAP 1.
MARGARET STREET
PRINCES STREET
REGENT STREET
JOHN STREET
CASTLE ST EAST
GT CASTLE ST
OXFORD MARKET
MARKET ROW
WINSLEY STREET
WELLS STREET
BERNERS STREET
NEWMAN STREET
CHARLES ST
OXFORD STREET
REGENT CIRCUS
PHOENIX YARD
SOHO SQUARE
SUTTON STR
ARGYLL STREET
LITTLE ARGYLL ST
MARLBOROUGH MEWS
BLENHEIM MEWS
BLENHEIM STREET
POLAND STREET
NOEL STREET
HOLLEN STREET
BERWICK STREET
WARDOUR STREET
CHAPEL ST
LITTLE CHAPEL STREET
CARLISLE STREET
DEAN STREET
GREEK STREET
FRITH STREET
PRINCES STREET
GREAT MARLBOROUGH STREET
PORTLAND STREET
WORK HOUSE
PORTLAND MEWS
BENTINCK STREET
ST ANNE COURT
RICHMOND BUILDINGS
RICHMOND MEWS
EDWARD STREET
QUEEN STREET
HANOVER SQUARE
HANOVER STREET
ARGYLL PLACE
MARSHALL ST
BROAD STREET
CAMBRIDGE ST
NEW STREET
PETER STREET
HUSBAND ST
CROSS ST
KING STREET
TYLER STREET
MADDOX STREET
GEORGE STREET
MILL STREET
CONDUIT STREET
OLD BURLINGTON MEWS
NEW BURLINGTON STREET
REGENT STREET
LITTLE WINDMILL STREET
GREAT PULTENEY STREET
BRIDLE STREET
SILVER STREET
OLD COMPTON STREET
CHURCH ST
KING ST
GOLDEN SQUARE
WARWICK STREET
UP JOHN ST
LITTLE PULTENEY STREET
GREAT WINDMILL ST
ARCHER STREET
RUPERT STREET
RICHMOND ST
GERRARD ST
LISLE STREET
PRINCES STREET
NEWPORT STREET
SAVILLE ROW
BURLINGTON STREET
OLD BURLINGTON STREET
CLIFFORD STREET
BOYLE ST
HEDDON STREET
HEDDON COURT
NEW BURLINGTON MEWS
LEICESTER ST
BREWER STREET
SHERRARD STREET
QUEEN STREET
ANGEL COURT
PANTON SQUARE
ARUNDEL ST
HAYMARKET
OXENDON STREET
COVENTRY STREET
TICHBORNE STREET
MARYLEBONE STREET
VIGO STREET
BURLINGTON GARDENS
VINE STREET
AIR STREET
REGENTS QUADRANT
PICCADILLY
REGENT CIRCUS
SACKVILLE STREET
ALBANY
SWALLOW STREET
CORK STREET
BOND STREET
NEW BOND ST
BRUTON ST
BARLOW MEWS
GRAFTON STREET
ALBEMARLE STREET
DOVER STREET
JERMYN STREET
PUMP

Cholera cases in the London epidemic of 1854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MARGARET STREET
PRINCES STREET
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BERNERS STREET
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WINSLEY STREET
CHARLES ST
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HOLLEN STREET
DEAN STREET
GREEK STREET
FRITH STREET
QUEEN STREET
OLD COMPTON STREET
CHURCH ST
KING ST
RUPERT STREET
RICHMOND ST
GERRARD ST
LISLE STREET
PRINCES STREET
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RICHMOND BUILDINGS
CARLISLE STREET
LITTLE CHAPEL STREET
WARDOUR STREET
POLAND STREET
NOEL STREET
GREAT MARLBOROUGH STREET
PORTLAND STREET
BERWICK STREET
WORK HOUSE
MARSHALL STREET
BROAD STREET
CAMBRIDGE STREET
CARNABY STREET
KINGLY STREET
GREAT PULTENEY STREET
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BRIDLE STREET
GOLDEN SQUARE
PETER STREET
LITTLE ST
ARGYLL STREET
ARGYLL PLACE
LITTLE ARGYLL ST
MARLBOROUGH MEWS
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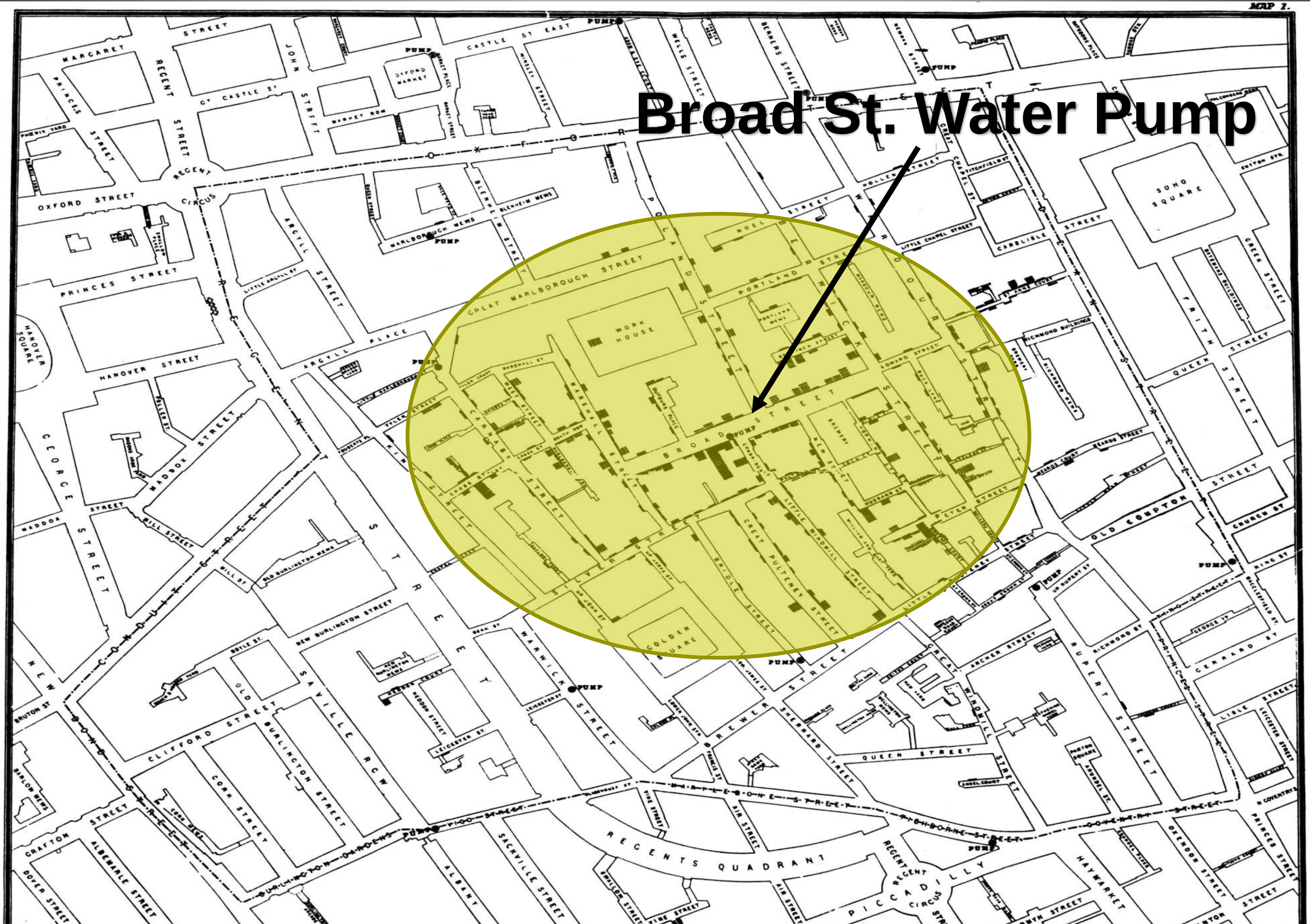
WARWICK STREET
HEDDON STREET
LEICESTER ST.
SWALLOW STREET
BREWER STREET
GLASSHOUSE STREET
VIGO STREET
BURLINGTON GARDENS
ALBANY
SACKVILLE STREET
VINE STREET
AIR STREET
REGENTS QUADRANT
REGENT CIRCUS
PICCADILLY
SHERRARD STREET
QUEEN STREET
GREAT WINDMILL STREET
ARCHER STREET
TICHBORNE STREET
JERMYN STREET
OXENDON STREET
MARYLEBONE STREET
PUMP

Cholera cases in the London epidemic of 1854



Broad St. Water Pump

MAP I.
OXFORD STREET
REGENT CIRCUS
MARGARET STREET
PRINCES STREET
REGENT STREET
JOHN STREET
CASTLE STREET EAST
GT CASTLE ST
OXFORD MARKET
WELLS STREET
BERNERS STREET
SOHO SQUARE
GREEK STREET
FRITH STREET
DEAN STREET
HANOVER SQUARE
HANOVER STREET
ARGYLL STREET
ARGYLL PLACE
GREAT MARLBOROUGH STREET
MARLBOROUGH MEWS
WORK HOUSE
POLAND STREET
NOEL STREET
PORTLAND STREET
BERWICK STREET
WARDOUR STREET
BROAD STREET
PUMP
MARSHALL STREET
CARNABY STREET
EDWARD STREET
PETER STREET
GREAT PULTENEY STREET
LITTLE WINDMILL STREET
BRIDLE STREET
GOLDEN SQUARE
QUEEN STREET
OLD COMPTON STREET
CHURCH ST
KING ST
RICHMOND ST
GERRARD STREET
RUPERT STREET
ARCHER STREET
GEORGE STREET
MADDOX STREET
MILL STREET
CONDUIT STREET
NEW BOND STREET
CLIFFORD STREET
OLD BURLINGTON STREET
NEW BURLINGTON STREET
SAVILLE ROW
CORK STREET
BURLINGTON GARDENS
VIGO STREET
ALBEMARLE STREET
DOVER STREET
GRAFTON STREET
ALBANY
SACKVILLE STREET
WARWICK STREET
BREWER STREET
SHERRARD STREET
GLASSHOUSE STREET
AIR STREET
VINE STREET
REGENTS QUADRANT
PICCADILLY
PICCADILLY CIRCUS
HAYMARKET
COVENTRY STREET
LEICESTER STREET

N.Y. / REGION 34 COMMENTS

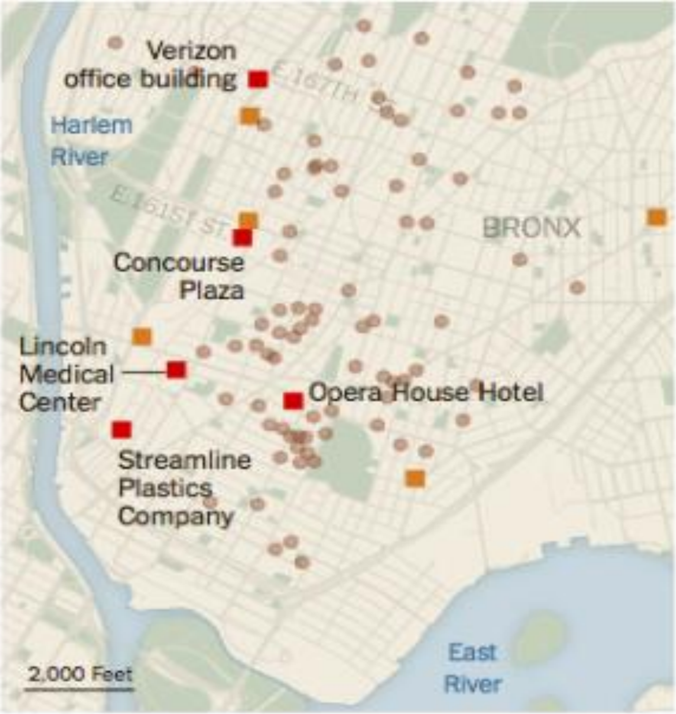
Hotel That Enlivened the Bronx Is Now a 'Hot Spot' for Legionnaires'

By WINNIE HU and NOAH REMNICK AUG. 10, 2015

Contaminated Cooling Towers

Five buildings have been identified as the potential source of the Legionnaires' disease outbreak in the South Bronx.

- 🟥 Possible sources of Legionnaires' outbreak
- 🟧 Additional sites found with legionella bacteria
- ● Locations of people with Legionnaires'


Verizon office building
E.167TH
Harlem River
E.161ST ST.
BRONX
Concourse Plaza
Lincoln Medical Center
Opera House Hotel
Streamline Plastics Company
2,000 Feet
East River

Source: New York Mayor's Office

By The New York Times

N.Y. / REGION 34 COMMENTS

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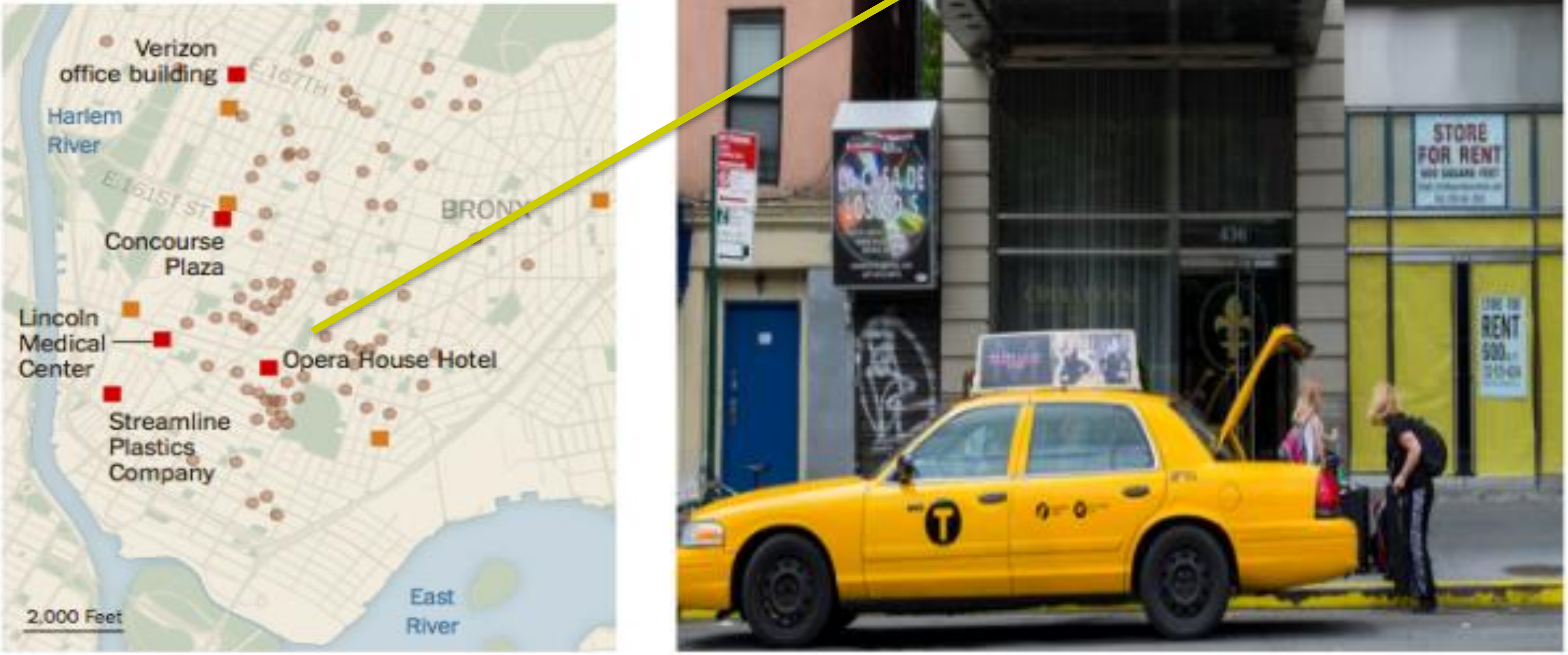


Verizon office building
Harlem River
E 167TH
E 161ST ST
BRONX
Concourse Plaza
Lincoln Medical Center
Opera House Hotel
Streamline Plastics Company
East River
2,000 Feet
OPERA HOUSE HOTEL
STORE FOR RENT

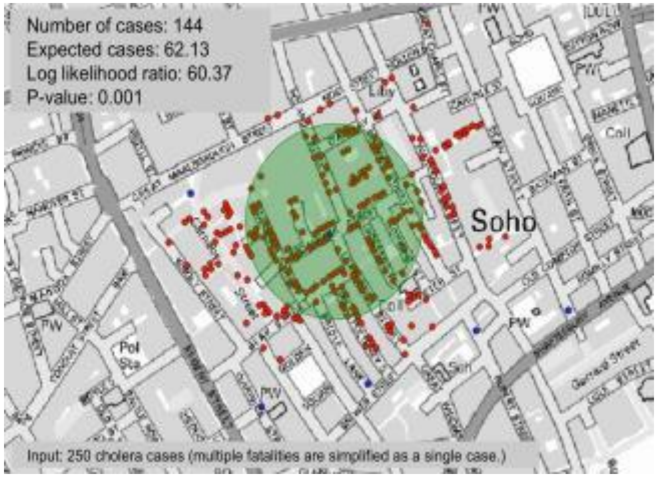
Source: New York Mayor's Office

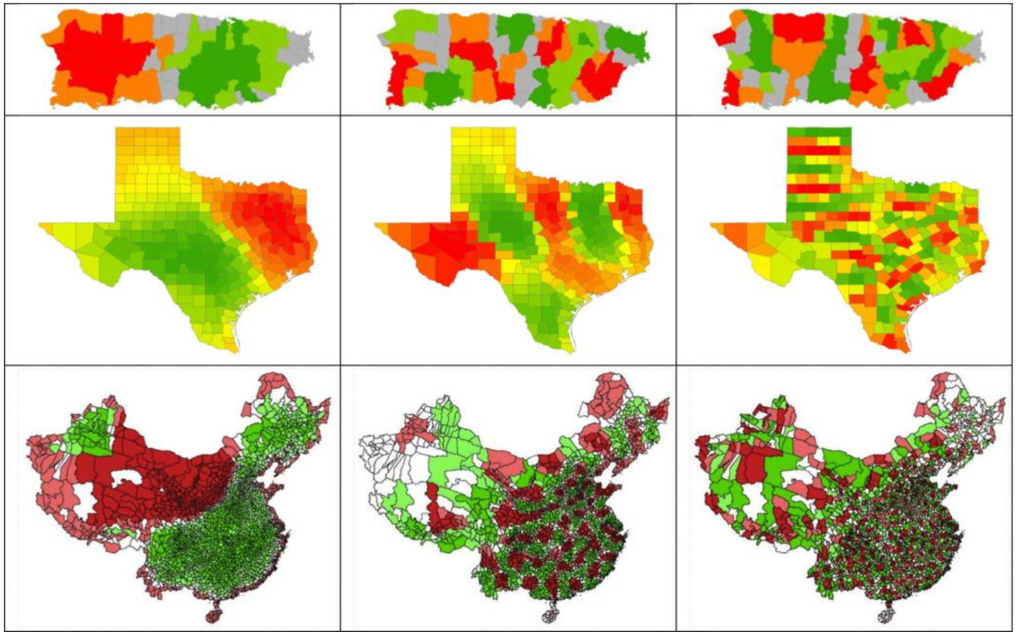
By The New York Times

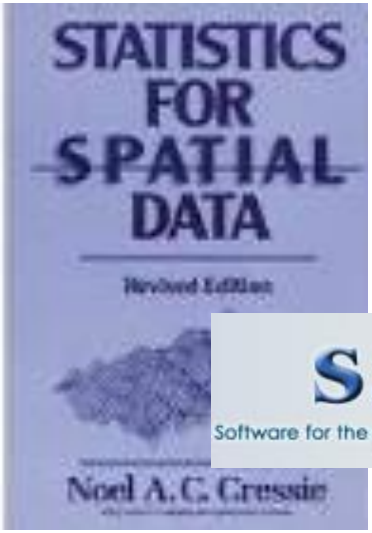
The Opera House Hotel is at the center of the outbreak. Edwin J. Torres for The New York Times

Spatial Statistics

- In the spatial space, statistical independence assumptions do not always hold
- Spatial Statistics
  - Hot spot detection
  - Spatial auto-correlation
  - Spatial-constrained clusters
  - Spatial uncertainty, confidence, etc


Number of cases: 144
Expected cases: 62.13
Log likelihood ratio: 60.37
P-value: 0.001
Soho
Input: 250 cholera cases (multiple fatalities are simplified as a single case.)



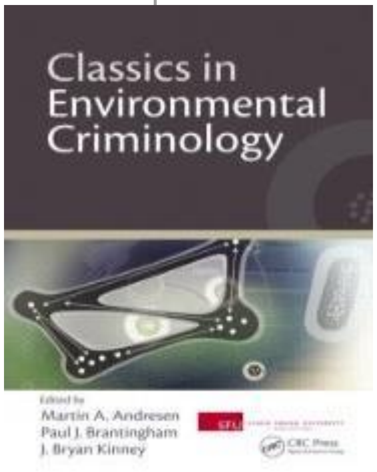

STATISTICS FOR SPATIAL DATA
Revised Edition
Noel A.C. Cressie

N
Östersund

SaTScan™

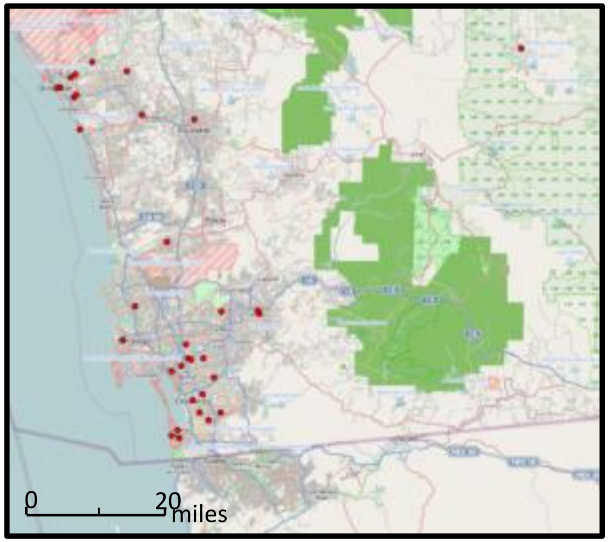
Software for the spatial, temporal, and space-time scan statistics

Detecting Spatial Patterns

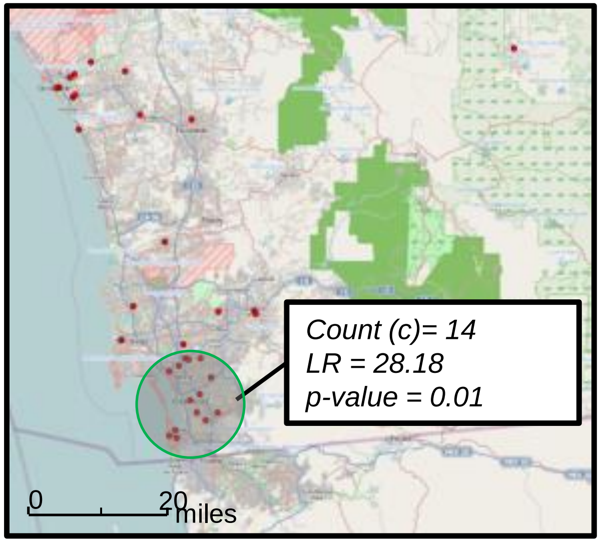

Classics in Environmental Criminology
Edited by
Martin A. Andresen
Paul J. Brantingham
J. Bryan Kinney
CRC Press

- Arson crimes in San Diego in 2013
  - Total 33 cases (red dots on the map)
  - Activity Area is appr. 3000 sq. miles.
- Arsonist caught in top green ring[2]

Input

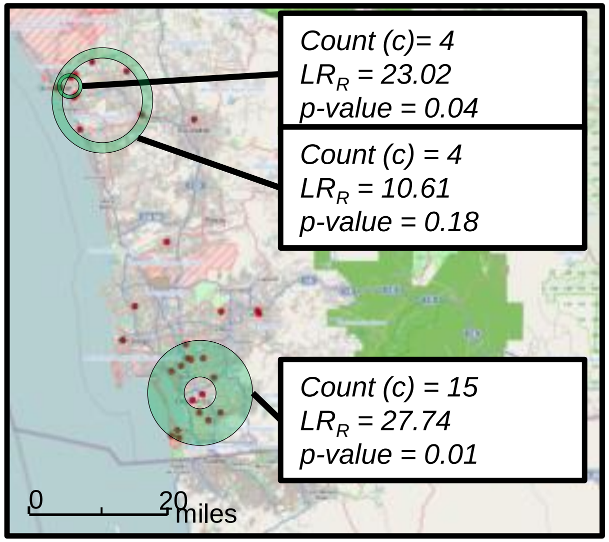


SaTScan output



Count (c)= 14
LR = 28.18
p-value = 0.01

Significant Ring Detection



Count (c)= 4
LR_R = 23.02
p-value = 0.04

Count (c) = 4
LR_R = 10.61
p-value = 0.18

Count (c) = 15
LR_R = 27.74
p-value = 0.01

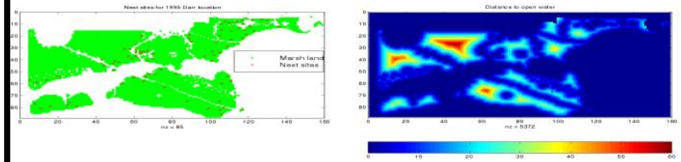
Green: Rings with LR >10 & p-value < 0.20

(1) http://www.sandiego.gov/police/services/statistics/index.shtml
(2) http://www.nbcsandiego.com/news/local/Suspected-Arson-Grass-Fires-Oceanside-Mesa-Drive-Foussat-Road-218226321.html
(3) Ring-Shaped Hot-Spot Detection: A Summary of Results, IEEE Intl. Conf. on Data Mining, 2014.

Location Prediction: nesting sites

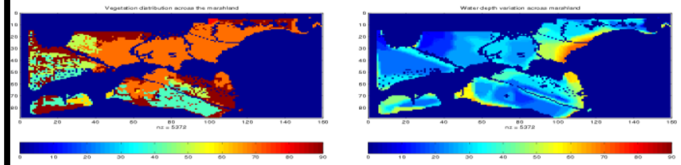
Nest locations

Distance to open water

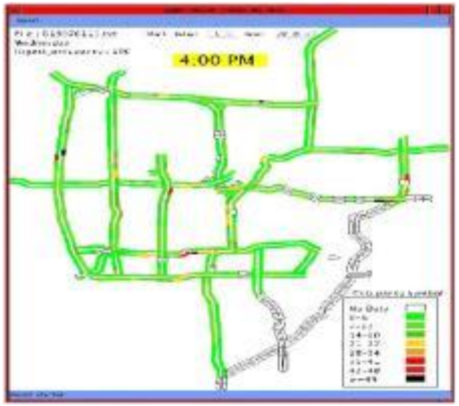


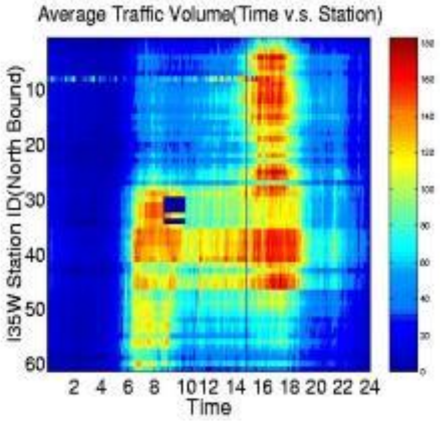
Vegetation durability

Water depth

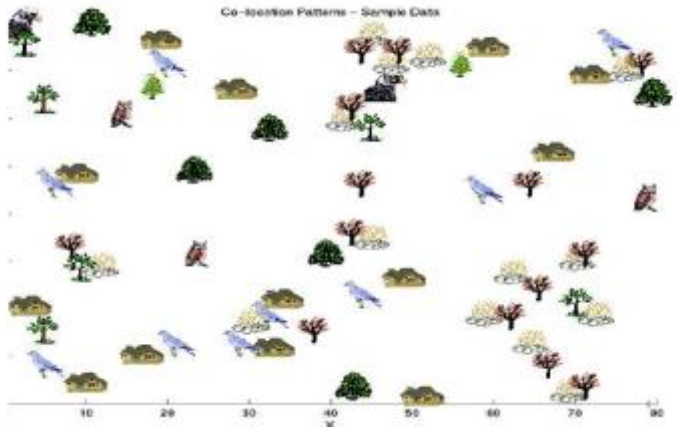


Spatial outliers: sensor (#9) on I-35

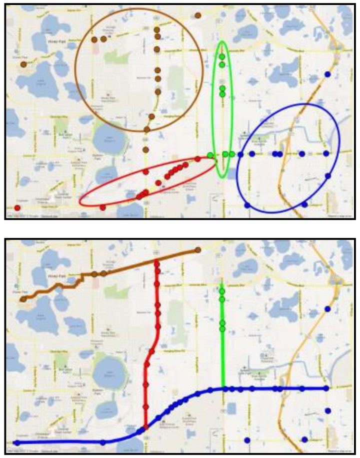


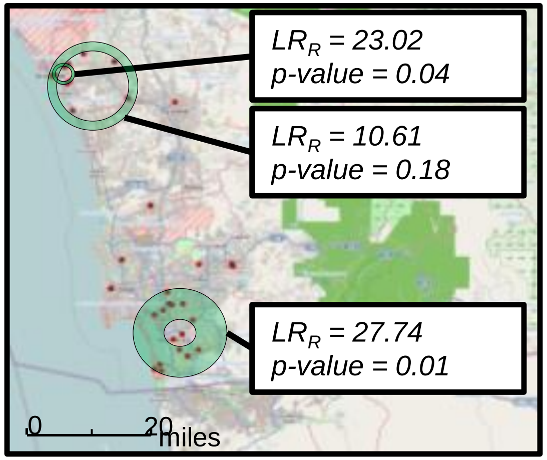


Co-location Patterns


Co-location Patterns – Sample Data
10
20
30
40
50
60
70
80

Spatial Concept Aware Summarization





$LR_R = 23.02$
p-value = 0.04

$LR_R = 10.61$
p-value = 0.18

$LR_R = 27.74$
p-value = 0.01

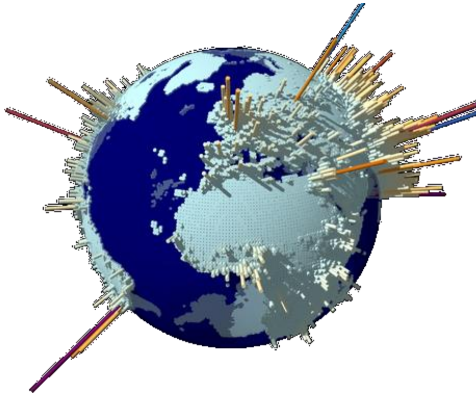
Major technologies and areas (past, present, & future)

- GPS
- Location Based Services
- Spatial Data Management Systems
- Geographic Information Systems
- Spatial Predictive Analysis (Spatial Statistics, or Spatial Data Mining)
- Virtual Globes and VGI (or CGI)

Virtual Globes and VGI (or CGI)

- LBS accessibility
- Visualization
- Volunteering (or Crowdsourcing) geo information
- Education

Google earth



United States

Virtual Globes and VGI (or CGI)

- LBS accessibility
- Visualization
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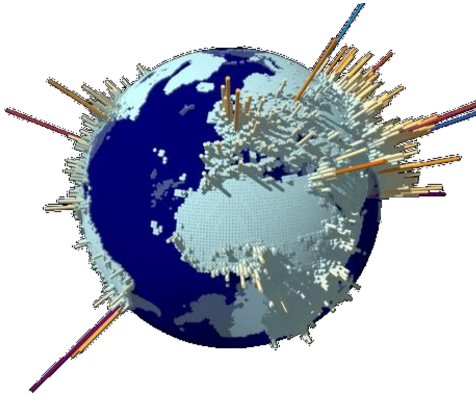
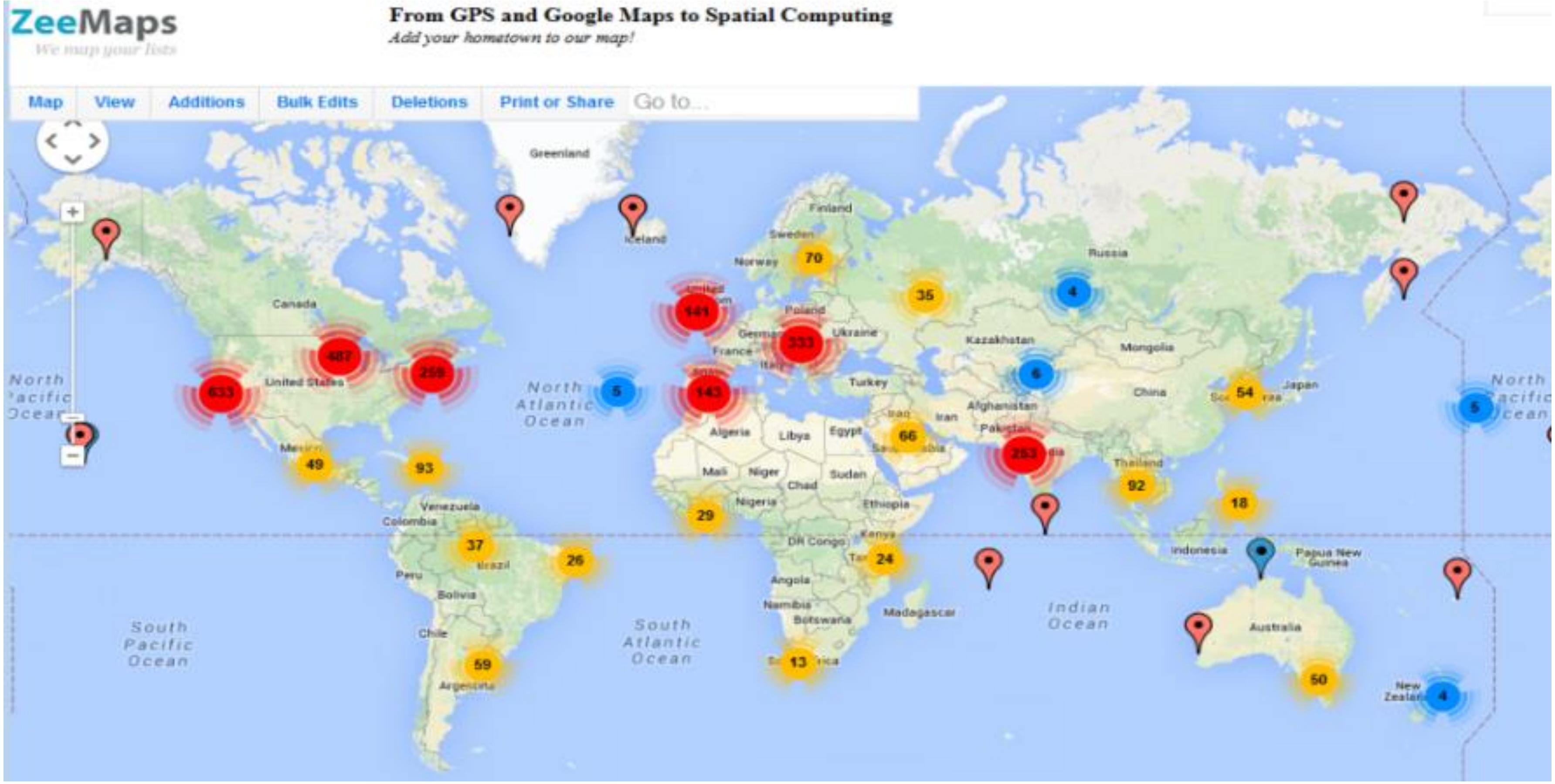


Google
1984

Dubai Coastal Expansion, 1984-2012

Virtual Globes in GIS Education

- Coursera MOOC: From GPS and Google Earth to Spatial Computing
  - 21,844 students from 182 countries (Fall 2014)
  - 8 modules, 60 short videos, in-video quizzes, interactive examinations, …
  - 3 Tracks: curious, concepts, technical



From GPS and Google Maps to Spatial Computing

Add your hometown to our map!

ZeeMaps
We map your lists
Map
View
Additions
Bulk Edits
Deletions
Print or Share
Go to...
Greenland
Iceland
Finland
Sweden
Norway
70
35
Russia
4
Canada
441
Poland
487
333
Ukraine
Kazakhstan
Mongolia
633
United States
259
France
North Atlantic Ocean
5
143
6
Turkey
54
Japan
China
North Pacific Ocean
5
Afghanistan
Iran
Algeria
Libya
Egypt
66
Pakistan
253
Mexico
49
93
Mali
Niger
Chad
Sudan
Thailand
92
Nigeria
Ethiopia
29
18
Venezuela
Colombia
37
26
Brazil
Peru
DR Congo
Kenya
24
Indonesia
Papua New Guinea
Bolivia
Angola
Namibia
Botswana
Madagascar
Indian Ocean
Australia
South Pacific Ocean
Chile
South Atlantic Ocean
59
Argentina
13
50
New Zealand
4

Map Orientation and Projections

- Mapping a 3D globe on a flat 2D plane
  - https://www.youtube.com/watch?v=klID5FDi2JQ

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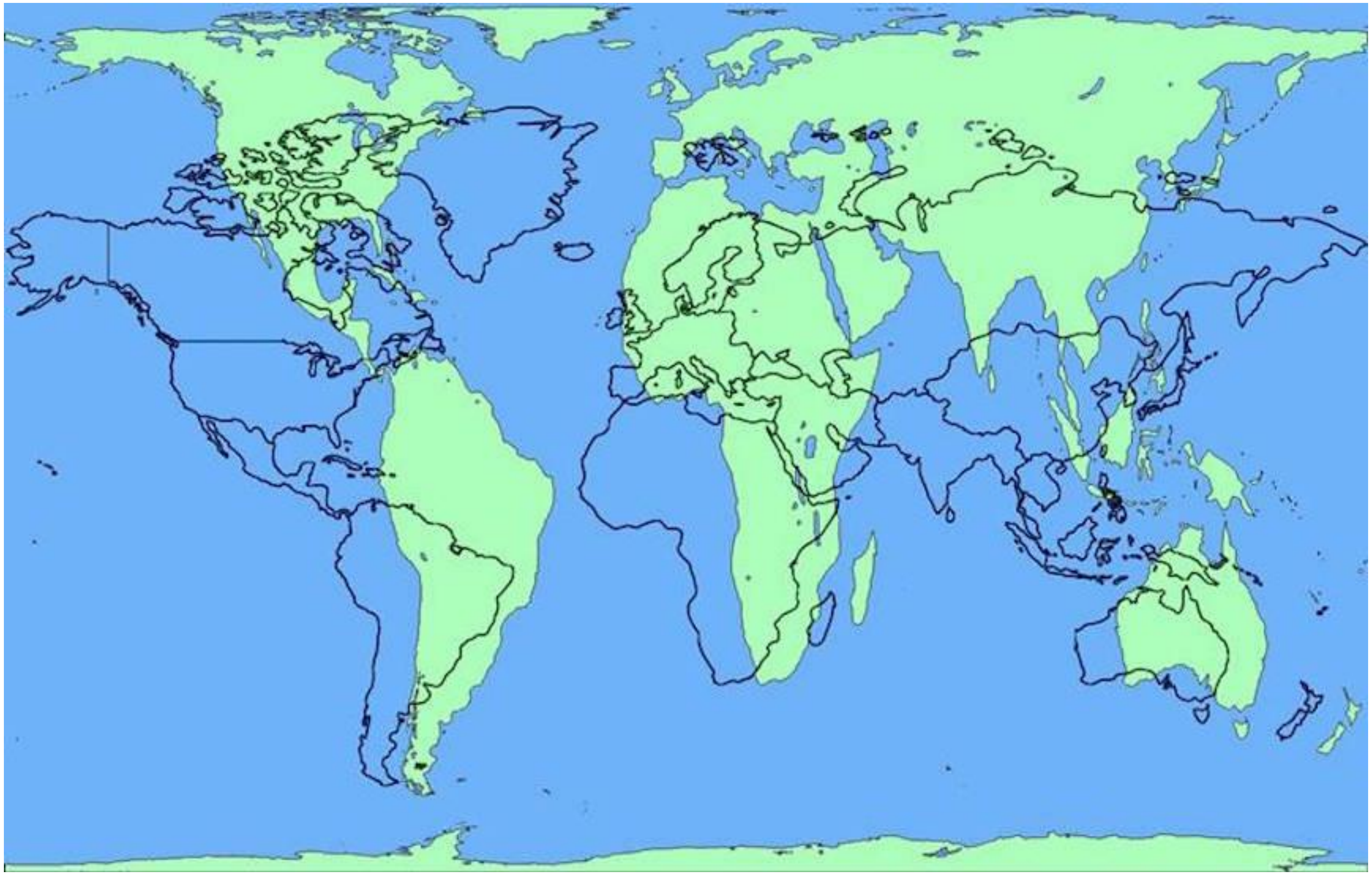
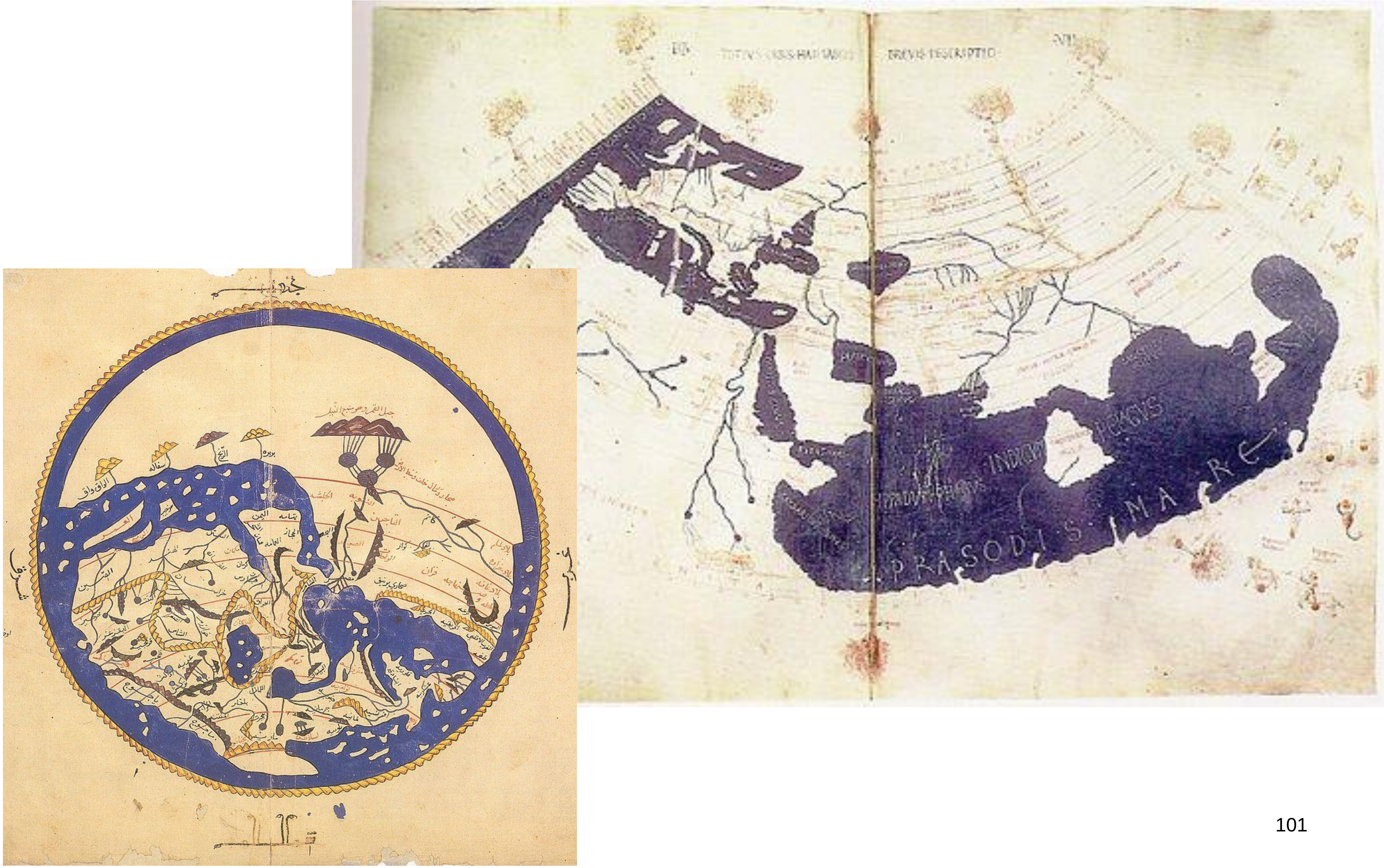
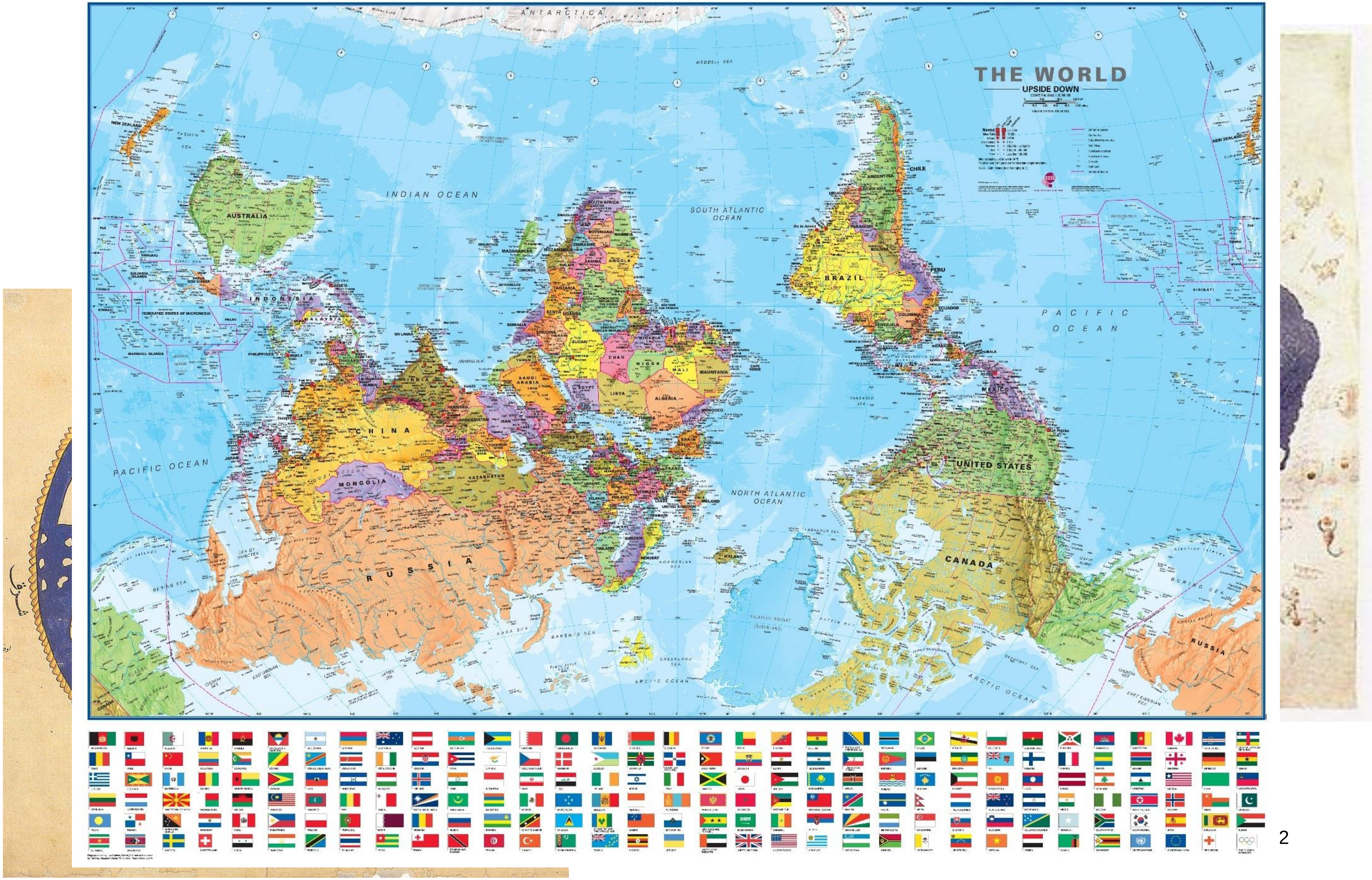


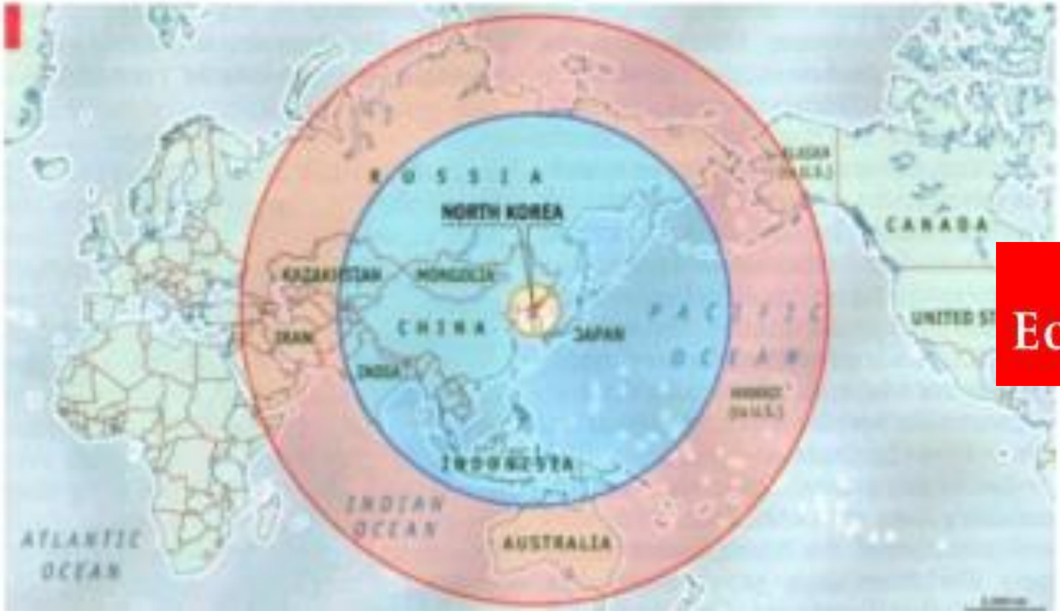
Map Orientation and Projections


PRASODIS MARE

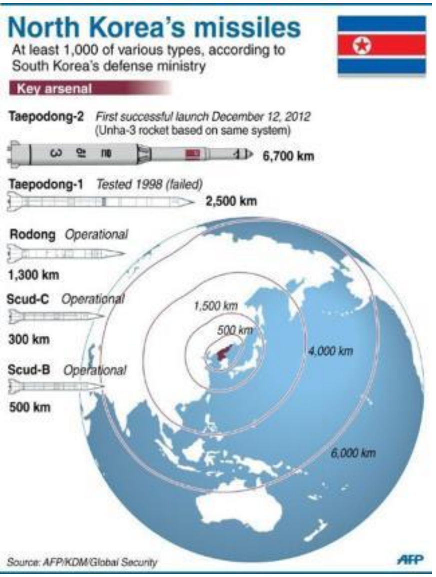
Map Orientation and Projections


THE WORLD
UPSIDE DOWN
ANTARCTICA
WEDDELL SEA
NEW ZEALAND
TASMAN SEA
AUSTRALIA
INDIAN OCEAN
SOUTH ATLANTIC OCEAN
ARGENTINA
CHILE
BRAZIL
PERU
PACIFIC OCEAN
INDONESIA
CHINA
MONGOLIA
KAZAKHSTAN
RUSSIA
NORTH ATLANTIC OCEAN
UNITED STATES
MEXICO
CANADA
BERING SEA
ARCTIC OCEAN

Map Orientation and Projections

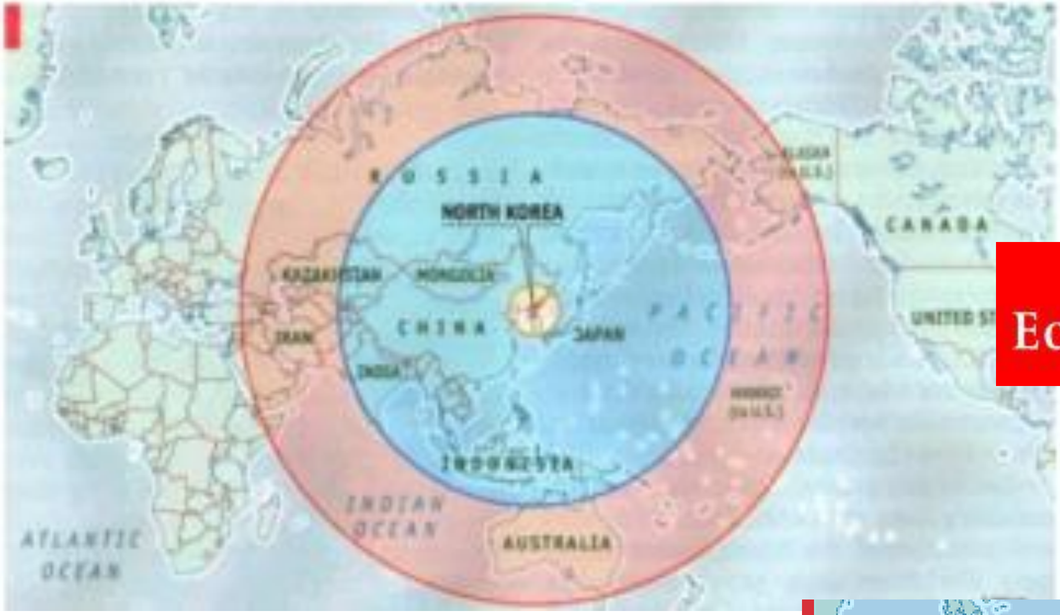

RUSSIA
NORTH KOREA
KAZAKHSTAN
MONGOLIA
CHINA
IRAN
INDIA
JAPAN
PACIFIC OCEAN
HAWAII (U.S.)
INDONESIA
INDIAN OCEAN
AUSTRALIA
ATLANTIC OCEAN
ALASKA (U.S.)
CANADA
UNITED ST

The Economist


North Korea's missiles
At least 1,000 of various types, according to South Korea's defense ministry
Key arsenal
Taepodong-2
First successful launch December 12, 2012 (Unha-3 rocket based on same system)
6,700 km
Taepodong-1
Tested 1998 (failed)
2,500 km
Rodong
Operational
1,300 km
Scud-C
Operational
300 km
Scud-B
Operational
500 km
1,500 km
500 km
4,000 km
6,000 km
AFP

Source: AFP/KDM/Global Security

Map Orientation and Projections


RUSSIA
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IRAN
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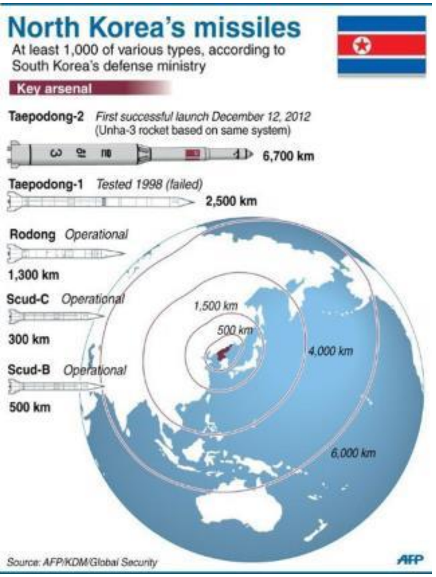
PACIFIC OCEAN
ALASKA (U.S.)
CANADA
UNITED ST
HAWAII (U.S.)
INDONESIA
INDIAN OCEAN
AUSTRALIA
ATLANTIC OCEAN

The Economist

Original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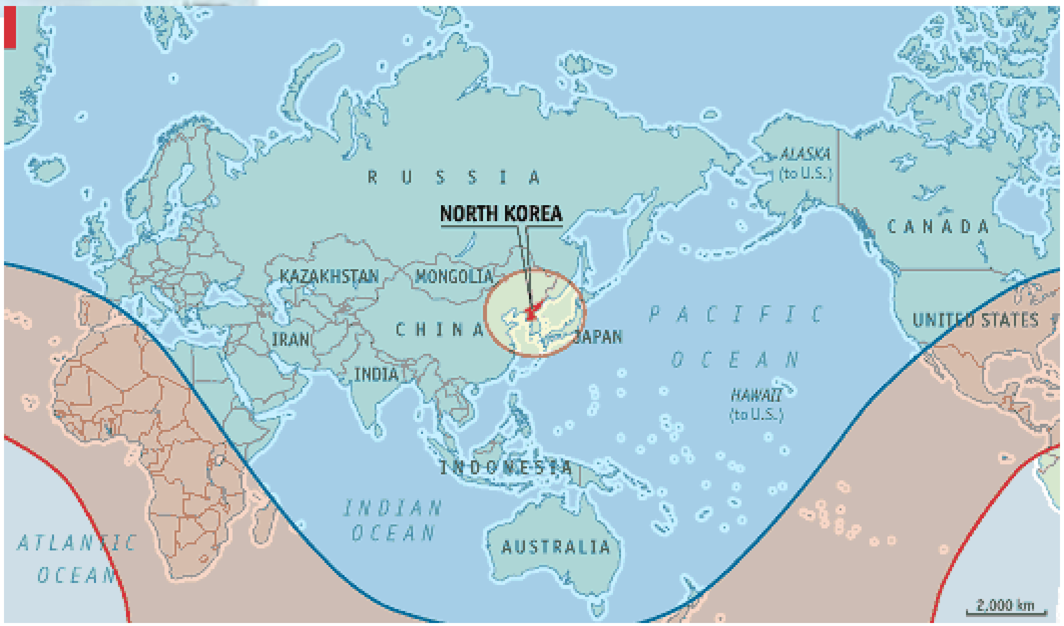
Scud-B Operational
500 km
1,500 km
500 km
4,000 km
6,000 km
Source: AFP/KDM/Global Security
AFP

Correction


RUSSIA
NORTH KOREA
KAZAKHSTAN
MONGOLIA
ALASKA (to U.S.)
CANADA
IRAN
CHINA
JAPAN
PACIFIC OCEAN
UNITED STATES
INDIA
HAWAII (to U.S.)
INDONESIA
INDIAN OCEAN
AUSTRALIA
ATLANTIC OCEAN
2,000 km

Readings and Credits

- Readings
  - CACM Article: https://cacm.acm.org/magazines/2016/1/195727-spatial-computing/fulltext
  - CCC Workshop Report: https://cra.org/wp-content/uploads/sites/2/2015/05/Spatial_Computing_Report-2013.pdf
  - Supp. book, Ch. 1
  - Spatial Computing Lectures: https://www.youtube.com/watch?v=ftwWfB7JWaQ&list=PLq_27Uv53bDm3hyXd5QWG-N8L4Vgvcy9J&index=1
- Credits:
  - Prof. Ahmed Eldawy and Prof. Mohamed Mokbel tutorial
    - http://www.vldb.org/pvldb/vol10/p1992-eldawy.pdf
  - Prof. Shashi Shekhar book slides
    - http://www.spatial.cs.umn.edu/Book/slides/
  - http://www.edugrabs.com/components-of-dbms/