A Position Statement
on

"G. I. Science Education: A Computing Perspective"

(A Panel Discussion in UCGIS Summer Assembly 2008)

By

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Outline

- What is G. I. Science?
  - Core
  - Edges (e.g. Application Domain Driven)
- What is exciting about Computing?
- How I teach Computational aspects of G. I. Science?

Core G. I. Science: 3 Views

- 3 Views of G. I. S. are important
  - Science of information
    - Conceptual and theoretical foundations – new & adapted
  - Systems: engineering of information **systems**
    - Structure, algorithms, behavior, and interactions of systems to
    - store, process, access and communicate information.
  - Services: practice of information processing
    - Computational, cognitive and social aspects
    - E.g. study of the social impact of information technologies.

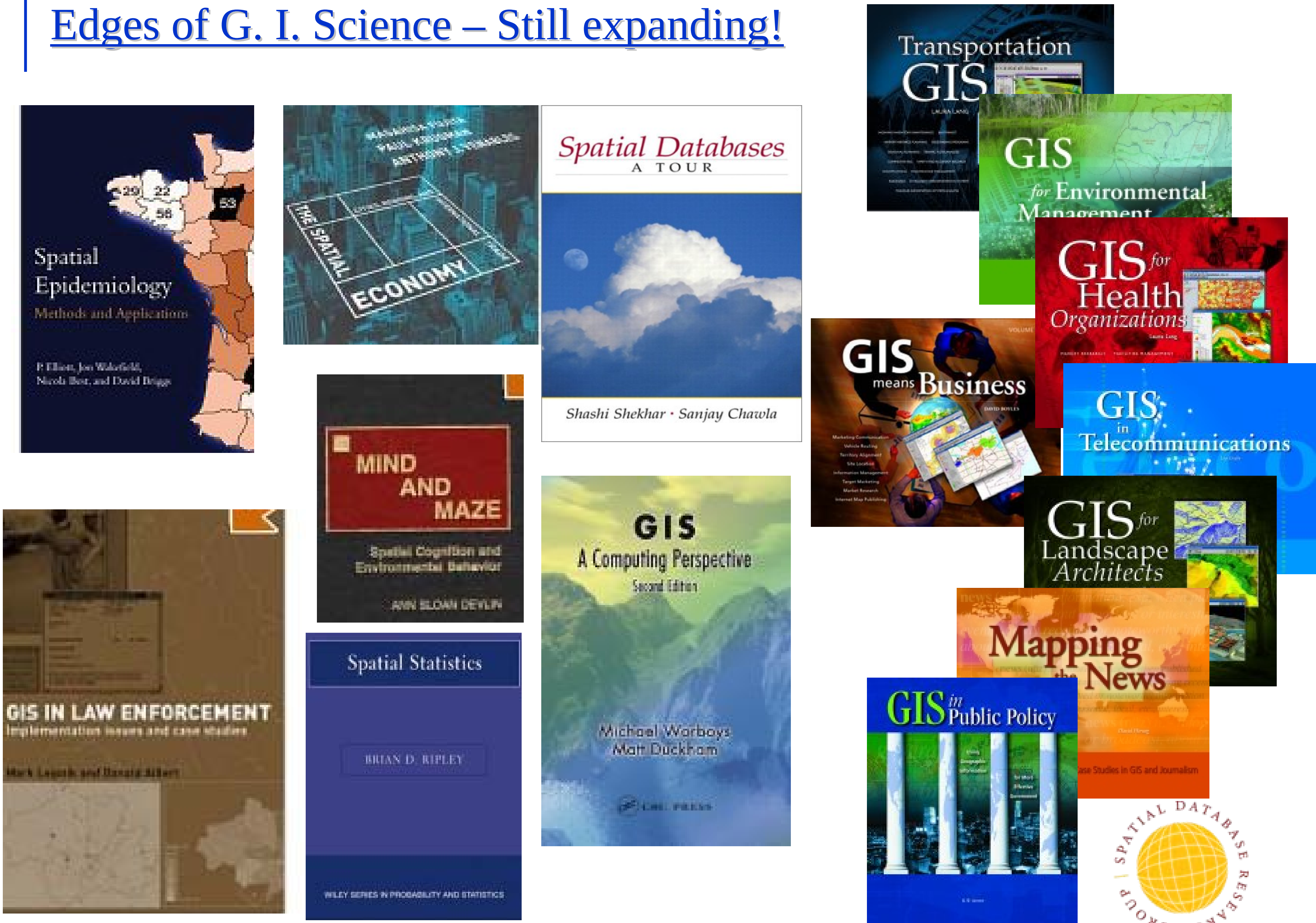
- Sources:
  - Wikipedia, Dictionary.com, M. Goodchild, Personal Interpretation

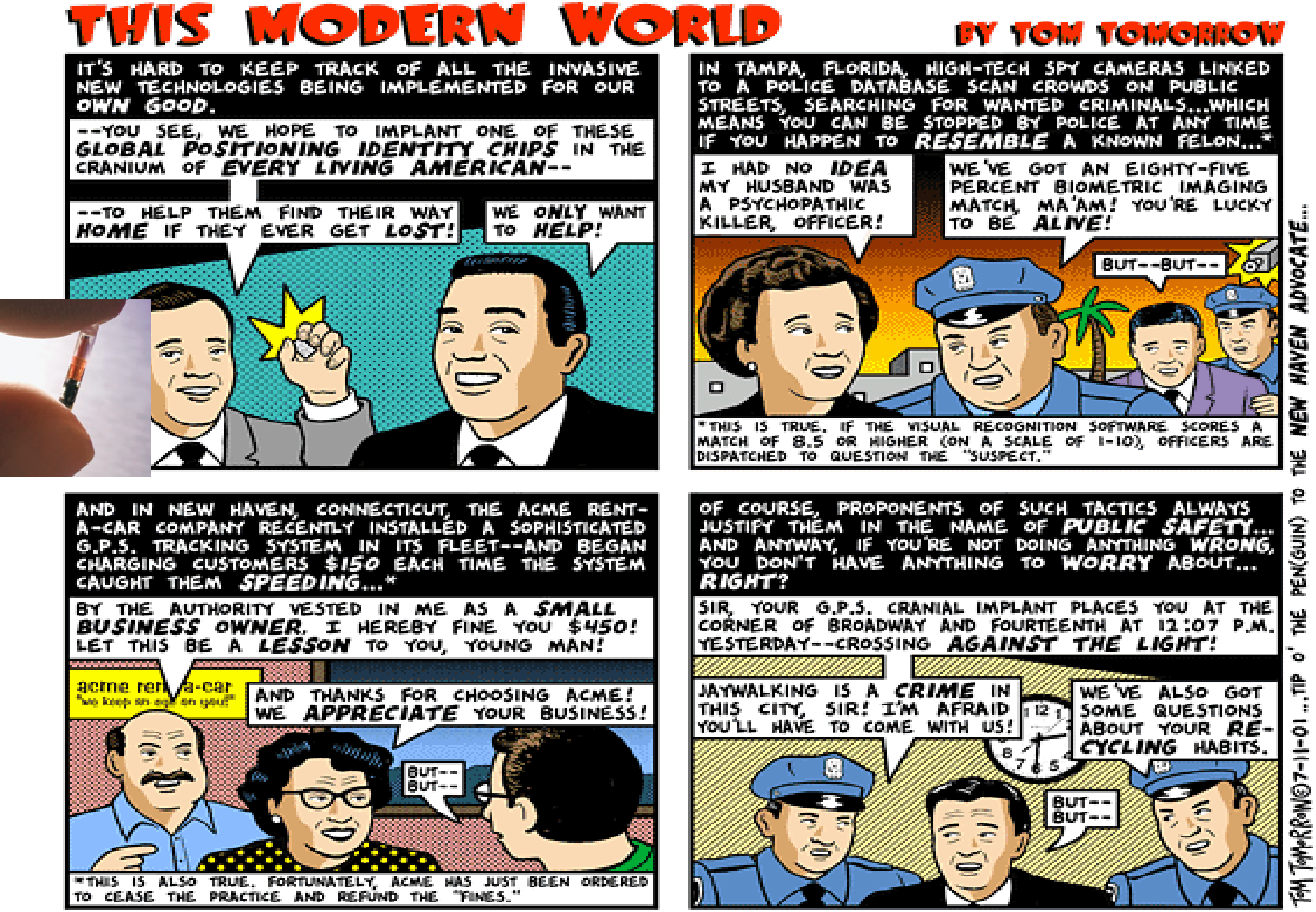
Core G. I. Science : Example Questions

- How do we conceptualize Physical and Cyber (P&C) worlds?
- How do we measure P&C concepts, recognize them in (remotely) sensed information or in the field, and identify their accuracy and quality?
- How do we represent P&C concepts with incomplete/ uncertain information, with alternative data models, and possibly with multiple representations for the same data, in digital environments?
- How do we store, access, and transform P&C concepts, facilitating data sharing, data transfer, and data archiving, while ensuring minimum information loss?
- How do we explain P&C phenomena through the application of appropriate methods of forward or inverse models of physical and human processes?
- How do we visualize P&C concepts on a variety of media such as maps on electronic displays or animated displays ?
- How do we use P&C concepts to think about spatio-temporal phenomena, and to seek explanations for spatio-temporal patterns and phenomena?
- Source: Adaptation from NCGIA proposal to NSF by Goodchild et al.

SPATIAL DATABASE RESEARCH GROUP

Edges of G. I. Science – Still expanding!





www.gpsworld.com/gpsworld/article/articleDetail.jsp?id=360842

Outline

- What is G. I. Science?
- What is exciting about Computing?
  - Trends
  - Implications for G. I. Science 2020
- How I teach Computational aspects of G. I. Science?

What is Exciting about Computing for G.I.Sc.?

- Continued improvement in computing technology
  - Ex. 2020 Projections [M. Gough, CEO (NCC)]
    - PC – Terflop CPU, Terabyte memory, Peta-byte disks, internet 2.0, cyberinfrastructure
    - Ubiquitous computing and sensing
    - Spatial Sensors: location + orientation + posture
    - Web 2.0, social networking, virtual life
    - …

- Q? What implication on G.I.Sc. in 2020?
  - Point and ask in real world (w/ laser pointer ?)
  - Increase computing capacity
    - Scale up spatial models (e.g. spatial autoregression, agent based)
    - Wider use of LIDAR, Global-Hawk UAVs
  - Will web 2.0 change importance of location ?
    - Impact on clustering of brainpower and wealth

Trends in Broader Technology beyond Computing

- Future Shock [Livewire, Summer 2007], AI Magazine, …
  - Robotics
  - Mind-controlled interfaces
  - Personal networking
  - Smart Building
  - Smart Fabric
  - Nano
  - Bio-technology
  - Semantic Web

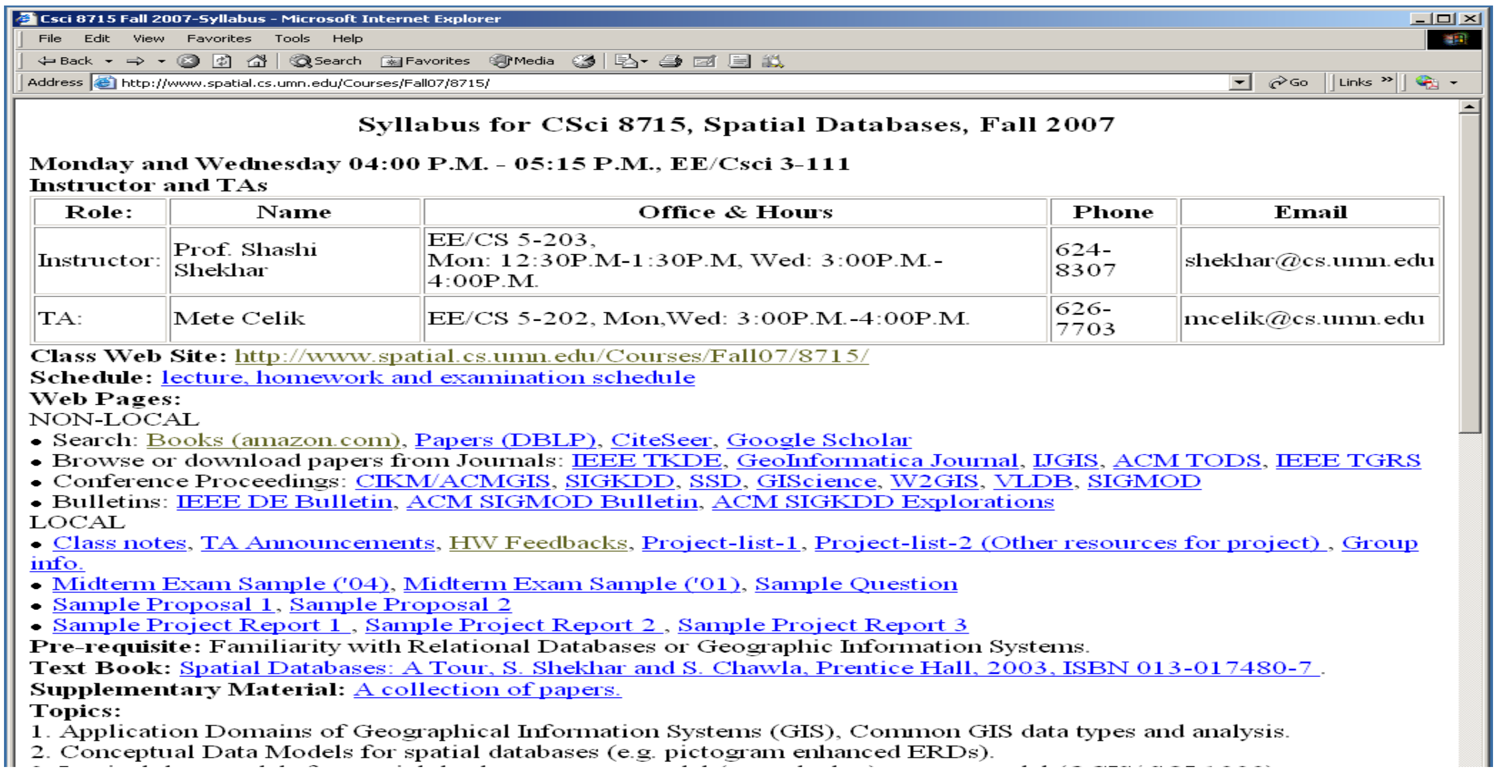
- Q? What is the impact on G.I.Sc. 2020 ?
  - Bio-technology
    - Neurosurgery – how to locate safe pathways to target in brain ?
  - Autonomous robots (.g. DARPA grand challenge)
    - Navigation on dessert terrain => real-time GIS

Outline

- What is G. I. Science?
- What is exciting about Computing?
- How I teach Computational aspects of G. I. Science?
  - Graduate students
  - Undergraduate students

How I teach GIS and Computing?

- Csci 8715: Spatial Database Course
  - Two dozen students across many disciplines
  - Offered at graduate level every other year
  - Focus on reading research papers and projects
  - Challenge: Diversity
  - www.spatial.cs.umn.edu/Courses/Fall07/8715/



Syllabus for CSci 8715, Spatial Databases, Fall 2007

Monday and Wednesday 04:00 P.M. - 05:15 P.M., EE/Csci 3-111
Instructor and TAs

Role:	Name	Office & Hours	Phone	Email
Instructor:	Prof. Shashi Shekhar	EE/CS 5-203, Mon: 12:30P.M-1:30P.M, Wed: 3:00P.M.-4:00P.M.	624-8307	shekhar@cs.umn.edu
TA:	Mete Celik	EE/CS 5-202, Mon,Wed: 3:00P.M.-4:00P.M.	626-7703	mcelik@cs.umn.edu

Class Web Site: http://www.spatial.cs.umn.edu/Courses/Fall07/8715/
Schedule: lecture, homework and examination schedule
Web Pages:
NON-LOCAL
- Search: Books (amazon.com), Papers (DBLP), CiteSeer, Google Scholar
- Browse or download papers from Journals: IEEE TKDE, GeoInformatica Journal, IJGIS, ACM TODS, IEEE TGRS
- Conference Proceedings: CIKM/ACMGIS, SIGKDD, SSD, GIScience, W2GIS, VLDB, SIGMOD
- Bulletins: IEEE DE Bulletin, ACM SIGMOD Bulletin, ACM SIGKDD Explorations

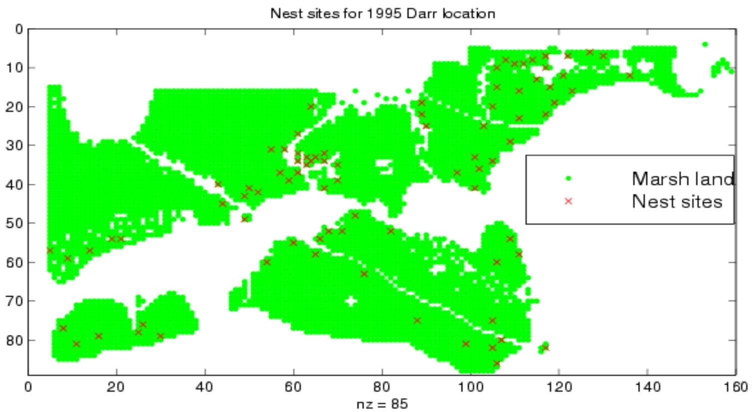
LOCAL
- Class notes, TA Announcements, HW Feedbacks, Project-list-1, Project-list-2 (Other resources for project) , Group info.
- Midterm Exam Sample ('04), Midterm Exam Sample ('01), Sample Question
- Sample Proposal 1 , Sample Proposal 2
- Sample Project Report 1 , Sample Project Report 2 , Sample Project Report 3

Pre-requisite: Familiarity with Relational Databases or Geographic Information Systems.
Text Book: Spatial Databases: A Tour, S. Shekhar and S. Chawla, Prentice Hall, 2003, ISBN 013-017480-7 .
Supplementary Material: A collection of papers.
Topics:
1. Application Domains of Geographical Information Systems (GIS), Common GIS data types and analysis.
2. Conceptual Data Models for spatial databases (e.g. pictogram enhanced ERDs).

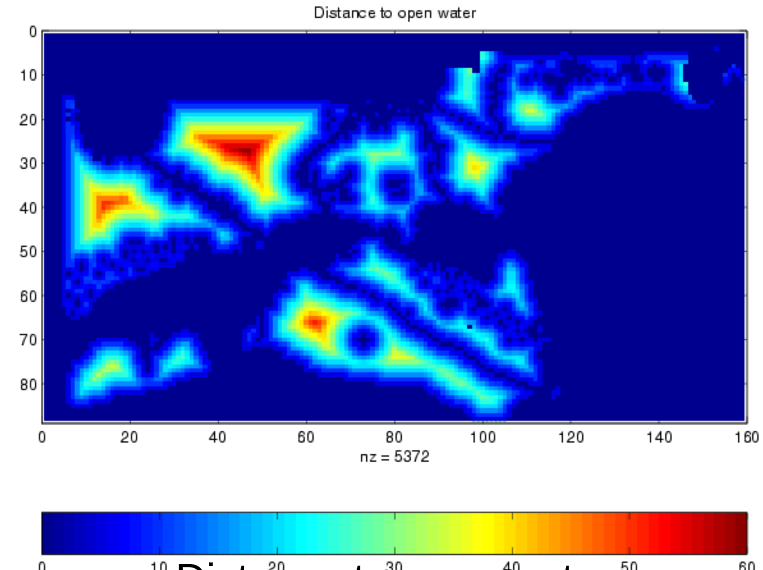
How I teach GIS and Computing to Graduate Students?

- Emphasize 6 elements
  - Problem
  - Why is it important?
  - Why is it challenging?
  - Solution / Approach,
  - In what sense is novel?
  - How is it better than state of the art?
- These 6 elements are used in
  - Critical reading of technical papers, books, etc.
  - Structuring student project proposals, reports, presentations
  - Peer reviews
  - …

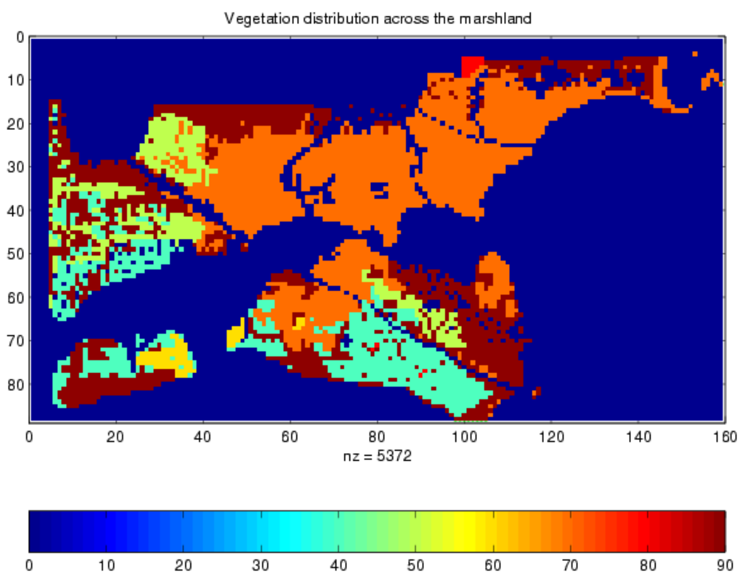
Six Elements Example1: Problem, Importance, Challenge



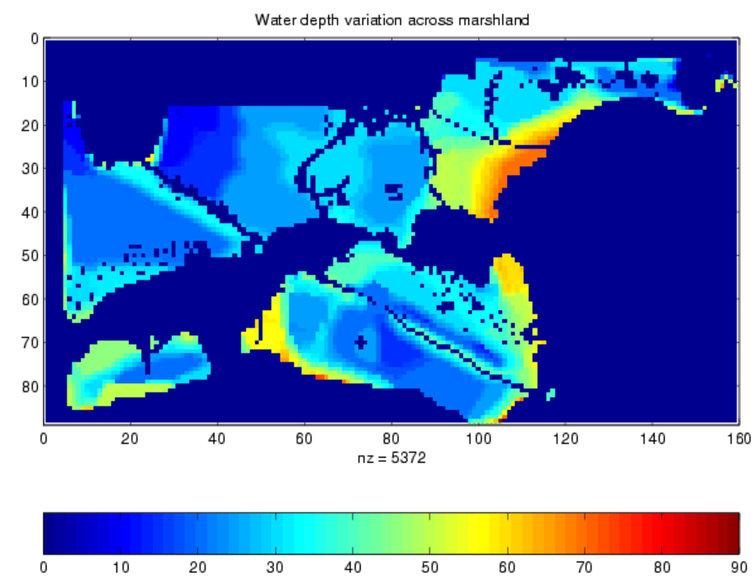
Nest locations



Distance to open water



Vegetation durability



Water depth

6 Elements Example 1: Challenge, Approach

Name	*Model*	*Classification Accuracy*
Classical Linear Regression	$\boxed{\mathbf{y} = \mathbf{x}\boldsymbol{\beta} + \boldsymbol{\varepsilon}}$	Low
Spatial Auto-Regression	$\boxed{\mathbf{y} = \boxed{\rho \mathbf{W}\mathbf{y}} + \mathbf{x}\boldsymbol{\beta} + \boldsymbol{\varepsilon}}$	High

ρ : the spatial auto - regression (auto - correlatio n) parameter

$\mathbf{W}$: n - by - n neighborho od matrix over spatial framework

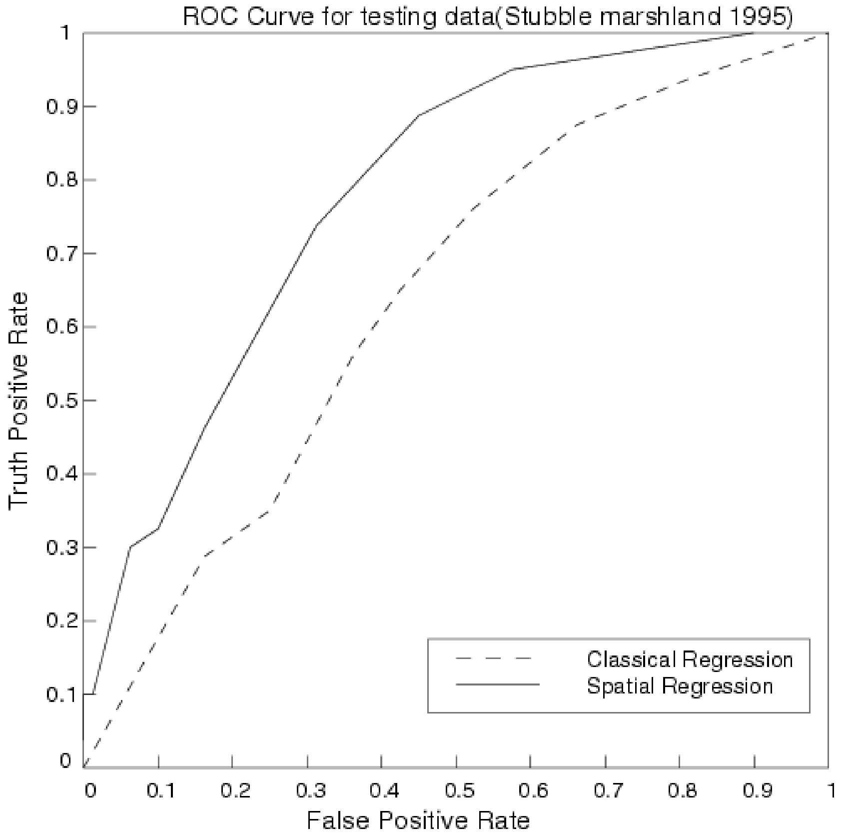
Computational Challenge:

Computing determinant of a very large matrix
in the Maximum Likelihood Function:

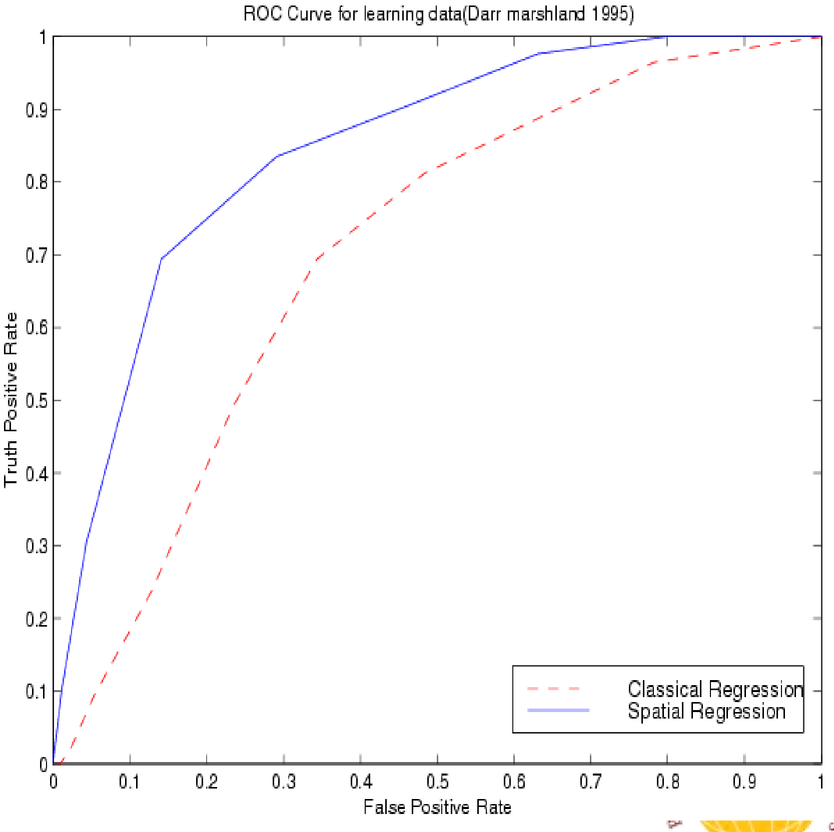
$$\ln(L) = \boxed{\ln\left|\mathbf{I} - \rho\mathbf{W}\right|} - \frac{n\ln(2\pi)}{2} - \frac{n\ln(\sigma^2)}{2} - SSE$$

6 Elements Example 1: Approach - Novelty, Better

- Linear Regression $y = X\beta + \varepsilon$
- Spatial Regression $y = \rho Wy + X\beta + \varepsilon$
- Spatial model is better



ROC Curve for learning

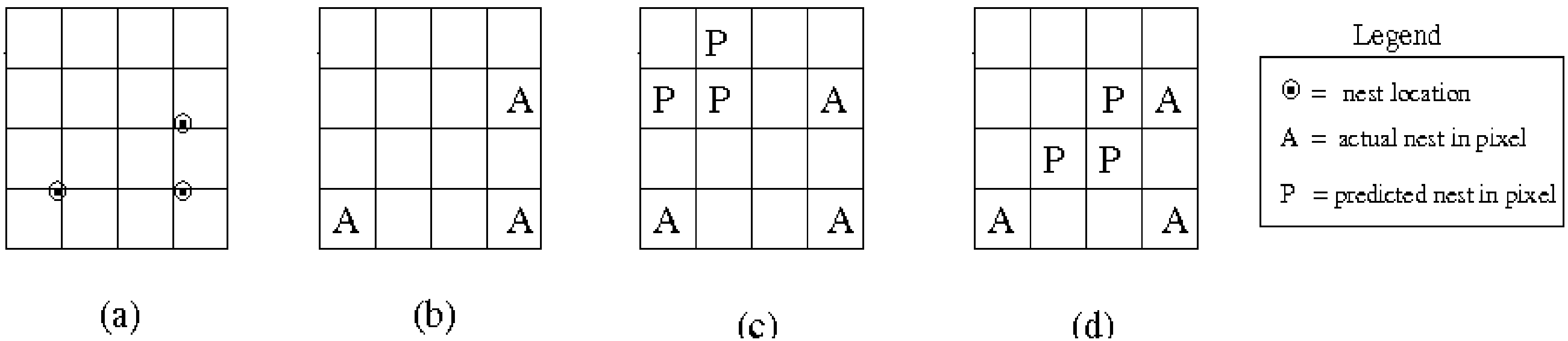


ROC Curve for testing

Future Work: Unresolved Challenges

- Location Prediction and

  Spatial interest measure: e.g., avg, dist(actual, predicted)



Actual Sites

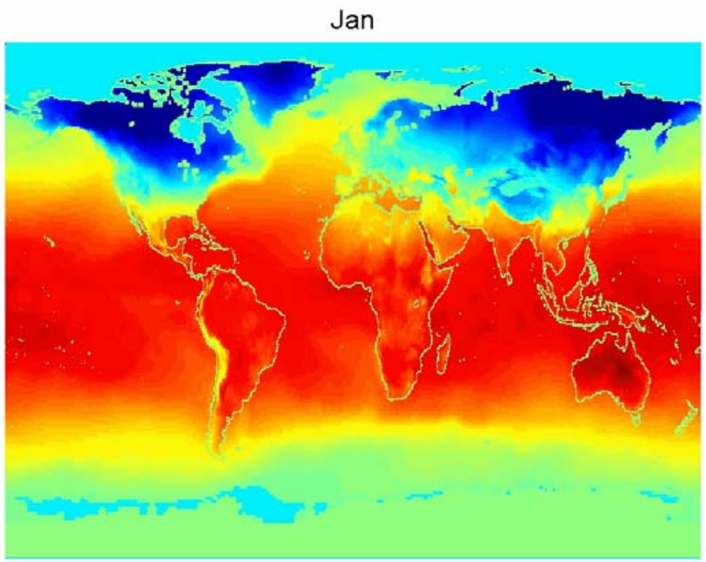
Pixels with actual sites

Prediction 1

Prediction 2. Spatially more accurate than Prediction 1

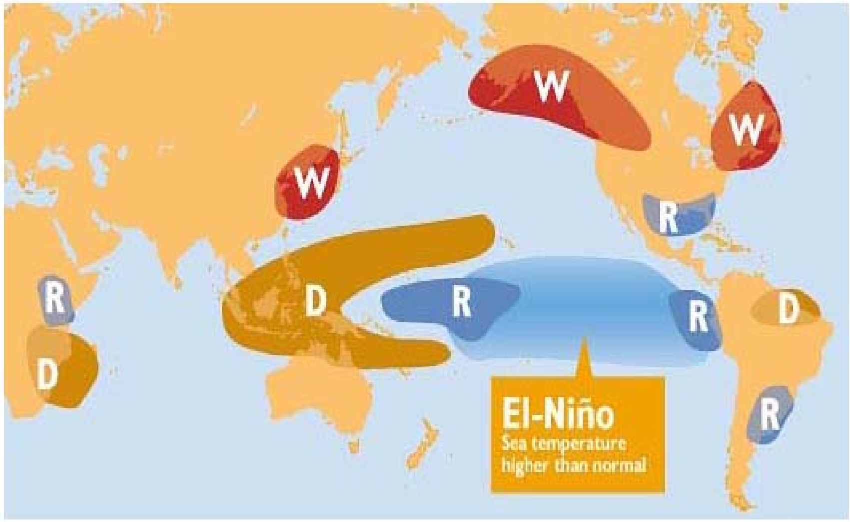
6 Elements: Another Example

- Teleconnection
  - Find (land location, ocean location) pairs with correlated climate changes
    - Ex. El Nino affects climate at many land locations



Average Monthly Temperature

(Courtsey: NASA, Prof. V. Kumar)



Global Influence of El Nino during the Northern Hemisphere Winter
(D: Dry, W: Warm, R: Rainfall)

6 Elements Example 2: Teleconnection (Cont')

- Challenge
  - high dimensional (e.g., 600) feature space
  - 67k land locations and 100k ocean locations (degree by degree grid)
  - 50-year monthly data
- Computational Efficiency
  - Spatial autocorrelation
    - Reduce Computational Complexity
  - Spatial indexing to organize locations
    - Top-down tree traversal is a strong filter
    - Spatial join query: filter-and-refine
      - save 40% to 98% computational cost at $\theta = 0.3$ to 0.9

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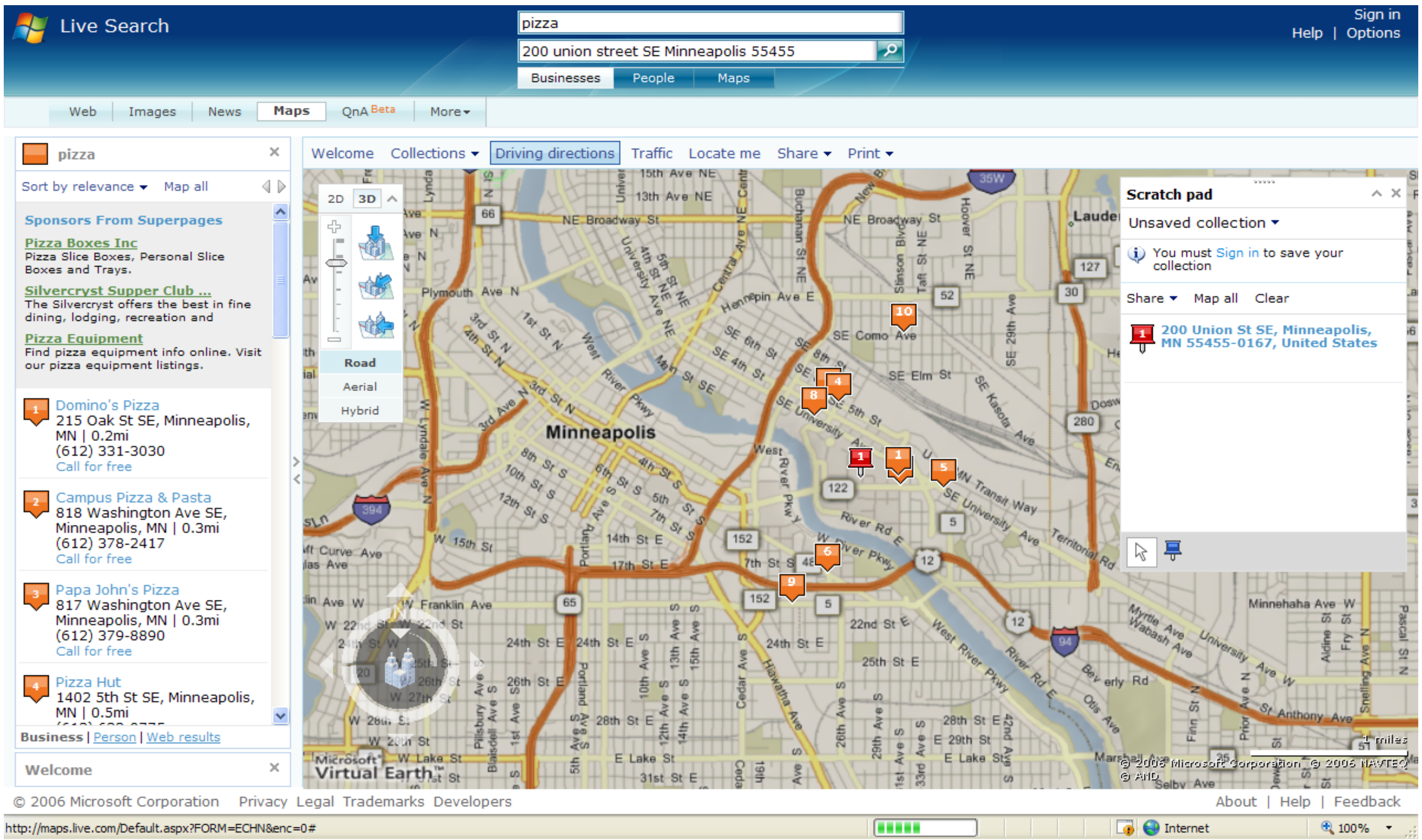
Undergraduates in Csci 8715

- Few Undergraduate Students
- They are interested in current issues
  - Location Based Web Services (LBS)
    - In-vehicle, on cell-phone, …
  - Navigation devices, GPS
    - Open operating systems in Cell Phones, e.g. Google Android
  - Mash-ups
    - Google Earth or Microsoft Virtual Earth

LBS - Examples

- Q? Have we used the following ?
  - E.g.: MapQuest, Google Maps, …
  - Q? Are these location-based services ?

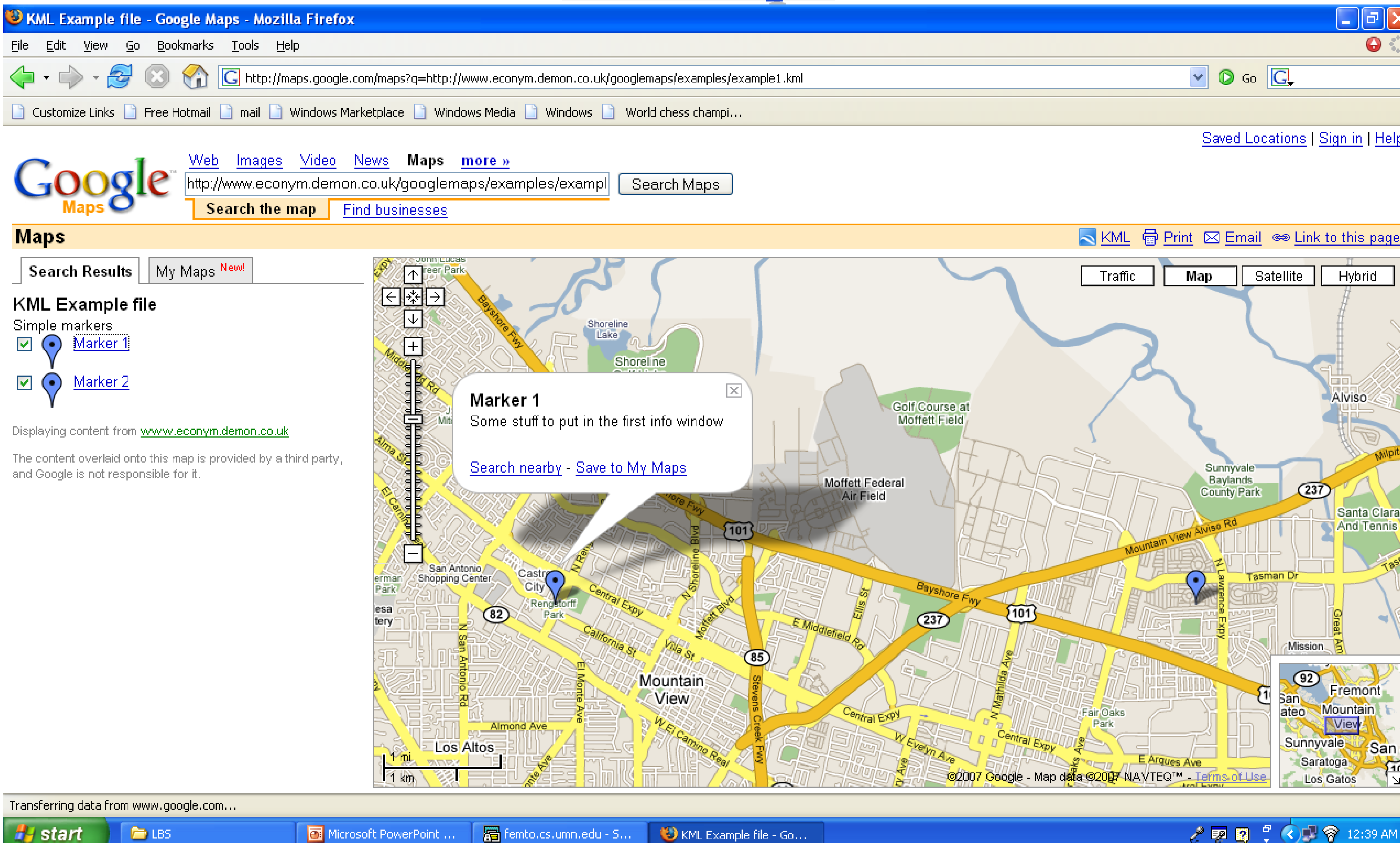


Courtesy: Microsoft Live Search (http://maps.live.com)

Navigation Devices

- Cell-phone, watch, custom
  - Open platforms, e.g. Android
- For in-vehicle or portable use

Mashups


KML Example file - Google Maps - Mozilla Firefox
File Edit View Go Bookmarks Tools Help
http://maps.google.com/maps?q=http://www.econym.demon.co.uk/googlemaps/examples/example1.kml
Go
Customize Links
Free Hotmail
mail
Windows Marketplace
Windows Media
Windows
World chess champi...
Saved Locations | Sign in | Help
Web Images Video News Maps more »
http://www.econym.demon.co.uk/googlemaps/examples/exampl
Search Maps
Search the map
Find businesses
Maps
KML Print Email Link to this page
Search Results
My Maps New!
KML Example file
Simple markers
Marker 1
Marker 2
Displaying content from www.econym.demon.co.uk
The content overlaid onto this map is provided by a third party, and Google is not responsible for it.
Traffic Map Satellite Hybrid
Marker 1
Some stuff to put in the first info window
Search nearby - Save to My Maps
Shoreline Lake
Golf Course at Moffett Field
Moffett Federal Air Field
Alviso
Sunnyvale Baylands County Park
Santa Clara And Tennis
Mountain View Alviso Rd
Tasman Dr
Bayshore Fwy
Central Expy
California St
Villa St
Mountain View
Los Altos
Almond Ave
W El Camino Real
Stevens Creek Fwy
E Middlefield Rd
W Evelyn Ave
Fair Oaks Park
E Arques Ave
Mission
San Antonio Shopping Center
Rengstorff Park
N San Antonio Rd
El Monte Ave
Fremont
Sunnyvale
Saratoga
Los Gatos
1 mi
1 km
©2007 Google - Map data ©2007 NAVTEQ™ - Terms of Use
Transferring data from www.google.com...
start
LBS
Microsoft PowerPoint ...
femto.cs.umn.edu - S...
KML Example file - Go...
12:39 AM

Mashups:Under the Hood

- Simple APIs
  - Google Earth – KML
  - Microsoft Virtual Earth SDK

- Example Code: KML (Source:http://www.econym.demon.co.uk/googlemaps/kml.htm)

```
<?xml version="1.0" encoding="UTF-8"?>
<kml xmlns="http://earth.google.com/kml/2.0">
<Document>
  <name>KML Example file</name>
  <description>Simple markers</description>
  <Placemark>
    <name>Marker 1</name>
    <description>Some stuff to put in the first info window</description>
    <Point>
      <coordinates>-122.1,37.4,0</coordinates>
    </Point>
  </Placemark>
</Document>
</kml>
```

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