GIS and Modeling

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Outline

- What is modeling?
- GIS support for modeling
- Some immediate issues
- Model-sharing infrastructure

Tests of a model

- One or more variables are predicted
  - from inputs
  - at one point in time
    - Universal Soil Loss Equation
    - Spatial Interaction Model
  - dynamically
    - urban growth models
- Spatially disaggregated
  - inputs or outputs
  - two or more elements
- Not invariant under relocation

Types of model

- Conceptual
  - boxes and arrows
  - rules
- Mathematical
  - partial differential equation
- Numerical
  - finite difference approximation
  - scale-dependent
- Computational
  - code

GIS and modeling

- Using GIS to prepare data, display results
  - loosely coupled to modeling code
- Model and GIS working off the same database
  - component-based software architecture
  - tight coupling
- Writing the model in the GIS's scripting language
  - embedding
  - performance problems for dynamic models

PCRaster

- Utrecht group
- Designed for dynamic modeling
- Van Duersen's language
  - $c = a + b$
- Rich applications
  - geomorphic processes
  - seed dispersal
  - urban growth
- Simple models produce striking results

GIS within the scientific world

- Why would a modeler use GIS?
  - poor performance
  - limited mathematical tools
  - compare Mathlab, Stella, C
  - IT is a minor issue
- GIS becomes more attractive when
  - science must be integrated with policy
  - science must be multidisciplinary
  - space is highly disaggregated
  - spatial representation issues are important

Some representation issues

- Spatial discretization for solution of PDEs
  - finite difference
    - square mesh
    - raster
  - finite element
    - mix of triangles and quadrilaterals
    - polynomial variation within elements
    - continuity across elements
    - compare TIN
- Modeling on the sphere
  - global climate modeling in spherical harmonics

Support for FEM

- Mesh-generating code
  - e.g., given an estuary, develop an FEM mesh to model tides
  - adaptive meshes
    - redefined during iteration
- FEM representations of fields
  - in addition to current six
    - grid of points
    - raster of cells
    - TIN
    - digitized contours
    - irregular polygons
    - irregular points

Vector fields

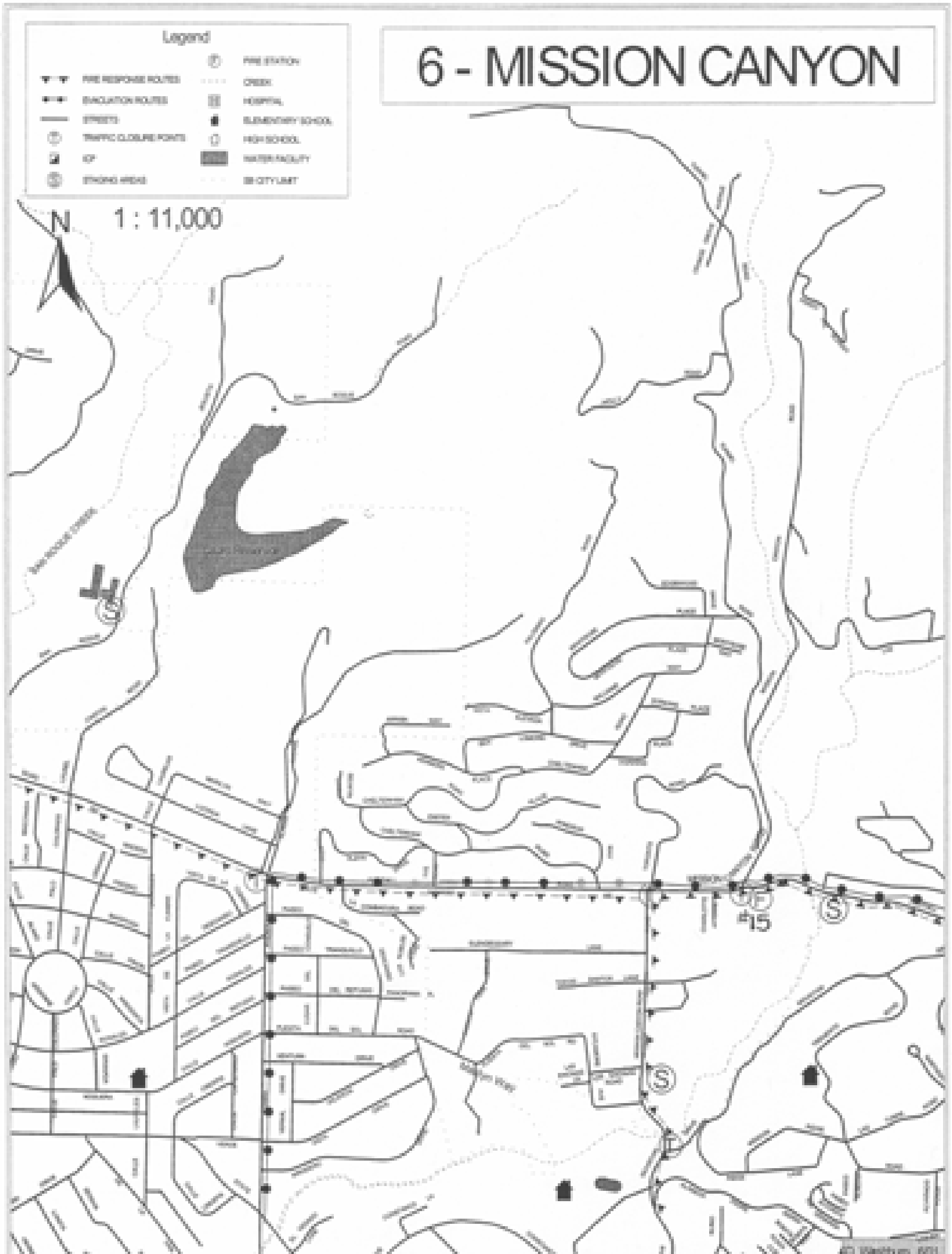
- *a* as scalar field
- *a* as vector field
  - linked components
  - enabling vector field operations
    - div, grad, curl
  - visualization

Kemp, Vckovski

- *a* should be independent of its representation
  - as irregular point sample
  - as regular cells
- Issues of representation exposed only when necessary or requested
  - e.g., raster cell size
  - vector/raster distinction disappears
  - GIS user interaction is vastly simplified

Support for transportation modeling

- Modeling of moving vehicles
  - driver behavior
  - e.g., Paramics
  - problem with polylines
  - arcs with zero- and first-order continuity


6 - MISSION CANYON
Legend
FIRE RESPONSE ROUTES
EVACUATION ROUTES
STREETS
TRAFFIC CLOSURE POINTS
ICP
STAGING AREAS
FIRE STATION
CREEK
HOSPITAL
ELEMENTARY SCHOOL
HIGH SCHOOL
WATER FACILITY
SB CITY LIMIT
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#15

Simulations

- 1.8 vehicles per driveway
- Driver behavior influenced by:
  - lane width
  - slope
  - view distances
  - traffic control mechanisms
  - information feedback
  - driver aggressiveness
- 770 homes
  - clearing times > 30 minutes

2D clip

3D clip

Integrating discrete objects and fields

- For modeling
  - e.g., modeling the movement of a buoy in a current
- For visualization
  - e.g., painting field values on probe objects
  - e.g., visualizing vector fields through particle motions

Model-sharing infrastructure

- Investment in data-sharing infrastructure
  - warehouses, clearinghouses, digital libraries
    - Geography Network
  - metadata standards, catalogs, Z39.50, XML
  - OGC Web specifications
  - Grid computing
    - transparent integration of services and data independent of location
- It's all bits
  - bits as data, papers, models, code
  - which bits are the most valuable?

Towards an infrastructure for dynamic models

- Infrastructure for sharing
  - search
  - discovery
  - evaluation of fitness for use
  - acquisition
  - execution
- Server-side or client-side execution

Current status

- Some archives
  - some pre-WWW
- Some community efforts
  - Earth System Modeling Framework
  - www.esmf.ucar.edu
- WSDL, UDDI
- ArcScripts
- www.ncgia.ucsb.edu/~scott

Research in Metadata for Computer Models

Models available over the Web
Model research and articles
Metadata & Cataloging: Examples, Ideas & Articles

Meetings
Interviews
Readings

Reporting Model 'Fitness of Use' or 'Validation' in Metadata
Comparison chart for Model Metadata
An Easier Method for Metadata Collection
Creating a Computer Model Metadata Standard

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link to Geography 5, Fall 2000

Building a metadata standard

- 1. A model is a transformation
  – characterized by metadata for inputs and outputs
- 2. Write down the key elements
  – compare FGDC CSDGM
- 3. How do humans do it?
  – we’ve been doing it for decades
- A first-draft standard

Model granularity

- How big are the pieces?
- Software as reusable components
  - what are the appropriate components?
  - Paul Densham
  - Dave Bennett

Where are we?

- Growing demand for integration of GIS and modeling
- Growing community
  - GIS and Environmental Modeling conferences
    - 1991, 1993, 1996, 2000
  - Geocomputation conferences
    - Southampton 2003
- An interesting technical agenda
- Some challenging institutional issues