Beyond OGC Standards: The New Challenges for Open Source GIS

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INPE: CONVERTING DATA INTO KNOWLEDGE

SATELLITES
Earth observation, scientific, and data collection satellites

GROUND SYSTEMS
Reception, processing and distribution of satellite data

R&D
Weather Prediction and Earth System Science

SOCIETAL BENEFITS
Innovative products to society

User institutions (51% are private companies) 16,000
CBERS as a global satellite

CBERS ground stations will cover most of the Earth’s land mass between 30°N and 30°S
“The international community (*should* explore ways to reduce global-warming emissions from deforestation. (...) This information can now be extracted fairly accurately from satellite images. (...) A few satellites can cover the entire globe, but there needs to be a system in place to ensure their images are readily available to everyone who needs them. Brazil has set an important precedent by making its Earth-observation data available, and the rest of the world should follow suit.”
Why do we want open source GIS?

- Alternative to proprietary GIS
- Support for innovative applications
What has Open GIS given us?

Interfaces based on the OpenGIS Specification
WMS, WCS, WFS

NETWORKS AND CLIENT/SERVER TECHNOLOGY

OGC SQL extension

Traditional DBMS

Non-traditional DBMS

Real-Time Data Feed

File Format

OGC archival formats
What has Open GIS given us?

OrbiGIS WMS reader

QGIS + GRASS
Open GIS can do much more: support decision-making in a changing world

Nature: Physical equations
Describe processes

Society: Decisions on how to
Use Earth’s resources
The fundamental question of our time

How is the Earth’s environment changing, and what are the consequences for human civilization?

source: IGBP
Where are changes taking place?
How much change is happening?
Who is being impacted by the change?
Open GIS-21

Data-centered, mobile-enabled, contribution-based, field-based modelling

sensor networks

ubiquitous images and maps
Modelling Nature-Society Interactions

How do humans use space?

How to describe and predict changes resulting from human actions?

What computational tools are needed to model nature-society interactions?
ST DBMS as a basis for data integration

Visualization (TerraView)

Modelling (TerraME)

Spatio-temporal Database (TerraLib)

Statistics (aRT)

Data Mining (GeoDMA)
GIS-21: Dynamical modelling integrated in a spatio-temporal database

GIS-21: Dynamical modelling integrated in a spatio-temporal database

- Eclipse & LUA plugin
  - model description
  - model highlight syntax

- LUA interpreter
  - model syntax semantic checking
  - model execution

- TerraME/LUA interface

- TerraME framework

- TerraView
  - data acquisition
  - data visualization
  - data management
  - data analysis

- TerraLib database

MODEL DATA

Model source code

TerraME INTERPRETER
GIS-21: Dynamical spatial modelling with Agents in Cell Spaces


Cell Spaces

Generalized Proximity Matrix – GPM
Hybrid Automata model
Nested scales

TerraME: Based on functional programming concepts (second-order functions) to develop dynamical models
R-Terralib interface

Loaded into a TerraLib database, and visualized with TerraView.
Where is Lua?

Inside Brazil
- Petrobras, the Brazilian Oil Company
- Embratel (the main telecommunication company in Brazil)
- many other companies

TerraME Programming Language: Extension of LUA

LUA is the language of choice for computer games

Lua and the Web

Outside Brazil
- Lua is used in hundreds of projects, both commercial and academic
- CGILua still in restricted use until recently all documentation was in Portuguese
- LUA is the language of choice for computer games

source: the LUA team

[ierusalimschy et al, 1996]
TerraAmazon - open source software for large-scale land change monitoring

Spatial database (PostgreSQL with vectors and images)

2004-2008: 5 million polygons, 500 GB images
INPE’s support for open source GIS

TerraLib (multi-user database + viewer) €250 K/an

SPRING (single-user) 100,000 registered users €200 K/an

TerraME (modelling software) €150 K/an
How can GIS technology handle spatio-temporal data?

What algebra is needed for spatio-temporal data?

How can this algebra be handled in an object-relational DBMS?
Modelling change...from practice to theory

Outline of a theory for change modelling in spatio-temporal data
Basic spatio-temporal types

S: set of locations (space)
T: set of intervals (time)
A: set of values (attributes)
Field (static)

\[ \textbf{field} : S \rightarrow V \]

The function field gives the value of every location of a space
Time-varying fields

\[
\text{TField : } T \rightarrow S \rightarrow V
\]

A temporal field stores the state of the space at each time.
Moving objects

Object: (S,A) located in space, has attributes

TObject: T→(S,A) location and attributes change
Evolving objects

Object: \((S, A)\) located in space, has attributes

Object: \(T \rightarrow (S, A)\) location and attributes change
Evolving and moving objects

(a) Space changing continuously

(b) Space changing in discrete steps
Moving objects have trajectories.

trajectory : TObject \rightarrow T \rightarrow S

Records where the object has been.
Sensors: sources of continuous information

3159 Argo Floats

ARGENTINA (11)  CHILE (8)  EUROPEAN UNION (28)  IRELAND (4)  MEXICO (9)  RUSSIAN FEDERATION (1)
AUSTRALIA (163)  CHINA (11)  FRANCE (152)  JAPAN (381)  NETHERLANDS (15)  SPAIN (2)
BRAZIL (7)  COSTA RICA (0)  GERMANY (153)  SOUTH KOREA (99)  NEW ZEALAND (10)  UNITED KINGDOM (101)
CANADA (87)  ECUADOR (3)  INDIA (88)  MAURITIUS (4)  NORWAY (7)  UNITED STATES (1813)
Sensors are temporal objects

Object: (S,A)
located in space, has attributes (sensor measures)

TObject: T → (S,A)
location and attributes change
Sensors: time serie

TSeries: TObject $\rightarrow$ T $\rightarrow$ A

each temporal object (sensor) produces a time series
Object Algebra: some operations

state : TObject → T → Object

times : TObject → set (T)

range : TObject → set (A)

inters : TObject → S → set(TObject)
When did animal L01 come close to island I01?

L01 : TObject - moving
I01 : Object - static

buf = buffer (I01, 20 km)

L01_part = intersect (L01, buf)

tclose = times (L01_part)
When did animal L01 come close to animal L02?

L01, L02 : TObject - moving
tsl : Tseries
tl: Time

 tsl = distance(path(L01),path(L02))
 tl = times (filter (<2) tsl )
 tclose = min (times (A01_part))
Evolution of a volcano eruption

state : TField $\rightarrow$ T $\rightarrow$ Field

times : TField $\rightarrow$ set (T)

range : TField $\rightarrow$ set (A)

inters: TField $\rightarrow$ S $\rightarrow$ set(TField)
When was the biggest SO2 emission of volcano eruption?

```python
plume: TField
ts = timeSeries (plume, S02, COUNT)
maxVal = max ( range (ts) )
```
Conclusions

Managing change is a major challenge for the open GIS community.

We need new algebras, data representation and handling techniques to handle spatio-temporal data.