Qualitative Spatio-Temporal Reasoning & Spatial Database Design

Focus on 2 research topics at the Unit of Geomatics of the University of Liège

J-P. Donnay – P. Hallot – F. Laplanche
Curriculum in « Surveying & Geomatics »
in the Faculty of Sciences of the University of Liège

Only education programme devoted to this field in the French-speaking Belgian Universities!

<table>
<thead>
<tr>
<th>Any other Bac. Degree in Sciences or Engineering</th>
</tr>
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<tbody>
<tr>
<td>Common 1st year</td>
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<tr>
<td>2nd year</td>
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<tr>
<td>3rd year</td>
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<tr>
<td>1st year</td>
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<tr>
<td>2nd year</td>
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<tr>
<td>2nd year</td>
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<tr>
<td>2nd year</td>
</tr>
<tr>
<td>Doctorate Degree in Sciences</td>
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</table>

Other Master Degrees in Sciences or Engineering
International Education Networks

Master Degree in Applied Geomatics

Sherbrooke

Montpellier

Master Degree in Surveying & Geomatics

Laval

Paris – Le Mans - Strasbourg
The Unit of Geomatics

Chairs and shared research domains

<table>
<thead>
<tr>
<th>Geodesy</th>
<th>Photogrammetry</th>
<th>Topography</th>
<th>Remote Sensing</th>
<th>Cartography</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>GNSS</td>
<td></td>
<td></td>
<td></td>
<td>Spatial Analysis</td>
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<tr>
<td></td>
<td></td>
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<td></td>
<td>GIS</td>
</tr>
</tbody>
</table>

Staff

Professors: 5  
Prof. Assistant (Dr): 1  
Researchers - Assistants (PhD Students): 7  
Researchers: 5  
Tech/Admin: 2
Typical applied researches

- **Federal & Regional Agencies**
  - GIS design & reengineering
  - See Poster 1
    - Distributed GISystem based on network technology
  - RTK GPS network assessment
  - « Crime mapping » & « Geographic profiling »

- **Academic subcontracting, Local Authorities & Private Companies**
  - Web GIS development
  - Maps and Atlas design and production

- **International projects**
  - Geodesy & mathematical cartography (border conflicts)
  - GIS & SDI design
Examples of fundamental research topics

- **GNSS**
  - See poster 2
    - Ionosphere Modelling for GALILEO Single-Frequency Users

- **Satellite photogrammetry**
  - See poster 3
    - DTM extraction and validation from SPOT 5 satellite imagery

- **Qualitative spatial reasoning**
  - Spatio-temporal reasoning: Lecture 1

- **GIS design**
  - Open Source Spatial Database Design: Lecture 2
Qualitative Spatio-Temporal Reasoning

Research on a generalized spatio-temporal reasoning model

J-P. Donnay – P. Hallot – F. Laplanche
Outlines

• Introduction
• Life-lines representation
• Research objectives
• Spatial “states”
• Spatio-temporal configurations
Qualitative spatio-temporal reasoning

- Growth of **dynamics data acquisition systems** (on-board GPS, RFID-tags, Wi-Fi, …)
- Huge quantity of **spatio-temporal data**
- Necessity to develop **spatio-temporal reasoning model** to extract information
- Several ways to develop spatio-temporal reasoning model:
  - Combining a spatial and a temporal logic
  - Create a mereotopology from the analysis of spatio-temporal histories
- Users expects **simple** systems, useful and easily integrated
The wolf eats the red rabbit.
Intersection between the ST histories
Moving points in a 1D space

1D spatial space

Primitive Space

Spatio-temporal situation

No topological intersection between the two life-lines (blue and grey)
-> No ST meeting

Topological touch between the two life-lines (red and grey)
-> ST meeting

J-P. Donnay – P. Hallot – F. Laplanche

EuroSDR ‘07
General research objectives

• The underlying idea of this research is to extract spatio-temporal information by applying topological calculi on the life-lines.

• Research’s steps of PhD:
  • Construct an exhaustive set of ST configurations mixing topological relationships and Allen’s time intervals.
  • Develop a ST model based on topological calculi.
  • Study the relevance of such a model / generalisation.
To fully encompass the ST information complexity, we propose 3 degenerated topological relationships between points.
Degenerated topological relationships

- A «state» is a particular relationship between objects at a given time.
- JEPD set of relationships:

\[ U \]
\[ \exists A \land \exists B \]
\[ \neg (\exists A \land \exists B) \]

• topological state
- \( t \)
  - \( A = B \)
  - \( A \neq B \)

• non topological state
- \( \neg t \)
  - \( \neg A \)
  - \( \neg B \)
  - \( \neg A \land \neg B \)
33 Topological relationships between lines
Conclusion and further research

- Check if generalisation of ST configurations provides enough ST meaning to perform ST analyses.
- Extend model to higher spatial dimensions and extend to moving regions or bodies.
- Check possible integration / combination with others ST models.
Qualitative spatial reasoning

Binary projective relationships model


Ternary projective relationships model

**Spatial Database Design**

Web2GIS: a spatial database conception environment

J-P. Donnay – P. Hallot – F. Laplanche
Web2GIS

- **Realized in the framework of a PhD defended on September 8th 2006**
- **Assessment:**
  - Integrated tools for Spatial Databases conception stay essentially proprietary
    - High cost
    - Lack of standardization
  - Solution: Using Open Source software implementing well-known standards
- **Some problems still penalize Open Source solutions:**
  - Maintenance and compatibility problems due to fast update
  - Lack of user-friendly interfaces
  - Lack of technical support
Web2GIS

- **Our original solution: Web2GIS**
  - **Spatial database conception environment centralized on a web server**
    - No need of particular tools on client, just a web browser
  - **Adapted to a large panel of users**
    - Spatial data producers, spatial database designers, spatial data users...
  - **Giving priority to Open Source products and international standards**
    - Apache, Php, PostGIS, MapServer...
    - ISO/TC 211 (19 1..), OGC...
  - **In the philosophy of WEB 2.0**
    - «Web 2.0 is the business revolution in the computer industry caused by the move to the internet as platform…»
The 5 modules of Web2GIS

While the use of spatial data is increasing, while we can notice a diversification in the actors of spatial data and while free and Open Source are now so able to compete with commercial software, spatial database conception stays dominated by complex and proprietary tools.

The main problem which continues to penalize free products is the lack of userfriendliness, their difficulties of implementation and their too fast updates. To fill this gap we offer to a large panel of users a spatial database conception environment called Web2GIS. Being centralized on a server it removes maintenance activities for the user and the necessity to have specific tools on the client. Indeed a simple web browser is enough to use it. The environment gives also priority to the use of Open Source products and has recourse to international standards to increase the tools’ universality.
**Web2GIS – Feature Cataloguing Module**

- **Goal:**
  - Generate Feature Catalogues for data producer communities wishing to describe their specifications

- **ISO/TC 211 – 19110: Methodology for feature cataloguing**
  - Metabase model is inherited from the norm

- **More important purpose than just a textual description**
  - Reflection on the concept of object
  - UML design of associations
    - Reflection on the concept of cardinality
    - Possibility to reuse associations during conceptual modelling
### Current Catalogue: Carteco_Catalogue v1

<table>
<thead>
<tr>
<th>Visualization</th>
<th>Modification</th>
<th>Addition</th>
<th>Deletion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Show all feature types</td>
<td>Modify a feature type</td>
<td>Add a feature type</td>
<td>Delete a feature type</td>
</tr>
<tr>
<td>Show a feature type</td>
<td>Modify an attribute / operation</td>
<td>Add an attribute / operation</td>
<td>Delete an attribute / operation</td>
</tr>
<tr>
<td></td>
<td>Modify an attribute value</td>
<td>Add an attribute value</td>
<td>Delete an attribute value</td>
</tr>
<tr>
<td></td>
<td>Modify a feature association</td>
<td>Add a feature association</td>
<td>Delete a feature association</td>
</tr>
<tr>
<td></td>
<td>Modify a constraint</td>
<td>Add a constraint</td>
<td>Delete a constraint</td>
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</table>

<table>
<thead>
<tr>
<th>Version Number</th>
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<tbody>
<tr>
<td>Version Date</td>
<td>2005-08-02</td>
</tr>
<tr>
<td>Scope</td>
<td>Données Topographiques des éléments du domaine public satisfaisant les exigences les plus grandes en termes de précision et complétude</td>
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<tr>
<td>Field of Application</td>
<td>Préalable à la reconceptualisation de la BD Carteco</td>
</tr>
<tr>
<td>Definition Source</td>
<td>Catalogue des objets de la BD Carteco</td>
</tr>
<tr>
<td>Definition Type</td>
<td>-</td>
</tr>
<tr>
<td>Producer</td>
<td>François Laplanche</td>
</tr>
<tr>
<td>Functional Language</td>
<td>-</td>
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</table>
### Feature Association

<table>
<thead>
<tr>
<th>Code</th>
<th>ASSOC006</th>
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<tbody>
<tr>
<td>Name</td>
<td>fa_EST_DU_TYPE_tob</td>
</tr>
<tr>
<td>Inverse Relationship</td>
<td>tob_COMPREND_fa</td>
</tr>
<tr>
<td>Definition</td>
<td>Les façades sont du type d'objet Bâtiments</td>
</tr>
<tr>
<td>Order Indicator</td>
<td>Yes</td>
</tr>
<tr>
<td>Constraints</td>
<td></td>
</tr>
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</table>

#### Feature Type

<table>
<thead>
<tr>
<th>Code</th>
<th>BB01</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>fa_EST_DU_TYPE_tob</td>
</tr>
</tbody>
</table>

pour tous les bâtiments, on portera sur la carte les façades principales et latérales effectives jusqu'à 5 mètres ou jusqu'au premier point adéquat.

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**VURL Notation:**

<table>
<thead>
<tr>
<th>façades</th>
<th>fa_EST_DU_TYPE_tob</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Objet</td>
<td>tob_COMPREND_fa</td>
<td>Type d'Objet Bâtiments</td>
</tr>
</tbody>
</table>


Web2GIS – Conceptual Modelling Module

• **Goal:**
  - Offering to the user a conceptual data model generator enabling to deal with specific applications from scratch or from one or several Feature Catalogues

• **UML has been chosen as formalism**
  - It’s based on a metamodel expressed in UML
  - UML can be extended

• **Metabase model is based on UML metamodel and spatio-temporal extensions**
  - ISO 19109 (Rules for application schema) and 19107 (Spatial schema)
  - Topological constraints based on (enriched) CONGOO concepts
Concepts taken into account thanks to the notion of package.
Complete the Topological Matrices of the package "Topological_area"

<table>
<thead>
<tr>
<th>Classical Topological Matrix</th>
<th>Strong Topological Matrix</th>
</tr>
</thead>
<tbody>
<tr>
<td>Batiments</td>
<td>Batiments</td>
</tr>
<tr>
<td>Parcelles</td>
<td>Parcelles</td>
</tr>
<tr>
<td>ZonesPS</td>
<td>ZonesPS</td>
</tr>
<tr>
<td>Secteurs</td>
<td>Secteurs</td>
</tr>
<tr>
<td>Communes</td>
<td>Communes</td>
</tr>
<tr>
<td>Arrondissements</td>
<td>Arrondissements</td>
</tr>
</tbody>
</table>

Enter the topological constraints stayed between "Batiments" and "Parcelles"

Cardinalities
- 0
- 1
- N
- L/N
- T

Constraints
- Partial superimposition (+)
- Total superimposition (+)
- No superimposition (+)
- Partial superimposition (-)
- Total superimposition (-)
- No superimposition (-)
- Partial adjacency (+)
- Total adjacency (+)
- No adjacency (+)
- Partial adjacency (-)
- Total adjacency (-)
- No adjacency (-)
Web2GIS – Spatial Databases Implementation module

- **Goal:**
  - Allowing to generate the schema of a spatial database from one or several UML models and to load data into the tables of this database

- **The « Case tool » part of Web2GIS**
  - Automatic generation of spatial databases

- **Data Loading**
  - **Spatial data:**
    - Shapefiles
    - Text files (geometry column in WKT)
  - **Non spatial data:**
    - Text files
Data loading in a temporary database

Select the topological rules you want to check

<table>
<thead>
<tr>
<th></th>
<th>Non constrained database</th>
<th>Final constrained database</th>
</tr>
</thead>
<tbody>
<tr>
<td>nodes</td>
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<td>public.nodes</td>
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<tr>
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<td>public.arcs</td>
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</tr>
<tr>
<td></td>
<td></td>
<td>check</td>
</tr>
</tbody>
</table>
Web2GIS – Cartographic Module

- Goal: Allowing an end user to visualize and carry out spatial queries through a cartographic interface
- 3 types of spatial data:
  - PostGIS spatial tables
  - WMS
  - WFS
- Functionalities:
  - Zoom, panning, object identification, classification on field values, links between POSTGIS tables...
Web2GIS – Privileges Management Module

**Goal:**
- Allowing a project manager to manage efficiently users and privileges for protecting users developments

**Registration needed before the first use**
- A valid email address is needed
- Users give a username and password

**A user receives full privileges on his developments and may provide access to other users**
- 3 levels of privileges
  - **Basic:** reading
  - **Large:** reading and edition
  - **All:** reading, edition, addition/deletion and privileges management
Web2GIS - Prospects

• **Reports generators**
  • For Feature catalogue and conceptual modelling modules

• **A metadata module**
  • Customization of proposed generic profiles (UML models) to generate new meta-database
  • Metadata publication and sharing of spatial data

• **Dealing with the temporal dimension**
  • For conceptual modelling and implementation modules

• **Dealing with the third dimension and integration of works on 3D data acquisition**