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!

Any other Bac. Degree in Sciences or Engineering

<table>
<thead>
<tr>
<th>1st year</th>
<th>2d year</th>
<th>3d year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Common 1st year</td>
<td>Geography</td>
<td>Surveying &amp; Geomatics</td>
</tr>
<tr>
<td>2d year</td>
<td>Geography</td>
<td>Surveying &amp; Geomatics</td>
</tr>
<tr>
<td>3d year</td>
<td>Geography</td>
<td>Surveying &amp; Geomatics</td>
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Bachelor Degree in Geographical Sciences

Master Degree in Applied Geomatics

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<tbody>
<tr>
<td>Master Degree in Applied Geomatics</td>
<td>Master Degree in Surveying &amp; Geomatics</td>
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Master Degree in Surveying & Geomatics

Doctorate Degree in Sciences

Other Master Degrees in Sciences or Engineering

J-P. Donnay – P. Hallot – F. Laplanche
International Education Networks

Master Degree in Applied Geomatics
- Sherbrooke
- Montpellier

Master Degree in Surveying & Geomatics
- Laval
- Paris – Le Mans - Strasbourg

Qualitative Spatio-Temporal Reasoning & Spatial Database Design

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

EuroSDR ‘07
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>GNSS</td>
<td></td>
<td></td>
<td>Spatial Analysis</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>GIS</td>
<td></td>
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</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

Spatio-temporal situation

1D spatial space
Moving points in a 1D space

Spatio-temporal situation

1D spatial space

space

time
Moving points in a 1D space
Moving points in a 1D space

Primitive Space

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

No topological intersection between the two life-lines (blue and grey)
-> No ST meeting
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.
Qualitative Spatio-Temporal Reasoning & Spatial Database Design

Topological relationships

Disjoint « d »

Equal « e »
To fully encompass the ST information complexity, we propose 3 degenerated topological relationships between points.

- Disjoint « d »
- Equal « e »
- Not A « ¬A »
- Not B « ¬B »
- Not A and Not B « ¬A ∧ ¬B »
Degenerated topological relationships

• A « state » is a particular relationships between objects at a given time.
• JEPD set of relationships:
### ST configurations of level 3 with continuity

<table>
<thead>
<tr>
<th>Configuration</th>
<th>Configuration</th>
<th>Configuration</th>
<th>Configuration</th>
<th>Configuration</th>
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<tbody>
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<td>{~A,d,d}</td>
<td>{~A,d,e}</td>
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<td>{~A,e,d}</td>
<td>{~A,e,e}</td>
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<tr>
<td>{~A^~B,d,e}</td>
<td>{~A^~B,e,d}</td>
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<td>{~B,d,d}</td>
<td>{~B,d,~A}</td>
<td>{~B,d,e}</td>
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<tr>
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<td>{~B,e,e}</td>
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### ST configurations of level 3 with continuity

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<tr>
<td>~B,e,d</td>
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<tr>
<td>d,e,~A</td>
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### Qualitative Spatio-Temporal Reasoning & Spatial Database Design


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<th>Configuration with Continuity</th>
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<td>3</td>
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<td>15626</td>
</tr>
</tbody>
</table>

- **A**: Anterior
- **B**: Posterior
- **A°**: Anterior (Reference)
- **B°**: Posterior (Reference)
- \(\delta A\): Distance to Reference
- \(\delta B\): Distance to Reference

Diagrams depict qualitative spatio-temporal relationships.
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
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.

Behaviour monitoring

Epidemiology

Crime mapping

Vehicle monitoring and management
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…”
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 VI

### Visualization

- Show all feature types
- Show a feature type

### Modification

- Modify a feature type
- Modify an attribute / operation
- Modify an attribute value
- Modify a feature association
- Modify a constraint

### Addition

- Add a feature type
- Add an attribute / operation
- Add an attribute value
- Add a feature association
- Add a constraint

### Deletion

- Delete a feature type
- Delete an attribute / operation
- Delete an attribute value
- Delete a feature association
- Delete a constraint

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<tr>
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<tbody>
<tr>
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<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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<td>Field of Application</td>
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<td>Producer</td>
<td>François Laplanche</td>
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Qualitative Spatio-Temporal Reasoning & Spatial Database Design

Feature Association

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<td>Order Indicator</td>
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<td>Constraints</td>
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VML Notation:

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URL Notation:

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Subtype of:

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<First <Previous Next Last>
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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
Qualitative Spatio-Temporal Reasoning & Spatial Database Design

Concepts taken into account thanks to the notion of package
Import a class from another Model into this Model

Conceptual Model

Class

Import

Terminé

TO_Limites
TO_Voies
TO_Points_de_ref
TO_Carteo
TO_Batiments
TO_Voies_ferrees
TO_Hydrographie
TO_Politiques
TO_Séparations

TO_Vegetation
Qualitative Spatio-Temporal Reasoning & Spatial Database Design

Concepts taken into account:

- Thanks to the notion of package

Current Model: Carteco_Vegetation.v1

User: carteco

Add Package

Delete Package

Add Class

Import Class

Add Link

Delete Selection

Save Model

Exit Module

Package:

Vegetation
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><strong>Batiments</strong></td>
<td><strong>Parcelles</strong></td>
</tr>
<tr>
<td>+Sm</td>
<td>-Sp</td>
</tr>
<tr>
<td><strong>Parcelles</strong></td>
<td></td>
</tr>
<tr>
<td>-St, At</td>
<td>+Sm</td>
</tr>
<tr>
<td><strong>ZonesPS</strong></td>
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</tr>
<tr>
<td>-St, At</td>
<td>+Sm</td>
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<tr>
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<tr>
<td>-St, At</td>
<td>-St, At</td>
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</table>

Enter the topological relationships stayed between "Parcelles" and "Secteurs"

**Permitted**
- Partial superimposition
- Total superimposition
- No superimposition
- Partial adjacency
- Total adjacency
- No adjacency

**Mandatory**
- Partial superimposition (+)
- Total superimposition (+)
- No superimposition (+)
- Partial adjacency (+)
- Total adjacency (+)
- No adjacency (+)

Apply Close
Complete the Topological Matrices of the package "Topological_area"

Classical Topological Matrix

<table>
<thead>
<tr>
<th>Batiments</th>
<th>Parcellles</th>
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<th>Secteurs</th>
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<td>ZonesPS</td>
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<td>Arrondissements</td>
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Strong Topological Matrix

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<tbody>
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</tr>
</tbody>
</table>

Enter the topological constraints stayed between "Batiments" & "Parcellles"

Cardinalities

- 0
- 0,1
- 1

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
Complete the Topological Matrices of the package "topological area".
Qualitative Spatio-Temporal Reasoning & Spatial Database Design

Implementation module

Spatial Database

eurosdr

Table: public.spatial_ref_ys

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Table: public.geometry_columns

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Qualitative Spatio-Temporal Reasoning & Spatial Database Design

Data loading in a temporary database

Select the topological rules you want to check

Data loading in the final database
Qualitative Spatio-Temporal Reasoning & Spatial Database Design

Web2GIS Web2GIS – Cartographic Module

• Goal: Allowing an end user to visualize and to carry on 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**