Improving Semantic Interoperability of Distributed Geospatial Web Services:

G-MAP SEMANTIC MAPPING SYSTEM

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Content

- Context: GWSs interoperability
- Problematic: Semantic mapping
- Objective: Improve semantic interoperability of GWSs
- Proposed Approach: G-MAP Semantic Mapping System and its components
- Benefits of G-MAP System
- Conclusion and Future Work
Distributed Geospatial Web Services ....

- GWS are modular components of geospatial computing applications
- Previously, geospatial services were available through GIS desktop application
- Nowadays, available on the Web, through distributed applications and networks

Need semantic interoperability to discover and combine relevant GWSs
Problematic

- Standards were created to support interoperability at the syntactic level (e.g., Web Service Modeling Language, WSDL; SOAP to support service binding)

- Those standards cannot help to overcome semantic heterogeneity, i.e. differences in meaning of concepts

- Differences arise because geospatial web services were build for different purposes, by different organizations
Problematic

Example of semantic heterogeneity of geospatial web services:

The function of this geospatial web service is to “display flooded regions” ...

Output: flooded regions which are adjacent to watercourse only

The function of this geospatial web service is to “display flooded regions” ...

Output: flooded regions which are close to cities only

GWS with similar functionalities have different outputs
Problematic

- Existing solutions:
  - **OGC Catalog of Geospatial Web Services**: tedious task for the user to search within a catalog; catalog needs to be updated any time a new service becomes available
  - **Semantic similarity measure**: indicates the degree of similarity between a query and existing web services descriptions
  - Semantic similarity (quantitative) is not expressive enough to help the user to select the most relevant service (e.g., does not indicate if the service is more specific, less specific than the query, or overlapping the query ...)
Objectives

- Propose a solution for semantic interoperability of geospatial web services which is:
  - Based on a rich service description
  - Produces qualitative relationships between a query and a service description, or between different services descriptions
  - Automatic (to be operational in ad hoc environments)
Proposed Approach

The G-MAP Semantic Mapping System:

- Uses an ontological service description based on our previous research: the Multi-View Augmented Concept (MVAC) Model
- Uses rule-based inference engine principle to automatically infer semantic relations between a query and a service description, or between different services descriptions
The MVAC represents the different **views** that a concept have in different **contexts**:

A MVAC concept is composed of:
- Name
- Properties
- Relations
- Spatial descriptors
- Temporal descriptors
- Views (defined based on **Contexts**)
- Dependencies

\[
C_{\text{MVAC}} = < n(c), \{p(c)\}, \{r(c)\}, \{\text{spatial}_\text{d}(c)\}, \{\text{temporal}_\text{d}(c)\}, \{v(c)\}, \{\text{dep}(c)\}>
\]
MVAC Model for Geospatial Web Services

- The MVAC:
  - represents the different **views** that a concept have in different **contexts** (examples of contexts are tourism, transportation, etc.)
  - uses “spatiotemporal descriptors” to describe semantics of spatiotemporal features (ex: surface of waterbody corresponds to “maximal waterlogged area”)
  - augments the concept with **dependencies** between concept’s features (ex: a dependency between “depth” and “status” is)
    \[ \text{depth}(\text{floodedLand}) = \text{high} \rightarrow \text{status}(\text{floodedLand}) = \text{navigable} \]
  - can be expressed with Description Logics (DL) to support reasoning
MVAC Model for Geospatial Web Services

- GWS are described with following parameters: a function, input and output, pre-conditions and post-conditions
- Each GWS parameter is described not only with a word, but with an enriched concept called “Multi-View Augmented Concept” (MVAC)

Example of a GWS: Compute distance between two locations
MVAC Model for Geospatial Web Services

Class(input complete restriction(is-A someValuesFrom(GML: surface)))
Class(pre-condition complete restriction(part-of someValuesFrom(NorthAmerica)))
Class(function complete restriction(is-A someValuesFrom(LocalisationOfFloodRiskZone)))
Class(output complete restriction(is-A someValuesFrom(GML: surface) restriction(hasContext someValuesFrom(floodDisasterResponse, floodPrevention)))
Class(output_FloodPrevention_Context complete restriction(is-A someValuesFrom(GML: surface) restriction(CloseTo someValuesFrom(waterbody))))
Class(output_floodDisasterResponse_Context complete restriction(is-A someValuesFrom(GML: surface) restriction(AdjacentTo someValuesFrom(waterbody))))
Class(post-condition complete restriction(hasSpatialAccuracy(5meters))))

Class(floodedLand complete restriction(is-A someValuesFrom(GML: surface) restriction(depth hasSomeValuesFrom(high)) restriction(status hasSomeValuesFrom(navigable)))
1. Formalization of GWS description with MVAC Model

2. Basic Matching

3. Complex Mapping

4. Augmented Mapping and issuing final relations
Basic Matching

- computes a lexical relation (synonymy, hyponymy, hypernymy, partonomy)

- uses several appropriate external resources to infer the lexical relation

- lexical relations are transformed into semantic relations
Complex Mapping

- **Inference Engine**
  Based on the idea of verifying a set of **logical rules**, which express the condition for a **semantic relation** between two features to be true.

Complex Mapping consider spatial, temporal and thematic features separately with distinctive **mapping rules**, which allow better understanding of the semantic relation between services descriptions.

1. Translate relations between words into logical statements (facts)
2. Match facts against mapping rules
3. If a rule is verified, relation stated in the rule is created and stored
Augmented Mapping Inference Engine

- uses a new structural matching criteria to discover more mappings: the dependencies
- principle: features that participate in structurally similar dependencies can be similar too

Example:
dependency1: depth (floodedLand) = high → status (floodedLand) = navigable
dependency2: water level (floodplain) = high → status (floodplain) = navigable

“depth” and “water level” participate in structurally similar dependencies
Implementation example

dis example of an augmented multi-view mapping result: semantic relation between the requested service description and two views of a given GSW description.
Benefits of G-MAP System

- Identifies several types of relations between GWS descriptions (equivalent, includes, overlap..), with several sub-types:
  - Thematic equivalence/spatially disjoint/temporal equivalence
  - Thematic inclusion/spatial equivalence/temporal inclusion
  - Etc.
- Varifies complex cases to improve the interpretation of relations between GWS but remain intuitive to understand
- Supports multi-context semantic interoperability:
  - Semantic mapping depends on the context
Conclusions

- **G-MAP** is a semantic mapping system useful to:
  - Discover relevant Geospatial Web Services beyond simple syntax comparison between concepts from GWS
  - Infering some implicit information in the description of GWS that helps to their interoperability

- **Limitation**
  - It is still difficult to have fully automatic semantic interoperability approach and human reasoning intervention is needed for final decision making
Future Work

- G-MAP Semantic Mapping System opens new research opportunities:
  - Investigate how G-MAP can support propagation of user queries to relevant services in an ad hoc network of geospatial web services.
  - Investigate how G-MAP can support dynamic classification of services, to support the user searching for relevant services.
THANK YOU