Mobile Queries using Semantic Processing into Augmented Reality

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***Abstract*— This article presents a mobile system to answer structured queries into a research-academic domain using a spatial Ontology. The answers to queries are displayed on an Augmented Reality (AR) interface. The structure of query is a triplet formed by: interrogative adverb, verb and direct object. The case study is in a university campus. Queries are solved using semantic processing, for example, {Who can advise on vector calculus?}. Then, possible answers (researchers or professors candidates) are obtained applying semantic similarity on attributes defined into Ontology (e.g., level of expertise, research line to which it belongs, topic, etc.). Additionally, spatial parameters are included into the answer, such as: where researcher is located, schedules, colleagues, etc. The functionalities of system are: search persons based on qualitative and spatio-temporal attributes. The combination of a semantic approach with an augmented reality interface provides new possibilities to express queries; not only in text or based on location, but using AR with interactions. It is useful to locate persons in outdoor environments.**

Keywords-Spatial Semantics; Augmented Reality; Mobile queries.

I. INTRODUCTION

Very often, in an academic environment, students are looking for professors, researchers or specialists with knowledge on different topics; even a thesis advisor. Then, when non-local students visit the facilities of a university, they look for professors to answer a particular question or doubt (expressed as a query from smartphone). They do not know researchers' names; in other words, information is imprecise. The only data they have is the specialty that a professor should belong to. Then, they need to ask more information about professors or researchers from other students or people on campus. Therefore, it would be useful to have a system to help find which professors are the experts on particular issues. We have to consider that the professors can be located based on schedule of work. In addition, when the search for a professor includes several criteria, such as level of experience, international recognition, among others, the task becomes a challenge.

This can be solved using a semantic processing approach combined with advantages of navigation using AR. In addition, once students have identified the professors that can support or advise them on a particular topic, it is useful to have a comprehensive tool in order to find out the schedule and specific geographical location within the campus where to find the professor or researcher in question. This functionality is enhanced when is displayed using AR.

This paper introduces a semantic mobile system using augmented reality with the following capabilities: 1) search of professor or researcher by criteria: topic, level expertise among others, 2) schedules and places where the researchers can be found and 3) an interface of navigation and AR. The case study is focused on a campus of IPN (Instituto Politécnico Nacional) in Mexico, in order to assist students with questions regarding to topics of thesis or other subject-matter.

The rest of the paper is organized as follows: Section II shows the related work; Section III explains the methodology used; Section IV describes the obtained results, and finally, the conclusion and future work are outlined in Section V.

II. RELATED WORK

AR technology augments the sense of reality by superimposing virtual objects and cues upon the real world in real-time [1] and indoor environments. AR has been the object of increasing development in outdoor and indoor environments [2][3][4][14]. In [11], an indoor technique is used for AR positioning system for indoor construction application by tracking the coordinates and its angles of vision. In order to, achieve indoor positioning in three dimensions. Nevertheless, no ontologies or semantic processing were used. AR was used in several ways but navigation is not provided by a semantic processing, such as in [12], where AR is used in a self-guided tour; the user can see environment information, sites or buildings, listen to audio touring narratives, or get directions.

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Ontology is also employed as a method for identifying categories, concepts, relations, and rules [5][6][7]. When combined with query languages, domain ontologies favor the design and development of domain-based search engines and their application to different areas [8]. In contrast, similar semantic approaches have been proposed; for example, GeoSpatial ontologies are applied in emergency systems for indoor disasters, for campus of University of Melbourne [13]. The semantic approach gets a spatial analysis; it is used for emergency management capabilities indoor and outdoors components. But, AR is not assisted using ontologies. Zhang et al. [9] proposed a technique that uses common sense geographic knowledge and qualitative spatial reasoning for the generation of a geographic Ontology. The tools for processing Ontology Web Languages (OWL) are numerous; One of the most popular is Pellet [10], we decided to use it in this research.

III METHODOLOGY FOR QUERYING AND SEMANTIC PROCESSING

In order to solve the queries submitted, a four stages methodology is defined: a) query contextualization, b) displayed results on AR, c) parsing, semantic and spatio-temporal processing, information retrieval, and d) visualization on AR interface. In Figure 1, general architecture of the system is shown.

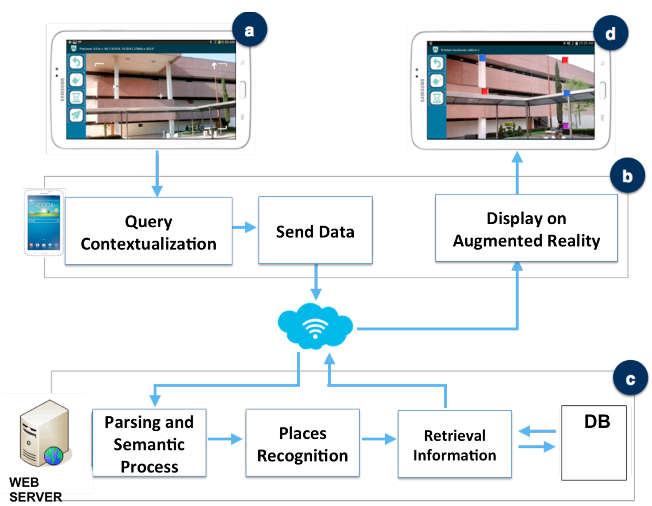

Figure 1. General architecture of the system.

In Figure 1, the labels a) and b) represents the stage of query contextualization, it means, the attributes required to build a query (e..g, "Who knows Electronics?"). This query is sent to stage c) where the query is analized sintactically and semantically; elements of query are associated with concepts in domains of space and time, in order to infer answer(s) to query. These answers, are attributes on time (e.g., hour) and location (e.g., a classroom) that will be sent to modules in stage b) in order to transform them in elements that can be displayed on AR interface, finally the stage d) shows the AR interface with the obtained results. In the case of semantic processing stage, it involves three steps: Ontology design, rules' definition and reasoner's implementation. They are described in the next section.

A. Ontology Model Design

The ontological model was designed to represent the knowledge of researchers, professors and their respective field of expertise and workplace. Ontology will be explored in order to answer queries. Ontology is built based on relationships from custom university academic domain. The model was built with the OWL language and using Protegé editor 4.3.0 [16]. The semantic consistency was checked using Pellet reasoner [15] that was coupled as a plug-in in the editor. In Figure 2, the basic hierarchical structure of Ontology is shown; it describes the context of spatial location of the professors at a university. In Ontology, the geographical entity class is the parent concept that defines the set of laboratory classes, classrooms, auditoriums, offices, buildings, etc. Each class, with its identifier, has three aspects: subclass, equivalents and the elements of which are disjoint.

The Ontology was implemented in Spanish; the concepts are related to geographical objects (classroom, level, office, building) events (exposition, conference) and classification of personnel (Academic, administrative, etc). In similar way, Ontology was complemented to spatial objects, temporal aspects and subjects. Figure 2 shows an Ontology fragment (in Spanish) of geographical objects.

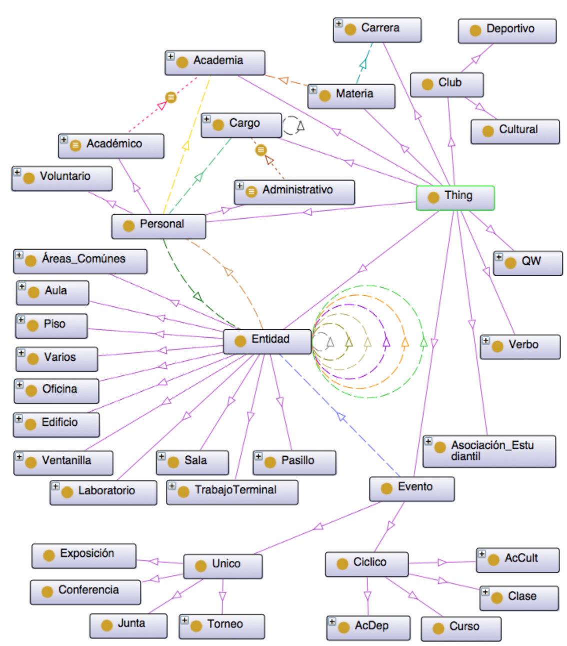

Figure 2. Spatio-Temporal Ontology.

The Ontology is explored in order to contextualize queries (find a matching concept between query and class or instance of Ontology); the Ontology is used to make inferences, too.

B. Semantic Processing

The Ontology describes academic knowledge and associated spatio-temporal attributes (e.g., specialist in mathematics, located in basic sciences office, available schedule 13:00 to 17:00). The reasoner Pellet is used to extract information that is not explicitly represented by the data (some inferences). In Table I, object's properties (denoted as P_n where n is the property identifier) are categorized for each type of relationship: spatial (e.g., P_1-withInThe), temporal (P_{13}-ocurredIn) and academic (P_5-knows). For example, "isLocatedIn" (P_{16}) is a spatial relationship to link people with their specialty and identify their specific positions, i.e., one can infer the following knowledge: if the teacher Luis Flores (instance of the class "Academic") "isLocatedIn" department of advanced technologies (it is an instance of "Office" class) and its location says that this office is *withInThe* academic department (then it follows that the teacher Luis *isLocatedIn* the entity called "Academic department"). Several inferences are made in order to solve imprecise queries (e.g., looking for physics researcher with works in modern physics) in opposite way with a precise query (e.g., looking for researcher Pedro). In Table 1, a sample of different properties of spatio-temporal Ontology's classes (from Figure 2) is shown.

TABLE I. AXIOMS OF FIGURE 2

	Property	Meaning
P_1	houses	Related offices with staff who reside there
P_2	limitShares	Related Contiguous entities
P_3	withCharge	Relates to administrative staff position held
P_5	knows	Personnel related to their area of knowledge (academy)
P_8	withIn	Relating a larger entity that contains
P_{16}	isLocatedIn	Reverse Property Shelter_to
P_{17}	over	Reverse Property below

The properties link entities, and in turn with entities' domain and their values are used as axioms in reasoning and detecting inconsistencies. This is useful for scalability of Ontology design. The properties defined in the Ontology are type transitive, i.e., the reasoner is able to conclude that if an object O_1 is related to another object O_2 by property P_1 and this in turn is related by the same property with O_3 object, then individuals O_3 and O_1 share the property P_1.

The domain of P16 isLocatedIn relationship is the staff of the institution, its range are different entities (offices, laboratories and staff rooms); where a teacher can be located. Figure 3 shows some of the 162 entities of courses offered by the university. The professors were characterized by defining their equivalents, the academy and career to which they belong. There are 256 people including information, such as names, titles and locations, academic and administrative staff of the institution (see Figure 3).

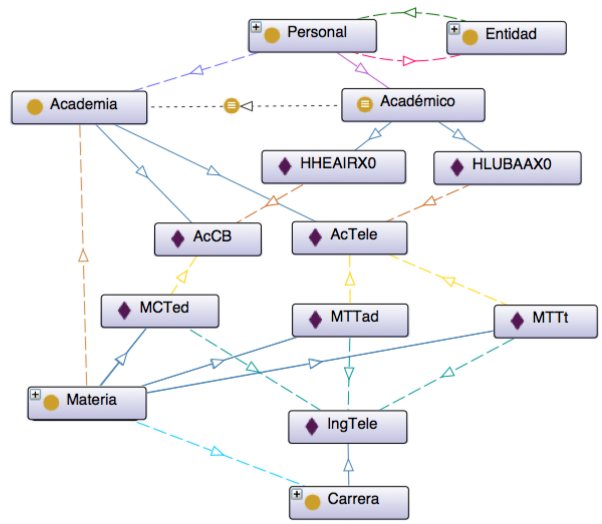

Figure 3. Entities, Relationships and Axioms for Academy Concept.

This fragment of Ontology is used to solve queries related to personnel search by their specialty; an example of modeled knowledge is as follows: Personnel is located in an entity, therefore an entity contains elements of Personnel class. Personnel (professors or researchers) know some element of academy class (e.g., Mathematics) then is of academic type. For example: person HHEAIRX0 (Pablo Hernandez) knows AcCB (basic sciences academy). The element MCTed (differential equations) is of type subject (topic) and belongs to Basic sciences academy, hence professor Pablo Hernandez knows differential equations.

C. Querying and Semantic Processing

The system uses two types of processing queries: precise and imprecise; an example of the former {Q_1 = Who knows Electronics?} to solve, the Ontology is explored to retrieve the name (find a semantic matching) of academy teachers belong to electronics subject; as it is to assume that all teachers know subjects of the academy they belong to.

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In the case of the latter type of queries, i.e. working with imprecise questions, let us consider the query such as Q_2 = Where is the office 122? To answer it, one use DESCRIBE relation to retrieve or infer facts about the concept "office 122" for example, what class are held here, if it has cubicles teachers, how spatial concepts share limit, on which floor and in which the building it is located, etc.

The overall set of steps to process queries is: 1) SPARQL [17] translation, 2) detection of the object of interest, 3) identification of keywords exploring the Ontology using words of query, which detects the interrogative adverb and verb, and 4) related to the query retrieves information from the Ontology. For example, the query Q_3: Who can help me with an issue in Electronics? is translated into SPARQL query format as follows:

```
PREFIX bibo:
http://www.semanticweb.org/itz/ontologies/2014/7/BIBO_v1#
SELECT ?personnelName ?AcademyName
WHERE {?subject bibo:withName?subjectName
FILTER (str(?nameSubject) = "Electronics")
{?subject bibo;belongsTo
?Academy.?academy bibo:withName?AcademyName.
?Personnel bibo:KnowsAbout?academy.
?Personnel bibo:withName? PersonnelName}
```

The query Q_3, retrieves teachers from academy where Electronics course is taught. The original query should be analyzed in order to identify the direct object (interest object), and then the terms of original query are compared with the elements of Ontology (using similarity). This way, we determined if the object of interest is referring to a subject, academy, and event or is an unknown concept for the Ontology. To determine how similar a text string is to another, the elements of the Ontology and the phrase are mapped to a vector space that allows the use of the dot product as a measure of similarity: In the first instance, it is required to extract the "universe" of words contained in the collection of items of Ontology and determine the frequency in which they appear.

Below is built a N×M matrix, where N is the number of elements and M to the number of terms (words without repeating) in the "universe". The vector representing the user's phrase, is constructed and the dot product between it and the rows of the matrix is calculated. Accordingly, the pair of vectors whose dot product is the largest will be the most similar to the phrase. Therefore; the system identifies it as the object of interest the user refers to. In the following section the results are discussed.

IV. TEST AND RESULTS

Testing was done using several queries; the first test was to evaluate the answer of the system when a query asks for data not stored in the Ontology. Hence, in order to answer, the processing should use similarity, and, then, the results obtained are shown.

Let us consider the query Q_4={who can help me with issues of vector calculus}

```
2015/02/9 21:04 Monday
Matches: 2
multivariable calculus ... 0.6544891121378675
Answer: There are two teachers who may like
help:
Francisco Perez
Mario Contreras
RA: false
Time: 168 milliseconds
```

For example, in the query Q4, user asked for vector calculus (but no data or concept of calculus vector is present into the Ontology). The system answers by relating Vector calculus with an entity of class named "multivariate calculus", although it has similarity just above of 60%, but not best candidates were found. This relation was made because both subjects-matter (vector and multivariable calculus) are in the area of Basic Sciences according to the hierarchy of Ontology. The next test is a query spatio-temporal, when a user requires to know when and where a subject matter is taught.

Let us consider the query Q5 ={Schedule of network security subject?}

```
2015/02/11 11:56
Matches: 6
network security ... 1.0
Task: I'm looking for the schedule network security
Answer: network security in 3TM3 group:
* Monday at 10:00 Telematics Laboratory II
* Tuesday at 10:00 in classroom 122
network security in 3TV3 group:
* Monday at 16:00 in classroom 102
* Wednesday at 16:00 laboratory telematics II
RA: false
Time: 181 milliseconds
```

In query Q_5, a query element has a matching of 100% with the event of Ontology: "network security". Nevertheless, when is an event occurred in two groups and the query not specified which one is required, then the reasoner retrieves both schedules.

The next test is based on spatial queries using current user's location and spatial relations (next, in front of, etc). These queries ask for information such as:

Q_6={available professors in building "A"?},

Q_7={researchers located next to telematics academy?},

Q_8={events occurred around to my current position?}.

In Figure 4, the user's position is represented using a user icon. The points marked by the user symbol and the orientation indicated by the sight lines from A to H. The GPS have a 5 meters error (in optimal conditions) that facilitates the deployment of virtual objects on screen (augmented reality) with equivalent margin of error.

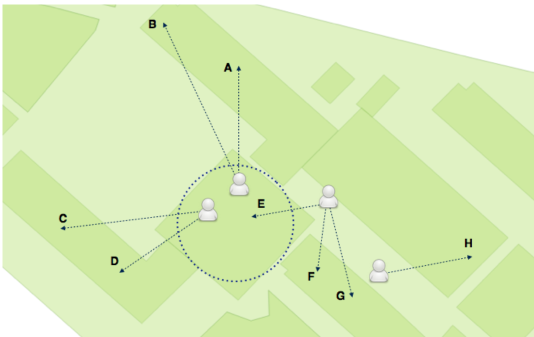

Figure 4. Several User's Position and Sight Line Directions.

The events are retrieved under sight line A, using user's position from GPS, and the neighborhood using spatial relations. The sight line is processed based on the actual position. Then, we calculated that line cross building "A" is located to 11.252 meters from user. The result obtained is as follows:

Data received: (19.511537 -99.126536) at 0 °
Fri 2015/02/20 10:45:00
Sight Line: LINESTRING (-99.126536 19.511537, -99.126431 19.517536)
Against: Building A
Central Crossing: POINT (-99.1265322955 19.5117492255) to 11,252 meters
Estimated Height: 6.97 meters
Information: * Classroom 423
Class: Distributed Systems
Group: 2TM5
Title: José Rodriguez
Floor: P2
Address: Left
Distance: 1555 meters
* Laboratory of Complex Systems
Entity no events registered
Floor: P1
Address: Left
Distance: 1828 meters
* Nanophotonics and laboratory techniques
Entity no events registered
Floor: PB
Address: Left
Distance: 1975 meters
* Classroom 422
entity unoccupied
Floor: P2
Address: Right
Distance: 7786 meters
* Classroom 412
Entity no events registered
Floor: P1
Address: Right
Distance: 7366 meters
Time: 4089 milliseconds

These results are displayed using AR; to achieve that, the building height is computed to determine the vertical position of virtual objects to be displayed on screen (according to corresponding level of building).

Each virtual object can be touched and relevant information of this object or event will be displayed. Hence, the following information is retrieved: event, level, address and distance regarding to cross point between view line and polygon. Figure 5 shows this result.

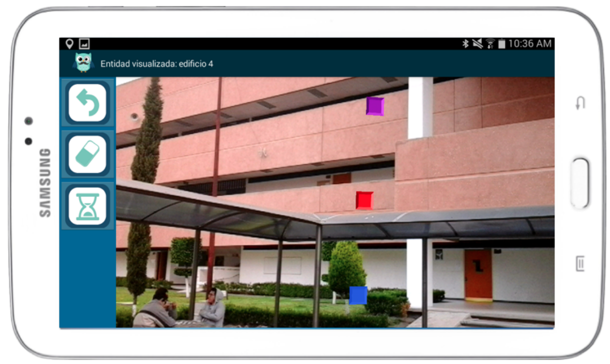

Figure 5. Augmented Reality Navigation for Query Types Q_6, Q_7 and Q_8.

In Figure 5, the app notifies the user that s/he is in front of building A. Then, the interface allows to navigate using AR, when the mobile device points to a different direction, less or equal to 30° degrees regarding to original line of sight (located in top of Figure 4). While, in Figure 6, information is retrieved, when virtual objects are touched. This data corresponds to events belong to time interval (defined by start and finish hour) and the temporal context.

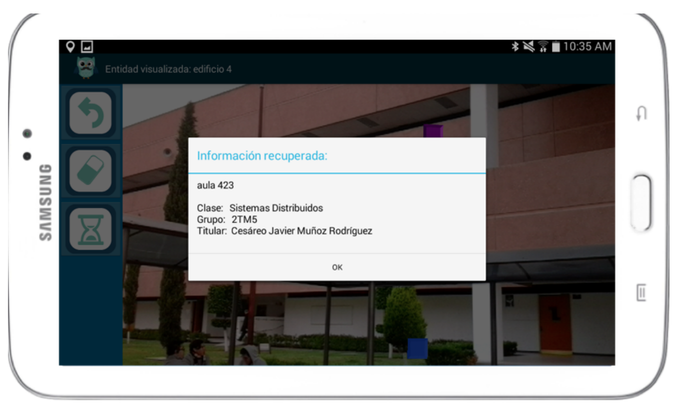

Figure 6. Retrieved Information in AR Interface Q_8.

In this case, the AR tests were conducted in portrait mode (vertical position); to display the position of the virtual objects the building height is dividing by three (floors of building). Converting meters to pixels is essential

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in order for the building to be displayed on screen from foundation to roof, in order to display all the elements on screen (see Figure 7).

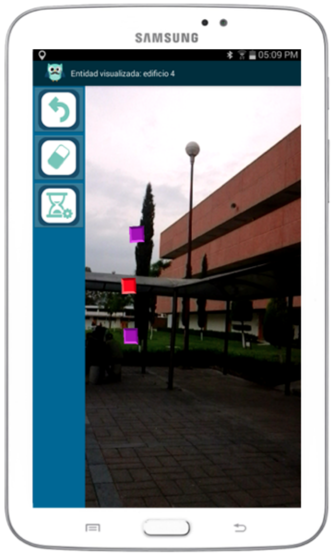

Figure 7. Information retrieval displayed on the AR interface.

In Figure 7, we note that the response to the sight line B presents a significant error (the square icons are displayed out of building). This is because although the system does not expect the user to visualize the entities full front, the algorithm that calculates the position of virtual objects does not consider the perspective introduced by lateral views. To remedy this deficiency, it was decided to deploy graphic elements only on the sub entities that lie within the range formed by an angle of 30° right or left regarding to user's line of sight.

V. Conclusion and Future Work

The use of semantic processing to find a knowledge profile represents a useful field for tasks of semantic similarity. The resolution of queries over Ontology exploration about spatial and temporal attributes can solve complex queries.

Displaying results in augmented scenarios provide a practical way to locate people. The combination of ontologies and AR for mobile phones represents a field of opportunity for various tasks and scopes. GPS and compass sensor require developing algorithms in order to compensate the error margin or use external devices with great precision, in order to offer a precise augmented navigation. Future work considers including speech recognition and AR using sensors instead of pattern recognition.

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