An Expert System for Wide Area Surveillance based on Ontology

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Abstract

An overwhelming amount of data arriving from disparate sources can be a bottleneck in realization of any service. This data, if properly processed and annotated, can be a useful source of information. This work builds an Area Profile Ontology (APO) and imports other related ontology to annotate rich data arriving from multiple sensor streams like cameras. The annotation process provides an impetus to the improvement of knowledge over time. APO provides the main concepts and properties to model an area which can span even a city. We define Jena rules to infer intelligent information about the position of an object of our interest. We illustrate ontology emergence by drawing upon a case study to show an actual application.

Keywords: Ontology, Expert Systems, Reasoning

1. Introduction

Over the past few decades, the way Information and Communication technologies (ICT) has evolved countless different systems to become interoperable. Particularly, the concept of open systems has led to new developments, one example of which is video surveillance. Compared to the surveillance system used 15 years earlier, the expense of monitoring a particular location has greatly reduced with the advent of video surveillance. Previously, there were guards who would routinely take turn after every fixed interval of time to take a round of the campus to observe any suspicious activity. Video Surveillance has reshaped the way the security systems are developed now. Businesses can now successfully monitor an entire building using only 1 security guard stationed at the entrance, monitoring multiple cameras positioned at key locations. Moreover, one security guard can monitor multiple buildings, from a remote location, using networking and other available devices.

Despite the success of such video surveillance systems, most small businesses cannot afford for full-time security personnel who exclusively monitor the streaming video. Thus there is a need for an economical multi-access remote system that can receive data from various devices (like sensors, cameras, RFIDs) and enables individuals to access remotely a security area as desired. Moreover, there should be no or little need for security personnel to actively monitor the incoming video at all times, and instead, the system should notify the system users at specific times such as when there is any suspicious activity or an alarm triggers. In our endeavor to further improve video surveillance systems such that minimum human effort is required by building an expert system. The proposed system consists of autonomous agents that stream the data which is stored in an ontology for processing by a reasoning system. The reasoning system draws inferences from the received information and instructs the security personnel to take appropriate action, if necessary.

We are designing and deploying a system for the wide area surveillance covering Gyeonggi province area, in South Korea, containing about 10 cities. The design of

architecture for surveillance of the area consists of an integrated framework of networked RFID sensors, CCTVs, and smart cameras. Various data such as video, feature data including biometrics and event alarms originate from many kinds of such input devices. Although sensor networks are distributed by geographic area hierarchy, they have their own knowledge base including ontology data about situation, inference engine and communication protocol between CCTVs for queries. This framework guarantees the consistency and expressivity of the ontology used in the data integration process. In the process of reasoning, each agent may process the consolidated data in order to generate inference based on its local ontology. Distributed and autonomous reasoning is already known to be scalable and efficient [1, 2]. It helps security personnel by presenting appropriate decisions or predictions based on the data about the situation it gathers.

In a nutshell, this work makes the following contributions:

1. Develop an Area Profile Ontology (APO) that allows annotation of geographical area and data arriving from sensor streams.

2. Define semantic rules to draw inferences.

3. Develop a web-based system with user interface that can be remotely accessed.

4. Present a case study to show the effectiveness of the proposed work.

2. Related Work

Ontology reasoning architecture [3, 4] can be used in many applications requiring images from multiple data sources to be combined in order to interpret the scene and understand the situation such as physical security surveillance [5], environmental surveillance, or disease surveillance [6]. For wide-area physical security surveillance, monitoring systems are connected to communicate with each other [7, 8]. However, they do not adopt artificial intelligence technique like ontology reasoning.

To ease merging of heterogeneous data, effort for standardization for physical security has been done by ONVIF (Open Network Video Interface Forum) [9] and PSIA (Physical Security Interoperability Alliance) [10]. They define, recommend, and promote standards for IP-based security products. Besides ISO [11], BSI group [12] and other standard organizations enact standards for general aspects of physical security. Our system is designed to meet the requirements of industry by providing functions recommended by such standard organizations.

Many of the existing security surveillance system depend on the knowledge annotated by experts [13]. There are few of surveillance systems adopting ontology-driven technologies. Another work [14] introduces artificial intelligence techniques only for interpretation of objects. Roberto et al. [15] uses ontology but does not build agents for web of data. Furthermore existing wide-area surveillance systems are closed systems and do not provide obtained information to the public.

Ontology and surveillance

There are four [16, 17, 18, 19] approaches that are similar to our work, i.e. they all deal with surveillance and uses ontology. They are similar to ours in that they all try to solve the problem of annotating data arriving from disparate sources. However, difference lies in the annotation of type of data. For instance, [17] builds an ontology to merge the visual and textual data together, using computer vision technologies and natural language processing in the domain of video surveillance. One of the major

differences from ours is the definition of rules. They also do not report any case studies or experiment work. Similarly, [16] designs an ontology for visual activity recognition. They tested their ontology qualitatively on airport and bank data sets that consist of video footage. The events are defined but there is no explanation about their execution. It is difficult to express complex knowledge such as entailments using event based model [18]. We believe that given the video footage, they would execute the events in an ad-hoc fashion. This is one major drawback, because the event execution is not automated which could seriously hamper the acceptance of the system.

We, on the other hand, present a case study that shows how the data is annotated and rule engine fires the rules to detect a possible intrusion by generating inferred instances. [19] is similar to [16] in that they also use event based model and objects to create the ontology. Along the same lines, [18] presents an ontology to annotate video sequences using MPEG-7 standard. They use Semantic Web Rule Language(SWRL) to define rules. Talking of rules, there are two popular rule engines that work with ontologies: JENA and SWRL. Any rule defined in JENA can be replaced with SWRL. The subtle difference between them is their acceptability by different editors that are used to create ontologies. For example, we found that Top Braid Composer doesn't support defining complex SWRL rules, therefore we resorted to using JENA instead of SWRL. To some greater extent, the work in [18] complements our work. We define APO ontology for annotation of streaming data that consist of latitude and longitude, and also to annotate the places so that, given the latitude and longitude, further inferences can be drawn about the object. The approach presented in this work is a mash-up combining different ontologies, adding few more concepts as required, defining rules that are triggered automatically as data arrives. Based on the input data that has arrived and annotated, inferences are drawn by firing rules. The inferred information can be directed to mobile device or computer screen or any other electronic devices.

3. Proposed System

Distributed surveillance algorithms heavily rely on collaboration among sensor devices, which require distribution of control and data. The elementary tasks are distributed and executed independently with a certain degree of autonomy and mobility. Each sensor network can be viewed as a knowledge processing engine to make a smart decision. The knowledge base has hierarchical architecture according to the geographic extent; country level, state level, city level, and village level. The set of knowledge bases includes facts, rules, and ontologies about situation, and is related to the raw data from various sensors.

In our wide-area surveillance system, various input devices are interconnected through Internet. Analysis of sensor data generally requires combining information from several sources. The data received from input devices is not only human processable but also machine processable. We would like to extend the current wide area surveillance system to a web of data and allow agents to exploit the data directly by communication with each other with complete independence irrespective of their geographic hierarchy. Because of the complex geographic relationships between subjects of interest, different sets of data sources may need to cooperate to analyze different subjects.
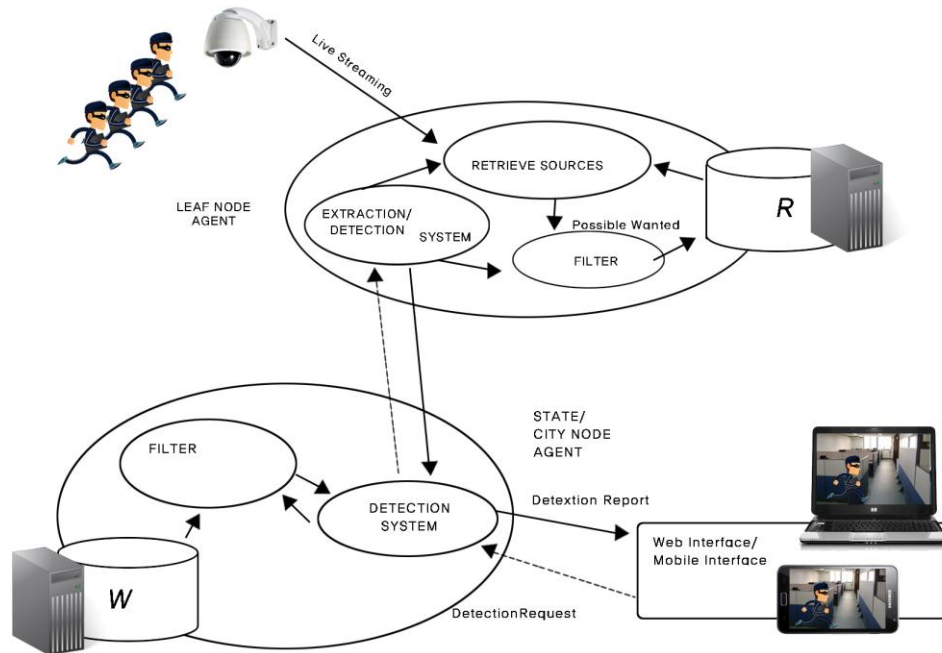
Figure 1. Wide Area Surveillance Scenarios

Distributed processing and decision making is an essential task in networked surveillance systems. There are two possible scenarios in wide area surveillance systems: continuous real-time detection and detection on request: in Figure 1, we try to explain both scenarios. Detection in real-time is represented as solid lines and detection on request as dotted lines. Extraction system, in leaf node agent, does local processing for efficient collaboration with other nodes. Because camera imagery is used to identify individuals, new algorithms are needed to protect privacy while allowing useful information to be gathered. By being able to perform local on-site image analysis and hence to avoid transferring raw data, our networked wide area surveillance system increases privacy and security. Detection system in state or city level node agent maintains a database for its own purposes. Extraction system, detection system and filter system make use of ontology about situation which is contained in the *R* and *W* knowledge base. Distributed processing must consider many aspects such as the amount of local processing, the trade-off between computation and communication, and the necessary accuracy on spatial and temporal calibration. If we can reduce the data transfer between processing nodes, we can make sure that minimum required data is directed to the necessary nodes so that the available bandwidth is used efficiently. For collaboration between distributed agents, each data stream should be uniquely identifiable, and we should allow data streams arriving from sensor nodes to link to each other and classify the data to convey some meaning.

Each agent builds a knowledge base to elaborate an inference engine such that it will return different decisions for each different context intelligently. For making better and more intelligent decisions, we collected background fact data, rules, ontology about situation and store them as instances in ontology. Inference engines make use of those data. It defines area

data for the inference rules. Each agent has asserted instances stored in area profile ontology. Area profile ontology is further used for inference and reordering query results. At each search request made by some agent or personnel, one will receive related data including still picture, video, feature data, event alarm, and recommended actions that are ranked from top to bottom.

When we connect several smart cameras or CCTVs, amounts of available video data grow. However transmitting video data in affordable rate consumes large amounts of network bandwidth. Furthermore the round-trip delay adds to the latency decision making. Developing interactive systems for efficiently querying this data about specific events has become a significant need in surveillance. Such a system should be able to bridge the gap between the high-level users' queries and raw data within leaf node agents. This can be achieved by providing the powerful user interface utilizing communication stack between agents, for submitting queries. It also provides a mapping from the query into a set of rules that can utilize the feature data provided by other agents to infer high-level semantics, and then displaying the results such that the user can reformulate the further in-depth query and use the search results to foster new search inputs. For the public web services and for standardized interface between agents, we developed functions which are remotely accessible. It forms an efficient and interactive system for querying surveillance data about events.

The surveillance system administrator can monitor and control the state of the system via a graphical interface that shows real time, high-level representation of the system status. The person can manage local agents and can inspect the status of the remote agents through a graphical user interface that supports the monitoring and deployment phases. To access remote agents the access control is performed and the configuration can be changed according to the privileges. Our wide area surveillance system is named as U-City Security System. U-City Security System's web interface and mobile interface have been implemented. They show listing of event alarms monitoring page. When a specific device icon is clicked, it shows the status information about the local and remote agents including location and privileges. It also shows video search result for the alarming location. On the background page, it shows a regular user interface. The system administrator can see the list of surveillance agents in its domain. By clicking specific item, live video from the designated server can be seen in the pop-up window also. The system administrator can choose other surveillance area under the user access control. The system administrator can see the list of alarming locations. By clicking some specific alarm, stored or the real-time video of the site can be seen. Depending on the characteristics of the event we can see various types of result data. The stored video can be reviewed again by application key strokes. Through the center pop-up search form, we can elaborate the search options. Our wide area surveillance system can be applied to other services such as smart homes, elderly care, or entertainment besides crime surveillance with specialized policies and distributed user access control.

4. Area Profile Ontology (APO)

The use of conceptual modeling in general, and ontology in particular, was initially incorporated by researchers to tackle information silo problem. There are mainly two facets to ontology: ontology as a field and ontologies as an artifact; however, both share

a common functionality i.e. ontology as a specification of vocabulary. Ontology is an explicit specification of conceptualization, i.e. ontology is a description of concepts and relationships that can exist between them. Ontology provides a shared vocabulary to model a domain. Instances are then fed into the ontology which can be further inferred to generate vital information.

In this paper, we define some concepts and their associated relationships, borrowing other concepts and relationships from existing ontologies like GEO[1], FOAF[2], etc. It is normal to borrow concepts from other widely-used ontologies; this puts ontologies to re-use. The basic objective to develop ontology is to model all the available information as instances in the ontology and making it available for later reuse. We model instances (data) of a geographical area in ontology. To annotate a geographical area and data arriving from sensor streams, we create and use Area Profile Ontology(**APO**) ontology.

In this section, we lay the foundation of **APO**; explain the various concepts and their associated properties. We follow the next five principles to develop **APO**: (i) identifying the ontology purpose, (ii) choosing a design approach for the ontology, (iii) identifying the concepts, properties, and conventions, (iv) ontology construction, and (v) ontology maintenance.

Definition 1. An ontology $\breve{O}$ is represented as

$$\breve{O} = \langle C, P, I_n, IN \rangle$$

where C is a set of classes(or concepts), P is a set of properties(or relations) , $I_n \subseteq C \times C$ is a set of relationships between classes defined using relations in P as a set of triples,

$$I_n = \left\{ \langle c_i, p, c_j \rangle \mid c_i, c_j \in C, p \in P \right\}$$

where IN is a power set of instance sets of a class $c_i \in C$.

Figure 2 shows a snapshot of the key features in APO. The source code of concepts and properties in APO, developed using OWL in Top Braid Composer, is shown in Listing 1. TopBraid Composer is a modeling environment for developing semantic ontologies, SPARQL queries, and defining JENA rules. It shows the imported ontologies, the prominent concepts and object properties.

In APO, the central concept is *Block*. Each instance of type *Block* is constrained using two pairs of coordinates defined using *Coord*. *Coord* is a subclass of *geo:Point* which is a subclass of *geo:SpatialThing*. This entails that each instance of type *Coord* inherits properties from *geo:SpatialThing*. An area normally consists of more than one *Block*. An area can be a stretch of road or a campus or a whole city.

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[1] http://www.w3.org/2003/01/geo/ - an ontology for spatial modelling like country, cities etc.
[2] http://xmlns.com/foaf/spec/ - an ontology for describing a person
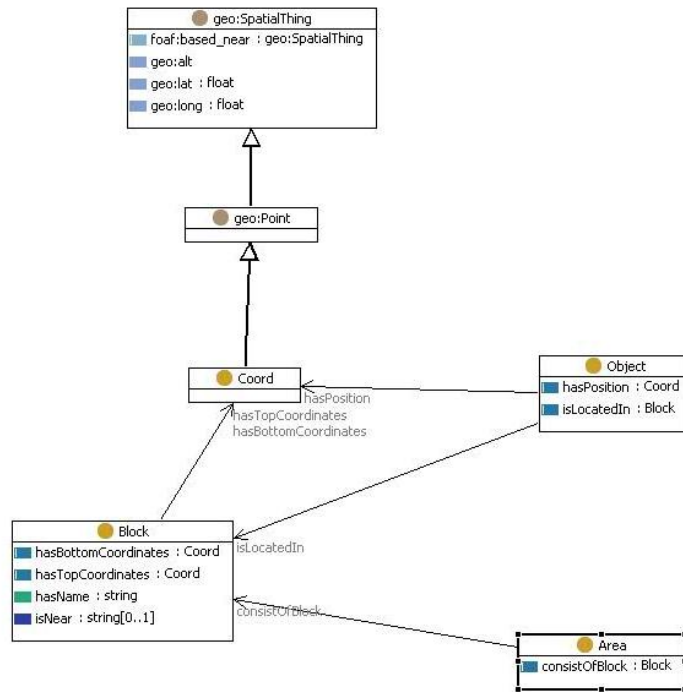
Figure 2. A Snapshot of APO

Listing 1. The Imported Ontologies, Prominent Concepts and Properties in APO Developed using OWL DL in Top Braid Composer

```
<owl:imports rdf:resource="http://www.topbraid.org//2007/02/jena.owl"/>
  <owl:imports rdf:resource="http://www.w3.org/2003/11/swrlb"/>
</owl:Ontology>
<owl:Class rdf:ID="Coord">
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2003/01/geo/wgs84_pos#Point"/>
  <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string">Every block
has 2 set of coordinates.</rdfs:comment>
  <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string">
Coordinates</rdfs:label>
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
</owl:Class>
<owl:Class rdf:ID="Area">
  <rdfs:comment rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
      This is the overall area of the campus</rdfs:comment>
  <rdfs:label rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
      This is the overall area of the campus</rdfs:label>
  <rdfs:subClassOf rdf:resource="http://www.w3.org/2002/07/owl#Thing"/>
</owl:Class>
<owl:ObjectProperty rdf:ID="isLocatedIn">
  <rdfs:domain rdf:resource="#Object"/>
  <rdfs:range rdf:resource="#Block"/>
</owl:ObjectProperty>
<owl:ObjectProperty rdf:ID="hasTopCoordinates">
```

```
   <rdfs:range rdf:resource="#Coord"/>
   <rdfs:domain rdf:resource="#Block"/>
 </owl:ObjectProperty>
 <owl:ObjectProperty rdf:ID="hasPosition">
   <rdfs:domain rdf:resource="#Object"/>
   <rdfs:range rdf:resource="#Coord"/>
 </owl:ObjectProperty>
```

The environment ontology, **EnvO**, is imported to annotate instances like cave, garden, river, ocean, etc. It also defines synonyms of a term to avoid any disambiguation. For example, the concept ENVO:00000020 defines a term lake with its synonyms lakes, loch, lochan, open water, etc. This allows to disambiguate the use of different terms by different people as all the terms map to a single concept ENVO:0000020. Each concept in **EnvO** is also linked to a concept in **GEONAMES** ontology, for example the concept ENVO:00000020 is linked to GEONAMES:LK and GEONAMES:LKS; GEONAMES:LK and GEONAMES:LKS are equivalent of concept Lake in **EnvO** ontology. It also provides additional information about concept ENVO:00000020 by defining *isA* relationship, for ex: the concept ENVO:00000020 has as its super concept "Water Body". For that matter, terms like stream, ocean, lake, pond has as its super concept "Water Body". This kind of hierarchy allows inferring additional information that an object near lake is also near "Water Body". A concept lake also has sub concepts, like fresh water lake, pond, defined using an *isA* relationship, i.e. fresh water lake *isA* Lake.

We see the **APO** ontology bringing similar benefits to those that can already be achieved with other ontologies (ex: GEO, foaf, SKOS, EnvO etc); through consistent annotation grounded in an ontological framework, we hope to facilitate the semantic retrieval of any record anchored to **APO**. The focus of our effort is to develop an ontology that supports the annotation of the sensor streams arriving from multiple sensor devices. However, we hope that **APO** can also be used for annotation of any record that has location information associated with it. For example, one might like to tag a dummy location value to an object where some remote sensing devices are currently capturing data.

4.1. Semantic Annotation

Data streams arriving from sensors are annotated using the concepts in **APO** ontology. The semantic annotation derives relevant semantic meta-data from the **APO** ontology for making the semantic streams understandable. In other words, the sequence of streams arriving from a sensor is transformed into sequences of OWL meta-data. Further, the annotated data instances are executed by the inference engine (defined in next section) to deduce intelligent information related to the location of the object. The annotation process also allows defining relationships between annotated data stream at the instance level. This enables to deal with heterogeneity problem often related with data originating from disparate sources, in this case sensors. As an example in Listing 2, the semantic annotation of data streams is represented in OWL DL. It illustrates the coordinates of a concept Block, *block_13*, using *Coord* concept. The instance, *block_13*, has two types of coordinates defined using two properties: *hasBottomCoordinates*, *hasTopCoordinates*. Also, it defines the proximity location of instance *block_13*.

Listing 2. An Example of Instance in APO

```
<Block rdf:ID="Block_13">
   <hasName rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
   >Block13</hasName>
   <hasBottomCoordinates>
    <Coord rdf:ID="Coord_26">
     <geo:lat rdf:datatype="http://www.w3.org/2001/XMLSchema#float"
     >37.209409</geo:lat>
     <geo:long rdf:datatype="http://www.w3.org/2001/XMLSchema#float"
     >126.975319</geo:long>
    </Coord>
   </hasBottomCoordinates>
   <hasTopCoordinates>
    <Coord rdf:ID="Coord_25">
     <geo:lat rdf:datatype="http://www.w3.org/2001/XMLSchema#float"
     >37.209860</geo:lat>
     <geo:long rdf:datatype="http://www.w3.org/2001/XMLSchema#float"
     >126.974892</geo:long>
    </Coord>
   </hasTopCoordinates>
   <isNear rdf:datatype="http://www.w3.org/2001/XMLSchema#string"
   >near library, near IT </isNear>
</Block>
```
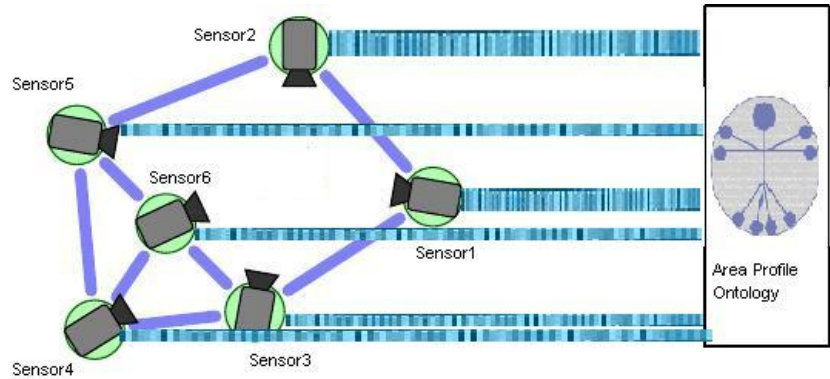

Figure 3. Sensor Network with Area Profile Ontology

Figure 3 shows the sensor data originating from multiple sensor nodes that are part of a sensor network. This data is stored in the **APO** ontology. The APO ontology annotates the received data, execute inference rules to deduce new information to get details about the location of the object. In the future work, we would like the sensor nodes to communicate with each other and re-direct information from one node to adjacent node the possible movement of the object thus distributing the processing at intermediate nodes and alleviating a part of work load from the central node containing the ontology and reasoning system.

4.2. Semantic Rules and Inference

Given the session data, arriving from sensor streams, annotated using concepts and properties from **APO** ontology, Environment Ontology, GeoNames Ontology, and Geo Ontology, the next step requires drawing inference to disambiguate the location of object

understandable by end user. Note that, sensors, which are cameras in our case, store and annotate streaming data using concepts in APO and other imported ontologies. It is the semantic rules that allow inferring the location of an object. We use JENA rule language and JENA API to define rules and process rules, respectively. The richness of the proposed rule allows us to define one rule that can process and draw inference from the streaming data. Listings 3 and 4 show the proposed rules in Jena syntax. After execution of rule, inferred instances are produced. Based on the inferred instances, we execute the SPARQL query to output further information about the object, its location, time, etc.

Listing 3. Jena rule to determine location of the object	Listing 4. Jena rule to determine additional information about the object based on information inferred from the rule in Listing 3.

``
<jena:rule rdf:datatype=
"http://www.w3.org/2001
/XMLSchema#string">
[Find: (?b rdf:type :Block)
    (?b :hasTopCoordinates ?ct)
    (?ct geo:lat ?tlat)
    (?ct geo:long ?tlong)
    (?b :hasBottomCoordinates ?cb)
    (?cb geo:lat ?blat)
    (?cb geo:long ?blong)
    (?o rdf:type :Object)
    (?o :hasPosition ?p)
    (?p geo:lat ?lat)
    (?p geo:long ?long)
    le(?lat,?tlat)
    greaterThan(?lat,?blat)
    ge (?long,?tlong)
    lessThan(?long,?blong)
  ->
    (?o :isLocatedIn ?b)
]</jena:rule>]
``
	``
	<jena:rule rdf:datatype=
	"http://www.w3.org/2001/XMLSchema#string">
	[AddNearbyPlaces:
	    (?o rdf:type :Object)
	    (?b rdf:type :Block)
	    (?o :isLocatedIn ?b)
	    (?b :isNear ?place1)
	  ->
	    (?o :isNear ?place1)
	]</jena:rule>
	``

The JENA rule titled "Find", in Listing 3, can be interpreted as follows: Given an instance *o* of concept *Object* which has latitude represented by ?lat and longitude by ?long, find the position of object instance *o* by comparing the values of ?lat and ?long with the coordinates of instance of concept *Block*. The algorithm is every simple: it treats each box as a convex quadrangle block. Each block is defined using two points: *topLeftCoordinates* and *bottomRightCoordinates*, which are properties in the **APO** ontology. Each instance of

Coordinate is x-y coordinate represented by latitude and longitude values derived from Google Map. Given a position of an *Object o* as (*a*,*b*), the algorithm compares if value *a* is less than or equal to the *topLeftCoordinates* a_1 and greater than *bottomRightCoordinates* a_2. Secondly, it compares if value *b* is greater than or equal to *topLeftCoordinates* b_1 and less than *bottomRightCoordinates* b_2. These two computations allow to determine the exact location of *Object o*. An exemplary scenario is demonstrated in Figure 4. Note that, longitude values are increasing as object moves from left to right in horizontal direction, and similarly the latitude values increase as object moves from bottom to top in vertical direction. The Jena rule titled "AddNearbyPlaces", in Listing 4, enables to find nearby locations based on the inferred location of the object from the rule named "Find".
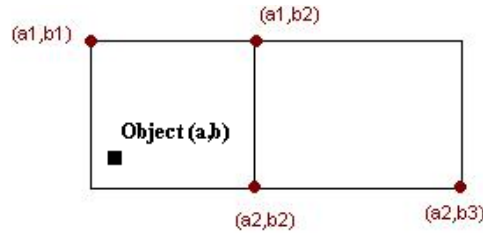

Figure 4. Exemplary Scenario

5. Case Study

We have deployed the proposed framework in university environment to evaluate the ontology and semantic rules. The web interface of the system was developed using Java, PHP, and AJAX. The APO, its instances, and semantic rules were created using Top Braid Composer. APO and semantic rules were then moved to the APACHE Tomcat Web Server which was used for hosting the web service. Various open source APIs were used to realize this work, for ex: Google Map API, Jena API, etc. In the exposition below, we describe an example scenario to verify execution of the developed ontology and Jena rules.
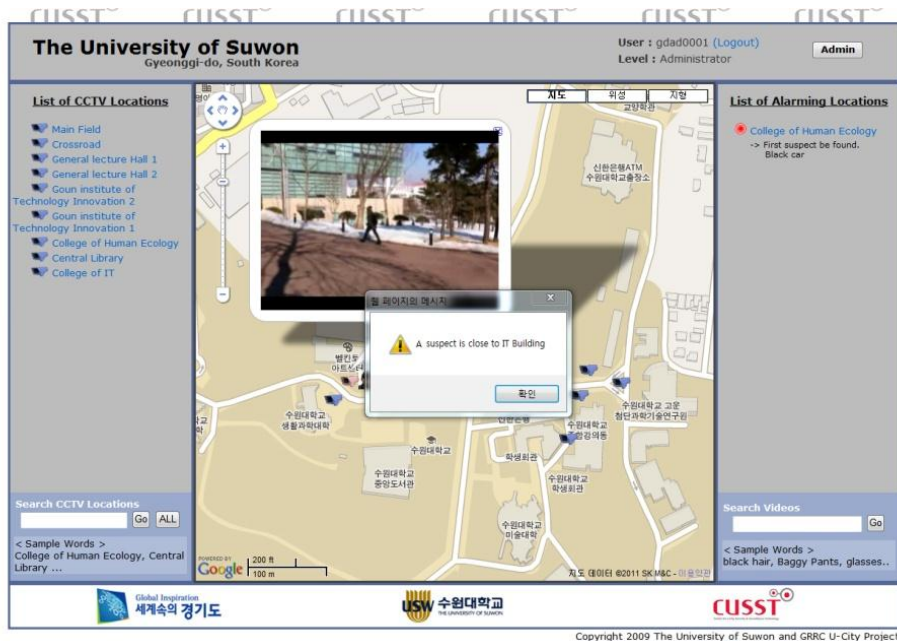

Figure 5. The Web Interface of the Proposed System

Figure 5 shows the front end web interface of the system; it includes the Google map, listing of CCTVs, event alarms, search-forms for the specific CCTVs and search-forms for some specific events. When a specific device icon is clicked, it shows the status information about the local and remote agents including location and privileges. It also shows video search result for the alarming location. By clicking a specific device item, live video streaming from the designated server can be seen in the pop-up window as shown in Figure 5. The system administrator can see the list of alarming locations. By clicking some specific alarm, previously stored or the real-time video of the site can be seen. Depending on the characteristics of the event we can see various types of result data such as video, feature data obtained directly by detection system or inferred through ontology reasoning. Furthermore, through the center pop-up search form, system administrator can elaborate the search options.

Table 1. The Coordinates Below, Latitude and Longitude Values for the Area Located in University of Suwon, are the Actual Values that we Input to the APO Ontology for Mapping the Area Spanning from Koowon Research Center to IT Building

block	hasTopCoordinates	hasBottomCoordinates	Position
B1	37.209862, 126.979409	37.209644, 126.979415	near Koowon Research Center
B2	37.209640, 126.978988	37.209409, 126.979415	near Koowon Research Center
B3	37.209860, 126.978583	37.209640, 126.978988	near restaurant
B4	37.209644, 126.978591	37.209409, 126.978993	near restaurant, near bank
B5	37.209858, 126.978143	37.209409, 126.978599	near bank
B6	37.209860, 126.977784	37.209409, 126.978232	near bank, near student hall
B7	37.209858, 126.977422	37.209409, 126.977902	near bank
B8	37.209860, 126.977108	37.209409, 126.977030	near crossroad to the side of bank side
B9	37.209860, 126.976215	37.209409, 126.976665	near crossroad towards river
B10	37.209860, 126.975842	37.209409, 126.976263	near crossroad, near library
B11	37.209860, 126.975517	37.209409, 126.975721	near Belcanto Arts Center, near library
B12	37.209860, 126.975842	37.209409, 126.976263	near Belcanto Arts Center, near library
B13	37.209860, 126.974892	37.209409, 126.978232	near Belcanto Arts Center, near library, near IT Bldg
B14	37.209860, 126.978116	37.209149, 126.978409	near bank

A span of area under University of Suwon Campus that extends from IT building to Kowoon research center was selected as a test bed for the validation of proposed system. It consists of 14 blocks; the details of each block are listed in Table 1. It lists top left coordinates and bottom right coordinates, which is in latitude and longitude, of each block.

An object is allowed to move from Koowon research center towards the IT building. During the movement of the object, the cameras along the path capture its position, and stream the required data to the back end system. The back end system consists of ontology, instances, and Jena rules. It receives the input information and infers the location of the object, for example, it is close to IT building. Using this inferred information, further information can be drawn for ex: the object is near the IT building in University of Suwon, and the IT building is near the library and so on. The position of the object being input to the ontology, in this

example, is (37.209446, 126.975464). The information is streamed to the back end server and tagged by the ontology. Further, the execution of Jena rule infers that the current position is close to IT building; this can be manually verified from data instances, Block instance B13, in table Table 1. Based on the inferred information that object is located in Block 13, the second rule executes to draw further information about block B13. Each block instance contains additional information associated with it. This additional information was entered manually and tagged using EnvO ontology, that the IT Building is actually a building next to Belcanto Arts Center.

In the future work, we would like to build a faceted semantic browser, so that users can go on searching further by just clicking on the results. This will shift the focus from using closed and relatively small information spaces towards open and comparatively larger informative spaces. Faceted browser is based on an ontology that describes important aspects of instances which are then used to define restrictions on the instances. Users can minimize the total number of displayed instances by enabling one or more restrictions thus providing to the point results.

6. Conclusions

In this paper we made the design of ontology reasoning architecture for the surveillance of the wide area consisting of an integrated framework of networked smart cameras. In the intelligent wide area surveillance system, each agent has autonomy and collaborates with each other. The data received from various sensor nodes is annotated using the Area Profile Ontology. Given the annotated data as an instance of APO, it is further exploited by Jena Rules and SPARQL query to generate inferred information. This allows building an intelligent wide area surveillance system that can detect the location of an object and alert the system administrator about possible intrusion. The wide area surveillance system is deployed as a web service, and a proof of concept is provided to test the system by segmenting a part of area, from IT building to Kowoon Research Center in University of Suwon, as blocks, defined using latitude and longitude, that are input to the APO as asserted axioms.

We see our system makes a complex decision based on ontology reasoning which is an essential task in wide area surveillance systems. Our wide area surveillance system can be applied to other services such as smart homes, elderly care, or entertainment besides crime surveillance with specialized policies and distributed user access control. Such an approach is indispensable not only for its enormous application value which is the facilitation of automatic annotation of CCTV video streaming, but also because it attempts to simulate the cognitive ability of humans to learn by combining information and interpreting it.

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