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THE ROLE OF GEOGRAPHICAL CONTEXT IN MOBILE SURVEILLANCE SYSTEMS

Summary. The role of geographical context and its machine readable representation in mobile surveillance systems has been presented in the paper. It has been shown how the appropriate semantic description of a surrounding geographical context can improve the configuration and operation of a mobile video surveillance system.

Keywords: GIS, context, ontology, semantics, surveillance systems, situational awareness

ROLA KONTEKSTOWEJ INFORMACJI GEOGRAFICZNEJ W MOBILNYCH SYSTEMACH MONITORINGU

Streszczenie. W artykule zaprezentowano rolę geograficznej informacji kontekstowej w systemach monitoringu. Przedstawiono, jak odpowiednio zamodelowany opis semantyczny informacji o otoczeniu geograficznym może wpłynąć na poprawę działania systemów monitoringu. Dokładniejsza informacja o otoczeniu pozwala na bardziej odpowiednie skonfigurowanie systemu i tym samem jego efektywniejsze działanie.

Słowa kluczowe: GIS, kontekst, ontologia, semantyka, mobilne systemy dozoru, świadomość sytuacyjna

1. Introduction

Existing intelligent surveillance systems keep evolving towards automated detection of more and more sophisticated activities of thieves/destructors. The latter tend to exploit vulnerabilities of infrastructure (e.g. dark corners, terrain with trees, etc.) or simply focus on threatening people to reach their malicious goals. Recent research shows that image based detection of human activities at the parking lot based on soft-computing may reach up to 71% of reliability (on average) depending on the particular activity being recognized and the algorithm used (e.g. Hidden Markov Model, Context Free Grammar) [1]. The best distinguishable human actions such as Walk, Loiter and Enter/exit vehicle, score about 80%. While activities like Turn, Run, Check vehicle and Fight are harder to distinguish and their performance is about 65%. On the other hand considering the main building block underlying such algorithms i.e. background subtraction algorithms – it is shown that two cameras observing at the same time the same phenomenon (e.g. person walking across a parking lot) but from separate locations may require totally different algorithms to detect and track objects in video feed with the improved efficiency [2]. Still the resulting performance of best matching algorithms (for a given camera) may be remarkably different. This is mostly because of the diversity of scene contents (its type, dynamics, etc.) that are observed from different points of view. The situation gets even more demanding when the monitoring infrastructure is mobile – i.e. it is no longer a permanent part of a local environment (whether parking lot, maritime scenario or another settings). In such case the intelligence of a system is challenged by continuous changes of surroundings that need to be captured and processed by visual sensors. Mobile and distributed surveillance systems need by definition to cope with varying spatio-temporal changes of surroundings (e.g. different parking lots, changing conditions weather / time of a day / season etc.). Mobile surveillance node may arrive at a parking where different facilities and objects are present. Limited ranges (and thus overall coverage) of cameras and lack of the meta-knowledge about the parking with its building blocks and relations between them may lead to increase in False Negatives or False Positives in results of threat detections. In the baseline settings (i.e. without improvements/enhancements) the typical mobile surveillance system visual detection and tracking capabilities depend on the exact position of the vehicle, the ranges of cameras mounted and the location of adjacent objects regarding the vehicle position and so on. Such portable system needs to cope with variety of conditions to ensure that threat assessment will be as much reliable and accurate as possible. The authors claim that the adaptation capabilities of overall mobile surveillance system would benefit from additional information about the local context (i.e. geographical one) that surrounds the mobile platforms. Similar challenges may be identified for the city CCTV (Closed-Circuit

Television) platforms equipped with the fast rotating cameras – there is an additional problem of different scenes plus the issue of periodical (fast) changes between contexts viewed by the same camera at different time points. The latter might be the important showstopper for the deployment of intelligent surveillance by city municipalities [3].

2. Rationale

It is especially valid in places where there is no CCTV monitoring to provision a flexible surveillance system for detection and recognition of threats towards deployment on mobile platforms such as trucks, trains, vessels, and oil rigs. In case of the lack of stationary monitoring systems, mobile assets provide the possibility of monitoring the area around them. The example project dealing with such issues is the FP7 ARENA[1] which main goal is to use already available sensors such as acoustic, thermal, seismic etc., instead of developing new sensors. It also acknowledges the necessity of having sensor-independent threat recognition. A collection of connected nodes forms an ARENA network with enhanced capabilities if compared to a single unit (which is consistent with concept of net-centric architecture [6][7]). Each node gathers data from available sensors and conducts analysis using available data-fusion modules according to JDL Data Fusion model [9] i.e. Object Assessment, Situation Assessment and Threat Refinement. The meta-information about the facilities visited by mobile surveillance nodes and local conditions should be properly structured with clearly defined concepts, but at the same time should be flexible and adjustable to particular space and time constraints. By combing threat detection mechanisms and context information (information about the background, infrastructure and objects around, geo coordinates and so on) – comprehensive view can be obtained in the target system. Such kind of context information can be provided in the form of semantically enriched data which enables both modelling of parking based on common concepts and its adjustment to specific features of a given parking. Therefore, ontology-based prototype module called Context Manager has been developed and presented in this paper.

3. Related work

General approach to defining parking ontology for Context Manager can benefit from the approach presented in previous publications. In one example public space patterns dimen-

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[1] ARENA project website: www.informationsystems.foi.se/~arena-fp7

sions are presented and grouped into five categories, i.e. City Objects (all objects such as buildings, areas etc.), and categories describing properties of particular objects and the place as a whole, i.e. Function, Material, Morphology, Mobility [4]. The example of a public square according to the five dimensions can be a good starting point to describe the parking lot. City objects/structures would by analogy become parking's objects/items and would be described by ontology classes. Remaining dimensions should be represented in parking ontology as properties of the objects, because they describe features or characteristics of the latter. Some classes (objects in the parking ontology) could be derived from existing ontology describing outdoor-indoor spaces and characteristics of the given area [8]. Existing ontologies presented above describe mainly a particular place or relations between (e.g. objects) locations. Although they do not describe a parking lot per se, they can be adapted or partially reused. That is why the target ontology should be a combination of reused, adapted concepts from above mentioned ontologies and newly added concepts that extend existing approaches. Moreover, in the further development stages the usage and integration of ontology for Context Manager with upper ontologies (top-level ontologies) like OpenCyc[2] and SUMO[3] will be considered. The Mid Level Ontology level of SUMO includes such domain ontologies as Geography or Transportation, thus in the further steps, integration of their concepts and usage of them for the purpose of ontology for Context Manager will be considered. All in all ontology will be used for providing information about the objects in the surrounding of protected vehicle and about particular objects in the defined proximity especially. Moreover, ontology should indicate objects visible to particular camera, considering its capabilities. These properties are described in the section dedicated to Context Manager.

4. Context Manager

ARENA system, as an example of intelligent, mobile surveillance – follows an assessment chain, where different modules sequentially create higher level information from lower level information (as presented in Fig. 2). Context Manager providing information about the surrounding environment is designed to be a part of this assessment chain and supports in this way threat assessment realized based on the appropriate algorithms. Central to the idea of such an assessment chain is that data flows from one module to another (arrows 1 and 2), and all functionality that transforms this information is in the modules. As ARENA system should function in various situations thus information such as "where a restaurant is" or "whether it is raining" should not be hard-coded. As different modules may use knowledge about the res-

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[2] OpenCyc ontology website: http://www.cyc.com/platform/opencyc
[3] SUMO ontology website: http://www.ontologyportal.org/

taurant or the weather, they should have a common understanding of what a restaurant is. Then, a module can use this information in their assessment, but also to control own configuration parameters. The role of ontology-based Context Manager in this assessment chain is to provide (arrows 3) – (a) the description of the objects and relations between them (description of the local world) and (b) the context, in which the system operates (local description e.g., the coordinates of objects). Next, an internal representation of this information will be realized in particular module, which uses it in its algorithms (arrows 4).

4.1. Context Manager main functions

Threat detection algorithms will benefit from information about the context (local environment) increasing reliability and accurateness of threat assessment. The concept of Context Manager is depicted in the figure below (Fig.1).
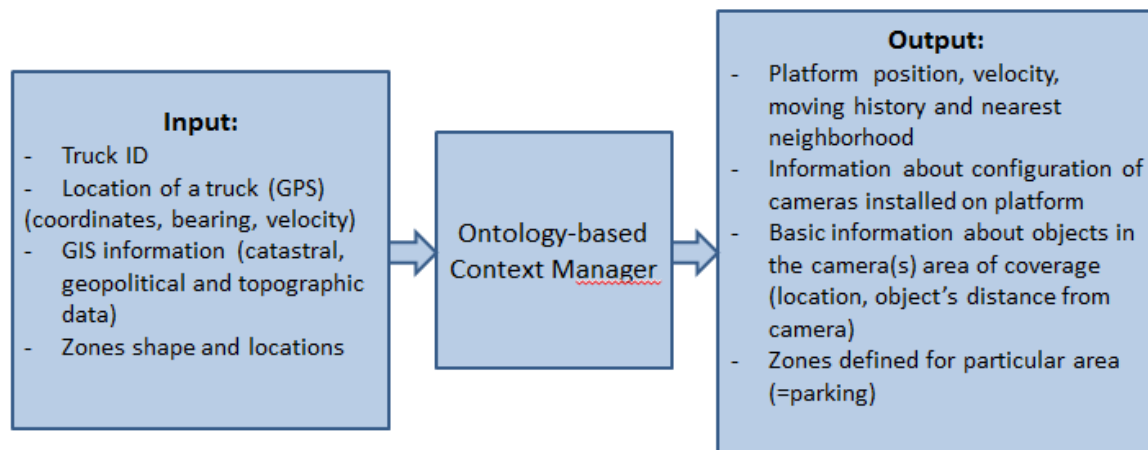

Fig. 1. Input and output of the Context Module
Rys. 1. Informacje wejściowe i wyjściowe dla narzędzia Context Manager

The GIS information is automatically derived from the Geoportal[4]. It is the Polish governmental initiative establishing the infrastructure of nodes of National Spatial Data Infrastructure and providing geospatial services (via Internet) – such as searching of objects using metadata, browsing various maps with configurable layers and data analysis. Analogical solutions are available in different countries as separate (independent from each other) platforms, but include the same standardized information/data. There is a number of web services compliant with OGC (Open Geospatial Consortium) available via Geoportal. providing additional information such as for e.g. data on building categories in terms of its primary usage, number of floors, and in some cases more detailed description of building. Considering parking areas – Geoportal services can provide mainly information about the buildings (with more or less

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[4] Geoportal website: http://www.geoportal.gov.pl

detailed description) but do not offer pre-provisioned information on parking zones (the issue of data quality).
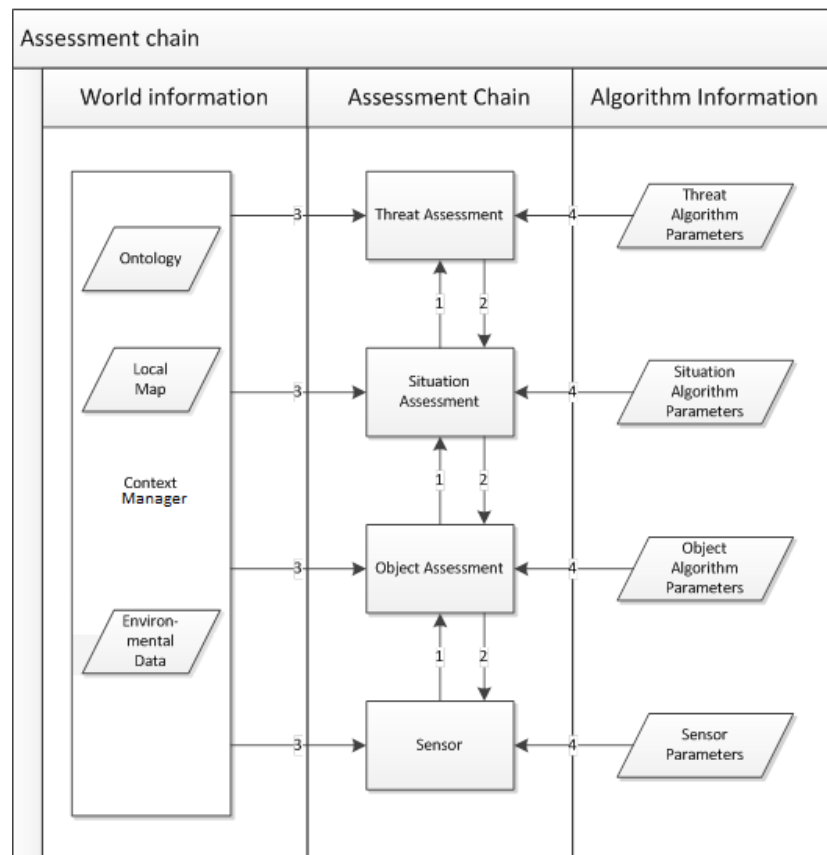

Fig. 2. ARENA assessment chain
Rys. 2. Proces oceny zagrożeń systemu ARENA

Therefore, modelling knowledge about given parking (i.e. layout) should be supported by human operator. Output from Geoportal is mapped into ontology model and stored in repository as a particular instance of a given parking and given vehicle with ARENA system. Based on ontology reasoning capabilities and features of Context Manager itself – value added information is produced. The above mentioned information is available to the ARENA system components and its operator (e.g. through the Web services paradigm).

4.2. Ontology for Context Manager

The target ontology is meant to support situational awareness objectives and shall address in the first place purely static objects (buildings, trees etc.). Although the capability of introducing quasi-dynamic elements (e.g. human, cars etc.) is foreseen, such ontology will not address highly dynamical objects – like movement of objects around the scene. Specific parking instances are composed of exact type and number of elements e.g. buildings and trees (static elements), vehicles and people (quasi-dynamic element – at the given moment) plus

relationships and distances between the objects. The target ontology has been developed following [5] "seven steps methodology". The main classes are as follows:

- Parking – the overall description of a particular parking lot with all objects and properties,
- General information about the parking- (e.g. Time, Weather, Historic data)
- Objects – all objects at the parking lot:
  - − Dynamic objects – Person, Vehicle (e.g. Car, Bus, Lorry, Truck)
  - − Static objects – Building, Infrastructure (e.g. Car parking zone, Entrance, Trees),
- Vehicle with ARENA – Vehicle with ARENA system and cameras installed,
- Camera – overall set of all cameras used by ARENA system, both those installed on truck and those available at the parking lot.

Objects as well as parking itself have features assigned like e.g. properties describing GPS coordinates "x" and "y". All the classes with properties compose the network of relationships describing parking area.

4.3. Reasoning capability

The Context Manager enables custom definition of rules, which are in turn applicable in certain cases and do not interfere with the basic semantic relationships. In this way – additional, valuable relationships may be included providing new knowledge, which is not directly included in the ontology. Rules are defined following the Semantic Web Rule Language[5] (SWRL), and the syntax of the SWRL rule is "Body of the rule (if condition) → Header of the rule (then action)":

$$condition\ (?x) \wedge condition\ (?x,\ ?y) \wedge condition\ (?y,\ ?z) \rightarrow rule\ (?x,?z) \qquad (1)$$

Using SWRL rules we can divide all objects in the particular parking into the "close objects" and "distant" ones (see formulas below). Objects are defined as close or distant through assessment of the distance between the vehicle and given object described by property "Distant parameter". This parameter is defined by the user (HMI operator) and it means the threshold determining when the object is categorized as "close object", and when as "distant object". The rule describing close objects is defined as:

Vehicle with ARENA System (?x) ∧ Object (?y) ∧ Object has distance (?y,?z) ∧ Distance parameter (?x,?a) ∧ swrlb: less Than or Equal(?z,?a) → Vehicle has close object (?x,?y). (2)

The rule describing distant objects is analogical. One of the output information provided by Context Manager is selection of visible and close objects for the vehicle. Based on the above mentioned rules – among the close objects – those which are in the range of given

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[5] Semantic Web Rule Language website: http://www.w3.org/Submission/SWRL/

camera are picked up. All cameras have its own range, which can be described as angle (minimal and maximal) – referring to the vehicle axis. Objects are located at particular angle according to the vehicle axis. Comparing those two values – objects which are close and are in the range of camera visibility are defined, using the following rule (3):

Vehicle with ARENA System (?x) ∧ Object (?y) ∧ Camera (?z) ∧ Vehicle has camera (?x, ?z) ∧ Vehicle has close object (?x,?y) ∧ Camera angle max (?z,?a) ∧ Camera angle min (?z,?b) ∧ Object has angle (?y,?c) ∧ swrlb: less Than or Equal(?c,?a) ∧ swrlb: greater Than(?c,?b) → Vehicle has visible object (?x,?y) (3)

Basing on the abovementioned rules – an output information about objects in the camera(s) area of coverage (location, object's distance from camera) is specified. An exemplary Context Manager usage is presented in the next section.

5. Case study

An example of steps' sequence to be taken to obtain required information within ARENA service bus is presented in this section. It includes activities realized offline, i.e. without a connection to the Internet, in such case before the truck departs from its initial location and online activities. The latter being performed after arriving at the particular parking lot. The interactions between the ARENA operator and Context Manager is depicted in the Fig. 3 in form of a flow diagram. The following steps would be realized by the operator: (1) Before the travel – ARENA operator provides to the system information about the parking lots, which are planned to be visited during the travel (2) Context Manager obtains the information about the given parking lots from the GIS-based platform (e.g. Geoportal) and stores it in the Ontology (3) ARENA operator completes the missing meta-data about the parking lots using dedicated GUI (i.e. modifies ontology with information not available on GIS-based platform) (4) As a result of above steps an instances of particular parking lots (requested in step 1) are created and stored in ARENA repository offline (e.g. if there is no internet on a parking lot the semantic data can be retrieved) (5) When the vehicle with ARENA system arrives at the parking lot (with the GPS sensor on board) the residing software agent triggers "arrived on the parking" message to initiate Context Module service (6) Context Manager combines information from ontology with the actual vehicle's GPS position (read from sensor) (7) As an output of Context Manager – user is provided with the following information:

a) the list of all objects at the given parking,

b) distances between the vehicle and those objects,

c) list of selected objects defined as "close" and "distant",

d) list of objects (and their distances) in the field of view of particular cameras mounted on the vehicle.
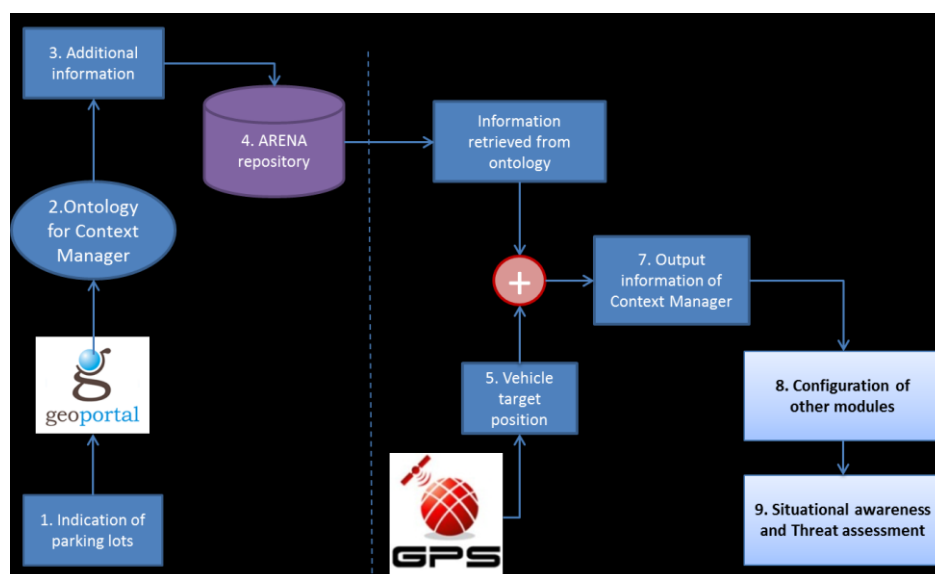

Fig. 3.   Context Manager case study
Rys. 3.   Przykład użycia narzędzia Context Manager

The above mentioned information could be used by other ARENA modules to configure its processing algorithms and properly perform mapping between 2D (camera pixels) and 3D coordinates (x, y, z geographical coordinates). Based on such outputs – situation assessment and threat detection can be tuned to operate more efficiently.

6. Conclusions

In this paper the approach for semantic description of local environment supporting surveillance system for threat monitoring and detection has been proposed. The way context module is designed makes it a universal solution for improving performance of mobile surveillance, with great level of flexibility due to its reference to semantic models of the environment. Semantic modelling relying on ontological concepts is used to provide additional information about the local environment enhancing threat assessment capabilities of the ARENA surveillance system. To make information the most reliable and accurate – governmental level GIS platform has been incorporated. Moreover, the solution takes advantage of reasoning and rule-based capabilities of ontologies. Context Manager by design becomes part of threat assessment chain contributing to the effectiveness of other modules in the system. The underlying ontology for Context Manager is inspired by concepts derived from existing approaches and also includes new developed ones – considering needs of mobile surveillance

systems. As a result the designed module is capable of increasing the level of situation aware-
ness and effectiveness of threat detection as well as decreasing the level of false warnings.

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Omówienie

W artykule przedstawiono podejście do semantycznego opisu geograficznej informacji kontekstowej dla systemów monitoringu. W tym celu zaprojektowano moduł o nazwie Context Manager dostarczający informację o otoczeniu i pozwalający na poprawę efektywności systemów monitoringu. Rozwiązanie koncentruje się na monitoringu parkingów dla samochodów ciężarowych przy użyciu systemu monitorującego wytworzonego w projekcie EU FP7 ARENA. Context Manager został zaprojektowany, by być uniwersalnym rozwiązaniem dla tego typu systemów; charakteryzuje się dużym poziomem elastyczności w związku z wykorzystaniem semantycznego modelu opisu środowiska. Modelowanie semantyczne oparte na ontologii umożliwia dostarczenie dodatkowej informacji o najbliższym otoczeniu (w tym przypadku o parkingu) i tym samym rozszerza możliwości oceny zagrożeń realizowane przez system monitoringu ARENA. Aby informacja była wiarygodna i dokładna, wykorzystano rządową platformę systemów informacji geograficznej Geoportal. Ponadto, rozwiązanie przedstawione w artykule czerpie z możliwości wnioskowania opartych na regułach zdefiniowanych w ontologii. Opisywane rozwiązanie jest częścią nadrzędnego procesu oceny zagrożeń zdefiniowanego w ramach systemu monitoringu. Dostarczając informację kontekstową do innych modułów systemu, przyczynia się on do zwiększenia efektywności ich działania, a co za tym idzie – efektywności wykrywania zagrożeń. Ontologia, na której opiera się Context Manager, zawiera zarówno pojęcia zainspirowane innymi, istniejącymi ontologiami, jak i nowe pojęcia zdefiniowane na potrzeby przedstawionego rozwiązania. W rezultacie funkcjonalność modułu Context Manager polegająca na dostarczeniu informacji kontekstowej podnosi poziom oceny sytuacji i efektywności wykrywania zagrożeń oraz obniża poziom fałszywych alarmów. W artykule przedstawiono również przykład, jak krok po kroku wykorzystywane jest proponowane rozwiązanie, w jaki sposób pozyskuje potrzebne informacje, jak je przetwarza, a następnie dostarcza do innych modułów systemu monitoringu.

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