

# An Ubiquitous Spatial Knowledge Framework for Car Driver Assistance

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**Abstract.** Advanced assistance systems for car driver's require a wide knowledge about the environment of the car. The SCORE architecture designs an ontology based approach to a car's high dynamic spatial context. From tracking systems, locally fixed federation collects data and offers it to car mounted reasoning systems. Those reasoning systems deduce spatial relationships between the car and other objects. The Implementation of SCORE in a fixed base driving simulator proved well and performant enough for such systems.

## 1 Driver Assistance

Advanced Driver Assistance Systems (ADAS) aim at supporting drivers with their driving task.

Mandatory basis for the analysis of traffic behavior is a rich sensing system. We assume that stationary systems along the road will be available to gather tracking data from passing cars and integrate it into local traffic models. For the area of ubiquitous computing, the challenges of a highly dynamic environment in conjunction with dynamic short range network connections are addressed. It will then be the responsibility of the individual cars to gather and interpret accumulated traffic data from such stationary providers along the road. ADAS systems then need to infer critical events from such traffic data and provide appropriate feedback to the driver.

Existing work, as the INVENT project [1] deal with stationary sensors as well as mobile sensors mounted to cars. The system uses a central unit for computation and deduction of relevant information.

We report on the *Spatial Context Ontology Reasoning Environment (SCORE)*. The system consists of separate autonomous components which federate and reason about contextual data that is related to spatial properties [2].

## 2 Tracking, Federation, Reasoning and Ad-Hoc Networking

Aiming at the problems of ubiquitous information management [3] and high dynamics of spatial data in associated traffic, SCORE supports ADAS applications on two separate layers that set up on the observed reality. In the *federation* layer, all data of a certain tracked area is federated in a spatial context model. In the next higher layer, ontology-based *reasoning* components can access the model. This approach supports the combination of spatial context models for efficiently processing low-level spatial data with ontological context representations for information deduction on top layer.

The two layers clearly separate highly dynamic assertional knowledge in traditional coordinate-based models and terminological information of real world concepts within interpretable ontology spaces [4].

All components of our architecture act as autonomous services, either in the environment as federation services or in the car as reasoning services.

SCORE profits one hand from the flexibility regarding spatial scope, an extensible spatial detail. On the other hand, SCORE profits from scalability with respect to dynamics of context acquisition.

*Tracking* To provide ubiquitous support along the road, the street network is separated into road sections, with each of them containing a number of vehicles at a certain point in time (see Figure 1). For each road section, a logically related tracking system observes the explicit spatial context states of all vehicles within that area. These area management components serve as *spatial context providers*.

*Federation* Regarding the volume of communication traffic, several stationary computers – each logically related to one road section – run federation components that collect spatial data within the respective areas. Software components, such as trackers, act as *spatial context providers*.

The federation warehouse organizes an efficient volatile data structure to continuously index and cache those data items in order to optimize query response times and to provide quick information retrieval.

*Reasoning* In each car a reasoning component dynamically connects to one or more federation servers in range to access spatial data necessary for interpreting the vehicle’s situational information.

Using a ontological rule-driven approach, the abstract query is handed to the reasoner subsystem, where it is processed by the description logic-based reasoner. T-box information contained in ontologies describe terminological entity relationships that are used by the reasoning component to understand how to interpret assertional spatial data collected in the entities’ environment [4].

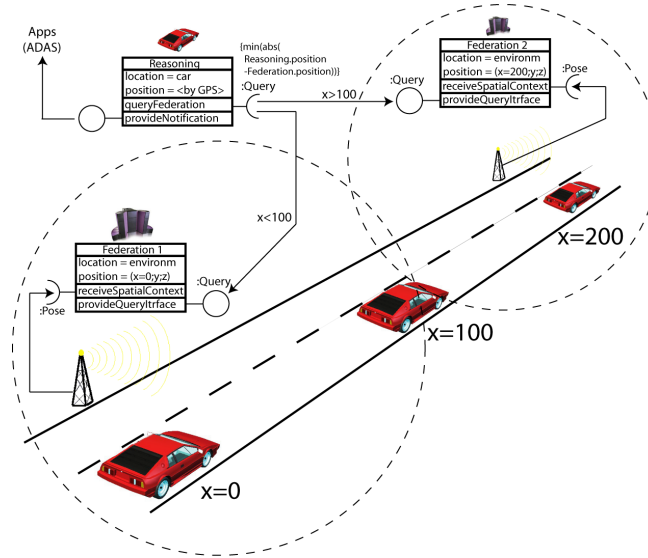
The terminological interpretation process is based on ontologies known from the *Semantic Web*. Ontologies are well-suited for logic-based reasoning, especially when description logic ([5]) is applied. This is due to the similarity between the language constructs of description logics and those of ontologies. Additional information can be deduced automatically from pre-defined ontologies

with properties such as equality, symmetry, transitivity, inversion, disjointness and others.

Ontological knowledge bases are not well-suited for maintaining a detailed history of highly dynamic assertional data due to the continuous growth of information resulting in inefficient data management. In spite of that and to cope with the increasing amount of data without giving up the benefits of an ontological representation of concept knowledge in application domains dynamic spatial context data is managed on the federation tier and only requested for interpreting situational information. The reasoning process is rule-based, since it addresses the objectivity of spatial relations, e.g. traffic rules, that in its own sense disregard a scope of varying interpretation [4].

*Ad-hoc Networking* The interconnections between the federation and the reasoning components require dynamic bindings, when a car leaves one federated tracked sector and moves to another. For this kind of ubiquitous networking we used the DWARF [6] architecture to describe and interconnect all components. The DWARF middleware supervises the components' localization attributes and interconnects corresponding services, therefore enabling data flow.

Figure 1 shows in a sketch how interconnection is executed while a car drives along a X-axis.



**Fig. 1.** Sketch of SCORE and dynamic reconnection of car internal reasoning service between two federation services as car moves along X-axis

### 3 Results and Conclusion

A generated test application registered for the *time to collision (TTC)* with various additional cars in a driving simulator. Positional data of foreign cars was disseminated to the federation layer running on another computer, thus defining some stationary spatial context providers.

The own car's position in the virtual world had been computed by a driving dynamics, substituting a GPS tracker.

The federation service gives a response time below 10 *ms* for up to five spatial context providers with up to 250 entities per provider. Compared to an average amount of cars on an road interval, these response times are clearly acceptable. The reasoning service responds to n-to-n queries on 50 entities, which are much on fast travelled roads like highways, in around 10 *ms*.

Our approach shows that a highly dynamic traffic environment can be split into separate independent areas of stationary data acquisition, while bypassing cars access this data and conclude relevant information. Dynamic short range network connections can get established to guarantee access to actual important data.

Identifying ADAS system's ontological structure will have a certain impact for ubiquitous computing technologies in the sector of intelligent ground transportation systems. The concept of Ubiquitous Augmented Reality [7] can focus new challenges in the head-up display of cars, enabling distraction reduced driver assistance from an egocentric AR point of view.

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