Modelling of an Ontology for a Communication Platform

More safety at football events by improving the communication between stakeholders

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***Abstract*— Safety and security in football events has been a heavily debated topic in the media for years. Especially communication processes between the police authorities, private security services, town councils, supporters and other spectators have often been neglected. Communication processes in the context of football matches can encounter technical limitations. Traditional communication channels are often characterized by a one-way communication structure, delayed forwarding of information or limited quality (e.g., stadium announcements). To address these problems, a new communication platform is explored. The semantic basis for this platform is formed by an ontology. The usage and benefits of the ontology are manifold: 1) The design process created a better understanding among the stakeholders. 2) The actors, roles and their relations are used for information filtering and access restrictions. 3) The relations of the ontology are used for structuring the information and navigating through it. 4) Heterogeneous information is fused into the platform from existing systems by annotating the data with concepts from the ontology. In this paper, the design of the ontology based on research of already existing ontologies is presented.**

Keywords-ontology design; communication platform; Web Ontology Language (OWL).

I. INTRODUCTION

In the football season 2013/2014, about 13 million people attended the matches of the German Bundesliga (first league) [1]. The games of the second, third and lower leagues were attended by several additional millions of spectators. On their journey to the stadium and back home, they travel through crowded urban regions and depend on using the local infrastructures.

In order to implement such big football events, a cooperation of police forces, local town councils, football clubs and private security services is necessary to provide a safe and secure environment. Together with spectators and supporter groups, these stakeholders strive for peaceful and positive sport events. By doing this, different perspectives on freedom, safety and security must be balanced. Following these presuppositions, the following research question emerges: How can the safety and security creation in the context of football games be optimized via communication?

The research project SiKomFan (Mehr Sicherheit im Fußball – Verbessern der Kommunikationsstrukturen und Optimieren des Fandialogs) [2], funded by the German Ministry of Education and Research (BMBF), therefore researches possible improvements of communication strategies, including technical solutions to support them. By using a broad perspective that involves 25 football locations in Germany's three professional football leagues the most relevant stakeholders are examined in order to contribute to a successful dialogue with supporters. So far, the inquiry revealed that there are different communication strategies in different locations leading to different results.

Examining the topic of communication processes in the context of football games can be done from different specialist perspectives and by using different methods. SiKomFan combines four disciplines, namely sociology, risk- and security management, law and computer science as well as their specific methods.

Communication processes in the context of football matches can encounter technical limitations. Traditional communication channels are often characterized by a one-way communication structure, delayed forwarding of information or limited quality (e.g., stadium announcements). New media, such as Twitter, provide opportunities for flexible, timely and rapid exchange of information, but have the disadvantages of information overflow [3] and uncertainty (the content is not reliable). To address these problems, a new communication platform is explored, implemented and tested in a demonstration scenario. All participating parties (e.g., police, private security services, supporters, etc.) can communicate with each other by means of the most appropriate way at football events. Using an app on a smartphone, football supporters and other stakeholders can access this platform in order to obtain relevant event information or to provide new information. The overall architecture of the SiKomFan system is described in [2].

The semantic base of this communication platform is formed by an ontology, which is presented in this paper.

The paper is structured as follows. The Section II starts with related work, followed by Section III describing the used methodology for designing the ontology. The following sections IV to VIII are structured along the lines of the methodology: Section IV describes the purpose of the ontology. In Sections V to VII the building of the ontology is shown. Section VIII is about evaluating the ontology. The paper ends with an outlook on future work and a conclusion in Section IX.

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II. Related Work

The research presented in this paper was influenced and partly based on several existing ontologies. Those ontologies can be clustered by forming the following groups: Generic base ontologies, geospatial ontologies, time related ontologies, event ontologies (in the meaning "something happening"), event ontologies (like concerts or sport events) and sport ontologies, especially for the topic football/soccer.

The "DOLCE+DnS Ultralite Ontology" (DUL) has been developed as a common base for ontologies in the field of context modelling, e.g., it provides concepts like persons, organizations and roles along with relations among them. Another widely used base ontology regarding the modelling of persons and their relations is the "Friend of a Friend" (FOAF) ontology. This ontology only covers a smaller spectrum of the needed concepts.

The *GeoNames ontology* does not only define the structure for modelling locations and relations between them, it also provides a large amount of actual data. The GeoNames ontology itself uses the "Basic Geo Vocabulary" for defining the structures.

The Basic Geo Vocabulary [8] is a vocabulary for representing latitude, longitude and altitude information in the WGS84 geodetic reference datum, defined by the W3C Semantic Web Interest Group.

Time modelling aspects are addressed in the "Ontology of Time for the Semantic Web" (OWL-TIME). It provides a vocabulary for durations, time intervals and instants of time.

The "Event-Model-F" is based on the DUL ontology and added support for representing time and space, objects, persons and relationships between events. In contrast to other event ontologies, it allows modelling of causality relationships and representing different interpretations of the same event.

Further relations are shown in Section VI, where the integration and reuse of existing ontologies is discussed.

III. Methodology

For the design process of the SiKomFan ontology, the methodology suggested by Uschold and King [9] was used, which is a general approach for ontology design with a focus on the informal aspects.

The methodology foresees several steps:

1) Identify the purpose of the ontology: It is important to be clear about why the ontology is being built, what its intended uses are. Furthermore, the stakeholders and their environment must be defined.

2) Building the ontology, splits up into several sub-steps:

a) Ontology Capture: Identification of the key concepts and relationships in the domain of interest. Production of precise unambiguous text definitions for concepts and relationships. Identification of terms to refer to such concepts and relationships. Agreeing on all of the above.

b) Ontology Coding: Explicit representation of the conceptualization captured in a formal language.

c) Integrating Existing Ontologies: Use existing ontologies, which are already in use and widely accepted in the research community.

3) Evaluation: make a technical judgment of the ontologies, their associated software environments, and documentation with respect to the frame of reference. The frame of reference may be the requirements specification, competency questions and/or the real world

4) Documentation: important for updating and re-using important assumptions for understanding (Meta models). Inadequate documentation is one of the main barriers for effective use of ontologies.

The following sections are structured by these steps of the methodology. Step 2b and 2c are swapped since it showed to make more sense to first research existing ontologies for reuse before starting to code.

IV. Purpose of the SiKomFan ontology

The application of the ontology in the communication platform is threefold:

1. It will store a model of the current situation during a football event. Information coming into the system will be annotated with elements from the ontology to create a common meaning. Having such a common meaning is especially helpful for data integration of already existing systems.
2. All actors, which are involved into an event, are modelled including their relations, tasks and roles.
3. The structure of the ontology (relations between concepts) is used to navigate the system and the mobile app.

V. Building the ontology – Ontology Capture

To identify the ontological classes and relations a workshop was held, which brought together the different stakeholders of the project with their different research and domain knowledge backgrounds. This group of about ten people was a good size for effective discussion and the interdisciplinary meeting brought many new insights into the domain.

As a side effect also caused by the formalized nature of an ontology, the understanding of the involved actors and their relations was hugely increased between the project partners during the necessary discussion. In addition, the requirement to be specific about the formalization brought up topics, which were so far not fully understood. These open issues created new research items and therefore influenced the research of the other work packages.

A. Stakeholders

Figure 1. displays the top-level of all stakeholders, which participate directly or indirectly in the event *football match* and therefore have specific information and communication needs. Each of these top-level stakeholders contains a tree of up to ten specific groups, which are not displayed to keep the figure small.

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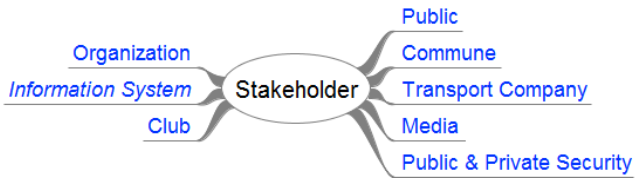

Figure 1. Top-level stakeholders of the event "football match"

A football *organization* is, e.g., an association like in Germany the Deutscher Fußball-Bund e.V. (DFB). They can send representatives to high-risk matches to check the safety precautions.

The stakeholder *Information System* is a special case since these are not human beings. Examples are existing systems for transport, police communication, information sites of clubs, etc. These systems provide information for the platform.

The *club* has several aspects: representatives of the guest and host club, the owner and manager of the stadium, the organizer, etc. The *public* is divided in visitors of the match and uninvolved people like abutters and affected travelers (train, car).

The *Transport Companies* are responsible for getting from and to the stadium, for example by train, bus or tram. Visitors are interested in delays and additional transport options for the match.

The *Media* are newspapers, radio, television, and Internet sites.

The *Public and Private Security* are emergency services like police, fire department, rescue services and private security companies. In Germany, there is the special situation that for one match there is police from different states involved and additionally also the *Bundespolizei* (federal police), which takes care about the railroad safety.

These stakeholders are the *actors* in the technical use-cases described in the following section.

B. Use-Case Scenarios

For inquiring communication processes between the different actors, a football event is split up into four scenarios.

The first one deals with the arrival and departure of spectators on the railway system of Deutsche Bahn AG (DB). In this sub-scenario, the (communicative) co-action of the federal police, the carriers and its services as well as the measures by football clubs are examined.

The second covers the travelling of spectators from a train station to the stadium. There are many different models in existence, for example the organized supporter march, the use of shuttle busses and the individual arrival by foot or with public transportation. The analysis in this context was focused on actions by state police and town councils but also accompanying measures by football clubs and public transport services.

The next scenario focuses on the interface of public area and the responsibility of the match-host: the entry controls. There, co-operation modalities between state police, town council and the club security commissioner as well as the private security service in the stadium are being included in the inquiry.

The fourth and last scenario examines the spectators' visit in the stadium area. Here, actions by private security services in the stadium, the cooperation of different safety and security actors, for example in the safety and security operations headquarter, and the integration of the stadium announcer into communication concepts are inquired.

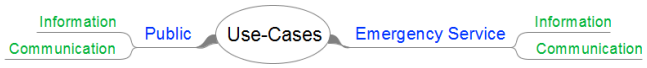

Figure 2. Top level Technical Use-Cases

From these scenarios, technical use-cases were created. Figure 2. depicts the top-level classification into the needs of the public and emergency services. Both of them are further divided into information (one-way) and communication (bi-directional). The complete mind map contains over 40 use-cases, therefore only some examples will be given:

- A father has lost his child in the crowded stadium and wonders whom to contact for support.
- A security officer wants to give an information to people in a certain area, e.g., "this entrance is overcrowded, please use entrance B".
- A supporter wants to know which supporter items are allowed to bring into the stadium.

VI. BUILDING THE ONTOLOGY – INTEGRATING EXISTING ONTOLOGIES

The evaluated ontologies (see Table I and also Section II) can be divided into the following categories:

- base ontologies (# 1 and 2)
- spatial ontologies (# 3 and 4)
- time related ontologies (# 5, 6, and 7)
- events (# 8 and 9), in the meaning of sport event or music event
- events (# 10 and 11), in the meaning that something happens and causes a reaction
- Sport and football (# 12, 13 and 14)

Additionally, ontologies from the domains of early warning and disaster would have been of interest but no suitable ontologies were found.

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Based on our study we decided to pick "DOLCE+DnS Ultralite Ontology" (DUL) as the base ontology because it already covers the basic elements like people, organizations, roles, events and all relations between them.

VII. BUILDING THE ONTOLOGY – ONTOLOGY CODING

Building on DUL all actors (supporters, transportation companies, clubs, unions, security organizations, police, press, etc.) and their roles were modelled. After that, time (for events and phases) and space (e.g., location of stadium) was added. Deciding on DUL set also the decision to use OWL (Web Ontology Language)/XML [10] as the coding language.

The decision to use automatic reasoning within the project poses an extra challenge for the combination of ontologies: The simple combination of different ontologies by defining equivalence relations between classes will lead to an inconsistent world model in most cases if not done carefully. This resulted in the definition of some criteria for the evaluation of other additional ontologies: The ontology should add substantial value to the base. It has to be combinable with DUL, i.e., it should have an OWL representation and defining classes from both ontologies as equivalent should not lead to inconsistencies. Furthermore, the integration of an ontology should only result in a minimal set of required dependencies since a larger number of involved ontologies will increment the potential of inconsistencies. In some cases, a consistent re-modelling of aspects from an existing ontology should be preferred over integrating the original ontology.

A. *Integration of Space and Time*

The "Geo-Pos" ontology [8] which was chosen for the spatial aspects is originally modelled as RDFS/XML and had to be transferred to OWL/XML.

The SiKomFan Ontology introduces the new class <#Position> (Fig. 3) as junction between the three ontologies DUL, Geo-Pos and SiKomFan. It is defined as subclass of <#SpaceRegion> from DUL since it is a spatial restriction in terms of the DUL terminology. The location attributes defined in Geo-Pos are added by declaring the Position class as EquivalentClass to <#Point> from Geo-Pos. With the help of this class, it is now possible to assign some absolute coordinates to entities.

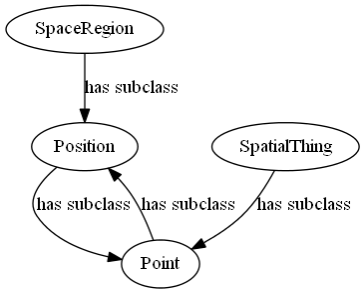

Figure 3. OWLClass Position

Some use cases of SiKomFan require the modelling of trajectories for persons and objects. This introduces the need for some time related attributes. To achieve this, the new class <#TemporalPosition> (Fig. 4) is defined that links <#Position> and <#TimeInterval>. It is defined by the restriction to have exactly one Position as location and to be observable at exactly one TimeInterval. The order of TemporalPositions within a trajectory is modelled with predecessor and successor relations between them.

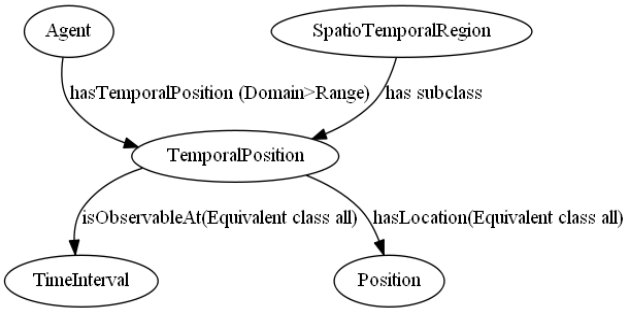

Figure 4. OWLClass TemporalPosition

B. *Extensions*

For the modelling of events (in the meaning of sport events), the decision was made to use a simple model based on the OWLClasses available in the DUL instead of importing a completely event-specific ontology. As an example, the football league is modeled as a new OWLClass <#League>, which is a subclass of <#Competition> which itself is a subclass of <#Event> from DUL. Other terms like arrival, match or season have been modeled in a similar way.

Persons acting as senders and receivers in the context of communication are important for the SiKomFan project. Based on research carried out by another work package in the project, some selected persons were modeled as part of the ontology. Therefore, the OWLClass <#SocialPerson> from DUL has been subdivided into several subhierarchies. The <#EmergencyServicesPerson> is the top-level class for all persons from emergency services, which are modelled in detail. In a similar way, the <#EventVisitor> is the top of another hierarchy for the persons visiting the event.

Besides the persons, IT systems can also be the origin of communication and have to be modeled also. In this case, <#System> is defined as the common base class for systems like Social Media, information pages, press portals and traffic information services. That class is defined as subclass of <#PhysicalAgent> from DUL.

The last major extension to the DUL is the subhierarchy beneath <#Organization> from DUL. This subhierarchy contains all the organizational aspects of emergency services as well as fan groups, companies (e.g., railway operators) and football clubs.

Table II shows some simple metrics of the three ontologies DUL, Geo-Pos and SiKomFan in comparison.

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VIII. EVALUATION OF THE ONTOLOGY IN THE COMMUNICATION PLATFORM

The system architecture of the communication platform has been derived from the use-case scenarios as well. Components of the sequence diagrams describing the technical use-cases have been grouped according to their functionalities: user interface (Apps and Desktop Applications), services (e.g., map or positioning services), data (e.g., information about the football event) and data sources (e.g., stakeholders or social media).

The main part of the system is the so-called Situation; it contains the connected information about the current football event. It can be visualized on a map showing various aspects for different actors and roles. For example, a visitor can see the location and availability of the transfer shuttle to the train station. The Situation is saved in an ontology store using OpenLink Virtuoso [7] facilitating the SiKomFan-ontology described above. The ontology store is connected to a web content management system (WCMS), which implements the additional functionality like visualization of a situation, role authorization, group notifications, etc.

The ontology was tested with queries and example data created from the SiKomFan use-cases.

Fig.5 shows a SPARQL [11] query, which returns positions of relief units at a specific time:

```
select ?crews ?position ?north ?east ?intervalstart
?intervalend where
{
 ?position wgs84_pos:lat ?north ;
           wgs84_pos:long ?east .
 ?tmp_position
           dul:hasLocation+ ?position ;
           dul:isObservableAt ?interval .
 ?interval sikomfan:hasStartDate ?intervalstart ;
           sikomfan:hasEndDate ?intervalend .
 ?crews sikomfan:hasTemporalPosition ?tmp_position;
 a sikomfan:ReliefUnit .
 FILTER(?intervalstart >=
        "2015-02-12T16:00:00+02:00"^^xsd:dateTime)
}
```

Figure 5. SPARQL query for evaluation

Several scenarios with up to 2000 police officers were simulated for the evaluation of the queries. Depending on the scenario size the query execution duration varied between 20ms and 3000ms.

IX. CONCLUSION AND FUTURE WORK

In this paper, the first iteration of the SiKomFan ontology was presented, which addresses the manifold stakeholders and use-cases of the event football match. Using the methodology suggested by Uschold the purpose of the ontology was identified first and their content was defined at a stakeholder's workshop. After that, the ontology was designed building upon existing established ontologies. Finally, the ontology was evaluated by testing the SiKomFan use-cases.

Moreover, but not presented here, parallel sub-projects examine supporter cultures and their perspectives on safety and security as well as legal recommendations for a better information exchange and for optimizing the cognizance of public actors around football matches. These sub-projects therefore seek to deliver suggestions to optimize the communication strategies of the stakeholders, the communication processes between the stakeholders and especially to optimize the dialogue between supporters and the stakeholders. The new results of this interdisciplinary research will be taken into account and the ontology will be adapted accordingly in the second phase of the project.

ACKNOWLEDGMENT

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TABLE I. RESEARCHED ONTOLOGIES FOR INTEGRATION INTO THE SIKOMFAN ONTOLOGY

#	URL	Coding	Language	License	Published	Comment
	Base ontologies					
1	http://www.ontologydesignpatterns.org/ont/dul/DUL.owl	OWL/XML	en, it			Organizations, Relations, Planning, Events, …
2	http://xmlns.com/foaf/0.1/	OWL/XML	en	CC BY 1.0	2014	Persons, Organizations and their relations
	Location ontologies					
3	http://www.geonames.org/ontology/documentation.html	OWL/XML	en, no, sv, bg, ru	CC BY 3.0	2012	Locations, Countries, Population, ZIP, …
4	http://www.w3.org/2003/01/geo/	RDFS/XML	en		2009	Geo locations
	Time related ontologies					
5	http://www.w3.org/2006/time#	OWL/XML	en		2006	Time
6	http://www.ontologydesignpatterns.org/cp/owl/timeindexedsituation.owl	OWL/XML	en		2011	Order of events
7	http://motools.sourceforge.net/timeline/timeline.html	OWL/XML	en		2007	Order of events, extends OWL-Time
	Events (in the meaning of sport event or music event) ontologies					
8	http://motools.sourceforge.net/event/event.html	OWL/N3	en	CC BY 3.0	2007	Rudimentary
9	http://linkedevents.org/ontology/	OWL/XML	en	CC BY-SA 3.0	2010	Rudimentary
	Events (something happens and causes a reaction) ontologies					
10	http://west.uni-koblenz.de/Research/ontologies/events/index_html	OWL/XML	en		2009	Time and space, objects, cause and impact; extends DUL
11	http://www.dcs.shef.ac.uk/~vita/files/ER-events.owl	OWL/XML	en		20xx	Diseases, fire protest, weather. No Properties.
	Sport events ontologies					
12	http://purl.org/ontology/sport/	OWL/XML	en		2011	Sport events, leagues, teams, etc.
13	http://www.r4isstatic.com/linkeddata/ontologies/football/football.owl	OWL/XML	en		2009	Leagues, teams, countries
	Ontologies about football (the game itself)					
14	http://www.lgi2p.ema.fr/~ranwezs/ontologies/soccerV2.0.daml	DAML/XML	en		2002	Events in the game

TABLE II. ONTOLOGY METRICS

Ontology	Class count	ObjectProperty count	DatatypeProperty count	Individual Count
DUL	75	104	5	-
Geo-Pos	2	1	3	-
SiKomFan (without DUL and Geo-Pos)	124	38	21	210

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