BALLON
An Ontology for Forensic Ballistics Domain

Arif Yılmaz, Hilal Tarakçı and Serdar Arslan
TUBITAK Space Technologies Research Institute, Ankara, Turkey

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Abstract: Forensic ballistics is the domain that analyzes the firearm usage in crimes, thus assisting in exposing connections between crime scenes. While concept of the ballistics domain is strict and well defined; to the best of our knowledge, there is no standard representation of knowledge on this domain open to the public use. In our study, we represent an open ballistics domain ontology in a ballistics identification system and our aim is to acquire an effective reasoning capability. The proposed ontology, models the real world relationships between the concepts, thus forming a very close semantic representation of the ballistics domain. Therefore, in our ontology, reasoning capability is effectively used in order to set up relationships between concepts automatically.

1 INTRODUCTION

Forensic ballistics is the domain that analyzes the firearm usage in crimes, thus assisting in exposing connections between crime scenes. This science depends on the fact that each firearm leaves unique marks on the bullet and cartridge case it fires due to the manufacturing imperfections on the firearm. Therefore, these marks on cartridge cases and bullets are compared to each other in order to identify the ones which were fired from the same firearm.

The comparison of bullets and cartridge cases is a complicated task. In order to automate this process, some ballistics identification systems are developed (Condor Homepage, 2010) (Baldur, 2001). Balistika series automated firearms identification system (Leloglu et al., 2003a and 2003b) is one of these systems, which enables taking images of bullets and cartridge cases via a camera, comparing the image against a huge database of previously taken images according to some given criteria in a fast and efficient way. Besides, roles of the people interfering in the crimes will also be gathered in order to support related queries.

While the concept of the ballistics domain is strict and well defined; to the best of our knowledge, there is no standard representation of knowledge on this domain open to the public use. This situation results in incompatibility between different ballistics identification systems. Recently, there is an ongoing project (Yates et al., 2009) claiming to address this incompatibility problem by using ontologies at several layers in their project stack. According to their paper, the ontologies being developed in this project have not been disclosed yet. Besides, the study is only an abstraction of the application concepts at a high level. Thus, it does not address the issues related to reasoning power of ontology

In this study, an open ballistics identification domain ontology is presented. It aims to add superior reasoning capability to new generation Balistika System: BALISTIKA 2010. The strictness and well defined nature of forensic ballistics domain makes this goal achievable. The proposed ontology defines the real world relationships between the concepts, thus forming a very close semantic representation of the domain. Therefore, reasoning capability is effectively used in order to set up relationships between concepts automatically.

In Section 2, some background information and related works are given. Our ontology is explained with a test scenario in Section 3. Finally, conclusions with further research directions are presented in Section 4.

2 BACKGROUND

The evidences (“cartridge cases” and/or “bullets”) collected from a crime scene are entered in the

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system as an envelope termed as “a case”. When “an evidence” is found in the crime scene, the high resolution images of this evidence or information derived from these images are compared with the other images of the evidences in the system database. If “a match” is found in the database, the evidences, groups of those evidences and wrapper cases are linked in the same chain.

The relationship between cases is a crucial goal of the ballistic investigation. This relationship defined as a “named chain”, can be helpful in investigation of other cases in this chain; so that if a firearm is found or a person is identified in one of these cases, this information can be used in the investigation of the current case. Besides; whenever evidences from each chain are matched in a latter comparison process, these chains have to be merged since all evidences linked within the same chain are shot from the same firearm.

A domain ontology is a reusable vocabulary of concepts and their meanings, the relationships between these concepts, and activities in a particular domain enabling reasoning capability within that domain (Gómez-Pérez et al., 2004).

In (Brinson et al.,2006), a cyber forensic ontology is proposed in order to use in curriculum development and educational materials. However, the ontology is not specialized for ballistics domain and not suitable for machine process purposes. Fortunately, this ontology is appropriate as an upper ontology for our domain of concern as future work.

To the best of our knowledge, there is currently only one study proposing an ontology about forensic ballistics domain. (Yates et al., 2009) tries to solve this problem by the development of interoperable data and systems as part of Odyssey Project (Odyssey Project Homepage, 2010).

3 BALLON: BALISTIKA 2010 ONTOLOGY

Fortunately, ballistics identification is a strict domain and has well defined nature. This feature facilitates describing it in a formal way. The entities in real world ballistics domain and the ones constituting the ontology conforms each other making understanding of the ontology easier.

3.1 Ballistics Ontology

In BALLON, case concept is defined to be an envelope that wraps all the ballistics evidence discovered at the crime scene besides metadata about the crime scene such as the region, the people and roles they played in the committed crime etc. The cartridge cases and bullets found are separated, since comparison of a cartridge case with a bullet is meaningless; in other words, cartridge cases are compared against cartridge cases, bullets are compared against bullets

In a crime scene, the possibility of finding sister ballistics evidences is very high, since most likely several shots made by the same firearm. Therefore, the forensic ballistics expert analyzes the evidences and groups the sister evidences manually, forming evidence groups in order to increase the efficiency of the automated ballistics identification system. In the ontology there are two subclasses of evidence group: cartridge case group and bullet group. Similarly evidence has two subclasses; cartridge case and bullet. In general, this situation holds for almost all concepts which are subject to this cartridge case-bullet separation.

Whenever a firearm is discovered in a crime scene, it is associated with the case. The test shoots for the firearm are carried out and cartridge cases and bullets obtained during test shoots are called as test evidences of that firearm (test cartridge cases and test bullets). In the ontology, test evidence groups are evidence groups that have test evidences shot from the same firearm. In other words, if an evidence group is defined in the ontology and some test evidences are indicated to be in that evidence group, the evidence group automatically becomes a test evidence group.

The link established between evidences, evidence groups or cases forms a chain. The concepts that are claimed to be in the same named chain are related to the same firearm somehow. Whenever two cartridge cases or bullets are indicated to be sisters, the ontology asserts that all the evidences that are in the same evidence group with those two evidences are in the same chain. Moreover, the cases those evidence groups belong to are also asserted to be linked with that chain, as well. If the test evidence of a firearm is indicated to be in that chain, other cases in that chain are also asserted to be related to that firearm.

Besides ballistics evidence, cases are also related to people and roles that people play in the case are indicated. In BALLON, people are automatically classified as suspect, victim or witness based on their role in the cases. For instance, if the person has a grabber or murderer role in a case, he/she is classified as the suspect of that case.

3.2 A Test Scenario

The aim of the ballistic investigation is to find the interfered people and/or firearms of the case being examined. For this purpose, the evidences gathered from the crime scene must be analyzed efficiently. The firearms, cartridge cases and bullets can be used for the analyzing process as well as people interfered in the case.

An example scenario (shown in Figure 1) is as follows; Cases are represented as rectangles and evidences (black circle) of the same firearm are grouped together into evidence group which is shown as gray circle in the figure.

The Police were informed a murder in Region1 (Case 1). Three cartridge cases have been found in crime scene while there was no suspect caught. The ballistics expert has stated that these cartridge cases are ejected from the same firearm which has not captured in this case. These evidences have been registered into the identification system in order to find the suspect(s) and firearm if they have been already found in previously registered cases. Unfortunately, the system has returned no match for those evidences.

Several months later, another crime was declared in the same region (Case 2). This time, there was a firearm found in crime scene, while there were two cartridge cases. Test shots of found firearm have been taken in order to compare to other evidences previously stored in the system but no match found for that firearm. Meanwhile, the expert has decided that two cartridge cases found in the crime scene have not been ejected from that firearm. So, they were registered into the system to find a match. The system has offered a match with evidence from Case 1. When the expert approved this match, a link between those evidences has been set up (Chain A). Our work, automatically delegates this link to groups of evidences (shown as gray circle) and also to the wrapper cases.

In another region (Region 2) similar cases (Case 3 and Case 4) have occurred and this time, the chain (Chain B) has been set up between them which has a firearm found. Later, the evidences from Case 2 and Case 3 have been declared as sisters and while these different evidences belong to different chains, these chains have to be merged (dotted arrow in the figure); since a chain is a container of evidences shot from the same firearm. An evidence cannot belong to two different chains because an evidence cannot be shot from two firearms.

With the help of inference capability on our ontology, this relationship is automatically set up and the chains A and B are merged. This merge is carried out by classifying two chains as identical. Without this reasoning capability, plenty of code must be written in order to carry out this operation. Fortunately, web ontology language (OWL Homepage, 2010) enables us forming automatically defined classes, defining necessary and sufficient conditions to fall into these classes via restrictions. In our ontology, there are automatically defined classes for evidences, evidence groups, cases and firearms for each named chains.

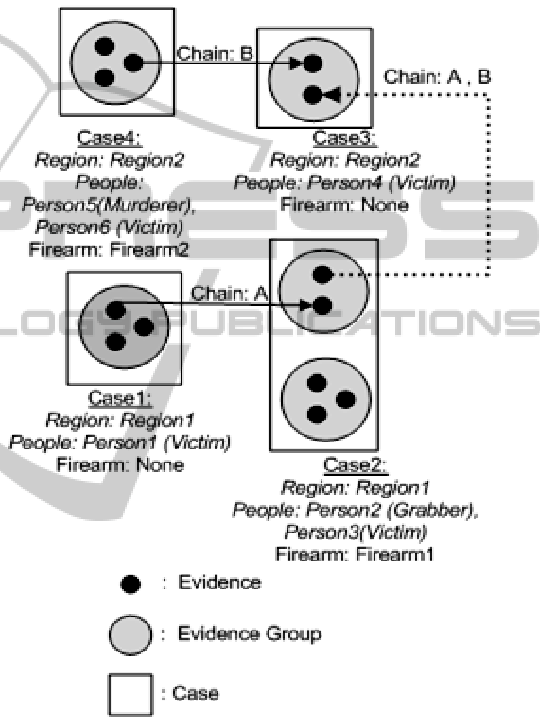

Figure 1: An example scenario for querying the ontology.

If a person is declared to be the owner of the found firearm in Case 4 and the firearm is linked to some other cases via chain, that person becomes the suspect of other cases automatically. Moreover, people interfered in the case with some role are also subject to reasoning. As a result of reasoning capability, people are classified according to their role. In the ontology, there are several roles and each person classification is a defined class that gathers people with roles specified in its necessary and sufficient condition. For example, the suspect of Case1 is reasoned as murderer in Case 4 and as grabber in Case 2 automatically depending on the type of the cases.

3.3 Implementation and Querying

The proposed ontology is created by using Protégé (Protégé Homepage, 2010) which is a well-known powerful ontology editor and knowledge acquisition system. Afterwards, the aforementioned test scenario is implemented by loading the previously created ontology, feeding it with required individuals for that scenario and serializing the final ontology with the help of Jena (Jena Homepage, 2010) which is a java framework for building semantic web applications. The consistency of the produced ontology is checked via using Pellet (Pellet Homepage, 2010) reasoner which run seamlessly in Protégé.

Besides the basic test scenario, the representation and reasoning power of ontology is also tested against some fundamental queries. A query module is implemented in Java using ontology API provided by Jena in order to accomplish these queries and some of them listed below. In fact, this query module can easily be extended to support more complex queries which are combinations of the listed fundamental ones. However, in the scope of this study, the focus is on the proposed ontology and its reasoning capability.

Some of the fundamental queries and how they are accomplished are as follows:

1. Query: "*Show Named Chains owned by the Case C1*".
   - Result: "ChainACase" ,"ChainBCase".
2. Query: "*Show Cases of Named Chain A*".
   - Result: "C1","C2","C3","C4".
3. Query: "*Show identical Named Chains of Named Chain A*".
   - Result: "Chain A", "Chain B".
4. Query: "Show Cases interfered by Person 4".
   - Result: "C3".
5. Query: "Show the same Cases of Named Chain A and Named Chain B".
   - Result: "C1","C2","C3","C4".

4 CONCLUSIONS

The lack of a common and open unified formal data model in ballistics domain results in incompatibility amongst existing ballistics identification systems. However, to the best of our knowledge, an open ballistics ontology is not proposed yet. In our study, we represent an open domain ontology for a ballistics identification system. Our ontology claims to be a formal representation of the domain, covering required key concepts and promising an effective reasoning capability.

As a future study, we will try to integrate our ontology with the relational database used in BALISTIKA 2010 project and enhance query support for practical use of proposed ontology.

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