Using an Ontology Network for Data Integration: A Case in the Public Security Domain

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Abstract. *Organizations often use several applications to support business processes. However, these applications usually are heterogeneous, autonomous and distributed. In this context, Enterprise Application Integration (EAI) initiatives are needed. Ontologies play a key role in EAI, capturing the conceptualization underlying the various applications to be integrated and providing an "interlingua" to support EAI. This paper presents a semantic EAI initiative in the Public Security domain, particularly in the Violent Crimes against Life subdomain. To assign semantics to the integrated applications, we developed and used the Violent Crime Process Ontology Network, which is partially presented in this paper.*

Keywords*: Semantic Integration, Public Security, Ontology Network*

1. Introduction

Enterprise applications have to work together to better support complex business processes involving different business areas [Wache *et al.* 2001]. These applications, however, are usually heterogeneous, autonomous and distributed (HAD applications) [Izza 2009], and they need to be integrated.

Ontologies have been used as an "interlingua" to support Enterprise Application Integration (EAI) [Izza 2009]. Ontology-based integration strategies are particularly relevant in e-Government (e-Gov), where applications often are: (i) commissioned and maintained by different public administration agencies; (ii) designed to address different tasks; and (iii) positioned to support different business processes. These features have important implications in integration efforts.

In a research project in the Public Security domain, particularly in the Violent Crimes against Life subdomain, we have employed an ontology-based approach for data integration, called OBA-SI [Calhau and Falbo 2010]. Recent data of the 2017's Violence Atlas [Cerqueira *et al.* 2017] shows that Brazil has the highest murder rate in the world. Solving crimes is a complex process, involving a large amount of information which permeates several public agencies (e.g., Public Security Secretary and Court of Justice). To support this process, agencies use several applications, which are not integrated. The lack of data integration leads to data inconsistence and impacts on decision-making. In this scenario, a solution based on a single monolithic ontology showed to be inadequate, since such ontology becomes hard to manipulate, use and maintain. As pointed out by Suárez-Figueroa *et al.* (2012), in such situations, an Ontology Network (ON) works better. An ON is a collection of ontologies related together through a variety of relationships, such as alignment, and dependency. Thus, we developed an ON called Violent Crime Process Ontology Network (VCP-ON). VCP-ON captures the conceptualization underlying the violent crime process (VCP) and provides an "interlingua" for integrating data from VCP-related applications.

This paper presents this EAI initiative focusing on the Investigation and Conviction processes. These processes are considered the VCP bottlenecks, because they produce/consume the largest amount of data in the VCP. This paper is structured as follows: Section 2 provides the background for the paper; Section 3 partially presents VCP-ON; Section 4 addresses the integration initiative; Section 5 discusses related work, and Section 6 presents some final considerations.

2. Background

In EAI, semantic conflicts arise when applications use different terms to refer to the same information item, or when information items seem to have the same meaning, but they do not. To address these conflicts, integration initiatives should address semantic issues. Ontologies have been used to solve semantic conflicts by making explicit and precise the meaning of the information to be interchanged across applications that are intended to interoperate [Izza 2009] [Wache 2001].

Since integration is not a trivial task, it is important to adopt a method that helps to deal with the complexity of this task by providing well-established steps, separation of concerns and reduction of subjectivity. In this work, we adopted OBA-SI (Ontology Based Approach for Semantic Integration) [Calhau and Falbo 2010]. OBA-SI uses ontologies to analyze the conceptual models of the applications to be integrated. Semantic mappings are set among the conceptual models and between the conceptual models and the ontology, to establish a common semantics between these two. The integration starts with the *Integration Requirements Elicitation* phase, when the integration requirements and goals must be established. In this phase the integration scenario is defined, indicating the business process activities that will be supported by the integration initiative, the applications that will be integrated to support those activities, and the domains involved in the integration scenario. Next, in the *Integration Analysis* phase, conceptual models of the applications to be integrated are obtained and the reference ontologies to be used are selected/developed. Mappings between the modeling elements of the applications' conceptual models (classes and associations) and the modeling elements of the ontologies (concepts and relations) are established, aiming to ensure a semantic bond among the models mediated by the ontology. Once the mappings are established, an integration model is built, which is used as basis for the next phases, namely: *Integration Design*, *Implementation*, *Testing* and *Deployment*.

Although OBA-SI refers to the use of ontologies for semantic integration, it is neutral regarding how these ontologies are to be developed or selected. In our case, as discussed before, we concluded that it is prohibitive and even undesirable to provide a large monolithic ontology. When interoperating e-Gov applications, in general, there is a large number of involved public agencies, processes and applications. This makes e-Gov a large and complex domain, even if we focus on a smaller portion, as it is the case of Public Security. Thus, developing an Ontology Network (ON) is more appropriate than a single monolithic ontology. Easiness of design (considering the well-known divide-and-conquer approach) and the possibility of reuse (a helpful characteristic for integration purpose) are some of the advantages when creating an ON instead of a single one [Suárez-Figueroa *et al.* 2012].

In this work, to develop the Violent Crime Process Ontology Network (VCP-ON), we adopted OntoUML. OntoUML is an ontologically well-founded profile for UML 2.0 class diagrams, grounded in the Unified Foundational Ontology (UFO) [Guizzardi 2005]. OntoUML introduces in class diagrams a set of stereotypes that represents some UFO categories, enabling the creation of ontologies that are consistent and aligned with that foundational ontology. Table 1 shows the subset of OntoUML stereotypes used in this paper.

Table 1. OntoUML Stereotypes Subset

Stereotypes	Main Features
<<kind>>	Rigid types that provide a uniform principle of identity for their instances (e.g. Person, Car). A type *T* is rigid iff for all instance *x* of *T*, *x* is necessarily an instance of *T*, i.e., if *x* instantiates *T* in a given world, then *x* must instantiate *T* in all other possible worlds in which *x* exists.
<<role>>	Anti-rigid types instantiated within the scope of a relational context (e.g. Student, Spouse). In the case of an anti-rigid type *T*, if an instance *x* instantiates *T* in a given world, there is a possible world in which *x* does not instantiate *T*.
<<relator>>	Types that objectify a material relational context (e.g., a Marriage is a *relator* that associates people playing the role of Spouses).
<<phase>>	Constitute possible stages in the history of a substance sortal (e.g., Alive and Deceased: as possible stages of a Person; Catterpillar and Butterfly of a Lepidopteran)
<<mode>>	Rigid types that capture (potentially complex) objectified intrinsic properties. Their instances are existentially dependent of exactly one other entity (e.g. Skill is a *mode* that characterizes a Person and so is the Intention of an Agent).
<<mediation>>	Formal relationships between a *relator* type and the roles related through that *relator* (e.g., the *mediation* relationship between Marriage and Spouse).
<<characterization>>	Formal relationships between a *mode* and the type that *mode* characterizes (e.g. the *characterization* relationship between a *mode* Belief and a *kind* Person).
<<2ndOT>>	Second-order types whose instances are other types, not individuals (often represented with the power type pattern) (e.g. “Crime Type” is a type whose instances are other types, “Kidnapping”, “Homicide”)

3. Violent Crime Process Ontology Network (VCP-ON)

The purpose of VCP-ON is to provide a common conceptualization about the violent crime process aiming to support EAI in the Public Security domain. VCP-ON was developed taking the violent crime process as a basis, and applying modularization principles based on Enterprise Architecture Models, as discussed in [Detoni *et al*. 2017]. Figure 1 shows the VCP-ON architecture. Each package represents a domain ontology. The domain ontologies are connected by dependency relations, which shows that they are interlinked, reinforcing the idea of “network”.

In this work, the following ontologies are used: Agent Ontology, Crime Description Ontology, Police Investigation and Accusation Ontology, and part of the Criminal Trial Ontology, called Conviction Ontology. Before presenting these ontologies, we need to explain the sub-processes of the violent crime process related to them, as defined in [Detoni et. al. 2017]:

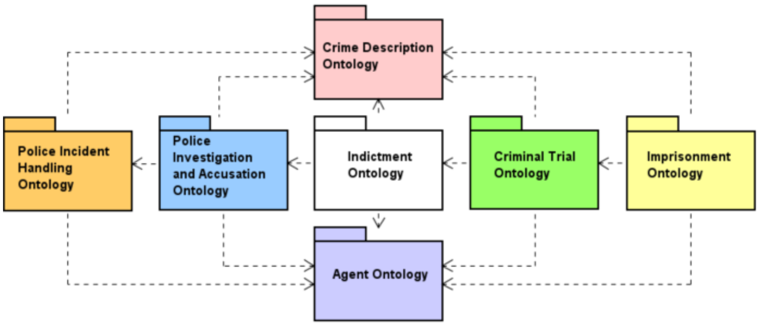

Figure 1. VCP-ON Architecture

- Police Investigation and Accusation: the Civil Police[1] establishes an investigation to determine authorship of an alleged crime. The police chief officer requests testimony from potential witnesses. Police investigators go to the crime scene to search for information. The autopsy and death reports, when ready, are sent by the Scientific Police. All these documents are attached to the police inquest. After the police investigation ends, if the evidences gathered are sufficient to declare who is the offender (i.e., it is confirmed that it was indeed the preliminary police suspect), an accusation is made. The police chief officer requests a public prosecutor to offer an indictment (formal complaint). The public prosecutor analyzes the police inquest and defines whether to offer the indictment or not.

- Criminal Trial: the indictment is sent to a judge, who can decide on its acceptance. If accepted, the police inquest, now turned in an indictment (represented by an indictment document), becomes the criminal procedure that will continue to the Judiciary. The criminal trial begins when the judicial act is established. The judicial act is a request with which the indictment is manifested, accompanied by an exposition of the fact and the law. A judicial act is usually accompanied by a court hearing, where the grand jury hears the parties through themselves or their lawyers. Parties of a legal proceeding are the defendant (the person against whom the legal action is opposed), victim (who has suffered the offense) and witness (who has seen or heard something and is called to testify). At the end of a criminal trial, the defendant is sentenced and can be subject to a penalty, in which the defendant receives the conviction, or acquitted. If the sentence was a conviction, the guilty party has to comply with the sentence determined by the judge after conclusion of the criminal trial.

The main concepts of the processes described above are captured by four ontologies: VCP Agents Ontology, Crime Description Ontology, Police Investigation and Accusation Ontology, and Conviction Ontology (part of the Criminal Trial Ontology). Although the Crime Description Ontology is not explicitly mentioned in the processes, it is important in this work. By studying the Public Security domain, we noticed that all the subprocesses of the violent crime process deal with descriptions of the alleged crime. Thus, we created the Crime Description Ontology that captures that an *Alleged Crime* is described by *Alleged Crime Descriptions*. An *Alleged Crime Description* is composed by other descriptions, such as *Alleged Victim Description*, *Alleged Weapon Description* and *Alleged Location Description*, among others. The

[1] The Civil Police is the State Police with criminal law enforcement duties. It has the function of investigating crimes committed in violation of Brazilian criminal law. It does not patrol the streets.

Alleged Crime represents information inherent to concepts of other networked ontologies, exemplifying the interrelation among the VCP-ON domain ontologies, as illustrated in Figure 1 through the dependency relations. The same applies to the VCP Agents Ontology, which aims to capture the main agents involved in the whole process.

Figure 2 presents the concepts of VCP-ON relevant to this work. Following the representation conventions adopted in Figure 1, classes in gray represent concepts from the Agent Ontology, classes in blue refer to concepts from the Police Investigation and Accusation Ontology, classes in green represent concepts from the Conviction Ontology and classes in red represent concepts of the Crime Description Ontology.

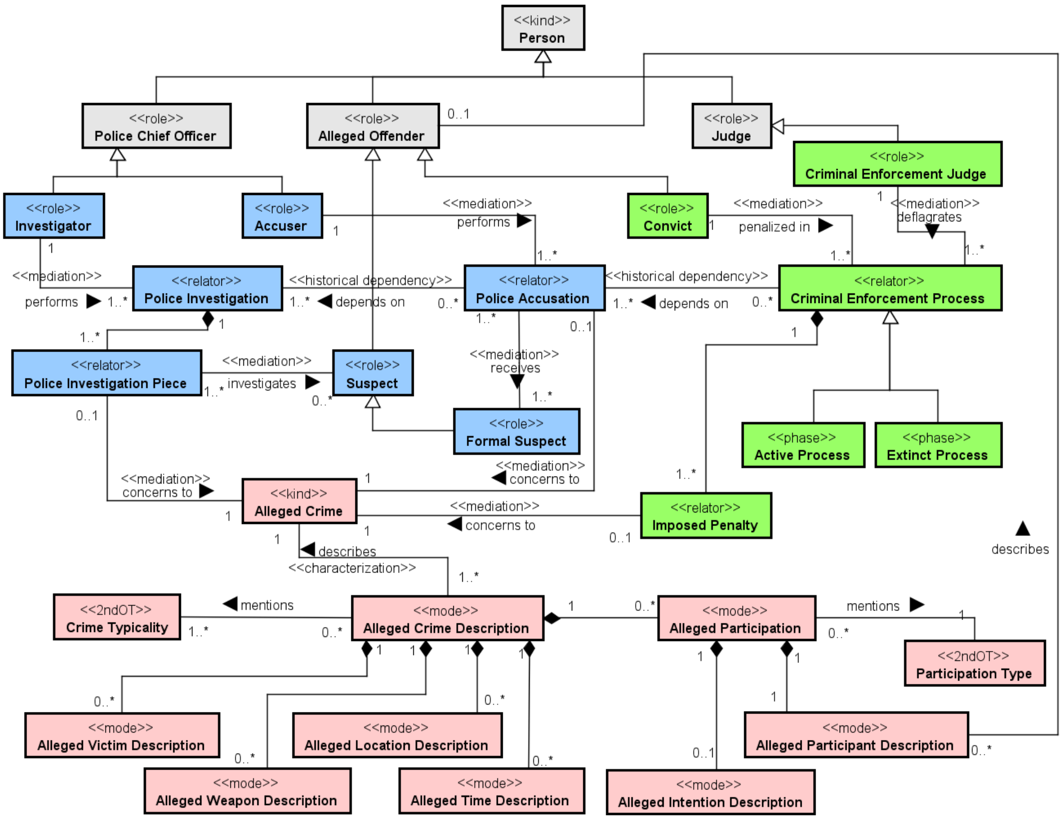

Figure 2. Fragment of VCP-ON

As Figure 2 shows, *Police Investigation* is a relator connecting the *Investigator* (the role played by a *Police Chief Officer* when performing an investigation) to the *Suspects* (the role played by a *Person* being investigated). The *Police Investigation* is fragmented in *Police Investigation Pieces*, each one concerning to an *Alleged Crime*. An *Alleged Crime* is described by an *Alleged Crime Description* that grounds the indication of some participant as *Suspect*, justifying the relation *refers to* holding between *Alleged Participant Description* and *Suspect*.

Based on the investigation, the *Police Chief Officer* (playing the role of *Accuser*) can accuse the *Suspect*, which is now the *Formal Suspect* of a *Police Accusation*. Like a *Police Investigation*, a *Police Accusation* concerns to an *Alleged Crime*. In case of the *Formal Suspect* being condemned in a criminal trial, the *Criminal Enforcement Judge* will deflagrate the *Criminal Enforcement Process* that will apply the *Imposed Penalties* to the *Convict*. This process remains active (*Active Process*) until the *Convict* complies with all *Imposed Penalties*.

We should highlight the historical dependence relation between *Police Accusation* and *Police Investigation*, and between *Criminal Enforcement Process* and *Police Accusation*. These relations capture the idea of processes sequence, in which a *Police Investigation* is required for a *Police Accusation* to exist, and consequently, a *Police Accusation* is required for a *Criminal Enforcement Process* to exist.

4. Public Security Data Integration

Our EAI initiative involved two important applications used in the Public Security area, namely: DEON, a web application used in Policy Stations and that deals mainly with information related to the investigation processes, and SIEP, which is used in the Jury's Court of Espírito Santo and deals with information related to indictment and conviction. The main purpose of the integration is to provide useful information to support monitoring violent crimes and the convictions related to them. The integration scenario involves the investigation, indictment and conviction processes. The integrated solution aims to answer the following integration questions:

Q1. What is the percentage of preliminary police accusations typified as homicides that led to crime enforcement processes for this type of crime (homicide)?

Q2. What is the average time elapsed between investigation and arrestment of the suspects of homicide?

Q3. What is the percentage of formal suspects indicted for homicide, not yet judged, that have already been convicted of another crime?

Q4. What is the percentage of formal suspects of homicide, not yet judged, that have already been convicted for homicide?

Q5. What is the percentage of formal suspects of a homicide, not yet judged, that have an active crime enforcement process and are fulfilling an imposed penalty?

Once the integration scenario (i.e., integration purpose, involved processes, applications to be integrated and questions to be answered) was established, we obtained the applications conceptual models. DEON focuses on supporting the investigation process, storing all relevant information, including the pieces from the Inquiry and from the possible Indictment made by the Police Chief Officer in the end of the process. Figure 3 presents the fragment of DEON's conceptual model considered in the integration.

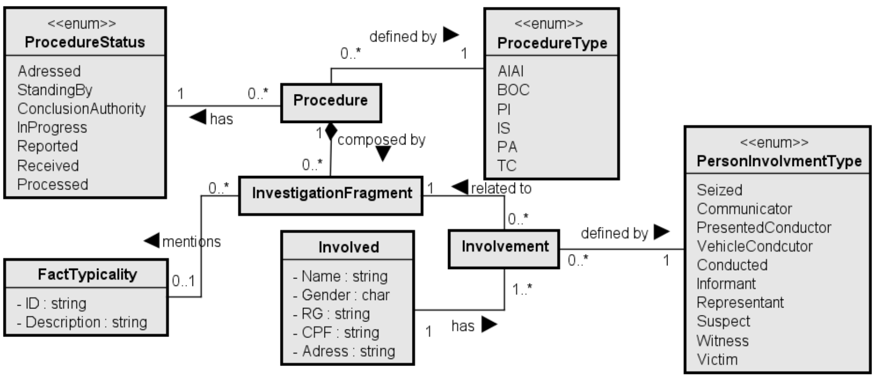

Figure 3. Fragment of DEON's Conceptual Model

A *Procedure* is defined by a type (*Procedure Type*) and it has a *Procedure Status*. In the context of this work, we are concern only with procedures of PI (*Police*

Inquest) type and with status (*Procedure Status)* = *Processed*. *Procedure* is composed of *Investigation Fragments* that individualize the facts of the alleged crime investigated in the *Procedure*. An *Involvement* relates an *Involved* to a specific *Investigation Fragment*. In the case of suspects (*Involved* that has an *Involvement* defined by the *Person Involvement Type* = suspect), the *Investigation Fragment* mentions a *Fact Typicality*, i.e., the type of crime (e.g., Homicide, Robbery) the suspect was investigated.

SIEP supports the indictment and conviction processes. After the trial, if the defendant is convicted, a large amount of data about him is registered and grouped, including information about the whole process, i.e., since the occurrence until the defendant's conviction. Figure 4 shows the fragment of SIEP's conceptual model considered in the integration.

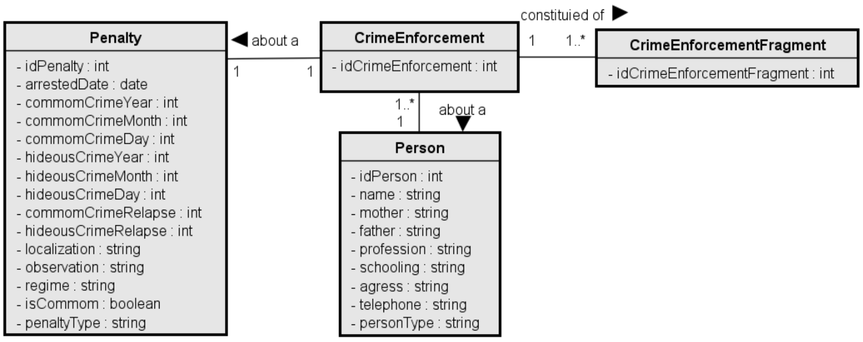

Figure 4. Fragment of SIEP's Conceptual Model

As illustrated in Figure 4, a *Crime Enforcement* is a set of *Crime Enforcement Fragments* that individualize the crimes in which the *Person* (if *PersonType* equal *Convict*) is accused. The *Crime Enforcement* represents a criminal record about a conviction, deflagrated by a *Judge* about a *Penalty*.

After obtaining the applications' conceptual models, we selected the VCP-ON view to be used as interlingua in the integration initiative. This view, shown in Figure 5, was used as the integration model for the further activities of this EAI initiative (design and implementation of the integration solution).

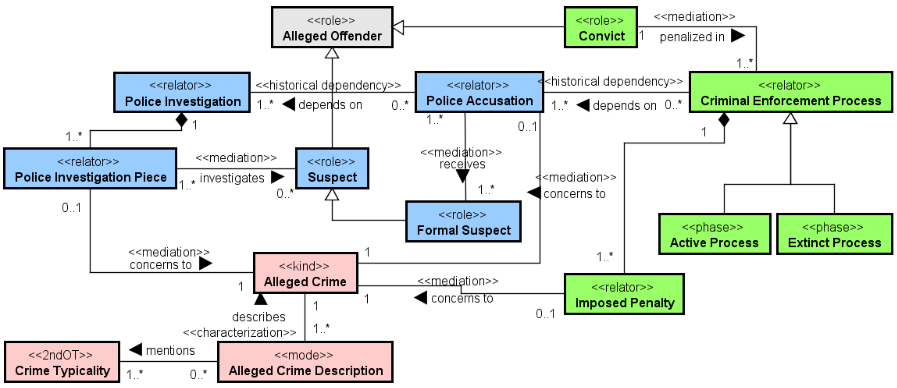

Figure 5. VCP-ON view used in the integration

Once the applications' conceptual models were obtained and the VCP-ON view selected, we performed the mappings. Each class and association in the applications' conceptual model was analyzed against the ontology concepts and relationships and the semantic mappings between them were established. Table 2 presents examples of the mappings between VCP-ON concepts and DEON/SIEP concepts.

Table 2. Examples of Vertical Mappings

VCP-ON	DEON	SIEP
Police Investigation	Procedure, if StatusProcedure != “Processed” and ProcedureType= “IP”	-
Police Accusation	Procedure, if ProcedureStatus = “Processed” and ProcedureType = “IP”	-
Criminal Enforcement Process	-	CrimeEnforcement
Suspect	Involved, if the Involved and a Investigation Fragment are associed to a same Involvement and the Involvement is related with a PersonInvolvementType in which the type is “Suspect”, and the InvestigationFragment is part of a Procedure, whose ProcedureType = “Police Inqueriment (PI)” and the ProcedureStatus != “Processed”	-
Formal Suspect	Involved, if the Involved and a Investigation Fragment are associed to a same Involvement and the Involvement is related with a PersonInvolvementType in which the type is “Suspect”, and the InvestigationFragment is part of a Procedure, whose ProcedureType = “Police Inqueriment (PI)” and the ProcedureStatus = “Processed”	-
Convict	-	Person, if PersonType = “convict”

In vertical mappings, we focus on two important aspects, the procedures that deal with the alleged crime and the role of an alleged offender at each procedure. Although there are no concepts of the ontology related with both systems, giving the impression that the applications’ concepts are not mapped, this link is made in the ontological layer. For example, the Police Accusation was mapped to DEON’s “Processed Procedure”, whereas the Criminal Enforcement Process was mapped to SIEP’s “CrimeEnforcement”. In ontology, there is a historical dependence relation between Criminal Enforcement Process and Preliminary Police Accusation, and both are related with an Alleged Crime, showing that there is an information flow among these procedures. Consequently, this flow also exists between the concepts from DEON and SIEP, which are mapped with the ontology, i.e., the investigation and conviction processes are aligned.

Moreover, the Formal Suspect was mapped to DEON’s “Involved” (with some conditions) and the Convict to SIEP’s “Person” (if PersonType = “Convict”). The same idea that the application’s concepts are related in ontological layer is applied here. In ontology, both Formal Suspect and Convict are specialization of Alleged Offender, showing that these roles are of a same individual and consequently, DEON’s "Involved" and SIEP’s “Person” are related.

Once the vertical mapping is completed, we start the development of the integrated solution. We used the Ontology-based Data Access (ODBA) paradigm [Botoeva *et al.* 2016] to provide to the user access to data sources through a conceptual layer, formulated with concepts from the domain and familiar to the user. This layer can be defined as an operational ontology, implemented in RDF and OWL languages. Mappings are established between the ontology and the applications’ databases. These mappings are specified as relations between the domain concepts and the data sources, so that one element in the database can be identified through an SQL query. After establishing the mappings, the ontology is populated with instances from the data sources, similar to relational databases.

Associated to ODBA, we used the Ontop platform [Calvanase *et al.* 2015] in order to allow users to search relational databases, such as Virtual RDF Graphs, using the SPARQL language and considering the ontology implemented in OWL. In summary, we performed the following steps to implement the integrated solution: *(i)* selection of the databases to be used (DEON and SIEP databases); *(ii)* implementation of the operational version of the ontology shown in Figure 5 in OWL languages; *(iii)* creation of mappings between the ontology and the databases (based on the mappings previously defined, as the ones shown in Table 2), relating concepts of the domain with elements of the relational database through SQL queries; *(iv)* configuration of the Ontop plataform, populating the ontology with the respective databases elements to serve as a SPARQL endpoint; and *(v)* creation of SPARQL queries based on the integration questions previously defined.

Once completed the first four steps, we wrote SPARQL queries based on the integration questions previously defined. For example, Q1 – *"What percentage of preliminary police accusations typified as homicides led to crime enforcement processes based on Art.121 (homicide)?"*, was translated into a SPARQL query that performs the follow procedures:

1. Retrieve all Preliminary_Police_Accusation instances and their relation with the respective Alleged_Crime instance jointly with the Crime Typicality.
2. Retrieve the Criminal_Enforcement_Process instances related with each Preliminary_Police_Accusation instance previously found, through the data property origin_process.
3. Count all Preliminary_Police_Accusation instances that have homicide as crime typicality.
4. Count all Criminal_Enforcement_Process instances related with a Preliminary_Police_Accusation instance of homicide type that also has homicide as crime typicality.

The Figure 6 presents a SPARQL query that contemplates the first two procedures. This query returns four columns, the first two deal with preliminary police accusations that are typified as homicide, and the last two columns present the criminal enforcement process related to these accusations and their respective typicality defined after the criminal trial.

In order to perform the last two procedures and obtain the final answer, the same query was run again with the COUNT and GROUP BY commands, resulting in the count of all Preliminary_Police_Accusation of homicide type and all Criminal_Enforcement_Process related to these accusations that are also of the homicide type (Figure 7).

Based on these results, we conclude that 10 Criminal_Enforcement_Process were classified as homicide in some preliminary police accusation, 2 were judged as theft (Art. 155), 2 were judged as kidnapping (Art. 148), and only 6 were really judged as homicide (Art. 121), i.e., 60% of preliminary police accusations typified as homicides led to crime enforcement processes based on Art.121.

SPARQL query:

```
PREFIX owl: <http://www.w3.org/2002/07/owl#>
PREFIX rdf: <http://www.w3.org/1999/02/22-rdf-syntax-ns#>
PREFIX rdfs: <http://www.w3.org/2000/01/rdf-schema#>
PREFIX ct: <http://www.semanticweb.org/nemo/ontologies/2018/5/criminal_trial#>
PREFIX cd: <http://www.semanticweb.org/nemo/ontologies/2018/5/crime_description#>
PREFIX iai: <http://www.semanticweb.org/nemo/ontologies/2018/5/InvestigationAndIndictment#>
PREFIX ipso: <http://www.semanticweb.org/nemo/ontologies/2018/5/integrated_public_security_ontology#>

SELECT DISTINCT  ?ppa ?type ?cprocess ?penaltycrimetype WHERE {
        ?ppa rdf:type iai:Preliminary_Police_Accusation.
        ?crime rdf:type cd:Alleged_Crime.
        ?penaltycrime rdf:type cd:Alleged_Crime.
        ?type rdf:type cd:Crime_Typicallity.
```

ppa	type	cprocess	penaltycrimetype
Preliminary_Police_Accusation_31939207	Crime_Typicallity_121	Criminal_enforcement_222201108777	Crime_Typicallity_155
Preliminary_Police_Accusation_31939205	Crime_Typicallity_121	Criminal_enforcement_222201108775	Crime_Typicallity_155
Preliminary_Police_Accusation_31939203	Crime_Typicallity_121	Criminal_enforcement_222201108771	Crime_Typicallity_121
Preliminary_Police_Accusation_31939211	Crime_Typicallity_121	Criminal_enforcement_222201108784	Crime_Typicallity_121
Preliminary_Police_Accusation_31939209	Crime_Typicallity_121	Criminal_enforcement_222201108780	Crime_Typicallity_121
Preliminary_Police_Accusation_31939210	Crime_Typicallity_121	Criminal_enforcement_222201108783	Crime_Typicallity_121
Preliminary_Police_Accusation_31939204	Crime_Typicallity_121	Criminal_enforcement_222201108773	Crime_Typicallity_121
Preliminary_Police_Accusation_31939208	Crime_Typicallity_121	Criminal_enforcement_222201108779	Crime_Typicallity_121
Preliminary_Police_Accusation_31939206	Crime_Typicallity_121	Criminal_enforcement_222201108782	Crime_Typicallity_148
Preliminary_Police_Accusation_32065756	Crime_Typicallity_121	Criminal_enforcement_222201108781	Crime_Typicallity_148

Figure 6. SPARQL Query 1

```
SELECT ?type (COUNT(?type) as ?typeCount) WHERE {
        ?ppa rdf:type iai:Preliminary_Police_Accusation.
        ?crime rdf:type cd:Alleged_Crime.
        ?penaltycrime rdf:type cd:Alleged_Crime.
        ?type rdf:type cd:Crime_Typicallity.
        ?penaltycrimetype rdf:type cd:Crime_Typicallity.
        ?cprocess rdf:type ct:Criminal_Enforcement_Process.
```

type	typeCount
Crime_Typicallity_121	"10"^^<http://www.w3.org/2001/XMLSchema#integer>

```
SELECT ?penaltycrimetype (COUNT(?penaltycrimetype) as ?typeCount) WHERE {
        ?ppa rdf:type iai:Preliminary_Police_Accusation.
        ?crime rdf:type cd:Alleged_Crime.
        ?penaltycrime rdf:type cd:Alleged_Crime.
        ?type rdf:type cd:Crime_Typicallity.
```

penaltycrimetype	typeCount
Crime_Typicallity_155	"2"^^<http://www.w3.org/2001/XMLSchema#integer>
Crime_Typicallity_121	"6"^^<http://www.w3.org/2001/XMLSchema#integer>
Crime_Typicallity_148	"2"^^<http://www.w3.org/2001/XMLSchema#integer>

Figure 7. SPARQL Query 2

In sum, this type of query provides an overview of the Violent Crime Process (VCP), linking the domain concepts, allowing each public agency to consume more complete and coherent information of the VCP and, thus fulfilling some gaps in the security domain. For example, currently there is no feedback in the VCP, the information created in the Preliminary Police Accusation suffer changes in subsequent activities but these changes are not reported back to initial activities, and this gap can reflect in future investigations, enabling inconsistencies. Such as, the same person being investigated and convicted more than once for the same fact, since this agency responsible by the accusation may not know that the offender has been convicted, because the typicality changed. In this context, to view the VCP as a whole allows the public agency responsible for the Police Accusation to know the progress of investigations when the information was left its jurisdiction.

5. Related Work

Some works have addressed the use of ontologies in EAI initiatives in the e-Gov domain. Fonseca *et al.* (2016) proposed a reference ontology for the Brazilian Government Budget domain using the OntoUML language. The ontology was used in an EAI initiative involving two applications used by Brazilian public agencies, namely: SIOP and SIAF. The authors extracted data from both applications as RDF files and transformed the OntoUML model in a computational artifact implemented in OWL. At last, they applied SPARQL queries to consume and connect data from the applications.

Gugliotta *et al.* (2008) proposed the use of Semantic Web Service (SWS) technology to integrate, mediate and reason with some UK e-Government databases. The authors propose a layers generic application architecture (based on IRS-III) that helped the development of ontologies (in OWL) and SWS descriptions. The ontologies and SWS descriptions supported the development and deployment of Web Services that provided a communication between two UK e-Government applications: Change of Circumstances and Emergency Management System.

Furthermore, concerning OBA-SI, this approach has been used in some integration initiatives such as in Quirino and Falbo (2013) the authors used a Project Time Management Ontology to support the integration of dotProject, a web-based project management system, to ODE, an ontology-based Software Development Environment.

Lastly, in contrast with ontology based integration approaches (like OBA-SI), Janssen and Cresswell (2005) present an approach to take a broader understanding of EAI in government. The initial step is to analyze the business process and application of an e-government and develop an "as is" model, which reflects the current situation of the domain. Based on this "as is" model, integration issues are identified and used to develop a "to be" model, in which the domain concepts are related, to provide an adequate architecture. This architecture represents a middle between the processes and applications.

It can be noticed that different form the cited works, our propose an integration solution includes both a mapping based on ontologies using OBA-SI and an automatized method to extract the databases information using OBDA, providing a complete solution to support the Violent Crime Process.

6. Final Considerations

In this paper, we presented an EAI initiative in the Public Security domain, particularly in the Violent Crimes against Life subdomain. We have used an ontology network (ON), the VCP-ON, to deal with semantic interoperability in this initiative. VCP-ON was used as an "interlingua" to assign semantics to the shared elements by mapping concepts from the applications' conceptual models to concepts from VCP-ON.

The EAI initiative involved the Investigation and Conviction processes, which were considered the VCP bottlenecks, because they produce/consume the largest amount of data in the VCP. The EAI initiative was carried out by following the OBA-SI and involved two applications, namely: DEON and SIEP. The main purpose of the integration was to provide useful information to support monitoring investigated violent crimes and the convictions related to them.

For the development of the integrated solution, we transformed the OntoUML model of VCP-ON in a computational artifact implemented in OWL and adopted ODBA to map the ontology (now in OWL) with the applications' databases. Based on the ontology, a data sample was selected on the two databases (DEON and SIEP) through a SPARQL endpoint. Integration questions, proposed in an integration scenario, were implemented as SPARQL queries.

Finally, the main contribution of this work is supporting the public agencies with an overview of the VCP and the information that flows through it. In sum, the integrated solution offering a middle between the domain and the databases, allowing us to perform queries that cross information of both databases and thus, obtain integrated information.

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