TrAcOn: a Traffic Accident Ontology for Identifying Accidents-prone Areas in Senegal

Abstract

Our research objective is to propose an approach to identifying areas at high risk of accidents in less developed countries like Senegal. In this article, we build an ontology of traffic accidents, called TrAcOn (Traffic Accident Ontology) for a traffic accident description system in Senegal. The ontology allows among others to identify highly accidental areas.

Keywords-traffic accident; ontology; descriptions; formaling; information representation

I. INTRODUCTION

In Senegal as in the world, traffic accidents are responsible each year for many deaths. According to Senegal Ministry of transportation, road insecurity costs at least 163 billion CFA francs per year, or 2% of GDP (Gross Domestic Product). The WAEMU (West African Monetary Economic Union), considering the United Nations resolution on road safety, has enacted the Directive 14-2009CM-UEMOA[1] whose objective is to allow member states to have an information system of traffic accident. In fact, most of underdeveloped countries, especially West Africa countries, have not yet integrated IT solutions into their transport management systems.

Our goal is to offer a computer system for traffic accidents management in Senegal, which can be adapted in other African countries. The system we propose is based on a domain ontology of traffic accidents that reuses existing ontologies in its conception. However, the particular context of road traffic in Senegal characterized by an obsolete car fleet, impassable roads, a lack of traffic signs, etc. involves the introduction of ontological concepts such as: "Car-Rapide", "Ndiaga-Ndiaye", "Clando", "Djakarta", "Charrette", "Pousse-Pousse" which describe specific transport vehicles.

In this article, we construct a domain ontology called Traffic Accident Ontology (TrAcOn) which takes into account all the factors implied in a traffic accident in Senegal and that will be integrated in the road accident management system.

The rest of the article is organized as follows. In section 2, we present the context and ontological needs. In section 3, we present the ontology building by starting with the delimitation of the domain and the scope. Section 4 is devoted to formalization where the ontology is represented by a model. We end with validation by describing an accident example through ontology before before concluding with a summary and outlook.

II. CONTEXT AND ONTOLOGICAL NEEDS

A. Context

Traffic accidents are one of the leading causes of death in the world, especially among people between the age of 5 and 29 according to the World Health Organization report on road safety [1]. Still in this report, the number of deaths caused by traffic accidents reached 1.35 million in 2016 and no low-income country has seen a decline in the number of road traffic fatalities. In Africa, the death rate from traffic accidents is the highest in the world (26.6 / 100,000 inhabitants). In fact, most of underdeveloped countries, especially West Africa countries, have not yet integrated IT solutions into their transport management systems. This situation is so different from that of developed countries which have revolutionized their transport systems in recent years with the advent of Intelligent Transport Systems (ITS). ITS are present in roads management and motorways, transit management systems, incident management systems, etc. They involve Semantic web and ontologies as a

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[1] http://www.uemoa.int/fr/directive-ndeg142009cmuemoa-portant-institution-et-organisation-dun-systeme-dinformation-sur-les

solution to the lack of semantics in the information representation (accidents descriptions) and inference.

Ontologies allow autonomous cars to understand driving environments [2] and to detect overspeed in real time [3]. They are used to define the relationships between autonomous vehicles [4] and thus make it possible to regulate the circulation of intelligent vehicles. In [5], authors propose an ontology-based approach to facilitate the interpretation of the information collected by VANET (Vehicular Ad-Hoc Networks). The ontology developed is interpreted in each vehicle, thus facilitating communication between vehicles and communication between vehicles and infrastructure. In [6], the proposed approach, through an ontology, sets up a system making it possible to make driving decisions at uncontrolled intersections and on narrow roads. The approach differs from that presented in [2] by the possibility of breaking down a complicated case into several situations and integrating the individual results to make a final decision. The approach in [7] uses an ontology to associate the perceived information and its context in the interpretation of traffic scenarios and the estimation of the perceived entities in relation to the subject vehicle. The ontology developed is made up of three elements: mobile entities (vehicles, pedestrians), static entities (roads, intersections) and context parameters that connect two entities according to their state and the distance between them. One of the limits of this approach is that the ontology developed does not allow inference in any context but in the one for which it was defined. A model based on ontologies is also proposed in [8]. It allows autonomous vehicles to make decisions when faced with unusual situations. The ontology proposed in [9] makes it possible to encode the information collected by the sensors of a vehicle for their interoperability with the other actors of the ITS. This ontology involves four components: the accident, the environment, the vehicle and the occupant.

However, these solutions are not suitable in African countries to here the context is different. In fact, most vehicles in these countries and infrastructure do not have intelligent technologies making thus communication between vehicles and their environment difficult. Added to this, the absence of concepts that can describe certain types of transport vehicles in ontologies presented above.

B. Ontological Needs

The aim of our research in this area is to provide a social and semantic web platform for describing and managing traffic accidents in Senegal. This work could be adapted in the context of other African countries having the same difficulties in traffic accidents management and road traffic regulation. The platform is based on an ontology of road accidents. With this ontology and the descriptions, inferences can be made in order to discover new knowledge related to accidents such as the main causes of accidents, the most accidental roads, drivers who commit more fatal accidents, etc.

Thus, in the platform for which the ontology is developed, traffic accidents can be described by three methods:

- manual description by firefighters, police, gendarmerie, witnesses;
- automatic description from images or videos with deep learning methods;
- semantic scraping in the online Senegalese press and social networks.

For illustration, we have collected an online press article of a road accident on Dakaractu[2], described by the following text: "*The public transport bus (Ndiaga-Ndiaye) commonly called "horaire" of Ndoffane which went to the weekly market of Birkelane (Louma) overturned in the early hours of this Sunday, March 8, 2020 near the village of Thiawando (Latmingué). The provisional assessment reports a death and several injured. Informed, the firefighters who deported to the scene of the accident, proceeded to their evacuation to the Kaolack Regional Hospital.*".

This press article informs that the description of road accidents in Senegal is done in a context where existing ontologies cannot take into account in terms of vocabulary. Indeed, the use of local languages terms such as "*Louma*" in the description of accidents in the online Senegalese press and of urban language in social networks like *"horaire"* makes it difficult to use this information. Added to this is the ignorance of the traffic rules which are often different from those of developed countries. Faced with this need, the conception of an ontology of traffic accidents in Senegal finds its relevance.

The following section presents the construction of this ontology.

III. ONTOLOGY BUILDING

To construct the ontology, we adopt the methodology proposed in [14] even if other methods exist in the literature [10, 11 and 12]. This method simplifies defining class hierarchies, properties of classes, instances and is adapted for declarative frame-based systems.

A. Domain delimitation of Traffic accident

An accident, as shown in Figure 1, takes place on an infrastructure and involves one or more vehicles. The accident occurs according to circumstances and produces consequences such as material damage, injured who may be seriously or slightly injured or death. It takes place during a given period and can be relayed by a press article, a tweet, a video, a story told by a witness or a report established by a traffic officer. Infrastructure on which the accident occurs can be a road and is characterized in this case by traffic conditions (visibility, humidity, temperature, pressure, precipitation, wind, etc.). The vehicle involved in the accident is conducted by a driver with a license who commits an infringement and has passengers on board.

[2] https://www.dakaractu.com/Kaolack-Le-Horaire-de-Ndoffane-se-renverse-et-fait-1-mort_a184995.html

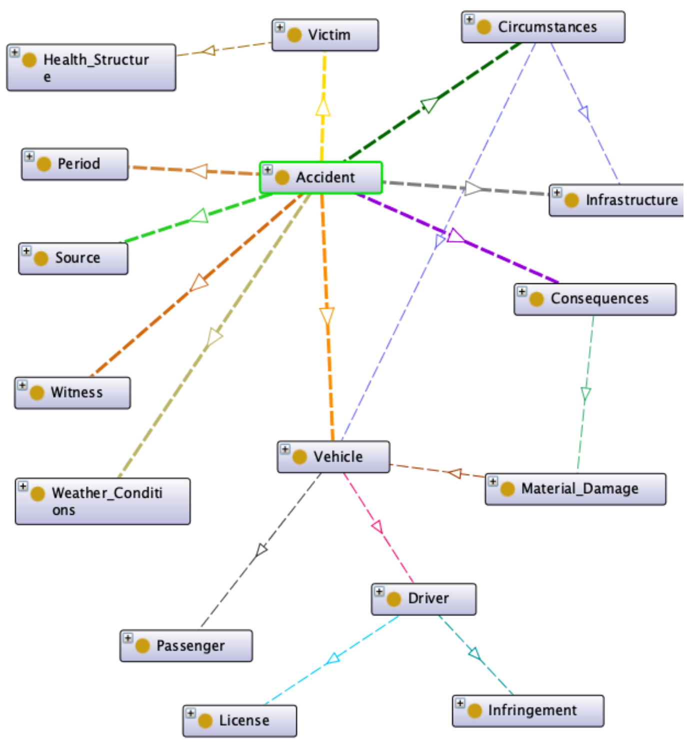

Figure *1*. Accident elements interaction

B. *Reusing existing ontologies*

In our approach, we plan to study the influence of human behavior in accidents. These are first and foremost the drivers, but also passengers, pedestrians and animals that can lead drivers to commit infringements. Thus, we align Traffic Accident Ontology to Neuro Behavior Ontology (NBO)[3], an ontology that describes human and animal behavior and behavioral phenotypes. Behavior is defined in [13] to be the response of an organism or a group of organisms to external or internal stimuli. The neurobehavior ontology [13] consists of two main components, an ontology of behavioral processes as shown in Figure 2 and an ontology of behavioral phenotypes.

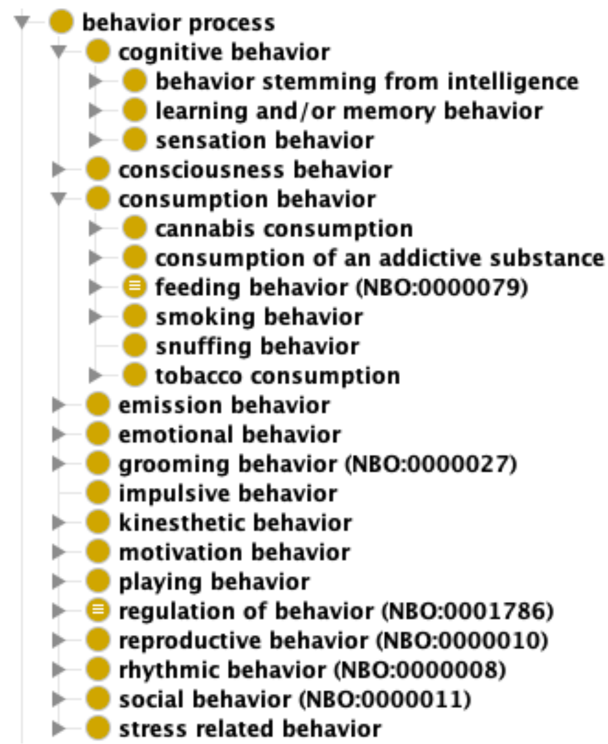

Figure 2. Behavioral process hierarchy in NBO

We will use in our system the Behavioral process to model driver movements in response to the lack of sleep or drug use. Indeed, the accident investigation reports on which we rely to record a traffic accident in Senegal mention the accident causes, in particular the faults committed by the driver. The investigation by security officers will reveal the driver's state of mind during an accident and the possible use of narcotic drugs. In the ontology that we are going to design, the Driver concept will contain a behavioral attribute which describes the set of attitudes observed in a driver during the accident. This attribute is then used for matching at the NBO using an alignment algorithm.

C. *Classes and the class hierarchy*

The ontology must give more information about place as the objective in approach is the identification of areas at high risk of accidents. Figure 3 indicates that an infrastructure can be an intersection, a road, a roundabout or a tunnel. A road is categorized as a tarred road (highways, national road, regional road, departmental road, municipal road, etc.) and untarred road.

[3] http://www.ontobee.org/ontology/NBO

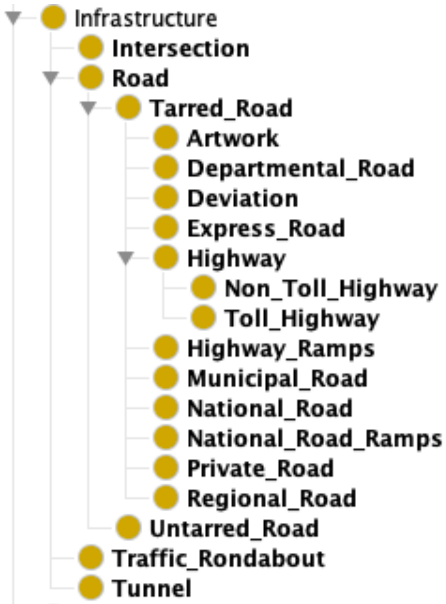

Figure 3. Infrastructures hierarchy

Traffic accident ontology specifies five family that are commercial vehicle, industrial vehicle, private vehicle, public transport vehicle and specific vehicle such as ambulance. Our conceptualization takes into account specific transport vehicles in Senegal such as the Ndiaga-Ndiaye, Car-Rapide and 7-place that are cargo transport vehicles transformed into passenger transport vehicles and the Clando which are non-regularized taxis. The specificity of our field of application means that terms from urban language are integrated into the ontology. Figure 5 illustrates this classification.

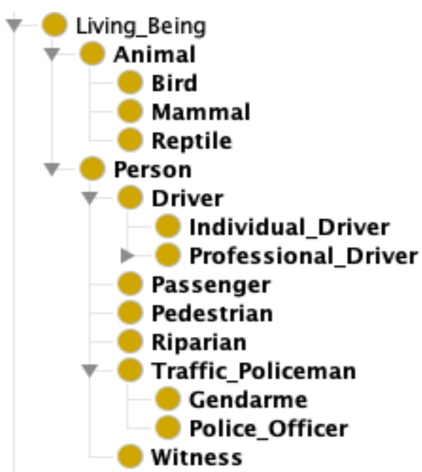

Figure 4. Illustration of the living being classification involved in traffic accident

Traffic Accident Ontology also conceptualizes living beings whose action impacts in accidents. These are animals which can push the driver to make a bad maneuver, pedestrians and neighbors of the road who can be victims, passengers of the vehicle, witnesses of the accident, traffic officers in charge of recording accidents and driver as shown in Figure 4.

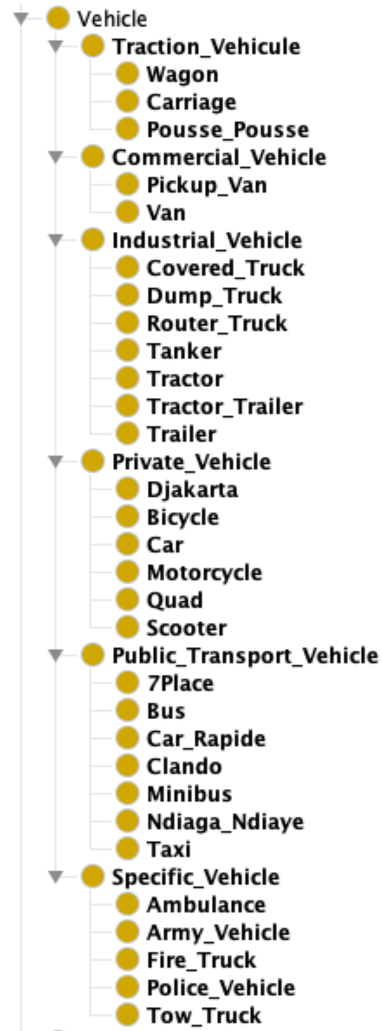

Figure 5. Vehicles hierarchy

In the next section, we formalize the ontology using a model. Model representation gives a clear specification of concepts, relationships, instances and axioms.

IV. ONTOLOGY FORMALING

According to Gruber, ontology defines a set of representational primitives with which to model a domain of knowledge or discourse. The representational primitives are typically classes, properties (attributes) and relations [15]. Such ontology, called light ontology, can be represented by a model O from [16, 17] defined as following:

$$O = \{C, R, A, T, CAR_R, H^C, \sigma_R, \sigma_{CARR}, \sigma_A\}$$

where

- C represents all the concepts of ontology;
- A, all attributes;
- T, a set containing the types of attribute;
- $R \subseteq (C \times C)$ defines associative relations between concepts;

- $H^C \subseteq (C \times C)$ defines hierarchy of concepts;
- CAR_R represents the associative relation R characteristic which can be symmetrical, transitive, reflexive, ...;
- $\sigma_R: R \rightarrow C \times C$ defines the signature of the associative R;
- $\sigma_{CARR}: R \rightarrow CAR_R$ is the signature of the relation specifying characteristic of the relation R. We note an associative relation R_k transitive by signature $\sigma_{CARR}(R_k$, Transitive).;
- $\sigma_A: A \rightarrow C \times T$ defines the signature of the attribute relation between a concept and an attribute.

Example: Consider the accident elements interaction in

Figure 1. The corresponding ontology formalization is defined as followed:

- C = {Accident, Vehicle, Victim, Witness, Damage, Weather_Conditions, Health_Structure, Period, Traffic_Policeman, Driver, License, Infringement, Passenger, Infrastructure, Traffic_Conditions}
- R = {causes, commits, engenders, is_evacuated, has, having, contains, involves, is_driven_by, is_noted_by, is_occurred_during, is_occurred_under, occurs_in_front_of, takes_place_on}
- A = {category, city, description, coordinates, place, visibility, start_time, end_time, age}
- T = {xsd:string, xsd:int. xsd:decimal, xsd:dateTime}
- S_{HC} = {H^c(Fatal_Accident, Accident), H^c(Non_Fatal_Accident, Accident), H^c(Material_Damage_Accident, Accident), H^c(Injured, Victim), H^c(Killed, Victim), H^c(Hospital, Health_Structure), H^c(Health_Center, Health_Structure), H^c(Health_Post, Health_Structure)}
- $S_{\sigma R}$ = {σ_R(Accident, causes, Victim), σ_R(Driver, commits, Infringement), σ_R(Vehicle, contains, Passenger), σ_R(Victim, is_evacuated, Health_Structure), σ_R(Driver, has, License), σ_R(Infrastruture, having, Traffic_Conditions), σ_R(Accident, involves, Vehicle), σ_R(Vehicle, is_driven_by, Driver), σ_R(Accident, is_noted_by, Traffic_Policeman), σ_R(Accident, is_occurred_during, Period), σ_R(Accident, is_occurred_under, Weather_Conditions), σ_R(Accident, occurs_in_front_of, Witness), σ_R(Accident, takes_place_on, Infrastruture)}
- $S_{\sigma A}$ = {σ_A(License, category, xsd:string), σ_A(Infrastruture, city, xsd:string), σ_A(License, delivery_year, xsd:int), σ_A(License, duration, xsd:int), σ_A(Accident, description, xsd:string), σ_A(Accident, place, xsd:string), σ_A(Accident, latitude, xsd:decimal), σ_A(Accident, longitude, xsd:decimal), σ_A(Weather_Conditions, visibility, xsd:string), σ_A(Period, start_time, xsd:dateTime), σ_A(Period, end_time, xsd:dateTime), σ_A(Victim, age, xsd:int)}
- $S_{\sigma CARR}$ = {σ_{CARR}(causes, Asymmetric), σ_{CARR}(causes, Irreflexive), σ_{CARR}(commits, Asymmetric), σ_{CARR}(commits, Irreflexive), σ_{CARR}(engenders, Asymmetric), σ_{CARR}(engenders, Irreflexive)}

The ontology we formalized currently contains 134 concepts, and 23 object properties.

V. VALIDATION

In this part, we describe a traffic accident recorded in the Minutes through our ontology. The first thing is to collect all the useful information, create the corresponding class instances and link them with the properties. An example created from the Minutes[4] is given below:

```xml
<owl:NamedIndividual rdf:about="#PV01">
    <rdf:type rdf:resource="#Minutes"/>
    <TrAcOn:author>Gendarmerie Nationale-Peloton routier de Boumnyebel</TrAcOn:author>
    <TrAcOn:case>Bilounga Armand et autres</TrAcOn:case>
    <TrAcOn:minutes_number>Proces-verbal no 1109 du 24/10/2017</TrAcOn:minutes_number>
</owl:NamedIndividual>

<owl:NamedIndividual rdf:about="#AC01">
    <rdf:type rdf:resource="#Accident"/>
    <TrAcOn:comes_from rdf:resource="#PV01"/>
    <TrAcOn:involves rdf:resource="#CETR-045-DA"/>
    <TrAcOn:involves rdf:resource="#CETR-566-CA"/>
    <TrAcOn:involves rdf:resource=#LT-370-GP"/>
    <TrAcOn:occurred_according_to rdf:resource="#CR-01"/>
    <TrAcOn:occurred_during rdf:resource="#P01"/>
    <TrAcOn:produces rdf:resource="#CQs-01"/>
</owl:NamedIndividual>

<owl:NamedIndividual rdf:about="#CQs-01">
    <rdf:type rdf:resource="#Consequences"/>
    <TrAcOn:includes rdf:resource="#DM-01"/>
    <TrAcOn:includes rdf:resource="#DM-02"/>
    <TrAcOn:includes rdf:resource="#DM-03"/>
    <TrAcOn:number_of_dead>14</TrAcOn:number_of_dead>
    <TrAcOn:number_of_injured>18</TrAcOn:number_of_injured>
</owl:NamedIndividual>

<owl:NamedIndividual rdf:about="#DM-01">
    <rdf:type rdf:resource="#Material_Damage"/>
    <TrAcOn:is_evaluated_on rdf:resource="#LT-370-GP"/>
    <TrAcOn:degree>trés important</TrAcOn:degree>
</owl:NamedIndividual>
```

[4] https://mkgaye.com/wp-content/uploads/2020/04/PV_Accident_General_Express1.jpg

```xml
<owl:NamedIndividual rdf:about="#DM-02">
    <rdf:type rdf:resource="#Material_Damage"/>
    <TrAcOn:is_evaluated_on rdf:resource="#CETR-045-DA"/
    <TrAcOn:degree>moins important</TrAcOn:degree>
</owl:NamedIndividual>

 <owl:NamedIndividual rdf:about="#DM-03">
     <rdf:type rdf:resource="#Material_Damage"/>
     <TrAcOn:is_evaluated_on rdf:resource="#CETR-566-CA"/>
     <TrAcOn:degree>neant</TrAcOn:degree>
 </owl:NamedIndividual>

<owl:NamedIndividual rdf:about="#INF-02">
    <rdf:type rdf:resource="#Infringement"/>
    <TrAcOn:nature>circulation en sens inverse</TrAcOn:nature>
</owl:NamedIndividual>

<owl:NamedIndividual rdf:about="#INF-01">
    <rdf:type rdf:resource="#Infringement"/>
    <TrAcOn:nature>mal stationne et non signale</TrAcOn:nature>
</owl:NamedIndividual>

<owl:NamedIndividual rdf:about="#INF-03">
    <rdf:type rdf:resource="#Infringement"/>
    <TrAcOn:nature>depacement interdit</TrAcOn:nature>
</owl:NamedIndividual>

<owl:NamedIndividual rdf:about="#WERICHOH">
    <rdf:type rdf:resource="#Driver"/>
    <TrAcOn:commits rdf:resource="#INF-01"/>
    <TrAcOn:name>WERICHOH MORYAH Gildert</TrAcOn:name>
</owl:NamedIndividual>
```

Once the ontology is populated, we can query it to calculate the frequency of accidents on each section of road and thus classify them by degree of dangerousness.

CONCLUSION

In this paper, we construct a domain ontology on traffic accident for identifying areas at high risk of accidents in less developed countries. We first built using an iterative construction method. We then proposed a model for formalizing the ontology before populating it with data from xxx for validation. Our proposal made it possible to have structured and semantic data on traffic accidents and also helped to resolve difficulties linked to traffic accidents management.

In the future work, we continue to populate the ontology with data from the Senegalese online press and police investigation reports which will allow an inference in any context of traffic accident**.** In a second step, the populating of the ontology will be done automatically with images recognition taken during accident. We will investigate the Graphs Theory including Bayesian Networks, Markov Chains, Propagation of beliefs among others for reasoning on the sanctions to be applied to drivers at fault.

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