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An Ontology for Intra-Campus Transport System (ICTS) (A Case Study of the University of Ibadan Campus)

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ABSTRACT

Knowledge representation can greatly improve the effectiveness and efficiency of an organization, business or firm if its benefits are properly harnessed. Ontology is a knowledge representation technique that involves formalization of world knowledge. Existing transport-related ontologies have not really captured and represented the basics of a transport system. This has made it difficult for information systems and machines to access, understand and share basic knowledge about transport domain. The Intra-Campus Transport System (ICTS) which handles the transportation of people within an institution can therefore serve as a prototype for transport systems. This research work is therefore aimed at developing a formal ontology for the intra-campus transport system which enhances availability of knowledge and a quick retrieval system. A very thorough knowledge engineering approach is adopted for this research work. It involves knowledge gathering, also known as ontology capture which gives important factual knowledge that exists in the ICTS domain. This is followed by knowledge refining and analysis, which involves categorizing the gathered knowledge into classes, properties and individuals. Knowledge formalization is used to translate the refined knowledge into a logical form using description logic tools. Lastly, the logical axioms were implemented with web ontology language (OWL) format using Protégé 5.0.

Keywords: Formal ontology, Intra-Campus Transport System (ICTS), Description logic, Web ontology language.

1. INTRODUCTION

The importance and usefulness of knowledge cannot be over-emphasized in the present age we live in. To be specific, artificial intelligence (AI) has single-handedly brought about the evolution of knowledge representation which might be mistaken by the layman as a trivial concept. It is based on the premise that intelligent thoughts can be regarded as a form of computation through formalization and mechanization [1]. Knowledge representation and utilization has been identified to be an important key to the success and sustainability of most establishments, organizations and even start-ups [2].

Knowledge representation is one of the central and in some ways most familiar concept in artificial intelligence [3]. It can be best understood via the roles it plays in areas of ontological commitments, fragmentary theory of intelligent reasoning, computation and medium for human expression. Basically, ontology helps to spell out the concepts available in a domain [4, 5], defining the concepts, discovering the underlying facts [6] and creating rules and constraints that binds the relationships between the concepts. It is therefore pertinent to understand that ontology can be applied to the intra-campus transport system (ICTS) in order to make it more effective. Even though ontology and knowledge representation have been applied to various domains including some aspects of transport domain in the recent past, yet, ontology that thoroughly captures and explicitly represents the operations of a transport system is hard to come by.

The intra-campus transport system (ICTS) is a body that coordinates the transportation system within an institution's campus. Currently, all the activities of the ICTS are based on primitive-oriented operations which involve and solely rely on the use of unprocessed information derived from ambiguous knowledge. This makes it impossible for information systems and machines to access, understand and share knowledge about the domain. It is therefore necessary to present this knowledge in such a way that will eliminate the ambiguity, promote clarity and achieve a more efficient workflow in the ICTS. Without mincing words, the motivation behind this research work is nonetheless due to the benefit that the ICTS would accrue from the ontological essence which is not only limited to the sharing of knowledge, reusability of knowledge and intergration-enability amongst others, but also solves the problem of knowledge availability, search and retrieval system.

Hence, this work develops a formal activity-based ontology for the intra-campus transport system domain which can be used as a framework for further implementation of a cutting edge ICTS. It spells out the entities, activities, relationships and all necessary operations involved in the ICTS. This formalization has created the possibility of information systems and intelligent machines to access, retrieve, understand and make use of this knowledge, thereby extending the domain to a further automated environment, allowing for reusability, sharing and unambiguous knowledge use.

2. REVIEW OF RELATED WORKS

One of the fundamental issues in artificial intelligence is the problem of knowledge representation [7]. Knowledge representation has to do with how knowledge and facts about the world can be represented and what kind of reasoning can be done with that knowledge. In order to achieve the purpose of artificial intelligence, the issue of knowledge representation must be addressed [1]. This is because the means by which information is communicated greatly affects the understanding of such information. Hence, the need to pay attention to the model or language used to represent the knowledge.

Knowledge representation involves a knowledge base and an inference engine. The knowledge base refers to the set of sentences that describes knowledge about a domain while inference engine is the set of procedures that uses the represented knowledge to infer new facts from existing knowledge or answer queries. There are various knowledge representation techniques such as logics, semantic net, frames, script and production rules [8]. Good knowledge representation languages must be expressive, concise, unambiguous, independent of context, efficient and effective. Formal logic and deductive reasoning have been able to address the problems in knowledge representation and common sense reasoning [9]. Ontology is a formal mechanism for representing the world knowledge, out of which effective and easy reasoning is possible during knowledge sharing [7]. The word "ontology" seems to generate a lot of controversy in discussions about AI. It has a long history in philosophy, in which it refers to the subject of existence. It is also often confused with epistemology, which is about knowledge and knowing.

In the context of knowledge sharing, the term ontology means specification of conceptualization i.e. ontology is a description (like a formal specification of a program) of the concepts and relationships that can exist for an agent or a community of agents [10, 11]. This definition is consistent with the usage of ontology as set-of-concept-definitions. An ontology defines the terms used to describe and represent an area of knowledge [12, 13]. Ontologies are critical for applications that need to search across or merge information from diverse communities. Ontology can also serve as a standard or source for vocabulary, content theory and an important tool for describing the world [14]. In the context of Semantic Web, ontologies describe domain theories for the explicit representation of the semantics of the data. Ontologies play an important role in achieving interoperability across organizations and on the semantic web [15].

Any logical deduction on the basis of a formal ontology is defined as reasoning [16]. Different reasoning services are offered by inference engines (also called reasoners) depending on the ontology language. An ontology language needs to be based on a logical form to enable inference and reasoning. Description Logics (DLs) consider a decidable subset of first-order logic (FOL) with well-understood inference rules, but FOL is not generally decidable; this decidability is very convenient for reasoning about ontologies [17]. Logics-based language is in fact required to facilitate inference and reasoning. Reasoning is used in several development phases to ensure the quality of ontologies [18]. It could be used to check whether concepts are consistent and to obtain implied relations during ontology design. Inference engines such as FaCT and RACER have been successfully implemented in practical reasoning systems to provide reasoning services. Some related works are described below.

2.1 An Ontology for Licensing Public Transport Services (Cledou and Barbosa, 2010)

This research work is focused on an important aspect of public transport which has to do with ensuring the licensing of transport services to fulfill existing government regulations. The paper proposed ontology for licensing such services following the REFSENO methodology. In particular, the ontology captures common concepts involved in the application and processing stage of licensing public bus passenger services. The main contribution of the ontology is to define a common vocabulary to share knowledge between domain experts and software engineers, and to support the definition of a software product line for families of public transport licensing services. The research however was limited in certain area which includes the need to further validate the adequacy of the ontology for the modeled domain, and the need for adopting an additional mechanism to model license specific requirements to guide the instantiation of particular license services [19].

2.2 Public Transport Ontology for Passenger Information Retrieval (Jain et al, 2014)

This research work was based on an ontology whose focus was on passenger information retrieval. The paper develops a domain specific ontology for public transport systems, which is further integrated with the domain-ontology of urban features with an objective of supporting multi-modal public transport information retrieval. The ontology thus developed is formalized using Web Ontology Language. However, as the ontology was solely focused on urban transportations and passenger information retrieval, the possibility of reusing some of the concepts and relations in smaller transport systems is discouraged. Also, certain entities involved in transportations were left out, hence, minimizing the reuse of the ontology at large [20].

2.3 Ontology-Driven Legal Support-System in Air Transport Passenger Domain (Rodríguez-Doncel et al, 2014)

This research is aimed at presenting a preliminary version of a support-system in the air transport passenger domain which relies upon an underlying ontological structure. The contribution of this research work includes rendering a user centric- legal information grounded on case-scenarios of the most pronounced incidents related to the consumer complaints in the EU. As mentioned, it was only presenting a preliminary version to legal issues as regards air transportation, which means most of the work is still ongoing; however, it was able to steer knowledge representation in the direction of the semantic web applied in the air transport passengers' domain [21].

3. METHODOLOGY

A proper ontological engineering procedure is used in the development of the ICTS ontology. The procedure is broken down into the following stages to achieve an effective and efficient ontology:

a Knowledge gathering, which is similar to ontology capture in ontology engineering

b. Knowledge refining and analysis, which categorizes gathered knowledge into classes, individuals and properties.

c. Knowledge formalization, which encompasses the use of description logic on accrued knowledge needed for coding the ontology.

d. Ontology coding, which has to do with the translation of the description logics into web ontology language (owl) using protégé ontology editing tool.

e. Testing the ontology with competency questions.

3.1 Knowledge Gathering

Structured and unstructured interviews were carried out in order to get the current knowledge that exists in the ICTS domain. Knowledge was gathered to capture all the operations and activities involved in the intra campus transport system. The knowledge gathered was further classified into facts, definitions and constraints. Examples are given below:

a. Facts: e.g.
   - i. The Intra campus transport system is affiliated to an Institution
   - ii. ICTS activities are divided into two categories; some are official activities, while others are unofficial activities.
   - iii. The Intra campus transport system has various vehicle parks
   - iv. The ICTS has vehicles that are used in its operations
   - v. Transport union screens all applications received
   - vi. A route is same as a path.

b. Definitions: e.g.
   - i. A passenger is a person that boards a vehicle at a source and alights at a destination
   - ii. A driver is a person that knows how to drive a vehicle.
   - iii. A passenger is a person
   - iv. An active driver is a driver that transports passengers in the ICTS and is also approved by the transport union to drive.
   - v. A personal vehicle is a vehicle owned by an active driver
   - vi. A vehicle leaser is a person that leases a vehicle and is not an active driver
   - vii. A leased vehicle is a vehicle owned by a vehicle leaser

c. Constraints: e.g.
   - i. A vehicle is called a drop vehicle if it can accommodate not more than 2 passengers
   - ii. A passenger cannot be a novice passenger and an acquainted passenger in an instance.
   - iii. An applicant cannot be both successful and unsuccessful in an instance; they are disjointed classes with each other.
   - iv. A driver is called an illegal driver if he transports passengers in the ICTS without the approval of the transport union.

3.2 Knowledge Refining and Analysis `

The knowledge gathered from the previous stage is refined and analyzed in this stage. This involves breaking down the raw facts, definitions and constraints into three categories (classes, individuals and properties) using the web ontology language requirements. This is necessary as the ontology will eventually be coded using owl.

a. Classes: e.g. Driver, Passenger, Vehicle, VehiclePark, Application, Applicant, Activity, Requirement, ApplicationFee, RegistrationFee
b. Individuals: e.g. UIICTS, UNIVERSITY_OF_IBADAN, SUB, ZOO_JUNCTION, SCHOOL_GATE
c. Properties: e.g. HasInstitution, HasVehicle, IsOwnerOf, ApprovedBy, IsDriverOf, HasDriver, NotFamiliarWith, HasFunction, HasDuty, IsVehicleParkOf.

The ICTS class hierarchy is shown in Figure 1

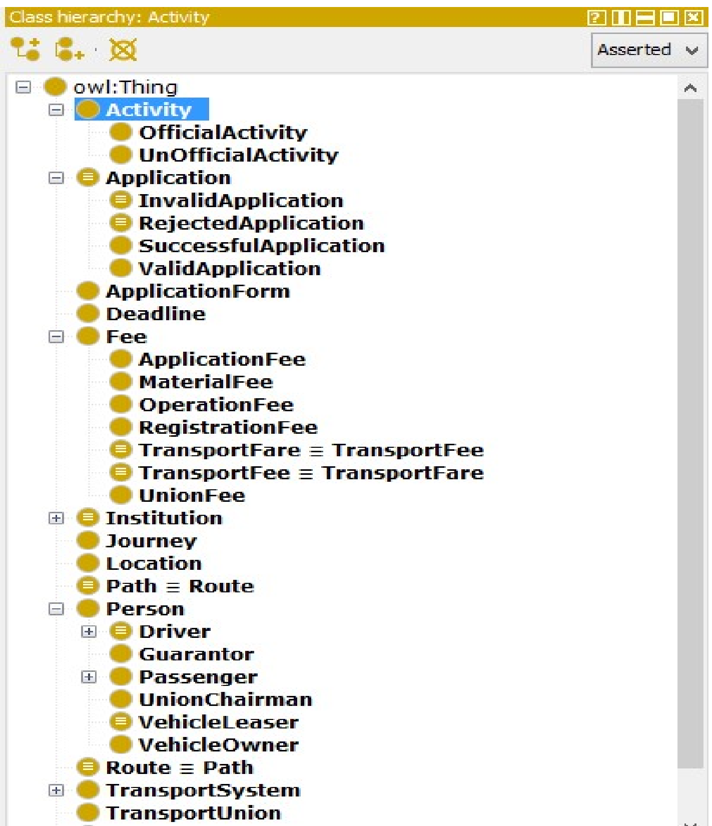

Figure 1: ICTS Class Hierarchy

3.3 Knowledge Formalization

Knowledge formalization involves the representation of the analyzed facts, definition and constraints using mathematical method called logic. Description logic is chosen for this purpose due to its ability to add semantics to information to give it meaning. Description logic terminologies such as conjunction, equivalence, negation, disjunction, concept inclusion, existential quantifier and universal quantifier were used to achieve the formalization purpose.

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3.3.1 Facts

Fact1: The Intra campus transport system is affiliated to an Institution
$\text{ICTS} \sqcap \text{hasInstitution.Institution}$
Fact2: The activities of the intra campus transport system can either be official or unofficial.
$\text{Activity} \equiv \text{OfficialActivity} \sqcup \text{UnofficialActivity}$
Fact3: The Intra campus transport system has various vehicle parks
$\text{ICTS} \sqcap \text{hasVehiclePark.VehiclePark}$
Fact4: The ICTS has vehicles that are used for its operations
$\text{ICTS} \sqcap \text{hasVehicle.Vehicle}$
Fact5: Transport union screens all applications received
$\text{TransportUnion} \sqcap \text{screensApplication.Application}$
Fact6: A route is same as a path.
$\text{Route} \equiv \text{Path}$
Fact7: All official activities of the ICTS is a function of the ICTS Transport union
$\text{OfficialActivity} \sqcap \text{isFunctionOf.TransportUnion}$
Fact8: All unofficial activities of the ICTS is a function of an active driver
$\text{UnOfficialActivity} \sqcap \text{isFunctionOf.ActiveDriver}$
Fact9: The Vehicle parks have certain locations within the institution campus.
$\text{VehiclePark} \sqcap \text{hasLocation.Location}$
Fact10: A vehicle park can either be a centralized vehicle park or a mini vehicle park
$\text{VehiclePark} \equiv \text{CentralizedVehiclePark} \sqcup \text{MiniVehiclePark}$
Fact11: The ICTS has certain payment attached to its activities which are called fees.
$\text{ICTS} \sqcap \text{hasFee.Fee}$
Fact12: The ICTS fee can either be an operation fee, registration fee, application fee, registration fee, material fee or union fee.
$\text{Fee} \equiv \text{OperationFee} \sqcup \text{ApplicationFee} \sqcup \text{RegistrationFee} \sqcup \text{MaterialFee} \sqcup \text{UnionFee} \sqcup \text{TransportFee}$
Fact13: A vehicle can be a personal vehicle or a leased vehicle
$\text{Vehicle} \equiv \text{PersonalVehicle} \sqcup \text{LeasedVehicle}$

3.3.2 Definitions

The formalisation of some of the definitions in the domain are given below:

Definition1: A passenger is a person that boards a vehicle at a source and alights at a destination
$\text{Passenger} \equiv \text{Person} \sqcap \exists\text{boardsVehicleAt.Source} \sqcap \exists\text{alightsVehicleAt.Destination}$
Definition2: A driver is a person that knows how to drive a vehicle.
$\text{Driver} \equiv \text{Person} \sqcap \text{knowsHowToDrive.Vehicle}$
Definition3: A passenger is a person
$\text{Passenger} \subseteq \text{Person}$
Definition4: An active driver is a driver that transports passengers in the ICTS and is also approved by the Transport union to drive.
$\text{ActiveDriver} \equiv \text{Driver} \sqcap \text{transportsPassenger.Passenger} \sqcap \text{approvedBy.TransportUnion}$
Definition5: A personal vehicle is a vehicle owned by an active driver
$\text{PersonalVehicle} \equiv \text{Vehicle} \sqcap \text{ownedBy.ActiveDriver}$
Definition6: A vehicle leaser is a person that leases a vehicle and is not an active driver
$\text{VehicleLeaser} \equiv \text{Person} \sqcap \text{leasesVehicle.Vehicle} \sqcap \neg\ \text{ActiveDriver}$
Definition7: An eligible applicant is an applicant driver who has a valid application and meets all necessary requirement
$\text{ElligibleApplicant} \equiv \text{ApplicantDriver} \sqcap \text{hasValidApplication.ValidApplication} \sqcap \forall\text{meetsRequirement.Requirement}$

3.3.3 Constraints e.g.

Constraint1: An application cannot be both valid and invalid at the same time. They are disjointed classes with each other.

$ValidApplication \subseteq \neg InvalidApplication$

Constraint2: A driver can be called illegal if he transports passengers in the ICTS without the approval of the transport union:

$IllegalDriver \equiv Driver \sqcap transportsPassenger.Passenger \sqcap notApprovedBy.TransportUnion$

Constraint3: A vehicle cannot be a drop vehicle and a passenger vehicle at the same time

$DropVehicle \subseteq \neg PassengerVehicle$

Constraint4: A vehicle cannot be a personal vehicle and a leased vehicle at the same time.

$PersonalVehicle \subseteq \neg LeasedVehicle$

Constraint5: An eligible applicant cannot be a rejected applicant or ineligible applicant in an instance.

$ElligibleApplicant \subseteq \neg (RejectedApplicant \sqcup InelligibleApplicant)$

Constraint6: An application is valid if and only if it consists of a correctly filled application form, submitted before deadline and application fee fully paid.

$ValidApplication \equiv Application \sqcap correctlyFilled.ApplicationForm \sqcap submittedBefore.Deadline \sqcap paysApplicationFee.ApplicationFee$

Constraint7: A drop vehicle is a vehicle that cannot accommodate more than two passengers

$DropVehicle \equiv Vehicle \sqcap \leq 2\ canAccomodate.Passenger$

3.4 ICTS Ontology Coding

The ICTS ontology coding phase is the process of representing the logical expressions that was formed based on the information gathered in a machine readable form. The language chosen is the web ontology language (OWL) and it is based on the Extensible markup language (XML) of the World Wide Web (WWW). Protégé tool is used to facilitate the coding process. The coding of the ICTS ontology is broken down into the following areas for ease of understanding.

a. Class representation: This is the first step in the ontology coding. It deals with the coding of the concepts that have been identified in the previous stages e.g.

```
Concept: Person
<Declaration>
        <Class IRI="#Person"/>
</Declaration>
```

b. Class hierarchy representation: This is used to model sub classes and super class i.e. to represent divisions and categories that exists between concepts. E.g.

```
Class hierarchy: Person (Driver, Passenger etc.)
        <SubClassOf>
                <Class IRI="#Driver"/>
                <Class IRI="#Person"/>
        </SubClassOf>
```

c. Object property representation: The object properties are defined here to serve as a form of communication link between concepts and classes. This is because concepts alone cannot provide meaning to an ontology:

Object property: Driven by

```
<SubObjectPropertyOf>
     <ObjectProperty IRI="#drivenBy"/>
     <ObjectProperty abbreviatedIRI="owl:topObjectProperty"/>
  </SubObjectPropertyOf>
```

d. Data type representation: This is defined to show the relationships with members of a class and data values (literals) e.g.

Data property: Fee amount

```
<Declaration>
     <DataProperty IRI=”#feeAmount”/>
</Declaration>
```

e. Domain and range relationship: This is used to define the relationships between classes, object properties and data properties in a given factual knowledge. E.g.

Fact: A vehicle is been driven by an active driver:

```
<ObjectPropertyDomain>
     <ObjectProperty IRI="#drivenBy"/>
     <Class IRI="#Vehicle"/>
  </ObjectPropertyDomain>
<ObjectPropertyRange>
     <ObjectProperty IRI="#drivenBy"/>
     <Class IRI="#ActiveDriver"/>
 </ObjectPropertyRange>
```

f. Disjoint class representation: Here, classes that cannot have overlapping individuals are represented e.g.

Fact: A vehicle cannot be a bus, car, minivan or motorbike at a time.

```
<DisjointClasses>
     <Class IRI="#Bus"/>
     <Class IRI="#Car"/>
     <Class IRI="#MiniVan"/>
     <Class IRI="#MotorBike"/>
 </DisjointClasses>
```

g. Complex definitions: This is used to represent complex facts about the ICTS domain e.g.

Fact: An elligible applicant is an applicant driver who has made a valid application and meets all specified requirement:

```
<EquivalentClasses>
     <Class IRI="#ElligibleApplicant"/>
     <ObjectIntersectionOf>
       <Class IRI="#ApplicantDriver"/>
       <ObjectSomeValuesFrom>
         <ObjectProperty IRI="#hasValidApplication"/>
         <Class IRI="#ValidApplication"/>
       </ObjectSomeValuesFrom>
```

```
                <ObjectAllValuesFrom>
                    <ObjectProperty IRI="#meetsRequirement"/>
                    <Class IRI="#Requirement"/>
                </ObjectAllValuesFrom>
            </ObjectIntersectionOf>
        </EquivalentClasses>
```

h. Restrictions: This is used to place restrictions on certain ontology classes e.g.

Restriction: A drop vehicle can accommodate not more than 2 passengers:

```
<EquivalentClasses>
        <Class IRI="#DropVehicle"/>
        <ObjectIntersectionOf>
            <Class IRI="#Vehicle"/>
            <ObjectMaxCardinality cardinality="2">
                <ObjectProperty IRI="#canAccomodate"/>
                <Class IRI="#Passenger"/>
            </ObjectMaxCardinality>
        </ObjectIntersectionOf>
    </EquivalentClasses>
```

3.5 ICTS Ontology Competency Questions:

Examples of the competency questions used to validate the ontology are given below:

a. Give the list of all successful driver applications.
b. What are the form identifications of all rejected applications?
c. Give the list of drivers who have paid registration fee?
d. Give a list of all vehicles that operate in the UIICTS.
e. Which locations are available for routes A, B, C, D, E and F?

4. IMPLEMENTATION & RESULT

This research work is not only based on building the ICTS ontology but on building a correct and consistent ontology. The reasoning of the ICTS ontology was ensured so as to have the various classes in the right hierarchy and the properties linked to the classes without contradictions. HERMIT reasoner was used in this research work. HERMIT is attached as a plugin to the Protégé 5.0 ontology editor and it is used basically for the following:

a. Consistency and contradiction: The Hermit reasoner checks for inconsistent and contradictory classes and properties in the ICTS ontology.

b. Equality: In the ICTS ontology, when two classes are represented as equal classes, the HERMIT reasoner automatically enables the properties of both classes to be replicated on both sides. Figure 2 shows the class TransportFare and TransportFee as equivalent classes.

Figure 2: Class Equality

c. Inverse property: Whenever an object property is represented as an inverse to another object property, the HERMIT reasoner automatically enables the domain of the main object property as range of the inverse property; it also enables the range of the main object property as domain of the inverse property.

4.1 Answer to the Competency Question: Give the list of all successful driver applications

Figure 3 shows the list of successful applicants.

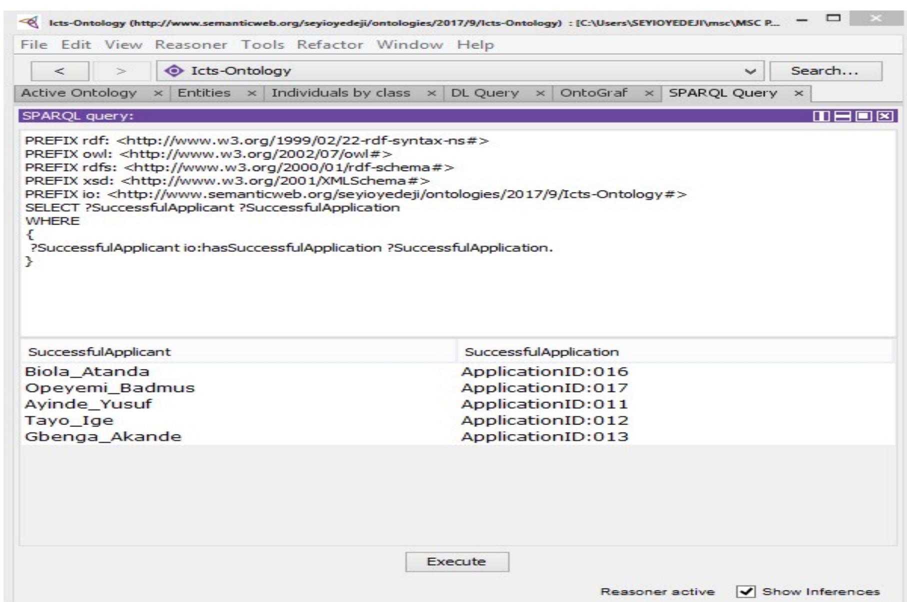

Figure 3: List of successful applications

4.2 Answer to the Competency Question: What are the form identifications of all rejected applications?

Figure 4 shows the list of rejected applications.

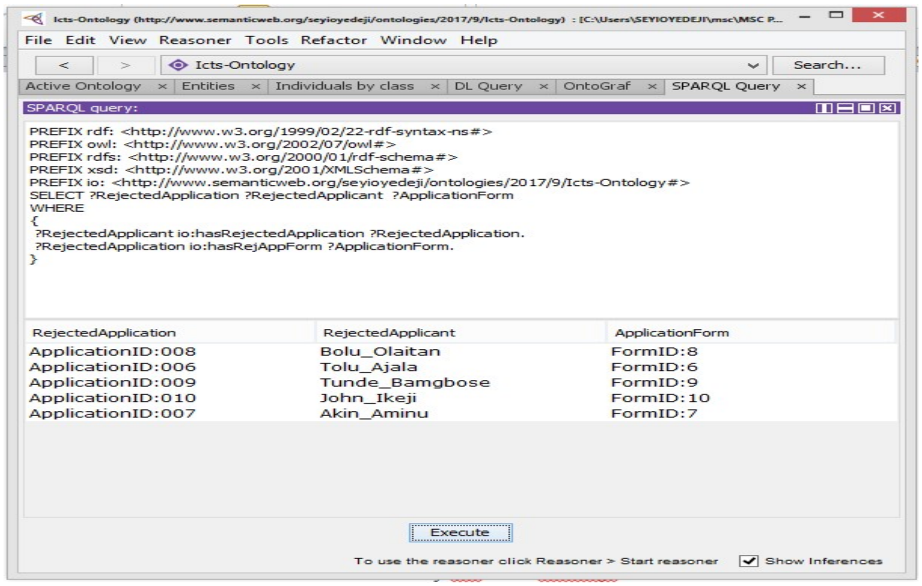

Figure 4: Form identifications of all rejected applications

4.3 Answer to the Competency Question: Give the list of drivers who have paid registration fee?

Figure 5 shows the list of drivers who have paid registration fees.

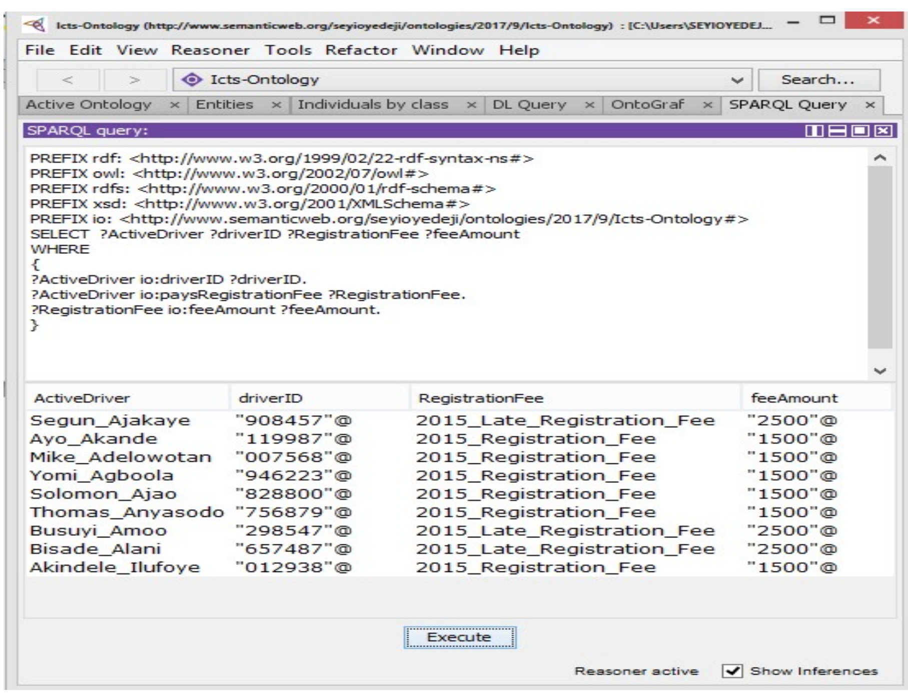

Figure 5: Drivers who have paid registration fee

4.4 Answer to the Competency Question: Give a list of all vehicles that operate in the UIICTS.

Figure 6 shows the list of all vehicles in the ICTS and their drivers.

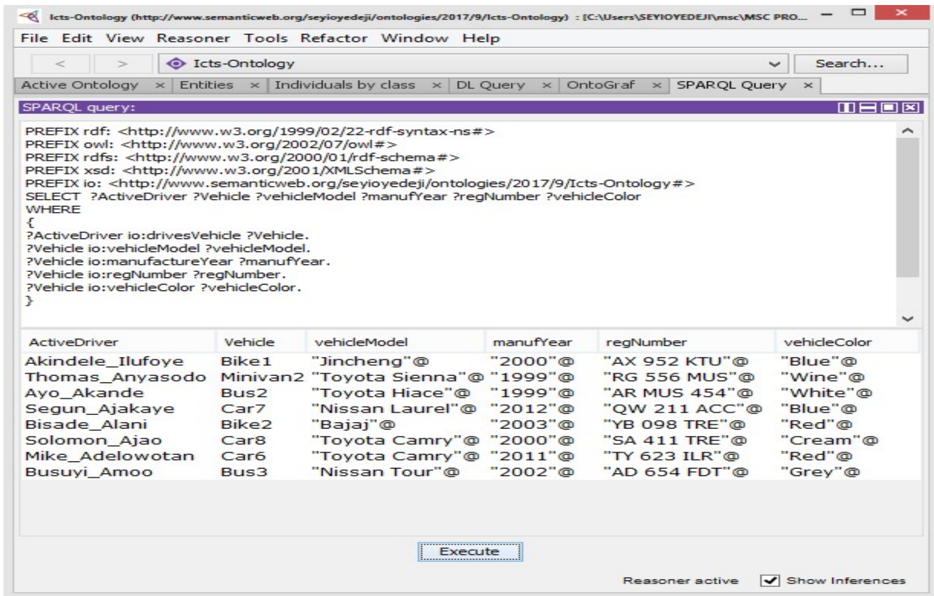

Figure 6: List of Vehicles in the ICTS

4.5 Answer to the Competency Question: Which locations are available for routes A, B, C, D, E and F?

Figure 7 shows the locations of the specified routes.

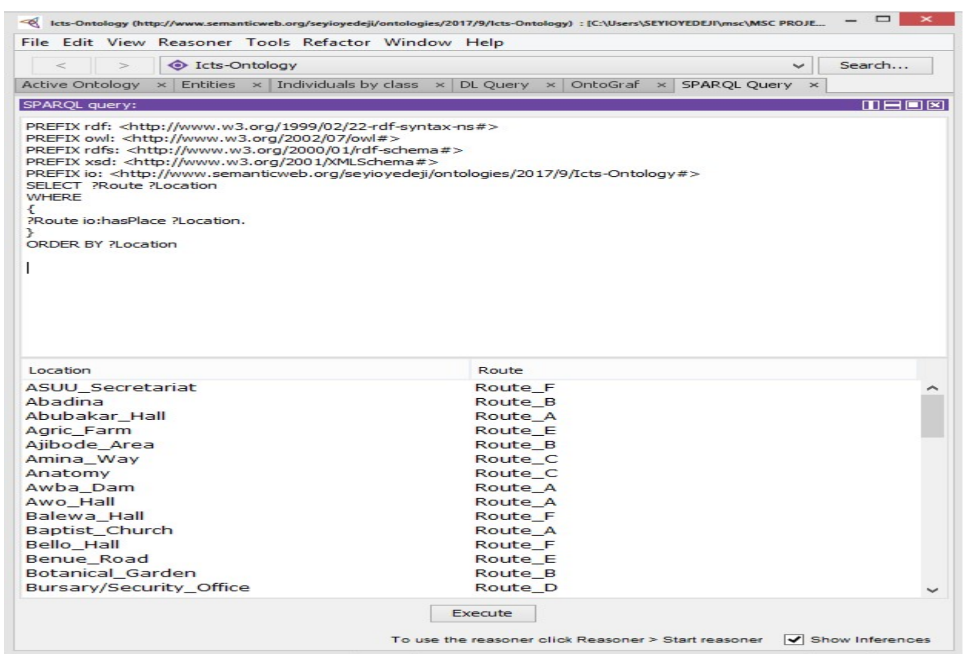

Figure 7: Routes and Locations

5. CONCLUSION

This ontology can assist people within the university community and those just paying a visit to know the necessary information about the transportation system in the campus. The evaluation of the ontology was done in an interactive manner using competency questions. The competency questions were used as a probe in form of a query to request knowledge from the ontology and the results were analyzed and compared with real life knowledge and found to be the same.

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