ONTOLOGY BASED UML2 COMPONENT ARCHITECTURE GENERATION

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Abstract: UML2 Component diagrams are mainly used to provide information about the technical architecture of the information system. The paper shows how a component diagram can be auto-generated from an ontology chart evolved from Semantic Analysis. A crowd management case study has been selected for its complexity and its capacity to illustrate all the properties that are developed in the paper. It is anticipated that the results of this paper would provide additional features for the system designers and developers.

1 INTRODUCTION

Component diagram is part of UML2 and is mainly used to provide information about the technical architecture of the information system. The main idea behind is that a component is a container that can contain class or other components as well as their associations. Components of the same systems may be in different physical locations and still be associated and can collaborate with each other. The same component may be serving multiple other components at the same time.

MEASUR's semantic analysis is a modelling methodology for modelling organizations. According to its founder R. Stamper, the method has a number of benefits for information systems (Stamper, 2008). The method identifies the agents – physical and legal persons, affordances – substances and their determiners – temporal attributes and demands that every affordance is directly or indirectly ontologically depended to an agent. An affordance is directly linked with an agent if one of its antecedents is an agent and indirectly if while following the antecedents of its antecedent's recursively we end up to having an agent. Every affordance must have an antecedent and can have up to two antecedents. The method produces a diagram called ontology chart. In this chart, every agent, affordance and determiner will be mapped to a node and the ontologically dependencies are shown by a line. Ontology chart can be mapped to database schemas, class diagrams (Ades, et al., 2007) and other software engineering artefacts (Poernomo & Tsaramirsis, 2008). In this paper we will take advantage of the ontological dependencies of the ontology charts and we will use them to produce UML2 component diagrams.

2 RELATED WORK

There are a number of papers that demonstrate how to transform an ontology chart to class diagram, prototype system and software architecture. The two most recent ones are the "SNF compliant implementation" (Ades, et al., 2009) and "course gain architectures" (Poernomo, et al., 2009) both were presented at ICISO 2009. The first of these papers compares two ways of implementing SNF compliant software namely, the Model Driven Architecture approach and the SNF native technology approach. The paper concludes that MDA is better for large scale development whereas the SNF native technologies are better for smaller systems. The paper also includes a simplified Meta model of an ontology chart. However this paper did not show how to build an ontology chart or how to auto-generate component architecture. The second

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paper discusses the MDA approach and a theoretical transformation but it focuses more on the presentation of norms. It did not show how to do an ontology chart and it did not give an example to demonstrate how to auto-generate component architecture. This paper builds on the weaknesses of component architecture the above mentioned papers and shows a step by step building of an ontology chart. It also contains a more sophisticated Meta Model for the extended version of the ontology chart.

3 ONTOLOGY CHARTS

The ontology chart is a graphical representation the ontologies identified by semantic analysis (Ades, et al., 2007). Each node of the ontology chart corresponds to an agent, affordance or determiner and they are associated with each other via lines. These lines show the ontological dependencies between the nodes. This implies that the existence of every ontologically dependant is also dependent on its antecedent. For example if we have a person (agent) that applies (affordances) for a contract (affordance). The application is ontologically depended on the person and the loan. If either the person or the loan siege to exist then the application will siege to exist. The graphical representation of this can be seen below.

Figure 1: Semantic unit example 1.

The position on the graph is important as it shows the ontological dependencies. Everything on the right site is ontologically depended on things at the left site. All the association from the antecedents to the dependants are one to many associations. The method also has the advantage that it reveals hidden requirements. Since every affordance must be ontologically depended to an agent and loan is not an agent, we know that loan must be depended directly or indirectly to an agent. In this case the loan is directly dependent to a bank that is an agent. This is shown below.

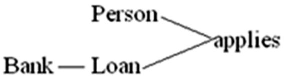


Figure 2: Semantic unit example 2

In this paper we will use a similar version of the ontology chart that was used by (Poernomo, et al., 2009) According to that ontology chart Meta model everything is an affordance. Affordances are divided to agents, entities, determiners, communication acts and other affordances. Communications acts can be translated as "an agent is talking to another agent about something". Additionally we add the concept of relationship. Relationships are affordances that associate two other affordances. Every node has in build start and finish times so it is capable of holding temporal data. For example consider that 'loan' will host all the loans, 'applies' will hold all the applications and the 'person' will hold all the persons. For simplicity, consider every node to be a database table with start and finish time fields within every table. Below we analyze a more complicated ontology chart focused on the Hajj case study (Yamin & Ades 2010) and (Hajj Core, 2010). We will then use this as our source ontology chart and show how it can be transformed to component architecture.

4 THE SOURCE META MODEL

The following figure shows the Meta model of the ontology chart.

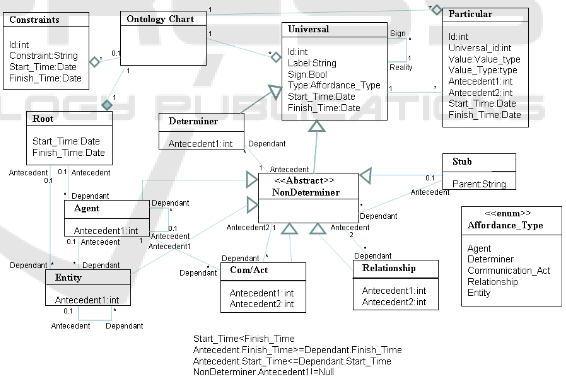


Figure 3: The ontology chart Meta model.

An Ontology chart contains a root and it may contain constraints, universals or particulars. A universal may be associated with a lot of particulars. A universal may be a sign of another universal. Universals are generalization of determiner and non determiner classes. A determiner has one non determiner as its antecedent. Non determiners are the generalization of Stubs, Agents, Entities, Com/Acts and Relationships. A non determiner may have a stub as its antecedent and a stub may have a lot of non determiner as dependants. Stubs have no antecedents. It worth to be noted, that we do not allow a stub to have any determiners as its dependants. If there are any determiners then they should be placed to the schema where the stub exist and not to this diagram. Also since determiners have no dependants then there is no point on having a stub determiner.

An agent may have another agent or the root as its antecedent and Entities, Com/Acts as their dependants. Additionally from Non Determiner class they inherit the ability to have Determiners and Relationships as their dependants.

Entities may have the root, an agent or another entity as their antecedent. Entities may be antecedents of com/acts and though inheritance of non determiners, entities maybe antecedents of relationships and determiners.

Com/Acts have two antecedents. The first antecedent is an agent and the second antecedent maybe any sign of a non determiner. Relationships have two antecedents and they can be any non determiners.

Finally following rules complete the Meta model:

- The startTime attribute of every affordance must be less than the finishTime attribute.
- The startTime of a dependant must be greater than or equal to the startTime of its antecedent.
- The finishTime of a dependant must be less than or equal to the finishTime of its antecedent.
- Except the agent and the stub every other affordance must have at least one antecedent.

Ontology charts can be valuable requirements analysis artefacts but do not provide information about the architecture of the system. In the following section we will demonstrate how a component diagram can be auto-generated from the above ontology chart.

5 THE HAJJ ONTOLOGY CHART

Assuming that we want to develop a system that will monitor the pilgrims (people) that participate in the religious event called the Hajj (Yamin & Ades 2010) and (Hajj Core, 2010). The Hajj is an annual pilgrimage to Mecca and the surrounding areas in Saudi Arabia. About four million people from various parts of the globe perform Hajj every year. During the travel and rituals, many pilgrims go missing; some become sick, needing medical attention. There may arise many other problems including overcrowding (resulting in stampede), traffic jams, hazards and accidents. We want to model a system which would allow us to capture all the data and possible locations of pilgrimages for better crowd management by the authorities. The following ontology chart shows our proposal for the

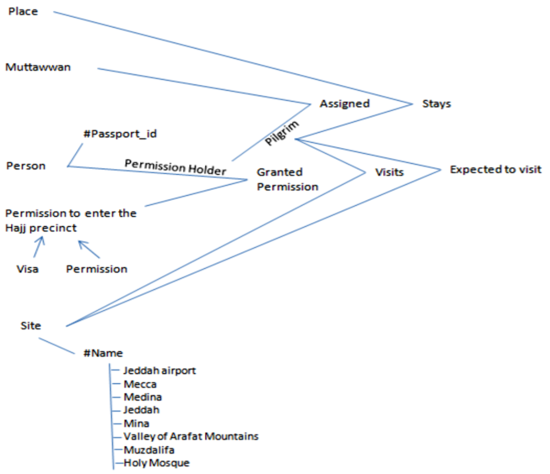


Figure 4: The Hajj Ontology Chart

The above ontology chart states that a person that owns a passport can be granted permission to enter the hajj precinct. There are two types of permissions namely, “visa” and “permission”. The permission holder is assigned to a Hajj Management group, known as Muttawaf, who is responsible for organising travel and accommodation within the Hajj precinct. A permission holder is considered as a pilgrim after she/he is assigned to a Muttawaf group. Pilgrims stay at a number of places, visit sites and participate in rituals at a number sites.

6 TARGET META MODEL

Below is the Meta model for the component diagram that will be used as target architecture in this paper.

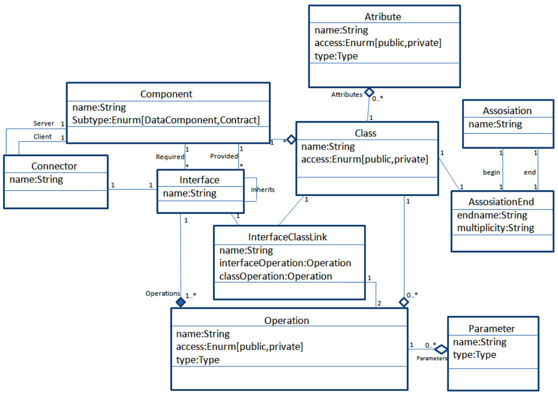


Figure 5: Component diagram Meta model

The Component diagram in the above figure describes a component that has a name and that could contain multiple classes inside. A class contains attributes and operations. Each operation may have many parameters. Two classes can be associated together. Every association has a beginning and an end. Both ends may have a label and multiplicity. A component can be used by or use other components via interfaces. Interfaces have a name and operations. An interface can be linked with a class inside the component via the interfaceClassLink. The connector links two components together via an interface. One of these two components will the client and the other will be the server. In our transformation we will generate components and two sub types of components. The data components and the contract components. The data components will be simple links to a database. The contract components will be a link between two other components and a data component.

7 TRANSFORMATION

A very important aspect of the transformation will be to produce a design capable of storing all temporal data. This includes storing all the component data as well as the data that come as a result of the interaction of the component with other components.

7.1 The Inner Structure

Every affordance that is transformed to components will have its determiners stored in a class called ParticularInstance that will be in a class of type ontologyClass within the component. Any non determiner affordances directly ontologically depended to the component, that will not be transformed to component will be transformed to a class called ontologyClass and is placed in the antecedent component.

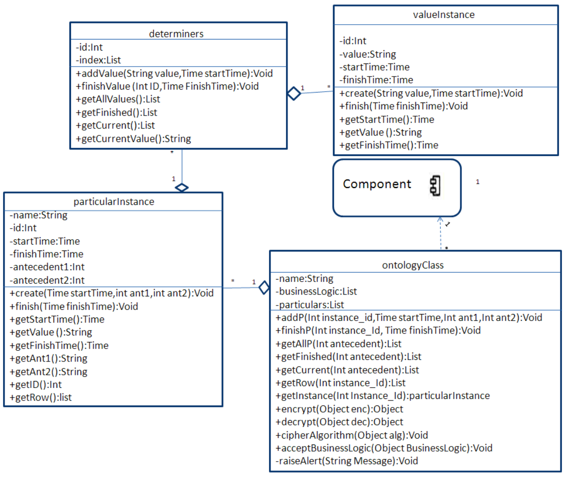


Figure 6: The inner structure

A brief description of the methods follows.

7.1.1 Particular Instance Class

`addValue (String value,Time startTime):Void`

The addValue method is used for adding a value instance to the universal linked list. The method takes the name of the determiner, the value and the start time as input parameters and it does not return any value. This method calls the create method of the valueInstance class.

`finishValue(int id,Time finishTime):Void`

The finishP is used to finish a value instance. For example if the telephone of a person is no more valid then we may want to terminate the current phone number. We can do this by calling the finishValue method with the id of the value instance that we want to finish and the finish time.

`getAllValues():List`

The getAllValues method returns a list with the value instances. Both current and finished instances will be displayed.

`getFinished():List`

The getFinished method takes returns a list of all all valueInstance instances that have finishTime value before the current system date. This way we can get all previous and finished instances like previous telephone numbers or previous addresses and so on.

`getCurrent():List`

The getCurrent method returns a linkedlist of all all valueInstanceinstances that have no finishTime value or the finishTime value is later than the current system date. This way we can get a active values such as all current telephone numbers or all current addresses of a person.

`getCurrentValue():String`

The getCurrentValue method can be used only if there is only one active value instance. The method will use the getCurrent method and will check if the size is one. If the size is different than one is going to return null else it is going to call the getValue method of the valueInstance class. This method hides all the complexity of the structure from a programmer who may want to store singe values as determiners. For example maybe we don't care for the history of names of a person and we just care for its current name. However, if we ever need it the functionality is there.

7.1.2 The ontologyClass

Apart from determiners we also store all other affordances that are directly ontologically depended to the component but are not themselves transformed to a component. For example, let us assume that a person owns a book. The person is an agent and will be transformed to a component, 'owns' is a relationship and 'book' is an entity and will be transformed to an entity component. In this case the relationship 'owns' will be converted to a ontologyClass class and placed in the person component. The ontologyClass class will have the name of the affordance, in our examples this will be 'owns' and instances of various ownerships. This is because a person may have owned different books in the past or owns more than one books in the present. Its ownership instance will hold information such as which person owned which books and when. The ontologyClass have methods for adding, searching, and finishing instances. Each particularInstance can have zero to many determiners within it. The methods of the ontologyClass are explained below:

`addP(Time startTime,int ant1,int ant2):Void`

The addP method is used to add instances of particular instances into the universal linked list. The method takes as parameters the start time, the first antecedent and the second antecedent. For example if George owns a book, then we need to give the start time of the ownership, the id of George and the id of the book.

`finishP(int p_id,Time finishTime):Void`

The method finishP takes the as parameters the id of the particular and the finishTime. In this way instance is "terminated". It is worth noting that we never delete anything. Every time we want to terminate something we put finish time.

`getAllP(null,int Antecedent1, int antecedent2):List`

The getAllP method will return a list with all the valueInstances instances if no parameter is passed. If the first antecedent is passed as parameter then it will return all the instances where the first antecedent is equal to the parameter. If the second antecedent is passed as parameter the it will return all instance where the second antecedent is equal to the parameter. This way we can get all instances or all instances associated with the first or the second antecedent. For example if a person own a book, we can get all the person who owns books, or all the books that a person holds or all the persons that hold a book.

`getFinished(null,int antecedent,int Antecedent2):List`

The getFinished method returns a list of all valueInstance instances that have finishTime value before the current system date. This way we can get all previous and finished instances like previous ownerships, owners, things owned and so on. Like the getAllP method, the getFinished can take null, the first or the second antecedent as parameter. So it can return all instances, or all instances associated with one of the two antecedents.

`getCurrent(null,int antecedent1,int antecedent2):List`

The getCurrent method returns a linkedlist of all valueInstance instances that have no finishTime value or the finishTime value is later than the current system date. Like the getAllP method, the getFinished can take null, the first or the second antecedent as parameter. So it can return all instances, or all instances associated with one of the two antecedents.

`getRow(Int P_Id):List`

The getRow method takes a particular id as parameter and returns a list with the last value of every determiner and start time for a given particular id.

`getInstance(Int particular_id):particularInstance`

The operation returns the particularInstance from the universal list where the id is equal to the parameter.

`encrypt(Object enc):Object`

The encrypt method is used to encrypt data

`decrypt (Object enc):Object`

The decrypt method is used to decrypt data

`cipherAlgorithm(Object alg):Void`

The inversion of control pattern was used to secure the data of the system. The cipherAlgorithm method is used to pass the encrypt or decrypt algorithm.

```
raiseAlert(String Message):Void
```

The raiseAlert method is used by all other methods of the ontologyClass if they want to report an anomaly. The method will then report to a log and other appropriate systems that can take action.

```
acceptBusinessLogic(Object
businessLogic):Void
```

All the dynamic rules of the system should separate from the instances. We propose storing business logic instances in a list and execute them accordingly. Similar with the Strategy Design pattern, this method accepts instances of Business Logic and stores them in the list businessLogic. This allow us to change the dynamic behaviour of the system even at run time.

All the 'get' methods of determiner and ontologyClass class will be linked with the 'provide' interface of the component while the interaction methods will be linked through the require interface with the transformation of the second antecedent of the affordance.

The transformation T will transform the ontology chart (OC) to component diagram (CD). Since ontology chart resides at the computational independent model level and the component diagram at the platform independent model level, this is a CIM to PIM transformation.

7.1.3 Inner Structure Explaination

Each affordance such as Person can have many determiners ontologically dependent on it, such as name, telephone, address and so on. Each determiner can have many instances associated with it, for example a person may had a previous name, or many telephones, previous addresses and so on. The determiners class will be responsible for holding this information. The class has two linked lists called index and universal. The is used for storing meta information about the determiners, such as the type of the value that they hold, their name and unique id. The linked list universal holds instances of the class valueInstance that will hold the name of the determiner, the value, the start time and the finish time. The determiners class methods for searching, retrieving and adding instances of determiners.

Apart from determiners we also store all other affordances that are directly ontologically dependent to the component but do not themselves transform to a component. For example, let us assume that a person owns a book. The person is an agent and will be transformed to a component, 'owns' is a relationship and 'book' is an entity which would be transformed to an entity component. In this case the relationship 'owns' would be converted to a ontologyClass class and placed in the person component. The ontologyClass class will have the name of the affordance; in our examples this will be owns and instances of various ownerships. This is because a person may have owned different books over the past or owns more than one books at present. Its ownership instance will hold information such as which person owned which books and when. The ontologyClass has methods for adding, searching, and finishing instances. Each particularInstance can have zero to many determiners within it. All the get methods of determiner and ontologyClass class will be linked with the provide interface of the component while the interaction methods will be linked through the require interface with the transformation of the second antecedent of the affordance.

Every time we generate a component we include the structure definer above. This way every time we generate a component the system will generate a class inside which will have the name of the label of the affordance and will be of type ontologyClass. This class will have a list inside, which will store all the particulars and their determiners value. To do this, we need to define a new type which will have the name of the label of the affordance and the word instance. Inside this class, we will add attributes of type determiner for every determiner dependant that the affordance has. Then we will create two provided interfaces and link the ontology class with them. We will call them ReadOnlyInterface and ReadWriteInterface. The first will include all the public get methods of the ontologyClass while the second will include all the public methods of the ontologyClass.

7.2 Linking Component Interfaces

Before linking components together we need to understand the permissions rights. As we have shown in the previous section, affordances have antecedents and dependants. The dependant is ontologically depended to the antecedent. The multiplicity is one to many from the antecedent to the dependant. An affordance can be ontologically depended to another, directly or indirectly. For example consider a bank, a loan that the bank offers and a determiner amount.

Bank — Loan —— #amount

The property of the loan is directly ontologically depended on the loan and indirectly to the bank. Affordances have less access rights to the affordances that they are ontologically depended and more access right to the affordances that are depended on them.

Based on the above if we want to connect the interfaces generated by T(A) and T(B) and B is ontologically depended on A, then B will be connected to the ReadOnly interface of A and A will be connected with the ReadWrite Interface of B. This means that the dependant has read only access to its antecedent while the antecedent has full access to its dependants. The following figure shows this.

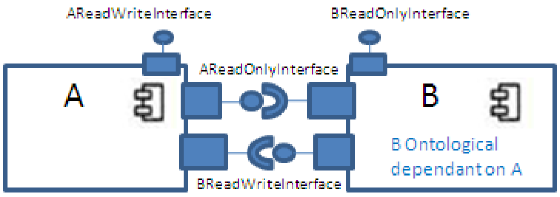


Figure 7: Linking component interfaces.

7.3 The Transformation

7.3.1 Dealing with Agents

For every agent generate a component. If the agent has another agent as its antecedent, then link the interfaces.

7.3.2 Dealing with Entities

Entities have only one antecedent and this can be the root, an agent or another entity.

If the first antecedent is a root then this entity will be a component.

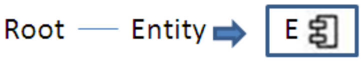


Figure 8: Entity to component.

If the antecedent is an agent then transform the entity to an ontologyClass and placed in the agents' component.

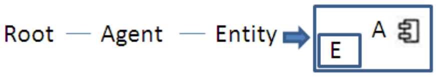


Figure 9: Entity to ontologyClass.

If the antecedent is an entity, we need to check if the first antecedent of the antecedent is an entity and if yes check its first antecedent and so on until we reach root or an agent.

7.3.3 Dealing with Communication Acts

A communication act is a communication between two agents about something. The first antecedent of the communication act is an agent and the second is a sign. The sign represents the affordance, the agents are communication actors. Since self is a communication act at least the first antecedent of that sign is an agent. The second may or may not be an agent.

For every communication act we generate a component. Then we link the interfaces with its antecedents.

7.3.4 Dealing with Relationships

A relationship will only be transformed to a component if both antecedents are agent or if both antecedents are relationships. In all other cases it will be an instance of ontologyClass.

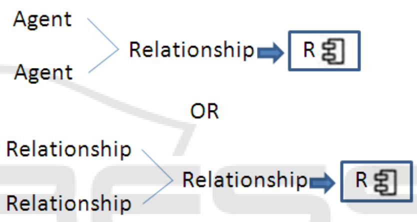


Figure 10: Relationship to component.

If one of the antecedents is an agent and the other is anything else, then R will be transformed to an instance of ontologyClass and placed in the T(agent).

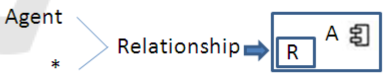


Figure 11: Relationship to ontologyClass 1.

The communication act is the second stronger category. So if an agent is not present and a communication act is present then it should go in the communication act. If there are two communication acts, it should go in the first antecedent.

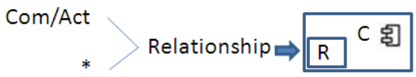


Figure 12: Relationship to ontologyClass 2.

If no agents or communication acts are present we have following cases:

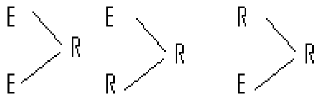
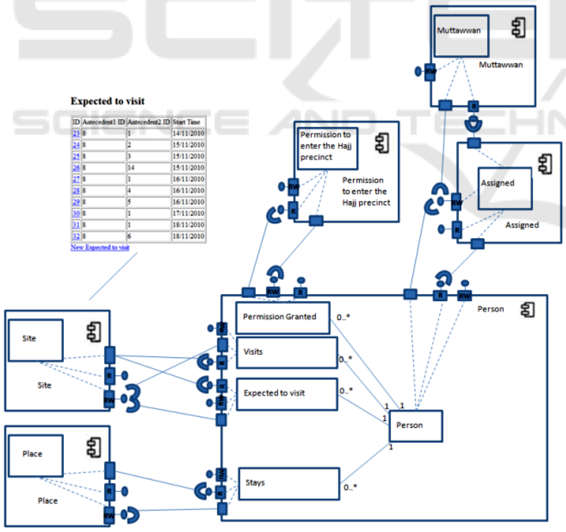


Figure 13: Relationship to ontology class 3

If any of the antecedents has been turned into a component then turn the Relationship to an ontologyClass and place it in the component. If both antecedents are entities and none of them has been turned into a component, then find in which component the first antecedents is located and place the ontologyClass there. Else if one of the antecedents is relationship and the other is entity place the ontologyClass in the same component with the relationship.

8 THE AUTO-GENERATED COMPONENT ARCHITECTURE

The following Figure shows the generated component diagram, describing the architecture of the system.



Expected to visit

ID	Antecedent1 ID	Antecedent2 ID	Start Time
23	8	1	14/11/2010
24	8	2	15/11/2010
25	8	3	15/11/2010
26	8	14	15/11/2010
27	8	1	16/11/2010
28	8	4	16/11/2010
29	8	5	16/11/2010
30	8	1	17/11/2010
31	8	1	18/11/2010
32	8	6	18/11/2010

New Expected to visit

Figure 14: The auto-generated component architecture.

Permission granted, visits, excepted to visit and stays nodes of the ontology chart, have been converted to ontologyClasses in the person component. Person and muttawan have been converted to components because they are agents. The assigned relationship has been converted to a component because both its antecedents are agents. Place and site entities have been turned into components because their antecedent is the root.

9 CONCLUSIONS

Design component architecture is a task usually performed by human experts. To the best of our knowledge, we have proved that ontology chart is semantically rich enough which is capable to being transformed to component architecture model. In this paper, we have presented a possible solution for auto-transforming ontology charts to component architecture models. The purpose of this paper has been to show that such a generation is possible. Other transformations can be defined which would allow auto-generation of component architecture tailored to specific problems.

ACKNOWLEDGEMENTS

This work would have not been possible without the initial work of Ronald Stamper on semantic analysis. We would also like to thank Yasser Ades who aided us with the evaluation of the Hajj ontology chart.

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