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RESEARCH ARTICLE

GUIDELINES FOR DESIGNING VISUAL ONTOLOGIES TO SUPPORT KNOWLEDGE IDENTIFICATION

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Appendix A

A Brief Description of OWL

This OWL overview is based on the official OWL documentation from the World Wide Web Consortium (W3C) (McGuinness et al. 2004) and a guide to build OWL ontologies (Horridge et al. 2004).

OWL is the most recently developed ontology language from the W3C. OWL is based on RDF (resource description framework), which is accepted as a formal language of meta-data describing any web resources. The key constructs of OWL are *classes*, *individuals,* and *properties*. Classes in OWL are intended to represent concepts in a domain. OWL classes are associated with a set of individuals (or instances) that represent objects in the domain. OWL properties are used to assert general facts about classes and specific facts about individuals. These three concepts are further described below.

Classes

Classes provide a mechanism for grouping resources with similar characteristics. A class in OWL can be defined by declaring it a name. For example, by writing the following OWL syntax— <owl:Class rdf:ID="Customer">—a class named Customer is defined. OWL classes should correspond to a naturally occurring set of things in a domain. A class named owl:Thing is predefined, which means every class that is defined in the ontology is a subclass of owl:Thing. OWL classes are further defined through class descriptions. A class description describes an OWL class by specifying the conditions that an individual must satisfy to be a member of the class.

Individual

OWL individuals can be referred to as being instances of classes. It is intended that individuals should correspond to actual entities that can be grouped into these classes. For example, we can define a class, Customer, with instances of this class (OWL individuals) representing some specific customers. An individual can be minimally introduced by being declared a member of a class (either of the predefined top class owl:Thing or some other class defined in an ontology). For example,

```
<owl:Thing rdf:ID="SomeBody">
<owl:Human rdf:ID="John_Doe">
```

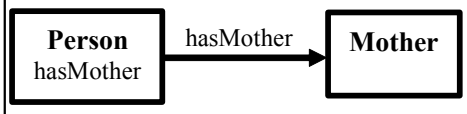
In the above syntax, the first statement introduces an individual SomeBody simply as an instance of owl:Thing (no further information about this individual has been provided yet). The second statement declares another individual John_Doe, as an instance of the class Human.

Properties

Properties in OWL are binary relationships. A property links *a subject* (an OWL individual) to *an object* (an OWL individual or a data value), and the object is considered to be a value of this property for the subject. These subjects and objects in OWL are termed *domain* and *range* respectively. Properties link individuals from the domain to individuals from the range.

Properties in OWL are mainly two types: *datatype* and *object*. Datatype properties link individuals to data values. For example, we may define a datatype property "hasAge" to represent the age of a person, that is, to link an individual (such as John) to a non-negative integer representing age (such as 25). Instances of object properties relate individuals to individuals. For example, in an ontology that describes persons, we can define an object property "hasMother" to relate individuals representing persons (as a class) to other individuals representing mothers (as a class). The syntax of this situation is shown below, and an equivalent diagram for the syntax is shown adjacent to it. It is a standard practice to show the object property in the diagram, both on the arrow and inside the class (from where the property originates).

```
<owl:Class rdf:ID="Person"/>
  <owl:Class rdf:ID="Mother"/>
  <owl:ObjectProperty rdf:ID="hasMother">
    <rdfs:domain rdf:resource="#Mother"/>
    <rdfs:range rdf:resource="#Person"/>
</owl:ObjectProperty>
```



References

Horridge, M., Rector A., Knublauch, H., Stevens, R., and Wroe, C. 2004. "A Practical Guide To Building OWL Ontologies Using the Protégé-OWL Plugin and CO-ODE Tool Edition 1.0," Volume 27, Manchester, UK: University of Manchester.

McGuinness, D. L., Smith, K. M., and Welty, C. 2004. *OWL Web Ontology Language Guide* (online at http://www.w3.org/ TR/owl-guide/; retrieved February 14, 2007).

Appendix B

Specific Rules to Model Interactions in OWL

The following rules are offered to provide additional assistance to help modelers implement the guidelines proposed in this paper. They are at a fairly low level of detail to provide specific direction to modelers working with OWL.

1. Instances of interacting classes must have at least *one* mutual property, which is modeled as the property of the interaction classes. In the absence of any mutual property, instances do not interact.

2. Each interaction class must have at least *two* object properties (that can be identified with appropriate prefixes such as "involves") linking it to the interacting class. This restriction reflects that at least two interacting classes are necessary to form one interaction class.

3. Each interacting class must have at least *one* instance. By enforcing this restriction, it is made explicit that instances that may interact with each other exist.

4. Each interaction class represents a set of related concurrent mutual properties (arising from the same interaction). Different interaction classes should be used if sets of properties are not concurrent.

Appendix C

Ontologies Used in Experiments 1 and 2

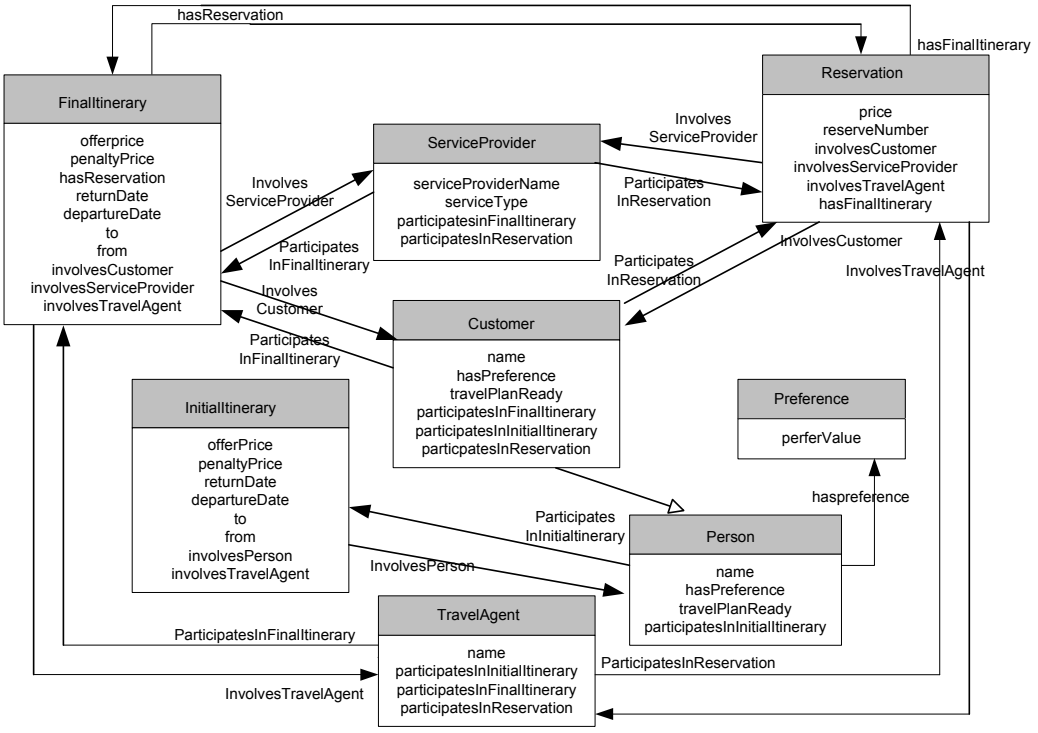


Figure C1. Experiment 1: Guided Travel Ontology

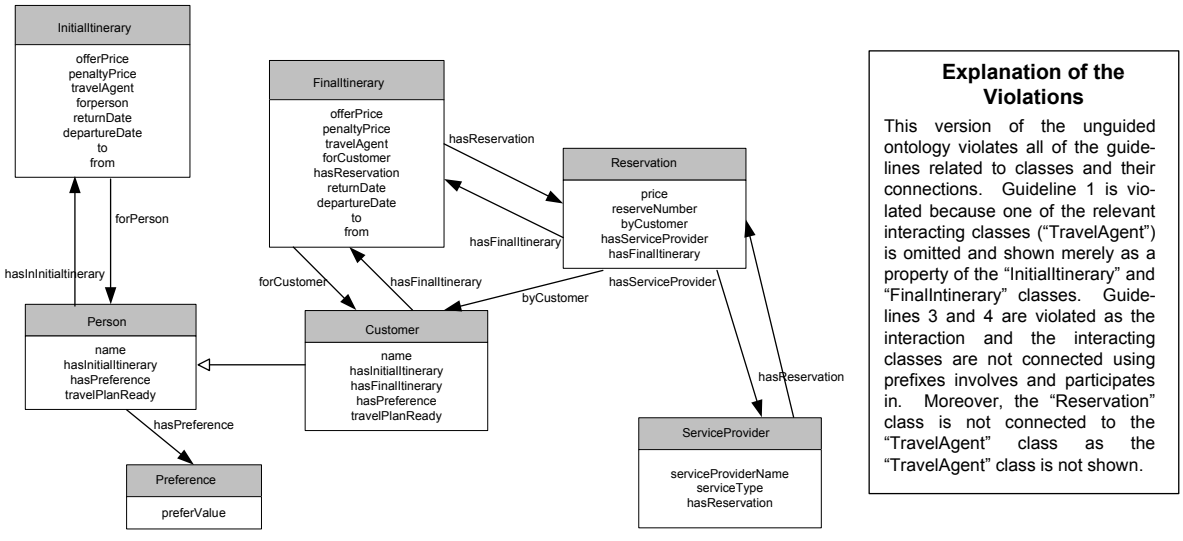


Figure C2. Experiment 1: Unguided Travel Ontology

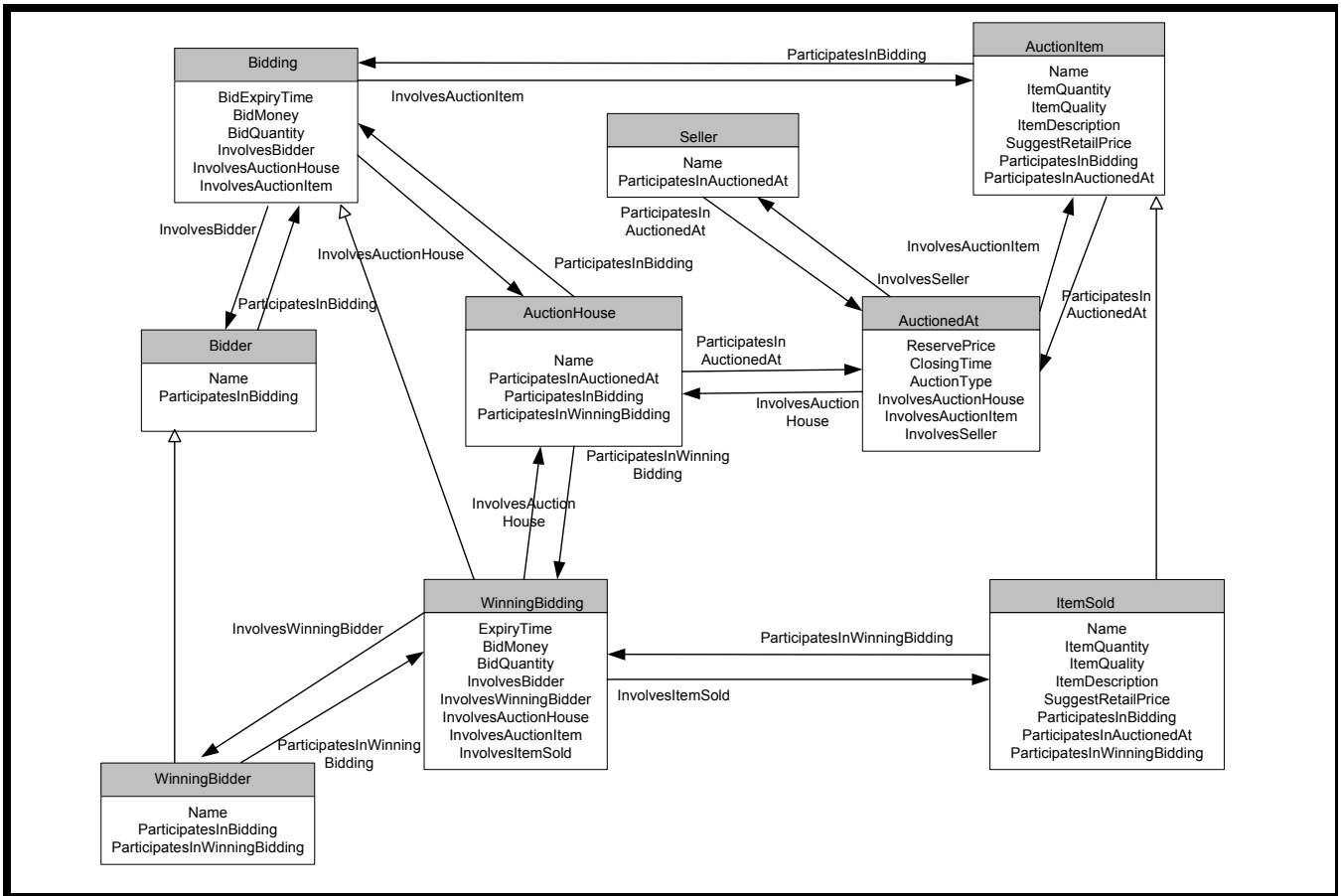
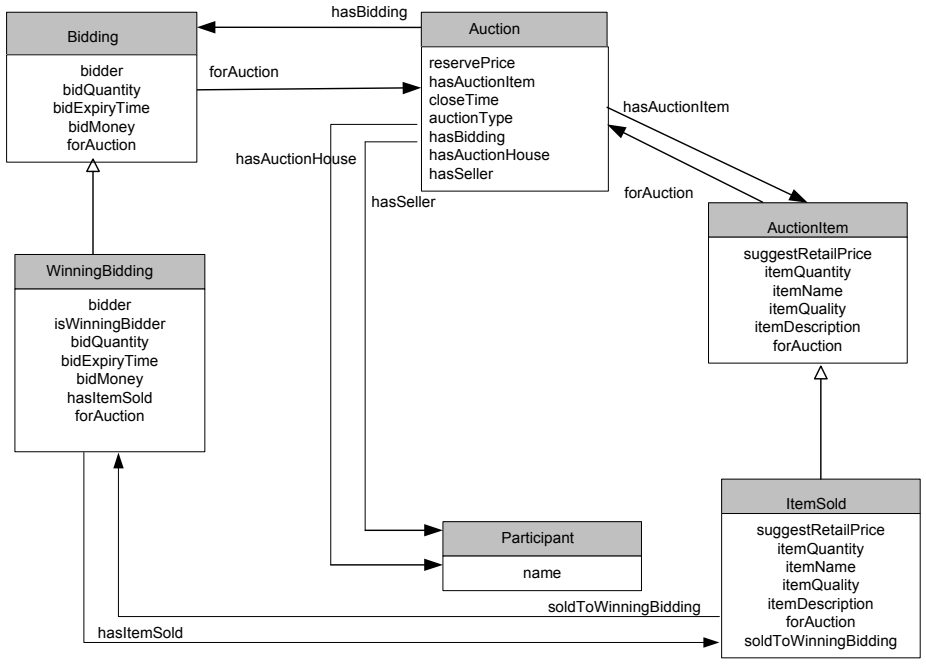


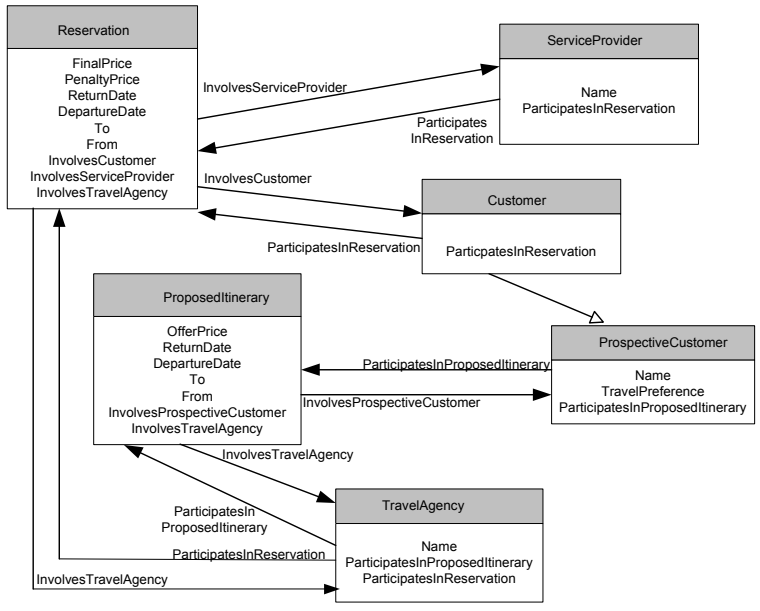
Figure C3. Experiment 1: Guided Auction Ontology



Explanation of the Violations

This version of the unguided ontology violates all of the guidelines. Guideline 1 is violated because several interacting classes are not shown; they are shown instead as properties of interaction classes. For example, "AuctionHouse" and "Seller" are modeled as properties of "Auction." Guideline 2 is violated as the interaction classes contain properties (such as "bidder" in "Bidding") that do not represent mutual properties. These properties are represented more clearly in the guided version (for example, by showing "involvesBidder" in the "Bidding" class, which makes the interaction explicit). Guidelines 3 and 4 are violated as the interaction and interacting classes are not connected using prefixes involves and participatesIn. Moreover, some connections are not shown at all, such as between "Bidding" and "Bidder" because the "Bidder" class is not shown.

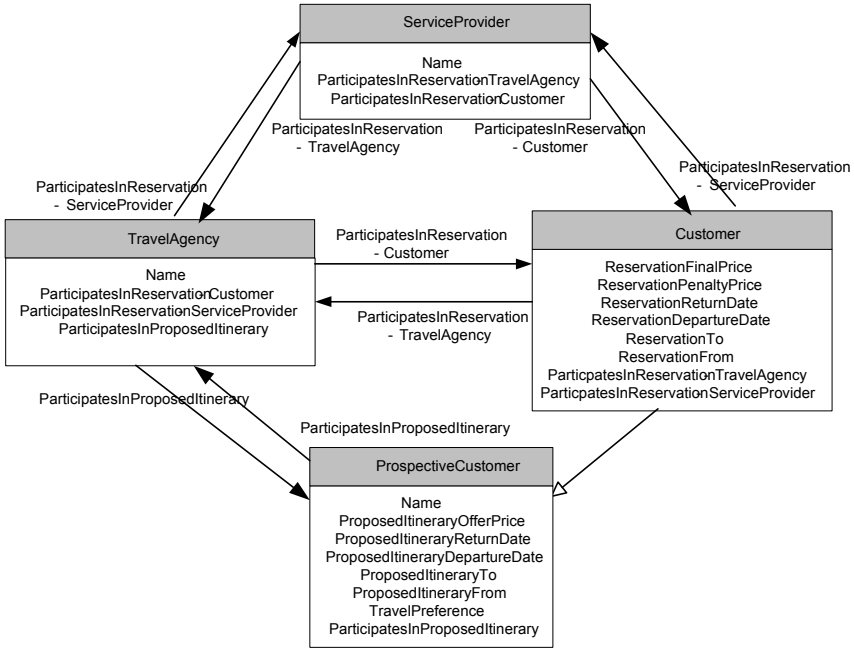
Figure C4. Experiment 1: Unguided Auction Ontology



Narrative for the Guided Ontology:

A travel agency helps prospective customers to organize trips. A prospective customer has travel preferences and informs the travel agency about them. The travel agency proposes several itineraries, the prospective customer reviews them and chooses the final one. A travel itinerary contains information about the destination, offered ticket price, departure and return dates and price. At a given time the travel agency deals with only one trip for a prospective customer. A reservation is a contract between the customer and the service provider arranged by the travel agency. Once an itinerary is agreed to, the reservation is made by the travel agency in consultation with the service providers (airlines, railways, etc.). A reservation also includes a penalty in case a customer cancels the reservation after a given date.

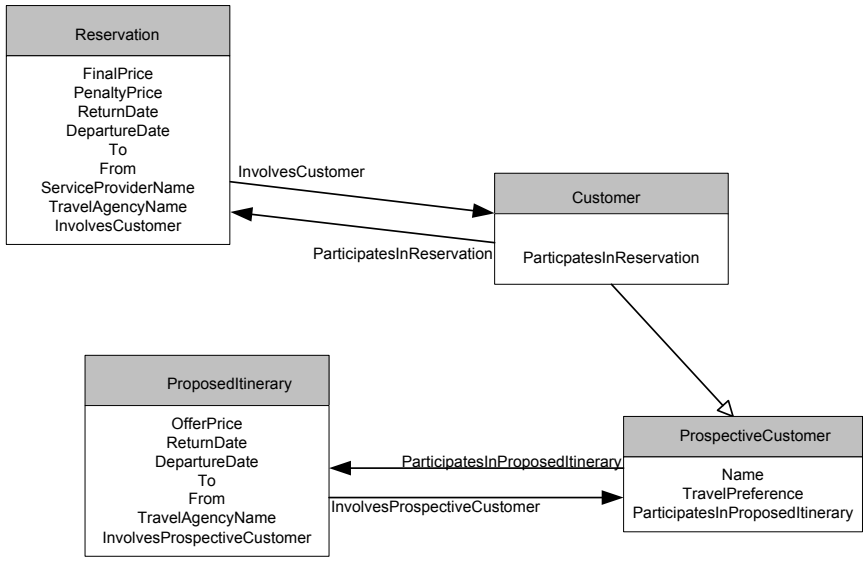
Figure C5. Experiment 2: Guided Travel Ontology and Associated Narrative



Explanation of the Violations

This version violates all four guidelines. Guideline 1 is violated by removing the interaction classes and modeling them as properties of interacting classes. For example, the class "Reservation" does not exist anymore in the diagram, rather the properties of the "Reservation" class (such as FinalPrice, PenaltyPrice) are modeled as properties of the Customer class. Guideline 2 is violated as the mutual properties of entities in the interacting classes are no longer in the interaction classes (such as ReservationFinalPrice). Because guidelines 1 and 2 are violated, guidelines 3 and 4 are violated as well (i.e., some of the links between interacting and interaction classes disappear).

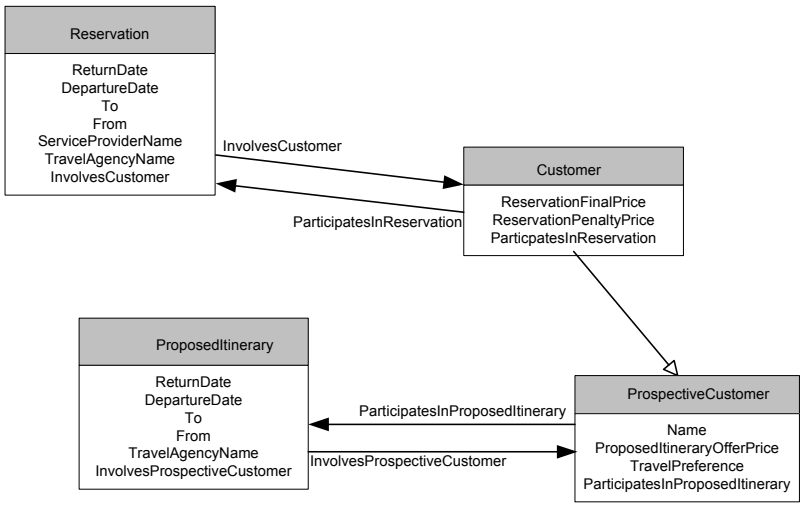
Figure C6. Experiment 2: Unguided Travel Ontology (Type 1)



Explanation of the Violations

This diagram violates guidelines 1, 3, and 4. Guideline 1 is violated as most of the interacting classes (such as "TravelAgency" and "ServiceProvider") are removed and modeled as properties of interaction classes (such as in "Reservation"). As guideline 1 is violated, guidelines 3 and 4 are violated as well.

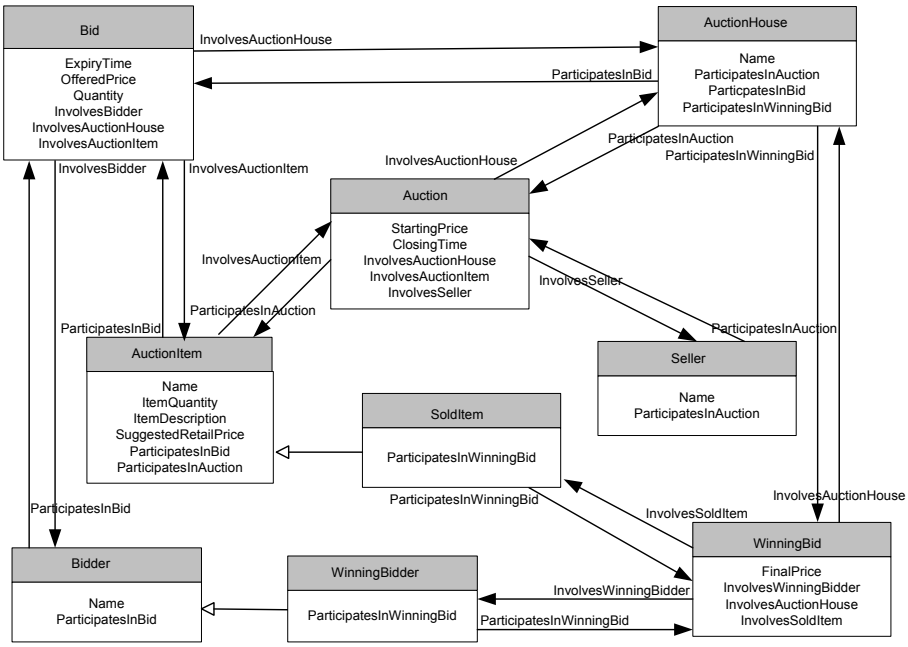
Figure C7. Experiment 2: Unguided Travel Ontology (Type 2)



Explanation of the Violations

In this version, all of the guidelines are violated. Guideline 1 is violated as most of the interacting classes (such as "TravelAgency" and "ServiceProvider") are removed and modeled as properties of interaction classes (such as in the "Reservation" class). Guideline 2 is violated as some properties of the interaction classes (such as FinalPrice and PenaltyPrice of "Reservation") are removed and placed as the properties of interacting classes (such as in the "Customer" class). Thus, guideline 2 is also violated. As guidelines 1 and 2 are violated, guidelines 3 and 4 are violated as well.

Figure C8. Experiment 2: Unguided Travel Ontology (Type 3)



Narrative for the Guided Auction Ontology:

In an auction there are three participants: a seller, an auction house, and a bidder. The bidder wishes to obtain the highest price possible. The auction house represents the seller and announces the current bids. The goods sold in the auction are termed the Auction Items. An auction item may comprise multiple goods, for example, a travel package may include two airline tickets and one hotel room. Two important aspects of an auction are the closing time and starting price. A suggested retail price may also be indicated in an auction item. A bidder submits a bid to the auction house indicating a price and an expiration time. Typically there may be several bidders for an auction item. The highest bidder becomes the winning bidder and pays the final price, which is equal to that of the winning bid.

Figure C9. Experiment 2: Guided Auction Ontology and Associated Narrative

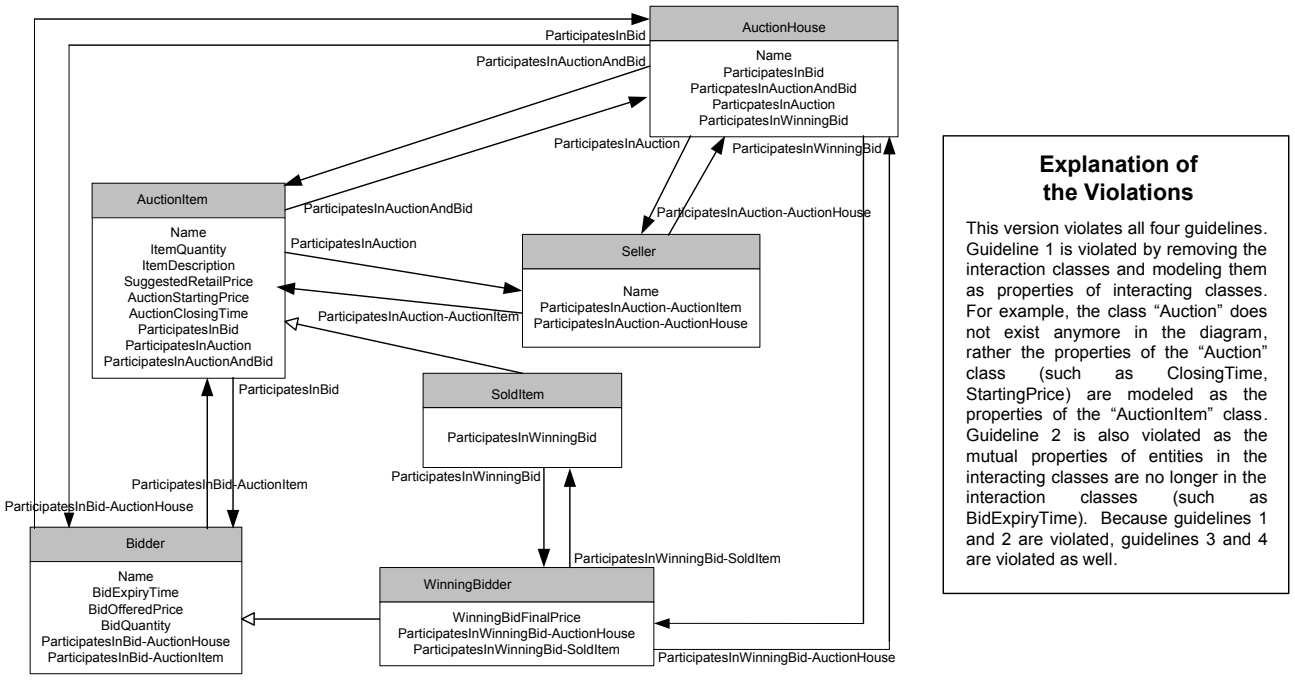


Figure C10. Experiment 2: Unguided Auction Ontology (Type 1)

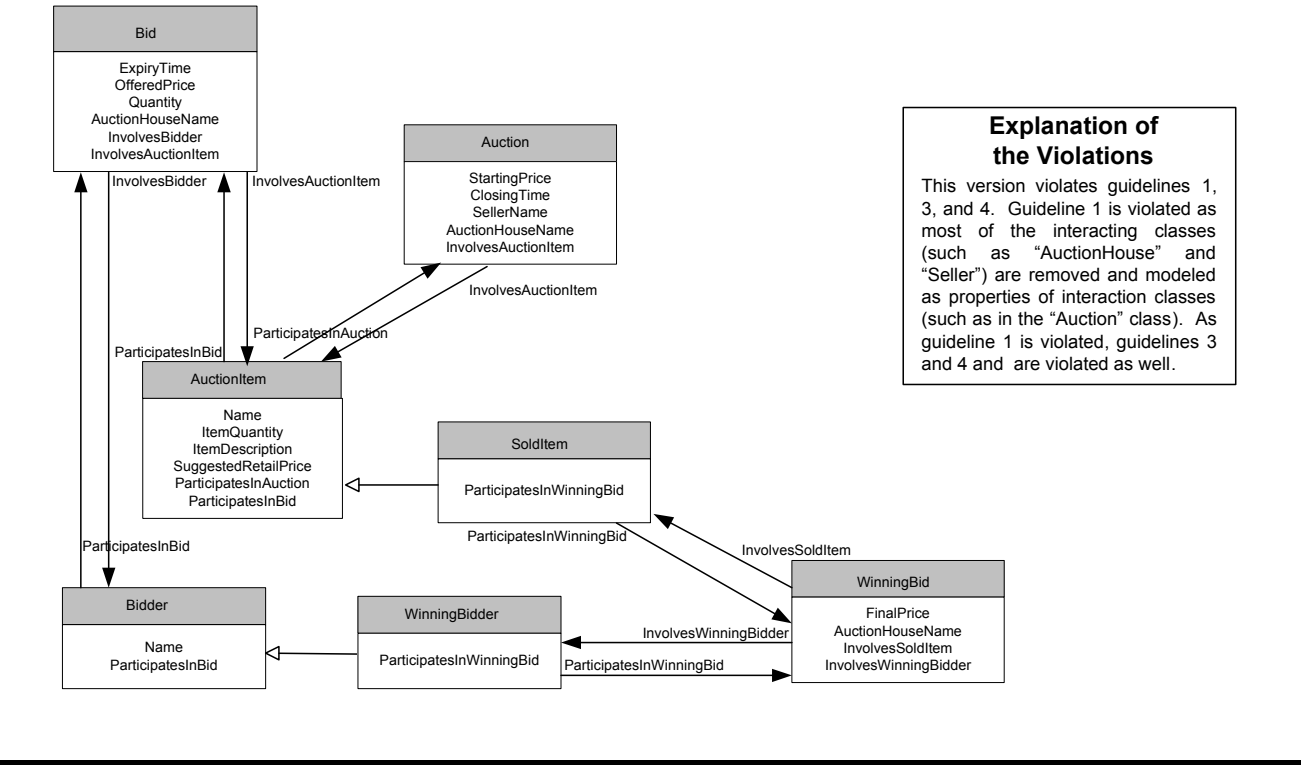


Figure C11. Experiment 2: Unguided Auction Ontology (Type 2)

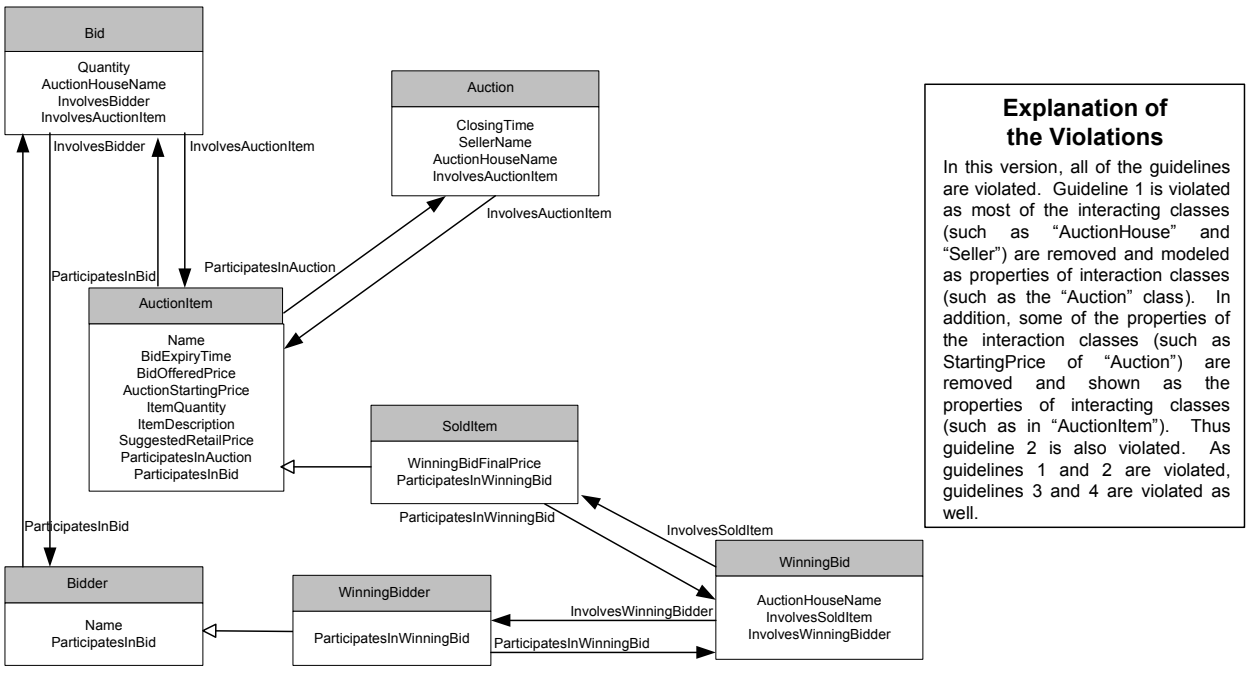


Figure C12. Experiment 2: Unguided Auction Ontology (Type 3)

Appendix D

Test Materials

The questions below were the same in Experiments 1 and 2.

Comprehension Questions: Travel Domain [Answers are true/false]

1. Every final itinerary must have a reservation
2. A service provider is involved in preparing initial itineraries
3. Every person is able to make reservations
4. Preparing final itinerary involves service providers
5. A reservation can be performed without involving a travel agent
6. A travel agent is involved in preparing final itineraries
7. Every initial itinerary must have a reservation
8. Reservation can be made without service provider's involvement
9. Every itinerary should include departure date and return date

Knowledge Identification Tasks: Travel Domain

1. You are asked to develop a procedure (a set of rules) for cancellation of a customer's reservation. Using the above diagram as guidance, please specify the **questions** you will ask in order to develop a procedure for canceling a customer's reservation. Provide as many responses as you can.

2. You are asked to develop a procedure (a set of rules) for allowing customers to travel without having reservations. Using the above diagram as guidance, please specify the **questions** you will ask in order to develop a procedure for allowing customers to travel without having reservations. Provide as many responses as you can.

3. You are asked to develop a procedure (a set of rules) for allowing customers to change their reservations. Using the above diagram as guidance, please specify the **questions** you will ask in order to develop a procedure for allowing customers to change their reservations. Provide as many responses as you can.

Knowledge Identification Tasks: Auction Domain

1. You are asked to develop a procedure (a set of rules) to allow canceling bids proposed by bidders. Using the above diagram as guidance, please specify the **questions** you will ask in order to develop a procedure to allow retracting bids proposed by bidders. Provide as many responses as you can.

2. You are asked to develop a procedure (a set of rules) for stopping bidders to buy directly from sellers without the knowledge of auction house. Using the above diagram as guidance, please specify the **questions** you will ask in order to develop a procedure to stop bidders buying directly from sellers without the knowledge of auction house. Provide as many responses as you can.

3. You are asked to develop a procedure (a set of rules) for preventing winning bidders not paying for the item that they have won. Using the above diagram as guidance, please specify the **questions** you will ask in order to develop a procedure for preventing winning bidders not paying for the item that they have won. Provide as many responses as you can.

Sample Answers for Knowledge Identification Tasks (Travel Domain) Used as Feedback

Response for Task 1
How to check the record of the customer who wants to cancel.
How to inform the customer about the penalty for cancellation.
How to pay the penalty price (if there is a penalty for cancellation).
How late will a customer be able to cancel a reservation?
How to contact the service provider/travel agent to cancel a reservation.
How would the travel agent inform the service provider about a cancellation?
How to refund the money to the customer from the travel agent.

Response for Task 2
How to inform the customers that all seats are reserved or not reserved.
Can a final itinerary printout be used as a substitute of a reserved ticket?
How do service providers deal with double booking?
How is the price assigned for customers who travel without reservations?
How does the customer pay when he/she travels without reservations?
How to provide (assure) customers' preference are available.
How to involve (inform) a service provider in preparing a final itinerary.

Response for Task 3
How to inform the service provider/travel agent about the change.
How late will a customer be able to change a reservation?
How to check the original reservation, itinerary and customer information.
How to inform the customer that the reservation has been changed (or not changed).
Is there a penalty to change reservation? If so, how can it be applied?
How to pay the penalty price (if there is a penalty) or additional amount for the change.
Whether to delete the current reservation before making the changes.
How should the final itinerary be changed according to the change in reservation?
Whether to issue another reservation number or keep the old reservation number.

Items for Prior Modeling Knowledge (Seven-Point Likert Scale)

1. To what extent do you know data modeling concepts (such as entities, classes, and properties)?
2. To what extent do you have experience in using data modeling concepts (such as entities, classes, and properties)?

Items for Prior Domain Knowledge (Seven-Point Likert Scale)

1. Over the last two years, to what extent have you made travel reservations?
2. Over the last two years, to what extent have you participated in auctions (including online auctions)?
3. To what extent do you have knowledge of reservation procedures (e. g. , used by ticketing companies, airlines)?
4. To what extent do you have knowledge of auction procedures?

Items for Perceived Ease-of-Understanding (Seven-Point Likert Scale)

1. To what extent is the information represented in the diagrams easy to understand?
2. To what extent is the information represented in the diagrams confusing?
3. Trying to understand all of the information represented in the diagram required a lot of mental effort.
4. Overall I found the information represented in the diagrams easy to interpret.

Items for Perceived Understanding (Seven-Point Likert Scale)

1. To what extent did you understand all of the information represented in the diagram?
2. To what extent did you comprehend all of the information represented in the diagram?
3. Overall I grasped all the information represented in the diagram.