Car Rental System
Domain Modeling Example

Dr. Michael F. Siok, PE, ESEP
UT Arlington
Computer Science and Engineering

Car Rental User Needs Statement

A car rental company operates a number of rental locations throughout a metropolitan area. Since the company has a great business model and provides customer-friendly service, its business has boomed over the last several years. As the business has grown rapidly, the costs of running its business has also increased. In particular, as the job market becomes hot, the labor cost has doubled over the last several years. The company wants to find a solution to reduce its operating cost. The business operation of the company is described as follows. The description is not meant to be complete, and the company is flexible enough to consider any good improvement proposals.

Vehicles can be taken from one location and returned to the same location or to a different location with an additional charge. Although the company is, at present, concerned only with passenger cars, it may branch out into other forms of vehicle rentals in the future and would like to be able to use the same reservation system. The company has several different makes of cars in its rental fleet, from different manufacturers. Each make may have several models. For example, Toyota has Corolla, Camry, etc. The models are grouped into a small number of price classes. The customer must be able to select the make and the model he or she wants to rent. If the selected car is not available, the system should display a message telling the customer that is car is rented out and let the customer select another make and model, or have the system suggest similar models of a different make.

Car Rental User Needs Statement (cont.)

The company has a number of different rental plans available to customers. For example, there is a “daily unlimited miles plan” and a “weekend 10% discount plan”. The company finds it important to have information available on the models of car, such as automatic or manual gear change, two or four doors, and sedan or hatchback. The rental prices may be different for different options and a customer will want to know such information when reserving a car. Currently, customers make reservations directly with the car rental company either in person or through the phone. The salespersons process the reservations manually using a reservation form and archive them in the file cabinet. No deposit is required at the time of reservation. The reservation is voided if the customer does not show up to sign the contract for more than a given period of time. Such reservation is honored only if there are still cars available to satisfy the request.

Sometimes a customer wishes to make a block reservation for several cars and to have the invoices for all rentals on the reservation handled together. As soon as a car is checked out to a customer, an invoice is opened. A single invoice may cover one or more rentals. Normally a customer will settle the invoice when the car is returned, but in some cases, the invoice must be sent to a company (such as the customer’s employer). When the customer pays by a credit card, the rental charge will be processed through a credit processing company.

Car Rental User Needs Statement (cont.)

A car may or may not be available for rental on a given day. Rental cars need frequent preventive maintenance and, in addition, any damage to a car has to be repaired as soon as possible. The company wants to keep track of the rental car purchase, repair, maintenance, and disposal information for business and tax purposes (e.g. depreciation of the rental cars).

Review of Functional Requirements

Req ID	Requirement Statement
R1	The car rental CRS (CRS) shall provide a secure means for customers to create an online account with the car rental business.
R2	The CRS shall provide a secure means for customers and employees to search rental vehicles.
R3	The CRS shall provide a secure means for customers to reserve vehicles online.
R3.1	The CRS shall allow customers to select vehicle make, model, and available options.
R3.2	The CRS shall suggest similar vehicles if the selected vehicle is not available.
R3.3	The CRS shall allow the user to select a rental plan including the Daily Unlimited Miles Plan and Weekend 10% Discount Plan.
R3.4	The CRS shall display the rental prices for vehicles with selected options.
R3.5	The CRS shall allow customers to make block reservations of more than one vehicle.
R4	The CRS shall allow customers to cancel reservations online.
R5	The CRS shall allow an employ to make reservations for a customer.
R6	The CRS shall void a reservation if the customer does not sign the rental contract for a reservation within a predefined amount of time.
R7	The CRS shall allow The CRS shall allow a customer to view reservations made by/for the customer.
R8	The CRS shall allow an employee to search reservations using a number of search criteria.
R9	The CRS shall allow an employee to cancel a reservation for a customer.
R10	The CRS shall open an invoice when a vehicle is checked out to a customer.
R11	The CRS shall generate invoices for rental contracts when vehicles are returned.
R12	The CRS shall maintain purchase, maintenance, repair, and disposal logs for each vehicle.
R12.1	The CRS shall allow an employee to update the logs.
R12.2	The CRS shall allow employees to view the logs.
R13	...

Constraints on the Functional Requirements

C1	The CRS must provide a means to ensure that every rental car that is checked in to the system meets federal and state safety and environmental regulations.
C2	The CRS must not allow vehicles that do not meet federal or state safety regulations to be displayed in search results or checked out.
C3	The CRS must provide a means to validate that the customer has a valid driver license.
C4	The CRS must provide a means to validate that the customer possess minimal liability insurance (which the customer may already have with her/his existing cars or can be purchased at time of check out).
C5	The CRS must secure customers privacy and financial information when transmitting such information over the Internet.

Develop Domain Model

- Identify
  1. Nouns or noun phrases
  2. X of Y or Y's X (e.g., make of car, car's engine)
  3. Transitive verbs (e.g. applies to the program)
  4. Adjectives, adverbs, and enumerations.
  5. Numerics and quantities
  6. Possession expressions (has/have, possess, etc)
  7. Constituents, part of, consist of expressions
  8. Containment or containing expressions
  9. "X is a Y" expressions or generalized/specialized concepts (e.g., Nurse Anesthetist is a kind of Nurse)

- Use this classification schema on the Car Rental System user needs description

Classification Schema on CRS

Description of Car Rental Business

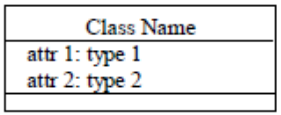
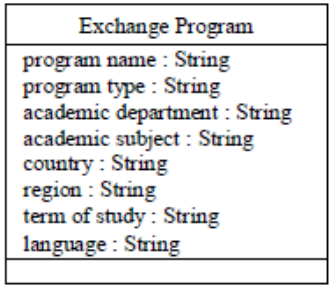
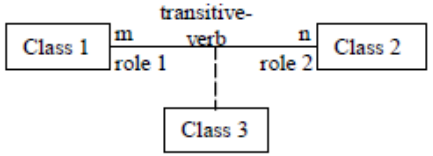
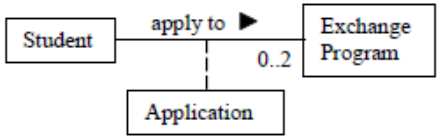
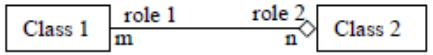
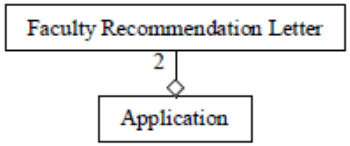
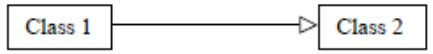
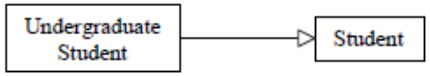
(1) Vehicles[1] can be taken from[3] one location[1] and returned to[3] the same
(2) location[1] or a different location with an additional charge[1]. Although
(3) the company is, at present, concerned only with passenger cars[1],
(4) it may branch out into other forms of vehicle rental[1] in the future
(5) and would like to be able to use the same reservation system.
(6) The company has several different makes of car[2] in its rental fleet,
(7) from different manufacturers[1]. Each make may have several models. For
(8) example, Toyota has Corolla, Camry, etc. The models are grouped
(9) into a small number of price classes[1]. The customer[1] must be able to
(10) select[3] the make and the model he/she wants to rent. If the selected
(11) car is not available[4], the system must display a message telling
(12) the customer that the car is rented out[4] and let the customer
(13) select another make and model or have the system suggest
(14) similar models of a different make. The company has a number
(15) of different rental plans[1] available to customers. For example,
(16) there are "daily unlimited miles plan[1]" and "weekend savings plan[1]".
(17) The company finds it important to have information available on
(18) the models of car[2], automatic[4] or manual[4] transmission[1], two[5]
(19) or four[5] doors[1], and sedan[1] or hatchback[1]. The rental prices[1] may be
(20) different for different options[1] and a customer[1] will want to know
(21) such information when reserving[3] a car. Currently, customers[1] make[3]
(22) reservations[1] directly with the car rental company either in person[4]
(23) or by phone[4]. The salespersons[1] process[3] the reservations[1]
(24) manually using a reservation form[1] and archive[3] them in the file
(25) cabinet[1]. No deposit is required at the time of reservation[2]. The
(26) reservation is voided[4] if the customer[1] does not show up to sign[3] the
(27) contract[1] for more than a given period of time[2]. Such reservation is
(28) honored only if there are still cars available[4] to satisfy request.
(29) Sometimes a customer[1] wishes to make[3] a block reservation[1] for several[5]
(30) cars and to have the invoices[1] for all rentals on the reservation
(31) handled together. As soon as a car[1] is checked out[3] to a customer[1],
(32) an invoice is opened[4]. A single invoice[1] may cover[3] one or more[5]
(33) rentals[1]. Normally a customer[1] will pay[3] the invoice[1] when the car is
(34) returned[3] but, in some cases, the invoice[1] may be sent to[3] a company[1]
(35) (such as the customer's employer). When the customer[1] pays[3] by a
(36) credit card[1], the rental charge[1] will be processed[3] through a credit
(37) card processing company[1]. A car may or may not be available[4] for
(38) rental on a given day. Rental cars need frequent preventive
(39) maintenance and, in addition, any damage to a car has to be repaired
(40) as soon as possible. The company wants to keep track of the rental car
(41) purchase[4], repair[4], maintenance[4], and disposal[4] information for
(42) business and tax purposes (for example, depreciation of the rental
(43) cars[2]).

Applying Modeling to the Schema

Rule #	Phrase Identified	Corresponding Modeling Concept
1	noun/noun phrase	
	(a) has independent existence	class
	(b) a role played by some object	role in association
	(c) describes an association	association class
	(d) is generalization/specialization of	superclass / subclass
	(e) does not exist independently in the application/domain	attribute of some class
2	"X of Y" expression	
	(a) X exists independently in the application/domain	X is part-of Y or Y is an aggregation of X
	(b) X does not exist independently in application/domain	X is an attribute of Y
	(c) X denotes a role played by some object	X is a role in an association
3	transitive verb	association relationship
4	adjective, adverb, enumeration	attribute value
5	numeric	
	(a) relevant concept is an attribute	attribute value
	(b) relevant concept is an object	multiplicity
6	possession expression (e.g., Y has/have/possesses X, etc.)	
	(a) X has independent existence in application/domain	Y is an aggregation of X
	(b) otherwise	X is an attribute of Y
7	consist of, part of, is composed of expressions	aggregation relationship
8	containment, containing expressions	
	(a) contained object(s) can be removed without affecting the integrity of the containing object	association
	(b) otherwise	aggregation
9	X is Y, or generalization/specialization expression	inheritance

Note: (1) X is an attribute of Y if X does not have independent existence in the application.
(2) X and Y are related via an inheritance, aggregation, or association relationship if both X and Y have independent existence in the application.

Applying Modeling to the Schema (cont.)

Classification Result	UML Class Diagram Representation
(C) Class Name (A) attr1: type 1 (A) attr2: type 2	
Example: (C) Exchange Programs (A) program name : String (A) program type : String (A) academic department : String (A) academic subject : String (A) country : String (A) region : String (A) term of study : String (A) language : String	
(AS) transitive-verb (Class 1, Class 2) (m, n) (role 1, role2) (AC) Class 3 (transitive verb)	
Example: (AS) apply to (Student, Exchange Program) (1, 0..2) (AC) Application (apply to)	
Part-of (Class 1, Class 2) (m, n) (role 1, role2)	
Example: Part-of (Faculty Recommendation Letter, Application) (2, 1)	
ISA (Class 1, Class 2)	
Example: ISA (Undergraduate Student, Student)	

Modeling the CRS

Brainstorming List	Classification Result	Rule
vehicle[1]	(C) Vehicle	1 (a)
manufacturer[1]	(A) manufacturer	1 (e)
price class[1]	(A) price class	1 (e)
rental price[1]	(A) price	1 (e)
available[4], not available[4]	(A) available: boolean	4
rented out[5]	(A) rented out: boolean	4
	(A) status	4
purchase[4]	(V) purchase	4
repair[4]	(V) repair	4
maintenance[4]	(V) maintenance	4
disposal[4]	(V) disposed	4
car[1], passenger car[1]	(C) Passenger Car	1 (a)
makes of car[2]	(A) make	2 (b)
model of car[2]	(A) model	2 (b)
transmission[1]	(A) transmission	1 (e)
automatic[4]	(V) automatic	4
manual[4]	(V) manual	4
	(A) number of doors : integer	5 (a)
two[5] or four[5] doors[1]	(V) 2, 4	5 (a)
	(A) body style : String	1 (e)
sedan[1]	(V) "sedan"	1 (e)
hatchback[1]	(V) "hatchback"	1 (e)
options[1]	(same as transmission, # doors, body style)	
additional charge[1]	(A) additional charge	1 (e)
depreciation of the rental cars[2]	(A) depreciation	2 (b)
location[1]	(C) Location	1 (a)
taken from[3]	(AS) taken from (Vehicle, Location)	3
returned to[3]	(AS) returned to (Vehicle, Location)	3
other forms of vehicle[1]	(TBD)	
customer[1]	(C) Customer	1 (a)
select[3]	(AS) select (Customer, Vehicle)	3
rental plan[1]	(C) Rental Plan	1 (d)
daily unlimited miles plan[1]	(C) Daily unlimited Miles Plan	1 (d)
weekend savings plan[1]	(C) Weekend Savings Plan	1 (d)
reserving[3]	(AS) reserve (Customer, Vehicle)	3
reservation[1]	(AC) Reservation (reserve)	1 (c)
time of reservation[2]	(A) time of reservation	2 (b)
period of time[2]	(A) grace period	2 (b)
	(A) means	4
in person[4]	(V) in person	4
by phone[4]	(V) by phone	4
voided[4]	(A) void : boolean	4
salesperson[1]	(C) Salesperson	1 (a)
process[3]	(AS) process (Salesperson, Reservation)	3
archive[3]	(AS) archive (Salesperson, Reservation)	3
reservation form[1]	(same as Reservation)	
file cabinet[1] (not used)		
sign[3]	(AS) sign (Customer, Contract)	3
contract[1]	(C) Contract	1 (a)
block reservation[1]	(C) Block Reservation	1 (a)
make[3]	(AS) make (Customer, Block Reservation)	3
invoice[1]	(C) Invoice	1 (a)
opened[4]	(A) opened : boolean	4
cover[3]	(AS) bill for (Invoice, Contract) (1, 1..*)	3
one or more[5]		5 (b)
rentals[1]	(same as contract)	
checked out[3]	(AS) check out (Customer, Vehicle)	3
pay[3]	(AS) pay (Customer, Invoice)	3
sent to[3]	(AS) sent to (Invoice, Company)	3
company[1]	(C) Company	1 (a)
	(AC) Payment	1 (c)
rental charge[1]	(A) rental charge	1 (e)
credit card[1]	(AC) Pay by Credit Card	1 (d)
processed[3]	(AS) processed by (Pay by Credit Card, Credit Card Company)	3
credit card processing company[1]	(C) Credit Card Company	1 (a)
	(I) ISA (Credit Card Company, Company)	9
	(I) ISA (Pay by Credit Card, Payment)	9
	(I) ISA (Daily unlimited Miles Plan, Rental Plan)	9
	(I) ISA (Weekend Savings Plan, Rental Plan)	9
	(I) ISA (Passenger Car, Vehicle)	9
several[5]	(AG) Part-of (Reservation, Block Reservation) (2+, 1)	7

Schema Key

(A)	attribute (of a class)
(AC)	association class (of an association)
(AG)	aggregation
(AS)	association
(C)	class, may be a subclass of another class
(I)	inheritance relationship
(m,n)	multiplicity of each class in a binary association
(r1,r2)	role name of each class in a binary association
(V)	attribute value (of an attribute of a class)

Develop the Domain Model

- Take the list of application concepts and develop a top-level domain model diagram using them

- Rules . . .

1. Team members should perform classification activities as a team rather than as individuals (e.g., Project team meeting)

2. Do not draw UML class diagrams during these classification sessions

3. Keep the domain model simple and expand it incrementally

4. Domain modeling may be performed simultaneously with Use Case modeling, state-chart development or activity modeling

CRS Domain Model