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Object Constraint Language (OCL) tutorial

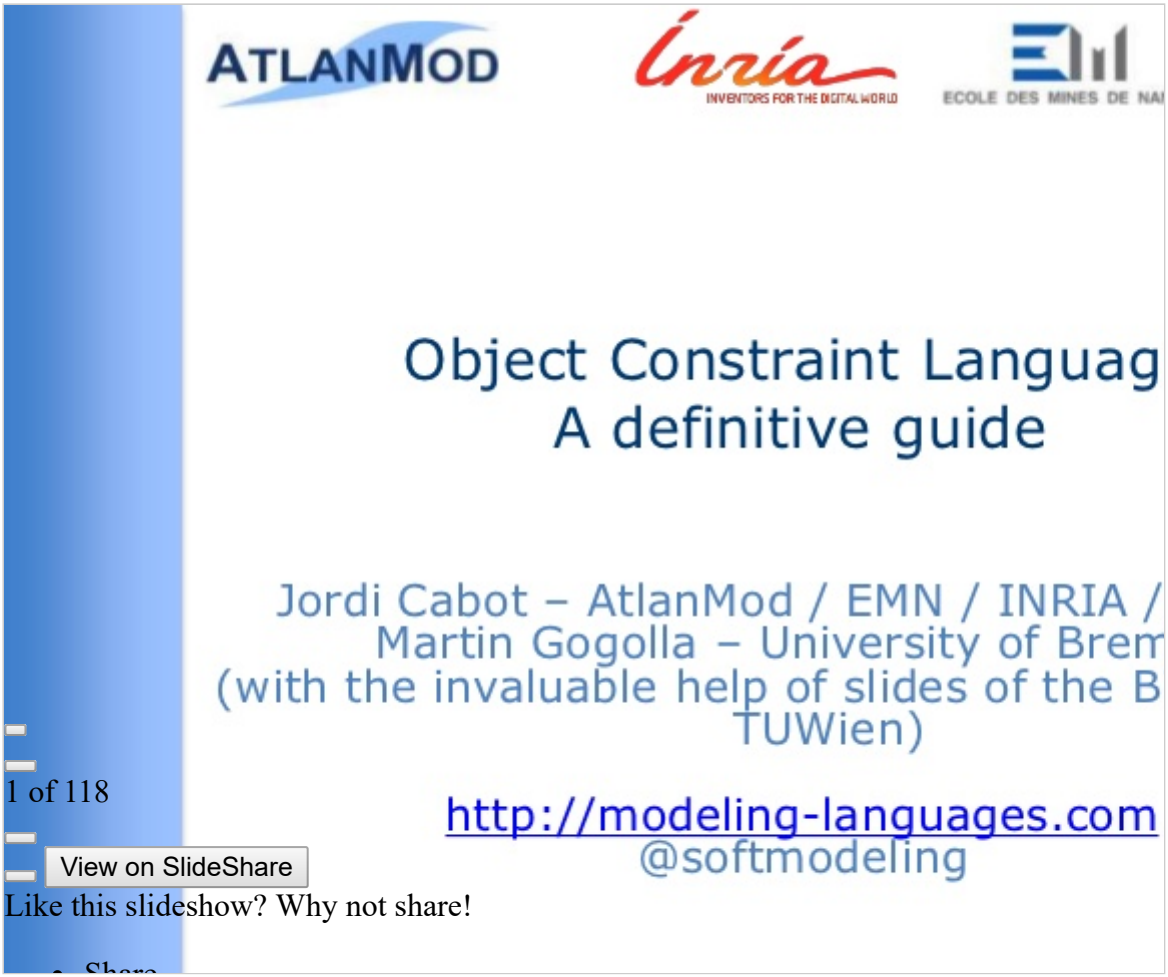
by Jordi Cabot | Mar 21, 2012 | book, teaching, UML and OCL | 4 comments

As part of my participation in the 12th Int. School on Formal Methods: Model-Driven Engineering (SFM´12) I´ve co-authored an OCL tutorial book chapter (together with Martin Gogolla) introducing the Object Constraint Language (you may want to read why you need to learn OCL first).

The **abstract** of the chapter is the following:

The Object Constraint Language (OCL) started as a complement of the UML notation with the goal to overcome the limitations of UML (and in general, any graphical notation) in terms of precisely specifying detailed aspects of a system design. Since then, OCL has become a key component of any model-driven engineering (MDE) technique as the default language for expressing all kinds of (meta)model query, manipulation and specification requirements. Among many other applications, OCL is frequently used to express model transformations (as part of the source and target patterns of transformation rules), well-formedness rules (as part of the definition of new domain-specific languages), or code-generation templates (as a way to express the generation patterns and rules). This chapter pretends to provide a comprehensive view of this language, its many applications and available tool support as well as the latest research developments and open challenges around it.

And these are the slides I used during the tutorial



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OCL tutorial from **Jordi Cabot**

The full text can be found here (© Springer-Verlag). I'm copying below the first three sections which I believe are the most useful for a real beginner (all the rest go to the previous link for the complete discussion):

1. Introduction to the Object Constraint Language tutorial

The Object Constraint Language (OCL) appeared as an effort to overcome the limitations of UML when it comes to precisely specifying detailed aspects of a system design. OCL was first developed in 1995 inside IBM as an evolution of an expression language in the Syntropy method [26]. The work on OCL was part of a joint proposal with ObjectTime Limited presented as a response to the RFP for a standard object-oriented analysis and design language issued by the Object Management Group (OMG) [26]. That standard came to be what we now know as UML and OCL became integrated in it in 1997.

Initially, OCL was only used as a constraint language for UML but quickly ex-panded its scope and now OCL has become a key component of any model-driven engineering (MDE) technique as the default language for expressing all kinds of (meta)model query, manipulation and specification requirements. Among many other applications, OCL is frequently used to express model transformations (as part of the source and target patterns of transformation rules), well-formedness rules (as part of the definition of new domain-specific languages, or code generation templates (as a way to express the generation patterns and rules). To adapt the language to these new applications,

several new (sub)versions of the language have been released. At the moment of writing this chapter, the current version of the OCL language is version 2.3.1 [20].

This chapter pretends to provide a comprehensive view of this language, its many applications and available tool support as well as the latest research devel- opments and open challenges around it. The rest of this chapter is structured as follows. Section 2 motivates the need for OCL. Section 3 gives a brief overview of the language, while Section 4 provides a more precise language description. Then, Section 5 classifies existings OCL tools. Finally, Section 6 outlines a possible research agenda for OCL and Section 7 provides some final conclusions.

2. Motivation: Why OCL is needed

Graphical modeling languages are the preferred choice for many designers when it comes to define the structural aspects of a domain (i.e., its main concepts, their properties and the relationships between them). The most typical example of a graphical notation is UML [21], specially its class diagram which is by far the most used UML diagram [13].

Nevertheless, this facility of use comes with a price. In order to keep the number of notational elements manageable, language designers must limit the expressiveness of the language. This means that graphical notations can only express a limited subset of all the relevant information of a domain. This is where OCL (and in general, any other textual language) comes into play. They are a necessary complement of the UML (or other graphical languages) notation in order to be able to precisely specify all detailed aspects of a system design.

As an example, take a look at the class diagram of Figure 1 that will be used as running example throughout the chapter. This diagram is an excerpt of the EU-Rent Car Rentals Specification [14], an in-depth specification of the EU-Rent case study, which is a widely known case study being promoted as a basis for demonstration of product capabilities. EU-Rent presents a car rental company with branches in several countries that provides typical rental services. EU-Rent was originally developed by Model Systems, Ltd.

This excerpt contains information about the rentals of the company (Rental class), the company branches (Branch class), the rented cars (Car), the category to which they belong (CarGroup) and the customers (Customer) that at some point in time may become blacklisted (BlackListed) due to delayed car returns, unpaid rentals, etc. Each rented car has one or more registered drivers and a pickup and drop off branch assigned.

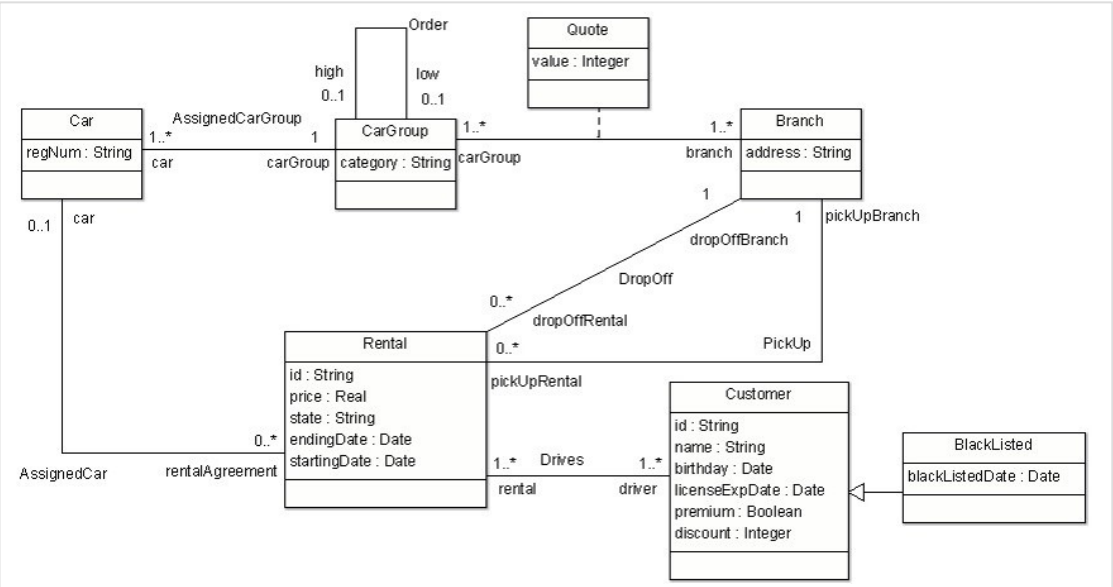

Fig. 1. Running Example – Partial Class Diagram of the EU-Rent company

This may look like a quite complete definition of the problem but in reality it is just the tip of the iceberg. Many important details cannot be defined just using the notation available for UML class diagrams. Just to mention some aspects that the UML diagram does not answer:

1. Can black listed people rent new cars? (common sense may suggest answering no to this question but in fact this is not specified anywhere in the diagram so different people may assume different answers)
2. How is the price of a rental calculated?
3. What are the conditions to be able to extend an existing rental?
4. Should the driving license of all drivers be valid throughout the full rental period? Is there a minimum driving seniority required? Can the same driver have two active rentals?
5. Can the pickup and drop off branches differ?
6. Can I choose a car already assigned to another rental?

The next section will show how OCL can be used to express all these addi- tional concerns.

3. OCL in a Nutshell

The goal of this section is to give you an informal short description of the OCL and show its usefulness by exemplifying how it can be used to solve the open questions left at the end of the last section.

OCL is a general-purpose (textual) formal language adopted as a standard by the OMG (see the current version of the OCL specification [20]) used to define several kinds of expressions that complement the information of (UML) models.

OCL is a typed, declarative and side-effect free specification language. Typed means that each OCL expression evaluates to a type (either one of the predefined OCL types or a

type in the model where the OCL expression is used) and must conform to the rules and operations of that type. Side-effect free implies that OCL expressions can query or constrain the state of the system but not modify

Declarative means that OCL does not include imperative constructs like as- signments. And finally, specification refers to the fact that the language definition does not include any implementation details nor implementation guidelines.

Among the many applications of OCL, it can be used to define the following kinds of expressions (for the sake of simplicity we focus on OCL usages in class diagrams) :

- Invariants to state all necessary condition that must be satisfied in each possible instantiation of the model.
- Initialization of class properties.
- Derivation rules that express how the value of derived model elements must be computed.
- Query operations
- Operation contracts (i.e., set of operation pre- and postconditions)

In the following we briefly introduce each expression type and explain some basic OCL construct along the way. The next section will present the full details of the language.

Invariants

Integrity constraints in OCL are represented as invariants defined in the context of a specific type, named the context type of the constraint. Its body, the boolean condition to be checked, must be satisfied by all instances of the context type.

Invariants are without a doubt the most common OCL expression since they allow designers to easily specify all kinds of conditions that the system must comply with.

Invariants can restrict the value of single objects, like the following *QuoteOverZero* :

```
context Quote inv QuoteOverZero: self.value > 0
```

stating that all quotes must have a positive value. Note that the self variable represents an arbitrary instance of the Quote class and the dot notation is used to access the properties of the self object (as the value attribute in the example). As stated above, all instances of Quote (the context type of the constraint in this case) must evaluate this condition to true.

Nevertheless, many invariants express more complex conditions limiting the possible relationships between different objects in the system, usually related through association links. For instance, this NoRentalsBlackListed constraint forbids BlackListed people of renting cars:

```
context BlackListed inv NoRentalsBlackListed: self.rental->forAll(r |
```

where we first retrieve all rentals linked to a blacklisted person and then we make sure that all of them were created before the person was blacklisted. This is done by iterating on all related rentals and evaluating the date condition on each of them; the forAll iterator returns true iff all elements of the input collection evaluate the condition to true.

Initialization Expressions

OCL can be used to specify the initial value that the properties of an object must take upon the object creation. Obviously, the type of the expression must conform to the type of the initialized property (this must also take into account cases where the property to be initialized is a collection).

For instance, the following OCL expression initializes to false the value of the premium attribute of Customers (we are assuming that customers can only promote to the premium status after renting several cars).

```
context Customer::premium: boolean init: false
```

Derived Elements

Derived elements are elements whose value/population can be inferred from the value/population of other model elements as defined in the element's derivation rule. OCL is a popular choice for specifying these derivation rules.

OCL derivation rules follow the same structure as init expressions (see above) although their interpretation is different. An init expression must be true when the object is created but the restriced property may change its value afterwards (i.e., customers start as non-premium but may evolve to premium during their time in the system). Instead, derivation rules constrain the value of a derived element throughout all its life-span. Note that this does not imply that the value of a derived element cannot change, it only means that it will always change according to the evaluation of its derivation rule.

As an example, consider the following rule for the derived element discount in class Customer, stating that premium members get a 30% discount while non- premium members get 15% if they have at least rented high category cars five times while the rest of the customers get no discount at all.

```
context Customer::discount: integer derive:
        if not self.premium then
           if self.rental.car.carGroup->select(c|c.category='high')->size
           then 15 else 0 endif
        else 30 endif
```

The select iterator in the expression returns the subcollection of elements from the input collection that satisfy the condition. Then, the size collection operator returns the cardinality of the output subcollection and this value is compared with the '5' threshold. Note that in this example, the input collection (self.rental.car.carGroup) is not a set but a bag (i.e., a collection with repeated elements) since a user may have rented the same car twice in different rentals or two cars belonging to the same car group.

Query Operations

As the name indicates, query operations are a wrapped OCL expression that queries the system data and returns the information to the user.

As an example, the following query operation returns true if the car on which the operation is executed is the most popular in the rental system.

```
context  Car::mostPopular():  boolean
body:  Car::allInstances()->forAll(c1|c1<>self
       implies c1.rentalAgreement->size()<=self.rentalAgreement->size())
```

Operation Contracts

There are two different approaches for specifying an operation effect: the im- perative and the declarative approach [27]. In an imperative specification, the designer explicitly defines the set of structural events (inserts/updates/deletes) to be applied when executing the operation. Instead, in a declarative specifica- tion, a contract for each operation must be provided. The contract consists of a set of pre- and postconditions. A precondition defines a set of conditions on the operation input and the system state that must hold when the operation is issued while postconditions state the set of conditions that must be satisfied by the system state at the end of the operation. OCL is usually the language of choice to express pre- and postconditions for operation contracts at the modeling level.

As an example, the following newRental operation describes (part of) the business logic behind the creation of a new rental in the EU-rent system:

```
context Rental::newRental(id:Integer, price:Real,  startingDate:Date,
        endingDate:Date,  customer:Customer, carRegNum:String, pickupBranch
pre:  customer.licenseExpDate>endingDate
post: Rental.allInstances->one(r |  r.oclIsNew() and
      r.oclIsTypeOf(Rental)  and r.endingDate=endingDate and  r.startingDat
      and r.driver=customer and  r.pickupBranch=pickupBranch  and r.dropOff
      and r.car=Car.allInstances()->any(c | c.regNum=carRegNum))
```

The precondition checks that the customer has a valid license for the duration of the rental5 while the postcondition states that by the end of the operation a new object r of type Rental must have been created and initialized with the set of values passed as parameters (note that postconditions are underspecifications, i.e., they only specify part of the system state at the end of the execution which leads to the frame problem [4] and other similar issues; this problem is not OCL-specific and thus it is outside of the scope of this chapter).

OCL Language Description

Figure 2 gives an overview of the OCL type system in form of a feature model. Using a tree-like description, feature models allow to describe mandatory and optional features of a subject, and they allow to specify alternative features as well conjunctive features. In particular, the figure pictures the different kinds of available types. Before explaining

the type system in a systematic way, let us discuss OCL example types which are already known or which can be deduced from the class diagram of our running example in Fig. 3.

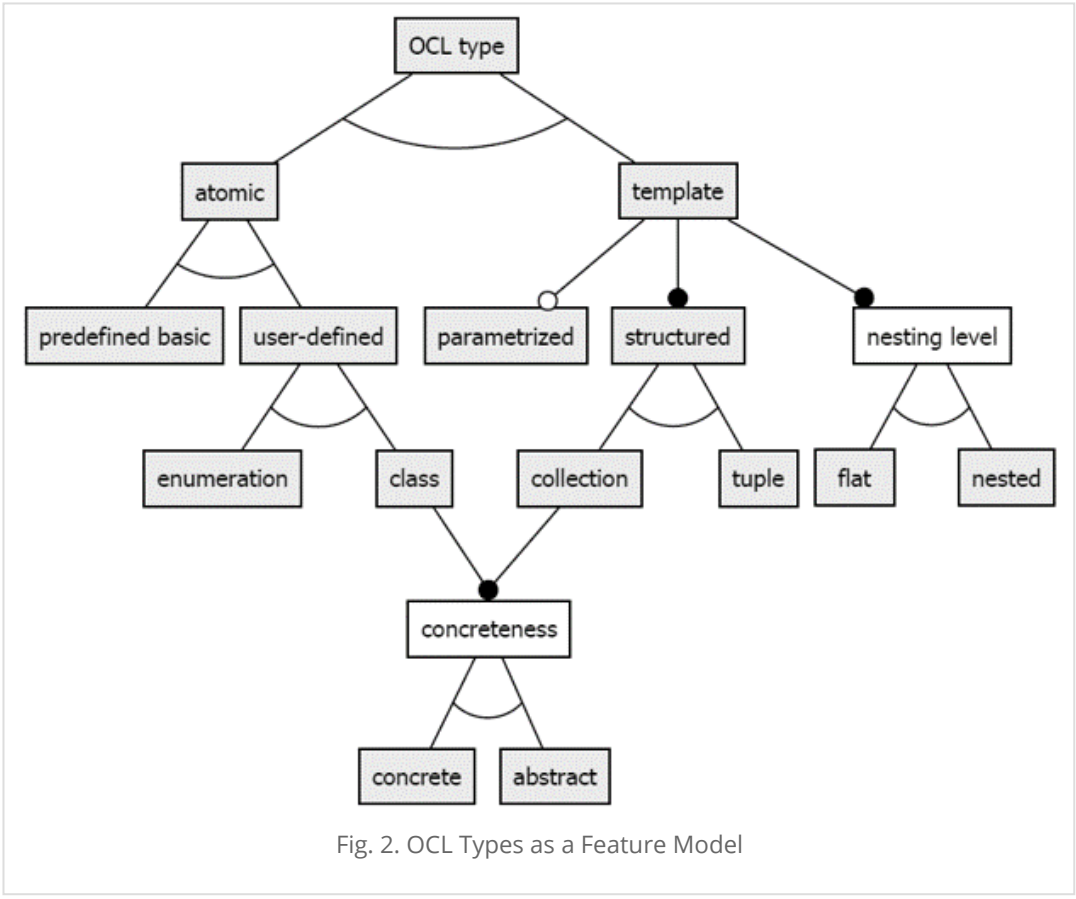

Fig. 2. OCL Types as a Feature Model

Attributes types, as for example in Car::regNum:String, are predefined basic, atomic types. Classes which are defined by the class diagram are atomic, user-defined class types. If we already have an expression cg of type CarGroup, then the OCL expression cg.car has the type Set(Car) due to the multiplicity 1..*. The type Set(Car) is a flat, concrete collection type. Set(Car) is a reification of the parametrized collection type Set(T) where T denotes an arbitrary type parameter which can be stubstituted. The type Sequence(Set(Car)) is a nested collection type being a reification of the parametrized, nested collection type Sequence(Set(T)). If cg:CarGroup is given, then the expression Tuple{cat:cg.category, cars:cg.car} has type Tuple(cat:String, cars:Set(Car)) which is a tuple type.

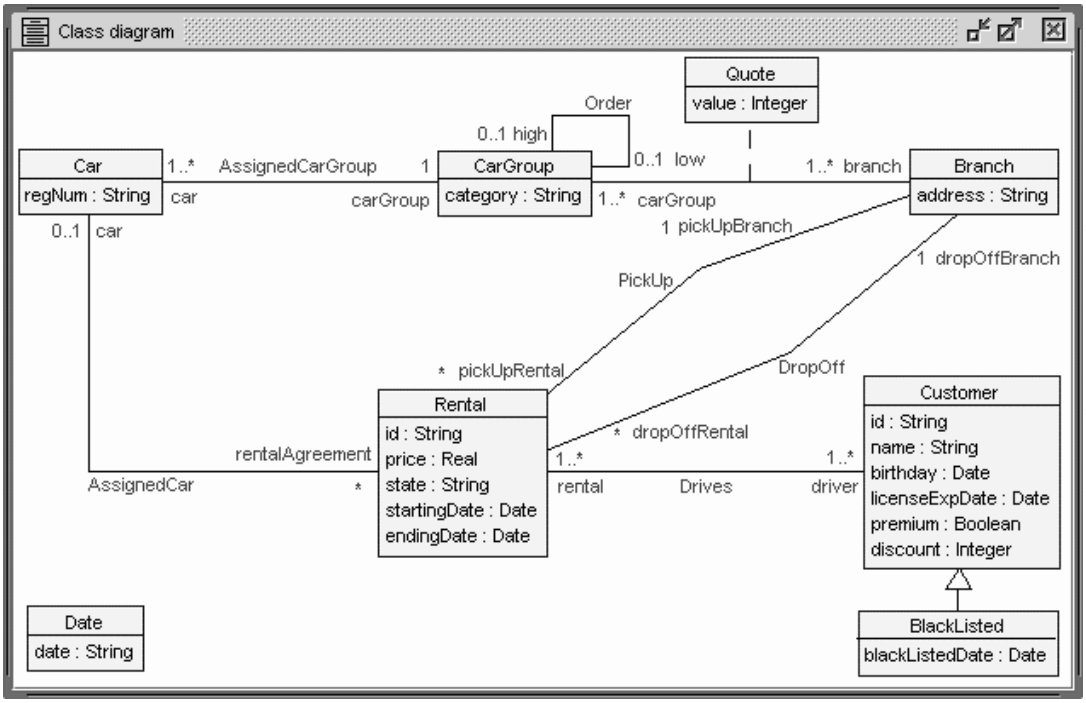

Fig. 3. Example Class Diagram in USE tool

Again, you can read the complete text of the tutorial for free by downloading this pdf

4 Comments

Chris on June 23, 2017 at 6:30 am

Really great article, thank you

Reply

Tony on August 24, 2017 at 4:13 pm

Excellent article with clear explanations. Great for novices and experts.

Reply

hanan on April 25, 2018 at 4:25 pm

Hello Sir,
Thank you very much for this article.
Actually I have questions about OCL. If I want to implement set of rules by OCL then detect the validity of these rules (check for conflicts) with my proposed algorithm (written in java, python.. etc) Is that possible with OCL??

I am still new for OCL!!

Reply

Jordi Cabot on April 27, 2018 at 8:16 am

Yes, you can check the consistency of the rules with any of the tools mentioned here: https://modeling-languages.com/state-art-static-model-verification-tools/

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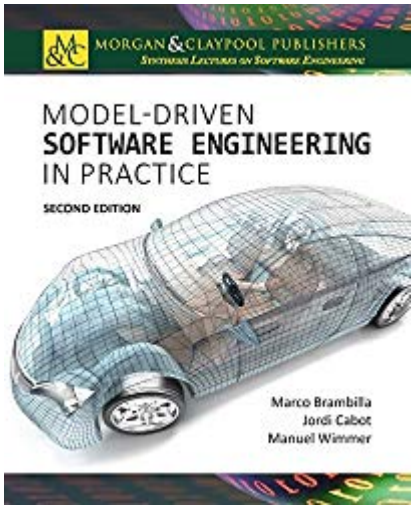
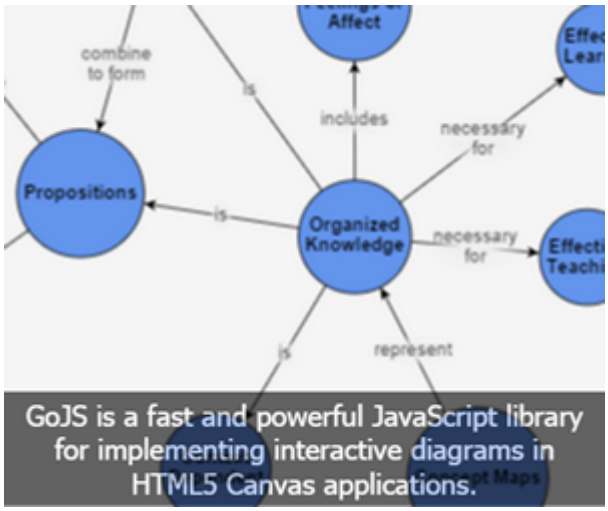


JavaScript diagrams



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