Semantic Web for the Working Ontologist

Modeling in RDF, RDFS and OWL

Dean Allemang

James Hendler

ELSEVIER

AMSTERDAM • BOSTON • HEIDELBERG • LONDON
NEW YORK • OXFORD • PARIS • SAN DIEGO
SAN FRANCISCO • SINGAPORE • SYDNEY • TOKYO
Morgan Kaufmann Publishers is an imprint of Elsevier

MORGAN KAUFMANN PUBL

CHAPTER 2
Semantic Modeling

What would you call a world in which any number of people can speak, when you never know who has something useful to say, and when someone new might come along at any time and make a valuable but unexpected contribution? What if just about everyone had the same goal of advancing the collaborative state of knowledge of the group, but there was little agreement (at first, anyway) about how to achieve it?

If your answer is "That sounds like the Semantic Web!" you are right (and you must have read Chapter 1). If your answer is "It sounds like any large group trying to understand a complex phenomenon," you are even more right. The jungle that is the Semantic Web is not a new thing; this sort of chaos has existed since people first tried to make sense of the world around them.

What intellectual tools have been successful in helping people sort through this sort of tangle? Any number of analytical tools has been developed over the years, but they all have one thing in common: They help people understand their world by forming an abstract description that hides certain details while illuminating others. These abstractions are called *models*, and they can take many forms.

How do models help people assemble their knowledge? Models assist in three essential ways:

1. *Models help people communicate.* A model describes the situation in a particular way that other people can understand.
2. *Models explain and make predictions.* A model relates primitive phenomena to one another and to more complex phenomena, providing explanations and predictions about the world.
3. *Models mediate among multiple viewpoints.* No two people agree completely on what they want to know about a phenomenon; models represent their commonalities while allowing them to explore their differences.

The Semantic Web standards have been created not only as a medium in which people can collaborate by sharing information but also as a medium in which people can collaborate on models. Models that they can use to organize the information that they share. Models that they can use to advance the common collection of knowledge.

How can a model help us find our way through the mess that is the Web? How do these three features help? The first feature, human communication, allows people to collaborate on their understanding. If someone else has faced the same challenge that you face today, perhaps you can learn from their experience and apply it to yours. There are a number of examples of this in the Web today, of newsgroups, mailing lists, and wikis where people can ask questions and get answers. In the case in which the information needs are fairly uniform, it is not uncommon for a community or a company to assemble a set of "Frequently Asked Questions," or FAQs, that gather the appropriate knowledge as answers to these questions. As the number of questions becomes unmanageable, it is not uncommon to group them by topic, by task, by affected subsystem, and so forth. This sort of activity, by which information is organized for the purpose of sharing, is the simplest and most common kind of modeling, with the sole aim of helping a group of people collaborate in their effort to sort through a complex set of knowledge.

The second feature, explanation and prediction, helps individuals make their own judgments based on information they receive. FAQs are useful when there is a single authority that can give clear answers to a question, as is the case for technical assistance for using some appliance or service. But in more interpretive situations, someone might want or need to draw a conclusion for themselves. In such a situation, a simple answer as given in a FAQ is not sufficient. Politics is a common example from everyday life. Politicians in debate do not tell people how to vote, but they try to convince them to vote in one way or another. Part of that convincing is done by explaining their position and allowing the individual to evaluate whether that explanation holds true to their own beliefs about the world. They also typically make predictions: If we follow this course of action, then a particular outcome will follow. Of course, a lot more goes into political persuasion than the argument, but explanation and prediction are key elements of a persuasive argument.

Finally, the third feature, mediation of multiple viewpoints, is essential to fostering understanding in a web environment. As the web of opinions and facts grows, many people will say things that disagree slightly or even outright contradict what others are saying. Anyone who wants to make their way through this will have to be able to sort out different opinions, representing what they have in common as well as the ways in which they differ. This is one of the most essential organizing principles of a large, heterogeneous knowledge set, and it is one of the major contributions that modeling makes to helping people organize what they know.

Astrologers and the IAU agree on the planethood of Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus, and Neptune. The IAU also agrees with astrologers that Pluto is a planet, but it disagrees by calling it a dwarf planet. Astrologers (or classical astronomers) do not accept the concept of dwarf planets, so they are not in agreement with the IAU, which categorizes UB313 and Ceres as such. A model for the Semantic Web must be able to organize this sort of variation, and much more, in a meaningful and manageable way.

MODELING FOR HUMAN COMMUNICATION

Models used for human communication have a great advantage over models that are intended for use by computers; they can take advantage of the human capacity to interpret signs to give them meaning. This means that communication models can be written in a wide variety of forms, including plain language or ad hoc images. A model can be explained by one person, amended by another, interpreted by a third person, and so on. Models written in natural language have been used in all manner of intellectual life, including science, religion, government, and mathematics.

But this advantage is a double-edged sword; when we leave it to humans to interpret the meaning of a model, we open the door for all manner of abuse, both intentional and unintentional. Legislation provides a good example of this. A governing body like a parliament or a legislature enacts laws that are intended to mediate rights and responsibilities between various parties. Legislation typically sets up some sort of model of a situation, perhaps involving money (e.g., interest caps, taxes); access rights (who can view what information, how can information be legally protected); personal freedom (how freely can one travel across borders, when does the government have the right to restrict a person's movements); or even the structure of government itself (who can vote and how are those votes counted, how can government officials be removed from office). These models are painstakingly written in natural language and agreed on through an elaborate process (which is also typically modeled in natural language).

It is well known to anyone with even a passing interest in politics that good legislation is not an easy task and that crafting the words carefully for a law or statute is very important. The same flexibility of interpretation that makes natural language models so flexible also makes it difficult to control how the laws will be interpreted in the future. When someone else reads the text, they will have their own background and their own interests that will influence how they interpret any particular model. This phenomenon is so widespread that most government systems include a process (usually involving a court magistrate and possibly a committee of citizens) whereby disputes over the interpretation of a law or its applicability can be resolved.

When a model relies on particulars of the context of its reader for interpretation of its meaning, as is the case in legislation, we say that a model is *informal*. That is, the model lacks a formalism whereby the meaning of terms in the model can be uniquely defined.

In the document web today, there are informal models that help people communicate about the organization of the information. It is common for commerce websites to organize their wares in catalogs with category names like "webcams," "Oxford shirts," and "Granola." In such cases, the communication is primarily one-way; the catalogue designer wants to communicate to the buyers the information that will help them find what they want to buy. The interpretation of these words is up to the buyers. The effectiveness of such a model is measured by the degree to which this is successful. If enough people interpret the categories in a way similar enough to the intent of the cataloguer, then they will find what they want to buy. There will be the occasional discrepancy like "Why wasn't that item listed as a *webcam*?" or "That's not granola, that's just plain cereal!" But as long as the interpretation is close enough, the model is successful.

A more collaborative style of document modeling comes in the form of community tagging. A number of websites have been successful by allowing users to provide meaningful symbolic descriptions of their content in the form of *tags*. A tag in this sense is simply a single word or short phrase that describes some aspect of the content. Examples of tagging systems include Flickr for photos and del.icio.us for Web bookmarks. The idea of community tagging is that each individual who provides content will describe it using tags of their own choosing. If any two people use the same tag, this becomes a common organizing entity; anyone who is browsing for content can access information from both contributors under that tag. The tagging infrastructure shows which tags have been used by many people. Not only does this help browsers determine what tags to use in a search, but it also helps content providers to find commonly used tags that they might want to use to describe new content. Thus, a tagging system will have a certain self-organizing character, whereby popular tags become more popular and unpopular tags remain unpopular—something like evolution by artificial selection of tags.

Tagging systems of this sort provide an informal organization to a large body of heterogeneous information. The organization is informal in the sense that the interpretation of the tags requires human processing in the context of the consumer. Just because a tag is popular doesn't mean that everyone is using it in the same way. In fact, the community selection process actually selects tags that are used in several different ways, whether they are compatible or not. As more and more people provide content, the popular tags saturate with a wide variety of content, making them less and less useful as discriminators for people browsing for content. This sort of problem is inherent in information modeling systems; since there isn't an objective description of the meaning of a symbol outside the context of the provider and consumer of the symbol, the communication power of that symbol degrades as it is used in more and more contexts.

Formality of a model isn't a black-and-white judgment; there can be degrees of formality. This is clear in legal systems, where it is common to have several layers of legislation, each one giving objective context for the next. A contract between two parties is usually governed by some regional law that provides standard definitions for terms in the contract. Regional laws are governed by national laws, which provide constraints and definitions for their terms. National laws have their own structure, in which a constitution or a body of case law provides a framework for new decisions and legislation. Even though all these models are expressed in natural language and fall back on human interpretation in the long run, they can be more formal than private agreements that rely almost entirely on the interpretation of the agreeing parties.

This layering of informal models sometimes results in a modeling style that is reminiscent of Talmudic scholarship. The content of the Talmud includes not only the original scripture but also interpretative comments on the scripture by authoritative sources (classical rabbis). Their comments have gained such respect that they are traditionally published along with the original scripture for comment by later rabbis, whose comments in turn have become part of the intellectual tradition. The original scripture, along with all the authoritative comments, is collectively called the Talmud, and it is the basis of a classical Jewish education to this day.

A similar effect happens with informal models. The original model is appropriate in some context, but as its use expands beyond that context, further models are required to provide common context to explicate the shared meaning. But if this further exposition is also informal, then there is the risk that its meaning will not be clear, so further modeling must be done to clarify that. This results in heavily layered models, in which the meaning of the terms is always subject to further interpretation. It is the inherent ambiguity of natural language at each level that makes the next layer of commentary necessary until the degree of ambiguity is "good enough" that no more levels are needed. When it is possible to choose words that are evocative and have considerable agreement, this process converges much more quickly.

Human communication, as a goal for modeling, allows it to play a role in the ongoing collection of human knowledge. The levels of communication can be quite sophisticated, including the collection of information used to interpret other information. In this sense, human communication is the fundamental requirement for building a Semantic Web. It allows people to contribute to a growing body of knowledge and then draw from it. But communication is not enough; to empower a web of human knowledge, the information in a model needs to be organized in such a way that it can be useful to a wide range of consumers.

EXPLANATION AND PREDICTION

Models are used to organize human thought in the form of explanations. When we understand how a phenomenon results from other basic principles, we gain a number of advantages. Not least is the feeling of confidence that we have actually understood it; people often claim to "have a grasp on" or "have their head around" an idea when they finally understand it. Explanation plays a major role in this sort of understanding. Explanation also assists in memory; it is easier to remember that putting a lid on a flaming pot can quench the flame if one knows the explanation that fire requires air to burn. Most important for the context of the Semantic Web, explanation makes it easier to reuse a model in whole or in part; an explanation relates a conclusion to more basic principles. Understanding how a pot lid quenches a fire can help one understand how a candle snuffer works. Explanation is the key to understanding when a model is applicable and when it is not.

Closely related to this aspect of a model is the idea of prediction. When a model provides an adequate explanation of a phenomenon, it can also be used to make predictions. This aspect of models is what makes their use central to the scientific method, where falsification of predictions made by models forms the basis of the methodology of inquiry.

Explanation and prediction typically require models with a good deal more formality than is usually required for human communication. An explanation relates a phenomenon to "first principles"; these principles, and the rules by which they are related, do not depend on interpretation by the consumer but instead are in some objective form that stands outside the communication. Such an objective form, and the rules that govern how it works, is called a *formalism*.

Formal models are the bread and butter of mathematical modeling, in which very specific rules for calculation and symbol manipulation govern the structure of a mathematical model and the valid ways in which one item can refer to another. Explanations come in the form of proofs, in which steps from premises (stated in some formalism) to conclusions are made according to strict rules of transformation for the formalism. Formal models are used in many human intellectual endeavors, wherever precision and objectivity are required.

Formalisms can also be used for predictions. Given a description of a situation in some formalism, the same rules that govern transformations in proofs can be used to make predictions. We can explain the trajectory of an object thrown out of a window with a formal model of force, gravity, speed, and mass, but given the initial conditions of the object thrown, we can also compute, and thus predict, its trajectory.

Formal prediction and explanation allow us to evaluate when a model is applicable. Furthermore, the formalism allows that evaluation to be independent of the listener. One can dispute the result that $2 + 2 = 4$ by questioning just what the terms "2," "4," "+," and "=" mean, but once people agree on what they mean, they cannot (reasonably) dispute that this formula is correct.

Formal modeling therefore has a very different social dynamic than informal modeling; because there is an objective reference to the model (the formalism), there is no need for the layers of interpretation that result in Talmudic modeling. Instead of layers and layers of interpretation, the buck stops at the formalism.

As we shall see, the Semantic Web standards include a small variety of modeling formalisms. Because they are formalisms, modeling in the Semantic Web need not become a process of layering interpretation on interpretation. Also, because they are formalisms, it is possible to couch explanations in the Semantic Web in the form of proofs and to use that proof mechanism to make predictions. This aspect of Semantic Web models goes by the name *inference*, and it will be discussed in detail in Chapter 5.

Mediating Variability

In any Web setting, variability is to be expected and even embraced. The dynamics of the network effect require the ability to represent a variety of opinions. A good model organizes those opinions so that the things that are common can be represented together, while the things that are distinct can be represented as well.

Let's take the case of Pluto as an example. From 1930 until 2006, it was considered to be a planet by astronomers and astrologers alike. After the redefinition of *planet* by the IAU in 2006, Pluto was no longer considered to be a planet but more specifically a *dwarf planet* by the IAU and by astronomers who accept the IAU as an authority. Astrologers, however, chose not to adopt the IAU convention, and they continued to consider Pluto a planet. Some amateur astronomers, mostly for nostalgic reasons, also continued to consider Pluto a planet. How can we accommodate all of these variations of opinion on the Web?

One way to accommodate them would be to make a decision as to which one is "preferred" and to control the Web so that only that position is supported. This is the solution that is most commonly used in corporate data centers, where a small group or even a single person acts as the database administrator and decides what data are allowed to live in the corporate database. This solution is not appropriate for the Web because it does not allow for the AAA slogan (see Chapter 1) that leads to the network effect.

Another way to accommodate these different viewpoints would be to simply allow each one to be represented separately, with no reference to one another at all. It would be the responsibility of the information consumer to understand how these things relate to one another and to make any connections as appropriate. This is the basis of an informal approach, and it indeed describes the state of the document web as it is today. A Web search for Pluto will turn up a wide array of articles, in which some call it a planet (e.g., astrological ones or astronomical ones that have not been updated), some call it a dwarf planet (IAU official websites), and some that are still debating the issue. The only way a reader can come to understand what is common among these things—the notion of a planet, of the solar system, or even of Pluto itself—is through reader interpretation.

How can a model help sort this out? How can a model describe what is common about the astrological notion of a planet, the twentieth-century astronomical notion of a planet, and the post-2006 notion of a planet? The model must also allow for each of these differing viewpoints to be expressed.

Variation and Classes

This problem is not a new one; it is a well-known problem in software engineering. When a software component is designed, it has to provide certain functionality, determined by information given to it at runtime. There is a trade-off in such a design; the component can be made to operate in a wide variety of circumstances, but it will require a complex input to describe just how it should behave at any one time. Or the system could be designed to work with very simple input but be useful in only a small number of very specific situations. The design of a software component inherently involves a model of the commonality and variability in the environment in which it is expected to be deployed. In response to this challenge, software methodology has developed the art of object modeling (in the context of Object-Oriented Programming, or OOP) as a means of organizing commonality and variability in software components.

One of the primary organizing tools in OOP is the notion of a hierarchy of classes and subclasses. Classes high up in the hierarchy represent functionality that is common to a large number of components; classes farther down in a hierarchy represent more specific functionality. Commonality and variability in the functionality of a set of software components is represented in a class hierarchy.

The Semantic Web standards also use this idea of class hierarchy for representing commonality and variability. Since the Semantic Web, unlike OOP, is not focused on software representation, classes are not defined in terms of behaviors of functions. But the notion of classes and subclasses remains, and it plays much the same role. High-level classes represent commonality among a large variety of entities, whereas lower-level classes represent commonality among a small, specific set of things.

Let's take Pluto as an example. The 2006 IAU definition of *planet* is quite specific in requiring these three criteria for a celestial body to be considered a planet:

1. It is in orbit around the sun.
2. It has sufficient mass to be nearly round.
3. It has cleared the neighborhood around its orbit.

The IAU goes further to state that a dwarf planet is a body that satisfies conditions 1 and 2 (and not 3); a body that satisfies only condition 1 is a *small solar system body (SSSB)*. These definitions make a number of things clear: The classes SSSB, dwarf planet, and planet are all mutually exclusive; no body is a member of any two classes. However, there is something that all of them have in common: They all are in orbit around the sun.

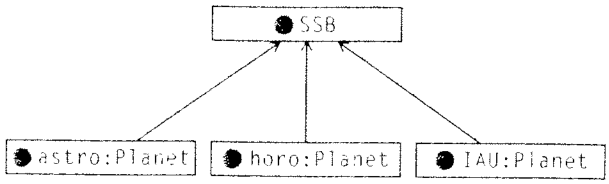


FIGURE 2-1

Subclass diagram for different notions of *planet*.

Twentieth-century astronomy and astrology are not quite as organized as this; they don't have such rigorous definitions of the word *planet*. So how can we relate these notions to the twenty-first-century notion of *planet*?

The first thing we need is a way to talk about the various uses of the word *planet:* the IAU use, the astrological use, and the twentieth-century astronomical use. This seems like a simple requirement, but until it is met, we can't even talk about the relationship among these terms. We will see details of the Semantic Web solution to this issue in Chapter 3, but for now, we will simply prefix each term with a short abbreviation of its source—for example, use `IAU:Planet` for the IAU use of the word, `horo:Planet` for the astrological use, and `astro:Planet` for the twentieth-century astronomical use.

The solution begins by noticing what it is that all three notions of *planet* have in common; in this case, it is that the body orbits the sun. Thus, we can define a class of the things that orbit the sun, which we may as well call *solar system body*, or *SSB* for short. All three notions are subclasses of this notion. This can be depicted graphically as in Figure 2-1.

We can go further in this modeling when we observe that there are only eight `IAU:Planets`, and each one is also a `horo:Planet` and an `astro:Planet`. Thus, we can say that `IAU:Planet` is a subclass of both `horo:Planet` and `astro:Planet`, as shown in Figure 2-2. We can continue in this way, describing the relationships among all the concepts we have mentioned so far: `IAU:dwarf` *planet* and `IAU:SSSB`. As we go down the tree, each class refers to a more restrictive set of entities. In this way, we can model the commonality among entities (at the high level) while respecting their variation (at a low level).

Variation and Layers

Classes and subclasses are a fine way to organize variation when there is a simple, known relationship between the modeled entities and it is possible to determine a clear ordering of classes that describes these relationships. In a Web setting, however, this usually is not the case. Each contributor can have something new to say that may fit in with previous statements in a wide variety of ways. How can we accommodate variation of sources if we can't structure the entities they are describing into a class model?

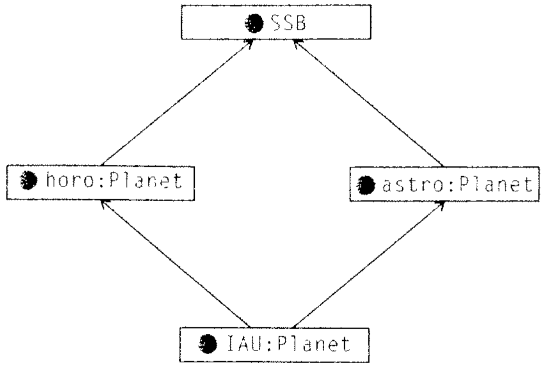


FIGURE 2-2

More detailed relationships between various notions of *planet.*

The Semantic Web provides an elegant solution to this problem. The basic idea is that any model can be built up from contributions from multiple sources. One way of thinking about this is to consider a model to be described in layers. Each layer comes from a different source. The entire model is the combination of all the layers, viewed as a single, unified whole.

Let's have a look at how this could work in the case of Pluto. Figure 2-3 illustrates how different communities could assert varying information about Pluto. In part (a) of the figure, we see some information about Pluto that is common among astrologers—namely, that Pluto signifies rebirth and regeneration and that the preferred symbol for referring to Pluto is the glyph indicated. Part (b) shows some information that is of concern to astronomers, including the composition of the body Pluto and their preferred symbol. How can this variation be accommodated in a web of information? The simplest way is to simply merge the two models into a single one that includes all the information from each model, as shown in part (c).

Merging models in this way is a conceptually simple thing to do, but how does it cope with variability? In the first place, it copes in the simplest way possible: It allows the astrologers and the astronomers to both have their say about Pluto (remember the AAA slogan!). For any party that is interested in both of these things (perhaps someone looking for a spiritual significance for elements?), the information can be viewed as a single, unified whole.

But merging models in this way has a drawback as well. In Figure 2-3(c), there are two distinct glyphs, each claiming to be the "preferred" symbol for Pluto. This brings up issues of consistency of viewpoints. On the face of it, this appears to be an inconsistency because, from its name, we might expect that there can be exactly one preferred symbol (`prefSymbol`) for any body. But how can a machine know that? For a machine, the name `prefSymbol` can't be treated any differently from any other label—for instance, `madeOf` or `signifies`. In such a context, how can we even tell that this is an inconsistency? After all,

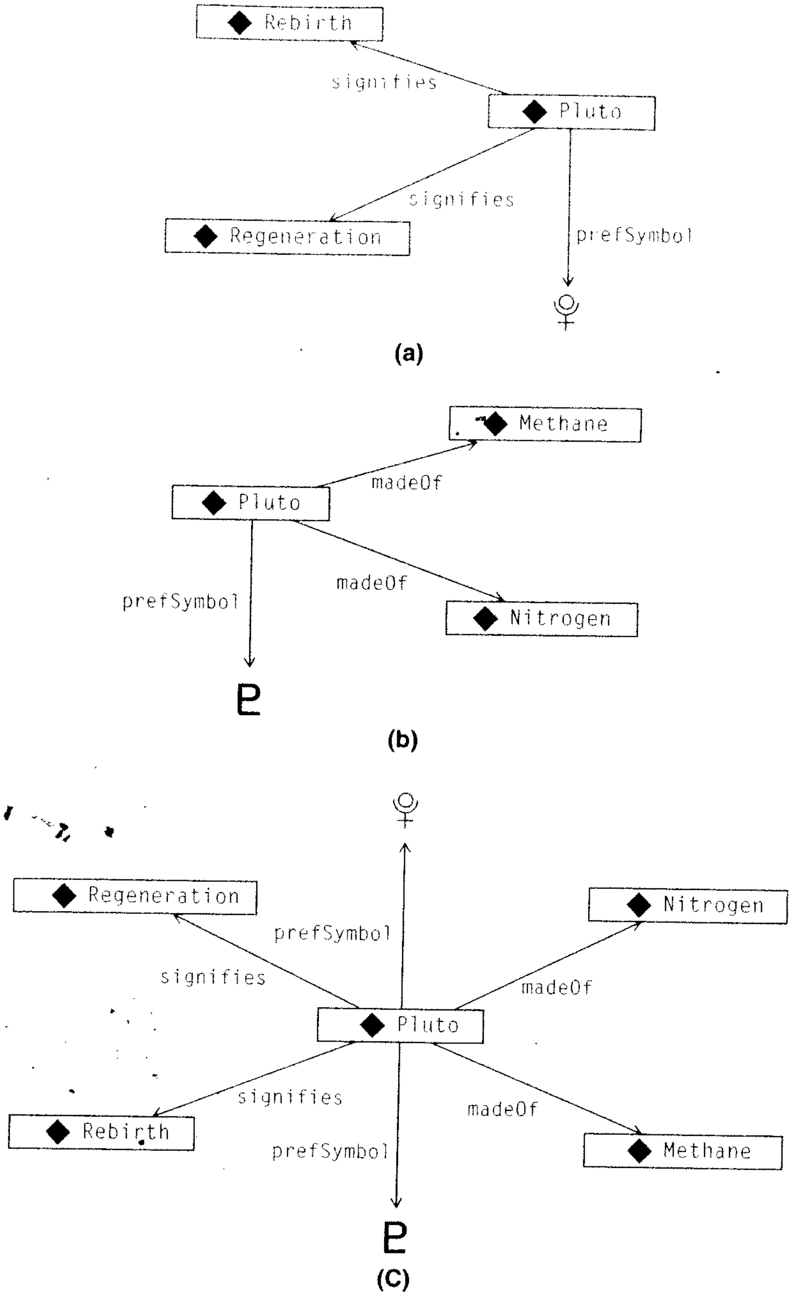


FIGURE 2-3

Layers of modeled information about Pluto.

we don't think it is an inconsistency that Pluto can be composed of more thar one chemical compound or that it can signify more than one spiritual theme Do we have to describe this in a natural language commentary on the model?

Detailed answers to questions like these are exactly the reason why w need to publish models on the Semantic Web. When two (or more!) view points come together in a web of knowledge, there will typically be overlap disagreement, and confusion before there is synergy, cooperation, and col laboration. If the infrastructure of the Web is to help us to find our wa through the wild stage of information sharing, an informal notion of how things fit together, or should fit together, will not suffice. It is easy enougl to say that we have an intuition that states there is something special abou `prefSymbol` that makes it different from `madeOf` or `signifies`. If we can inforn our infrastructure about this distinction in a sufficiently formal way, then i can, for instance, detect discrepancies of this sort and, in some cases, ever resolve them.

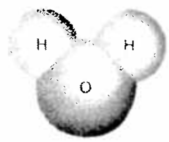
This is the essence of modeling in the Semantic Web: providing an infrastruc ture where not only can anyone say anything about any topic but the infrastruc ture can help a community work through the resulting chaos. A model car provide a framework (like classes and subclasses) for representing and organiz ing commonality and variability of viewpoints when they are known. But ir advance of such an organization, a model can provide a framework for describ ing what sorts of things we can say about something. We might not agree on th symbol for Pluto, but we can agree that it should have just one preferre symbol.

Expressivity in Modeling

There is a trade-off when we model, and although anyone can say anythin about any topic, not everyone will want to say certain things. There are thos who are interested in saying details about individual entities, like the preferre symbol for Pluto or the themes in life that it signifies. Others (like that IAU) ar interested in talking about categories, what belongs in a category, and how yo can tell the difference. Still others (like lexicographers, information architects and librarians) want to talk about the rules for specifying information, such a whether there can be more than one preferred label for any entity. All of thes people have contributions to make to the web of knowledge, but the kinds o contributions they make are very different, and they need different tools. Thi difference is one of *level of expressivity*.

The idea of different levels of expressivity is as well known in the history o collaborative human knowledge as modeling itself. Take as an example th development of models of a water molecule, as shown in Figure 2-4. In par (a), we see a model of the water molecule in terms of the elements that mak up the molecule and how many of each is present—namely, two hydroger atoms and one oxygen atom. This model expresses important information abou

H_2O (a)   H — O — H (b)



(c)

FIGURE 2-4

Different expressivity of models of a water molecule.

the molecule, it and can be used to answer a number of basic questions about water, such as calculating the mass of the molecule (given the masses of its component atoms) and what components would have to be present to be able to construct water from constituent parts.

In Figure 2-4(b), we see a model with more expressivity. Not only does this model identify the components of water and their proportions, but it also shows how they are connected in the chemical structure of the molecule. The oxygen molecule is connected to each of the hydrogen molecules, which are not (directly) connected to one another at all. This model is somewhat more expressive than the model in part (a); it can answer further questions about the molecule. From (b), it is clear that when the water molecule breaks down into smaller molecules, it can break into single hydrogen atoms (H) or into oxygen-hydrogen ions (OH) but not into double-hydrogen atoms (H_2) without some recombination of components after the initial decomposition.

Finally, the model shown in Figure 2-4(c) is more expressive still in that it shows not only the chemical structure of the molecule but also the physical structure. The fact that the oxygen atom is somewhat larger than the hydrogen atoms is shown in this model. Even the angle between the two hydrogen atoms as bound to the oxygen atom is shown. This information is useful for working out the geometry of combinations of water molecules, as is the case, for instance, in the crystalline structure of ice.

Just because one model is more expressive than another does not make it superior; different expressive modeling frameworks are different tools for different purposes. The chemical formula for water is simpler to determine than the more expressive, but more complex, models, and it is useful for resolving a wide variety of questions about chemistry. In fact, most chemistry textbooks go for quite a while working only from the chemical formulas without having to resort to more structural models until the course covers advanced topics.

The Semantic Web provides a number of modeling languages that differ in their level of expressivity; that is, they constitute different tools that allow different people to express different sorts of information. In the rest of this book, we will cover these modeling languages in detail. The Semantic Web standards are organized so that each language level builds on the one before so the languages themselves are layered. The following are the languages of the Semantic Web from least expressive to most expressive.

RDF—The Resource Description Framework. This is the basic framework that the rest of the Semantic Web is based on. RDF provides a mechanism for allowing anyone to make a basic statement about anything and layering these statements into a single model. Figure 2-3 shows the basic capability of merging models in RDF. RDF has been a recommendation from the W3C since 2003.

RDFS—The RDF Schema language. RDFS is a language with the expressivity to describe the basic notions of commonality and variability familiar from object languages and other class systems—namely classes, subclasses, and properties. Figures 2-1and 2-2 illustrated the capabilities of RDFS. RDFS has been a W3C recommendation since 2003.

RDFS-Plus. RDFS-Plus is a subset of OWL that is more expressive than RDFS but without the complexity of OWL. There is no standard in progress for RDFS-Plus, but there is a growing awareness that something between RDFS and OWL could be industrially relevant. We have selected a particular subset of OWL functionality to present the capabilities of OWL incrementally. RDFS-Plus includes enough expressivity to describe how certain properties can be used and how they relate to one another. RDFS-Plus is expressive enough to show the utility of certain constructs beyond RDFS, but it lacks the complexity that makes OWL daunting to many beginning modelers. The issue of uniqueness of the preferred symbol is an example of the expressivity of RDFS-Plus.

OWL. OWL brings the expressivity of logic to the Semantic Web. It allows modelers to express detailed constraints between classes, entities, and properties. OWL was adopted as a recommendation by the W3C in 2003.

SUMMARY

The Semantic Web, just like the document web that preceded it, is based on some radical notions of information sharing. These ideas—the AAA slogan, the open world assumption, and nonunique naming—provide for an environment in which information sharing can thrive and a network effect of knowledge synergy is possible. But this style of information gathering creates a chaotic landscape rife with confusion, disagreement and conflict. How can the infrastructure of the Web support the development from this chaotic state to one characterized by information sharing, cooperation and collaboration?

The answer to this question lies in modeling. Modeling is the process of organizing information for community use. Modeling supports this in three ways: It provides a framework for human communication, it provides a means for explaining conclusions, and it provides a structure for managing varying viewpoints. In the context of the Semantic Web, modeling is an ongoing process.

At any point in time, some knowledge will be well structured and understood, and these structures can be represented in the Semantic Web modeling language. At the same time, other knowledge will still be in the chaotic, discordant stage, where everyone is expressing himself differently. And typically, as different people provide their own opinions about any topic under the sun, the Web will simultaneously contain organized and unorganized knowledge about the very same topic. The modeling activity is the activity of distilling communal knowledge out of a chaotic mess of information.

The next several chapters of the book introduce each of the modeling languages of the Semantic Web and illustrate how they approach the challenges of modeling in a Semantic Web context. For each modeling language—RDF, RDFS and OWL—we will describe the technical details of how the language works, with specific examples "in the wild" of the standard in use.

Fundamental Concepts

The following fundamental concepts were introduced in this chapter.

Modeling—Making sense of unorganized information.

Formality/Informality—The degree to which the meaning of a modeling language is given independent of the particular speaker or audience.

Commonality* and *Variability—A fundamental aspect of the Semantic Web that a model can represent.

Expressivity—The ability of a modeling language to describe certain aspects of the world. More expressive modeling language can express a wider variety of statements about the model. Modeling languages of the Semantic Web—*RDF, RDFS,* and *OWL*—differ in their levels of expressivity.