Chapter 1

Models, Software Models and UML

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Abstract: The use of models in the design of complex engineering systems is a long-standing tradition that is almost as old as engineering. Yet, its applicability to software has often been questioned. In this chapter, we explain why modeling and model-based techniques are, in fact, the only viable way of coping with the kind of complexity that is encountered in modern software systems (and, in particular, in embedded and real-time systems). The essentials of model-driven development methods are explained and the role that the Unified Modeling Language plays in them is described. The ability to customize UML for such purposes is also covered.

Key words: engineering models, software modeling, Unified Modeling Language, UML

1. ON MODELS

1.1 The Role of Models in Engineering

In 1418 A.D., the guild of wool merchants of Florence announced a competition for a method of constructing the dome that was to cap the magnificent Santa Maria del Fiore cathedral. This presented a unique and very difficult engineering problem. First, the design called for a dome that was bigger than any built up to that time. Second, and even more challenging, this enormous dome was to have no external lateral supports, since the architect had deemed them “inelegant”. Such supports, usually in the form of so-called “flying buttresses”, served to counter the effects of the significant lateral forces generated by large vertical edifices.

The specifications for the cathedral and its dome were in the form of a scale model, which served to convey design intent to the construction team and also as a feasibility proof (the non-linear effects of scaling up were not
fully understood at the time). Accordingly, submitters were asked to provide scale models that would demonstrate the proposed construction method.

Perhaps surprisingly, the winning entry did not come from a master mason but from a goldsmith, Philippe Brunelleschi. His model was made out of wood, brick, and mortar and was large enough to allow members of the jury to walk inside and inspect its interior. The most distinguishing and innovative aspect of this proposal was the claim that this dome of unprecedented dimensions was to be constructed without the use of expensive wooden scaffolding to support the vaulted ceiling during construction—even though at its apex the ceiling leaned as much as 30 degrees away from the vertical! Nothing similar had ever been attempted previously on such a scale and it is no understatement to say that the proposal carried a great deal of uncertainty [1].

Nonetheless, based on the insight and experience gained during the construction of his model, Brunelleschi felt confident and, despite dire warnings from numerous skeptics, he was able to convince the jury that the project was technically feasible. So, the model served not only to demonstrate the proposal to the clients, but also as a testbed for validating a new method of construction. Today, the magnificent dome of Santa Maria del Fiore, still the largest dome ever constructed with bricks and mortar, stands as much a testament to Brunelleschi’s ingenuity as to the effectiveness of models in engineering.

The use of models for specifying systems is a long-standing engineering tradition that reaches into antiquity. There is evidence that it was a standard practice in Ancient Greece. Vitruvius, a Roman architect who lived in the first century B.C., discusses the use of models in the design of buildings and machinery of various kinds [2]. In the 15th century, Galileo introduced the notion of formal mathematical models that significantly increased the reliability of engineering design.

The main purpose of engineering models is to help us understand the interesting aspects of a complex system before going through the expense and effort of actually constructing it\(^1\). A good model can help shed light on features of a system where there is uncertainty either about requirements or about the adequacy of a proposed solution particularly where the complexity is such that unaided human reasoning is insufficient.

Besides risk mitigation, another fundamental purpose of engineering models is to communicate design ideas to the various parties interested in the system. This includes the many diverse members of the design and

\(^1\) Engineering models are also used to analyze existing systems; for example, in situations where it might be too expensive or impractical to experiment with the actual system or because a model better isolates the phenomenon of interest.