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Procedia Computer Science 12 (2012) 75 – 80

**Procedia**  
Computer Science

Complex Adaptive Systems, Publication 2  
Cihan H. Dagli, Editor in Chief  
Conference Organized by Missouri University of Science and Technology  
2012- Washington D.C.

# UML Profile and Extensions for Complex Approval Systems with Complementary Levels of Abstraction

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## Abstract

Extending the Unified Modelling Language (UML) version 2.0 with a profile and stereotypes that allow the modelling of an approval system with multiple levels, each with inherently dualistic complementarity, allows the high-fidelity characterization of the stacked levels of a real world approval hierarchy. The objective was to extend UML to model the complex, emergent and multi-level decision making which occurs within modern multi-disciplinary projects. At any level of abstraction, the logical and concrete processes of that level allow a consideration of local factors and decisions, generating and establishing a qualitative conclusion as the result. The high degree of certainty in the result creates the absoluteness of the qualitative conclusion, which can then be fed up or down one level of abstraction in order to take part in the local decision making at that level. The profile was applied to ground-breaking and ongoing engineering investigation concerning the expansion of a student busing system as it is proposed to be integrated into a city-wide busing system, where the student busing system can be considered to be a sub-system to the city-wide busing system, but in reality it is a self-standing, independent and complete system in its own right.

**Key words:** UML; profile; stereotype; abstraction; complementarity; self-reference; complex; system

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## 1. Introduction

The Student Busing System Project (SBSP) is an ongoing engineering investigation spearheaded at the University of Texas El Paso. This project addresses the expansion of a tailored, feasible commuting alternative for the students, to be integrated into a city-wide busing system. The student busing system can be considered to be a sub-system to the city-wide busing system, but in reality it is a self-reliant system on its own. For such a complex project to be successfully deployed and positively acknowledged, it has to be scrutinized by all the stakeholders with a decision making process at each identified level shown in Figure 1(a).

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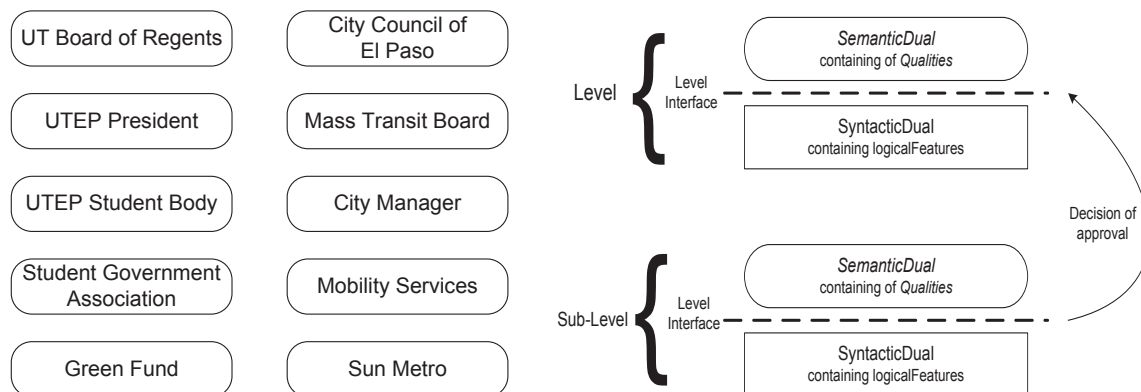


Fig. 1 (a) Decision making stack for the Student Busing Project; (b) Decision levels components

The Semantic side of a level portrays the qualities (such as reliability, effectiveness, characteristics, perceived benefits) associated and the Syntactic side portrays the logical features (such as Engineering Analysis and Mathematical models involved).

## 2. UML Profiles with Object-Oriented Design (OOD)

UML is a graphical language used for specifying, visualizing, constructing and documenting the artifacts of general purpose systems [1]. It is a general purpose modelling language that was commissioned by the Object Management Group (OMG) in the year 1997. The graphical nature of UML helps to specify the semantics of an object Meta Model and defines a notation for capturing and communicating an object's structure and behaviour. The extension mechanism supported by UML allows us to tailor UML to fit the needs of a specific domain [2].

With the help of the Student Busing System Project (SBSP) we extended UML to model the complex multi-level decision making which occurs within modern multi-disciplinary projects. At any level, the logical and substantial attributes of that level influence local decisions, chartering an outcome. A decision made at each identified level is dependent / influenced by the sub levels associated. At any specific level a decision made is dependent on a *Semantic Dual* and a *Syntactic Dual* as shown in Figure 1(b).

### 2.1 Profile Description

A Profile is an extension of reference meta-model, with the typical meta-model being the Unified Modeling Language (UML). The meta-model is customized for particular purposes with the use of Stereotype classes, which inherit attributes and functions from a meta-class. The stereotype may also have defined attributes, which are called Tagged Values. In addition, pertinent constraints may be defined.

Profiles are typically bundled in the form of a package, or, profiles may be illustrated with a structure diagram. They can also be directly associated with several other profiles to be applied on a same model. A defined profile cannot be self-contained and is derived from a meta-model which is always related to a reference meta-model created in UML. Creating a profile helps to customize a pre-defined meta-model specific to a domain. It is feasible to add new constraints to the profile without budging any meta-model constraints. Using a profile involves interpreting its declaration, which should not only be well defined but also be easily understood by readers.

A Stereotype is defined as a revised version of any of UML element within the UML meta-model. A stereotype cannot be defined as a brand new element, but should always be based on an existing UML element. There are some stereotypes that are already included in UML such as << includes >>, << extends >> which are defined to be special types of dependencies and << component >> that is defined to be a special type of class [3].

UML 2.0 is composed of thirteen types of diagrams which are divided into two main categories: Structural Diagrams and Behavioural diagrams as shown in Figure 2.

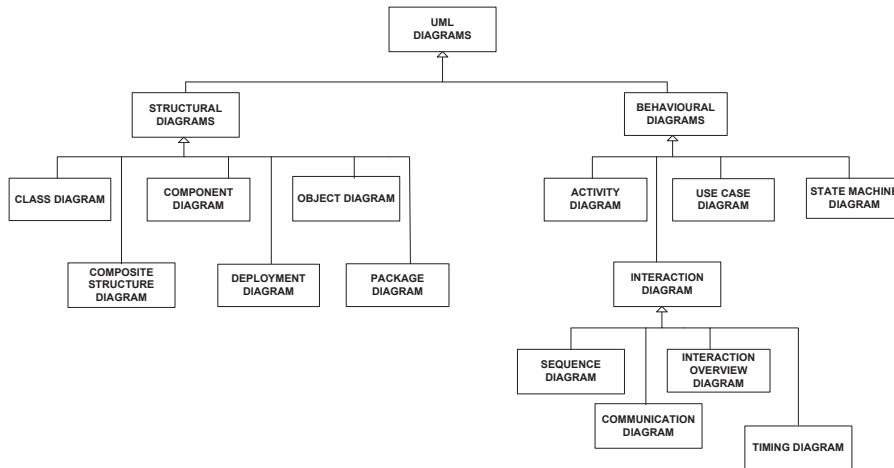


Fig. 2 Classifications of Diagrams in UML 2.0

An Example of a UML profile is Systems Modelling Language (SysML). It is a graphically modelled language developed using UML which represents a subset of UML2.0 with extensions. The main pillars of SysML are Structural diagrams, Behavioural diagrams, Requirements diagrams and parametric diagrams.

### 2.2 Profile for Complementary level based approval process

Complementarity is a measure of complexity and is described in the mathematics of quantum mechanics. It describes the relation of the evolving qualitative attributes [4] balanced with concrete and logical attributes of the system. Complementarity diagrams show the qualitative attributes as distinct, yet parallel with, logical elements [6]. The Profile representation for Complementary Level Systems can be illustrated as shown in Figure 3. The goal of this profile is to support and be helpful to approach the attributes and activities involved in a multi level decision making process in Complex Systems. This profile specification contains UML Meta Models.

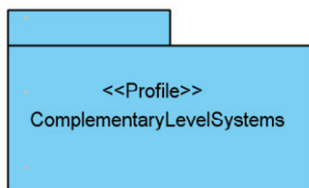


Fig. 3 Profile Complementary Level Systems

A profile Diagram is used to interpret a stereotype. A stereotype involves the use on Use case Diagrams, Class diagrams, deployment diagrams etc. A stereotype to be used or defined as a model element, it is declared as an instance of a Meta class. The name of the defined stereotype is shown with a pair of guillemets before the name of the model element.

### 2.2 Structural Diagram

Structure-based diagrams represent the static nature of the objects in a system, i.e. they depict the elements of a system that are independent / irrespective of time. These diagrams do not show the dynamic behaviour, which is

illustrated by the behavioural diagrams. However, they may show relationships to the behaviours of the classifiers exhibited in the structure diagrams. Structure Diagrams include the Class Diagram, Object Diagram, Component Diagram, Composite Structure Diagram, Package Diagram, and Deployment Diagram [5][1]. In the proposed profile, the structural aspects are defined and inherited from the Class and Package diagrams as shown in Figure 4 and Figure 5, and their associations help in accomplishing particular tasks. The Semantic and Syntactic side associated for decision making at each level is also represented.

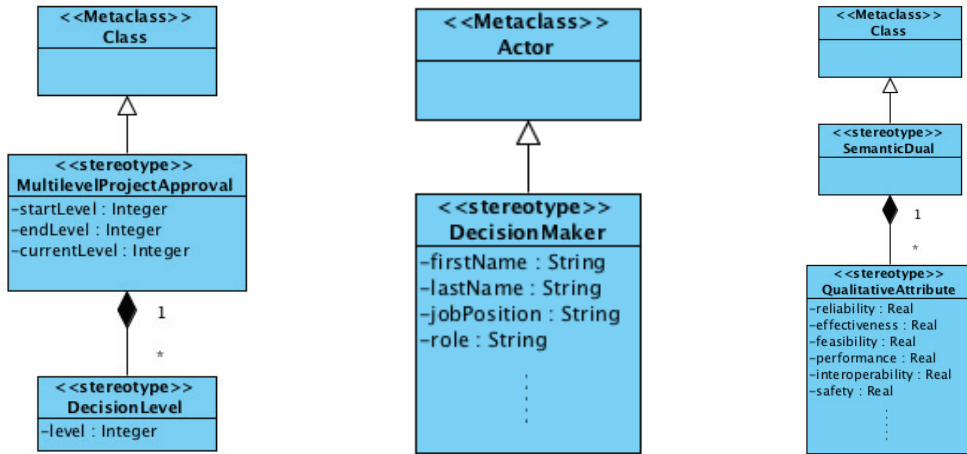


Fig. 4 Complementary Decision making Profile

Multilevel project approval models the various decision making levels associated in complex multidisciplinary projects. The levels associated for a project approval can be many based on the complexity involved. There are decision makers at each level who facilitate in the project approval process and they will normally be the ones who initiate this process.

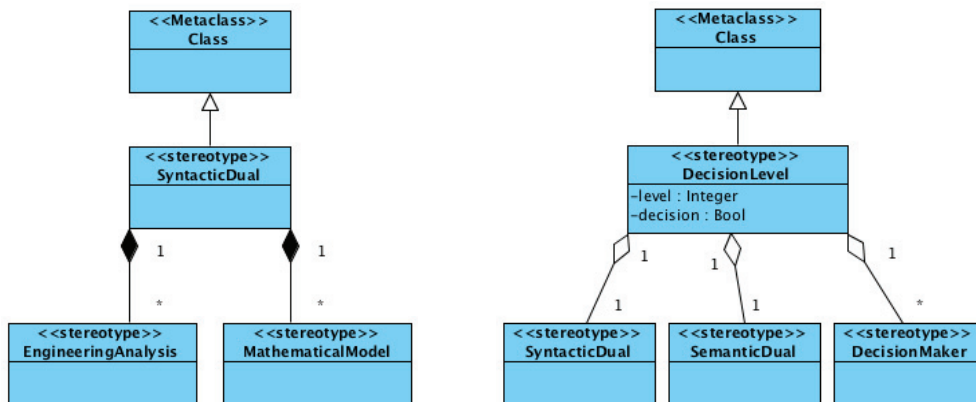


Fig. 5 Complementary Decision making profile

The Semantic Dual models the qualitative attributes such as reliability, effectiveness, feasibility, performance, interoperability, safety...etc along with all the potential attributes associated which are perceived by a decision maker. The Syntactic Dual models the quantitative attributes and reports generated such as mathematical models and engineering analysis. These models together, provide an effective approach to the decision makers involved in decision making process at each identified level.

2.3 Behavioural Diagram

Behavioural diagrams are built upon the Dynamic View of a system and they capture the dynamic use of semantics for decision making. Behavioural modelling helps to describe how a system works and to model the interactions and instantaneous states within the system over a period of time. These interactions may be modelled at many levels of abstraction. These models can be realized using seven types of UML diagrams which are: Use Case Diagrams, State Machine Diagrams, Activity Diagrams and Interaction Diagrams, of which there are four types- Communication, Timing, Interaction Overview and Sequence Diagrams [3]. The behavioural aspect of the proposed profile is defined and inherited from Activity diagrams, Use case diagrams as identified and represented in Figure 6(a) and Figure 6(b).

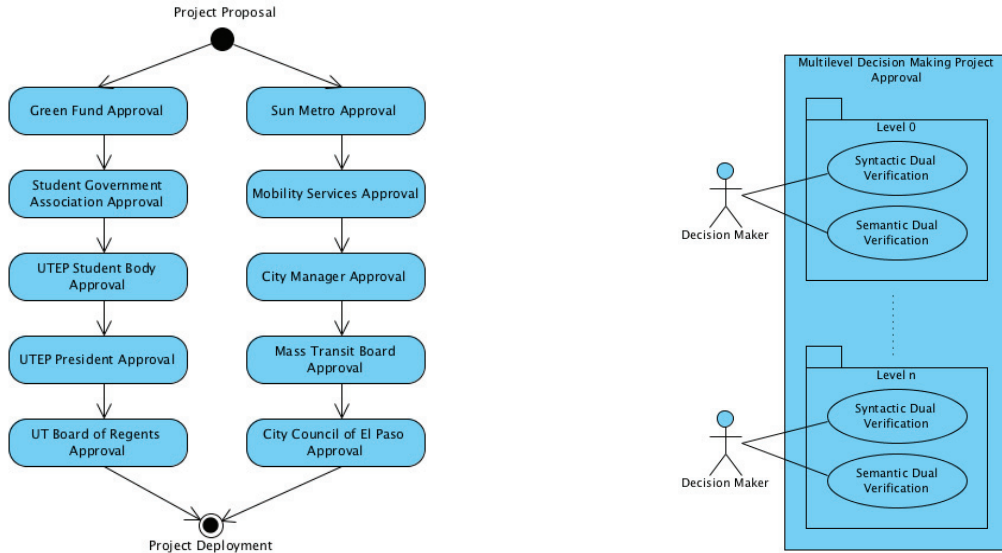


Fig. 6(a) Activity diagram; Fig. 6(b) Use Case diagram

An Diagrammatic Representation of the decision making levels involved and their influence on each other with respective to the attributes identified in an event of Ideal Condition where a project is approved at each identified level is shown.

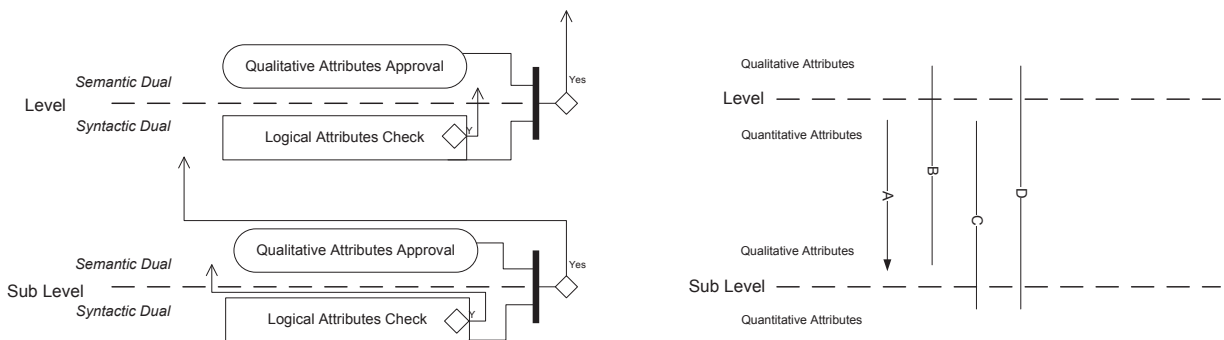


Fig 7(a) Activity Diagram; Fig. 7(b) Effects of Complementary Levels

Figure 7(a) illustrates a process where the logical attributes are checked and a decision is taken on the Syntactic side which results in an influence on the Qualitative attributes (Semantic Side) of the decision making process at a considered level. The overall decision making process then consists of the sequential and iterative processes that progress through all the levels. When deficiencies are found in the logical rationale or in the qualitative justification for an approval decision at any level, the decision making process must retreat by a level in order to demand the reformulation of the logical rationale and qualitative justification at the previous level. In this case, a search for flaws must take place.

Figure 7(b) shows the possible sources of flaws. A flaw found in the qualitative or the logical element of a level may have a source in the qualitative or the logical elements of the sub level below. The possible sources of flaws, shown by letter label, are described as:

A – Upper level Quantitative attribute flaw found in lower level qualitative attributes

B – Upper level Qualitative attribute flaw found in lower level qualitative attributes

C – Upper level Quantitative attribute flaw found in the lower level quantitative attributes

D – Upper level Qualitative attribute flaw found in the lower level quantitative attributes

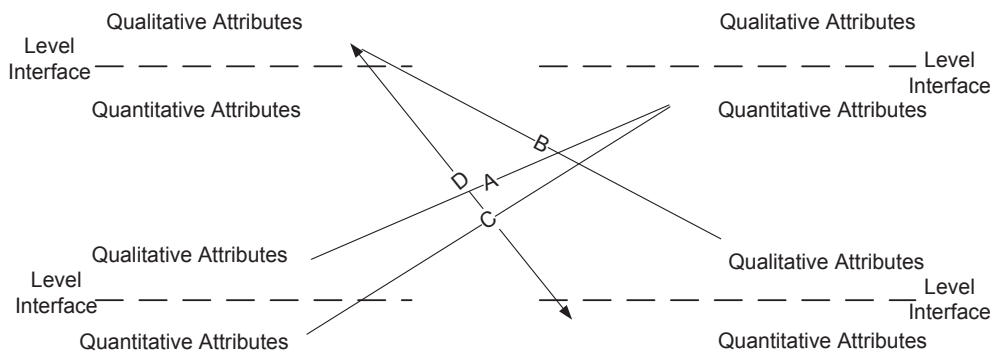


Fig 8 Effects of adjacent decision making Levels on each other

Now, when we consider the adjacent decision levels; the Syntactic and Semantic duals at each level are influenced by the Syntactic and Semantic duals at the other levels. We illustrate these interactions using Figure 8. Here we show a possible scenario of interactions within a 2-level 2-organization system. The number of interactions shown here are 16 out of the total 32 possible interactions. This figure directly addresses the complexity involved in the decision making process, in a project with 2 or more decision levels. For instance, if we expand this illustration to the 5-level 2-organization decision making system of the Student Busing project with reference to Figure 1(a), the total number of interactions which can occur are 450, where the number of Significant interactions (*the interactions between the adjacent levels*) are 192 and Non-Significant interactions (*the interactions between the non adjacent levels*) are 258. The detailed structures and interactions of these stacks are beyond the scope of this paper, but they do provide an interesting mental model of a collective system which is emergent and self-adaptive as a real-world solution is created.

### 3. Conclusion

The created UML profile and extensions for complex approval systems with complementary levels of abstraction exposes the decision critical aspects of carrying a project through a multi-level approval process. The profile has clarified the elements and tasks that the members and participants of the Student Busing System Project (SBSP) have already tackled or must address in the near future.

This profile can also be augmented by using other UML extensions for systems engineers, such as SysML, which is widely used by industries, vendors, academics and various other organizations.

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