Mapping Architectural Concepts to SysML Profile for Product Line Architecture Modeling

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Abstract— **There are different proposals for modelling Product Line Architecture. To model the Product Line Architecture (PLA), the most important elements are the explicit treatment of its commonality and variability representation. This paper concentrates on the use of Architecture Description Language (ADL) and its integration with object oriented modeling, for the representation of architecture in order to model PLA architecture construct and variability construct effectively. Consequently, the possibility of integration which involves the mapping between the xADL and SysML a UML2 based profile extension to enable the profile to be incorporated to an existing UML commercial tool was investigated. The result of the mapping is proposed extension to SysML profile. The profile is then applied to a case study of Autonomous Mobile Robot Product Line. Based on the case study evaluation, the profile has shown a significant improvement to the existing SysML for modelling PLA.**

Keywords-product line architecture (PLA); autonomous mobile robot (AMR),architecture description language, xADL

I. INTRODUCTION

Product line architecture (PLA) is the first artifacts which realise the requirements for the Software Product Line (SPL) and also is the abstraction for detail design. PLA modelling differs from other single system architecture modelling where PLA should be able to express commonality and variability explicitly in its architecture. Thus, in addition for modelling the basic architectural strucutre, PLA has to model variability information such as optional and variants structure and the rule in choosing between different variants and optional stuctures as it will affect the derivation of product specific architecture.

Therefore, it is essential to model architecture in a formal manner which ensures a better tool support and also a comprehensive architecture description. A consistent, complete and correct architecture description is by using Architecture Description Language (ADL) [1]. Nevertheless ADL is reported to not integrate well with software development methodology and tools [2]. Another paradigm for representing architecture is with UML which has been used as an architecture modelling language and also a de facto modelling language used in the industry, even so there are arguments concerning its modelling notations inadequacy for representing architecture [3, 4].

Integrating both languages, ADL and UML can be considered as having a synergistic relationships where the combination enables a precise and explicit architecture description and at the same time having a wider usage among UML users in commercial tool. Among the proposed integration approaches are from [2, 5]. This paper concentrates on how to map architecture concept from xADL to one of UML profile, SysML for an explicit representation of architectural and variability construct for modelling PLA.

SysML is a profile targeted for system engineering where the strength of SysML compared to UML 2.0 is based on its new addition of requirements and parametric diagram as well as its additional constructs in architecture modelling. xADL is chosen due to its specialised schema targeted for product line architecture description [6].

The remainder of this paper is organised as follows: In Section II, the paper discusses the problem background which motivates the focus of this paper. Section III discusses on the methodology of the mapping and the profile proposed based on the mapping. Section IV demonstrates the applicability of the proposed profile in modeling Autonomous Mobile Robot (AMR) Product Line case study. Section V discusses on the feasibility of the results. Lastly, Section VI discusses on the conclusion and recommendation for future work.

II. BACKGROUND

There are two extension mechanisms in customising UML metamodel. First class extension mechanism is by adding or removing metaclasses in Metamodel Object Facility (MOF) or can be referred as heavyweight extension. Another mechanism is by using profile which does not allow any modification of existing metamodel other than by adjusting the metamodel with constructs suitable for the particular domain, platform or method [7]. Profile extension is also known as lightweight extension. Thus, the latter option is opted as SysML is already an establish profile for modelling System Engineering applications. Thus, by extending the profile, the best aspect of SysML can be leveraged while lowering the learning curve. Furthernore, the profile extension is conformed to standard UML hence can also be supported by existing UML tool.

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The first notions of modelling architecture by using UML in a formal manner by mapping it to ADL were done in [3, 8] Nonetheless, both researchers do not concentrate on UML 2.0. Even so, they both highlight a useful consideration to be acknowledged in the mapping. Garlan, Cheng and Kompanek [8] discuss the pros and cons of using different metaclasses for representing architectural concepts. Medvidovic and Rosenblum [2] describe a more detailed mapping between C2 and Wright architecture style and UML which involved two strategies of either using UML "as is" or by using stereotypes with restrictions by means of OCL. The moves towards mapping of UML 2.0 with ADL were done in [9-11]. Only one of the researchers proposed on using UML 2.0 in order to model variability in architecture. Nonetheless, the concentration of Choi [11] is on representing variability in PLA behavior through connector . There is also a research done by Maga and Jazdi [12] on extending variability in SysML profile. Although the researchers have proposed a variety of variants in their extension, however they do not specifically address the PLA and its constructs in the extension. This research concentrates on filling in the gap in the PLA modelling by concentrating on a formal architectural and variability construct based on xADL and its mapping to SysML for profile extension.

III. MAPPING STRATEGY FROM ARCHITECTURE DESCRIPTION TO SYSML

The mapping strategy is basically divided into three steps: Mapping basic architecture construct; Mapping variability construct and mapping the constrain. However, the third strategy is not the focus for this paper hence is not being elaborated. The mapping steps are as shown in Figure 1. Each step is described in detail as follows:

A. *Mapping Basic Architectural Construct*

The corresponding elements of the mapping are between the *Structure and Types* schema in xADL which can be mapped into two corresponding packages in SysML, *Blocks* package and *Ports&Flows* package. The first mapping is between component from xADL and block from SysML. Block is equivalent to component where block is an extension of class metaclass in SysML. The same notion is also used by Medvidovic and Rosenblum [3] where their component is an extension of UML class metaclass instead of extending from component metaclass. In the case of mapping between Connector, Interface, Link, Point and Group from xADL *Structure and Types* schema, roughly all the elements are also present in SysML *Ports&Flow* package. Nonetheless, construct such as connector is not explicitly specified. Instead it can only be identified when a relationships between two roles in SysML are specified. Therefore, stereotypes were explicitly added for both connector and role. Signature schema in xADL construct is also added as stereotype extending an interface metaclass.

B. *Mapping Variability Construct*

The schema in xADL has to be in an equivalent metamodel form before the mapping to SysML can be done. Thus, for Variants package and Options package in xADL which do not have a corresponding matching in SysML, a package called Variability package is extended from the original SysML profile to support variability as shown in Figure 1. The added stereotype is extended from the class metaclass.

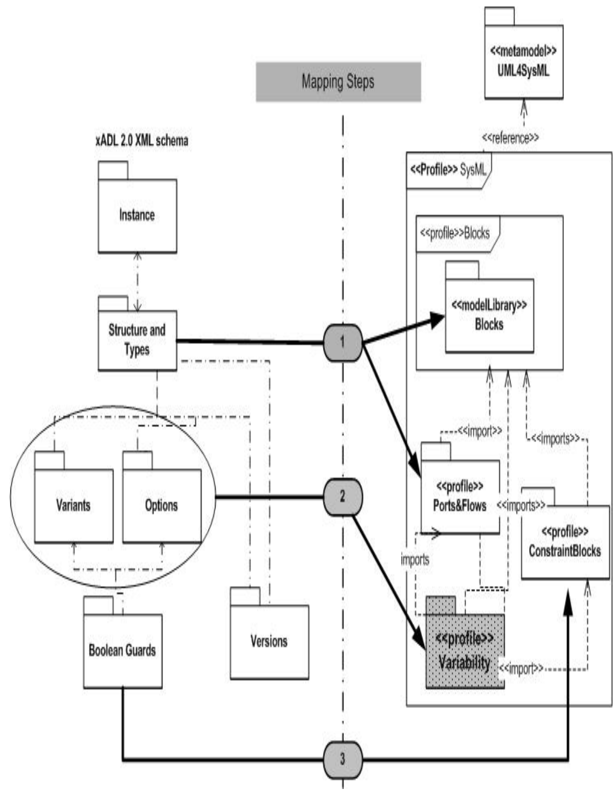

Figure 1. Mapping Strategy

C. *Mapping results*

Based on the specified strategy, the proposed profile for representing architecture based on the mapping is as shown in Figure 2. The profile is divided into three sections, the metaclass section which consists of UML classes reused in SysML known as UML4SysML. The architectural construct section which shows the extension of stereotype classes shaded in grey. The variability construct section which shows the extension of stereotype to represent variability, variants and option can be applied to the architecture construct since both the variability constructs extends from class metaclass. Another variability construct, representing guard in xADL schema is added as a stereotype extension from ConstrainBlock stereotype.

IV. CASE STUDY

In order to validate the applicability of the extended modelling in SysML, the extended model was applied to product line of Autonomous Mobile Robots (AMR). The product line consists of five different but similar applications of AMR. Four of the AMR are AMR for research, AMR for teaching, i-wheelchair and intelligent scooter based on the research collaboration done at Embedded Real Time and

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Software Engineering Research Lab (ERetSEL), Universiti Teknologi Malaysia. The fifth AMR is the parking assistant based on the work of Polzer, Kowalewski and Botterweck [13]. The five AMR product line (AMRPL) are as shown in Figure 3.

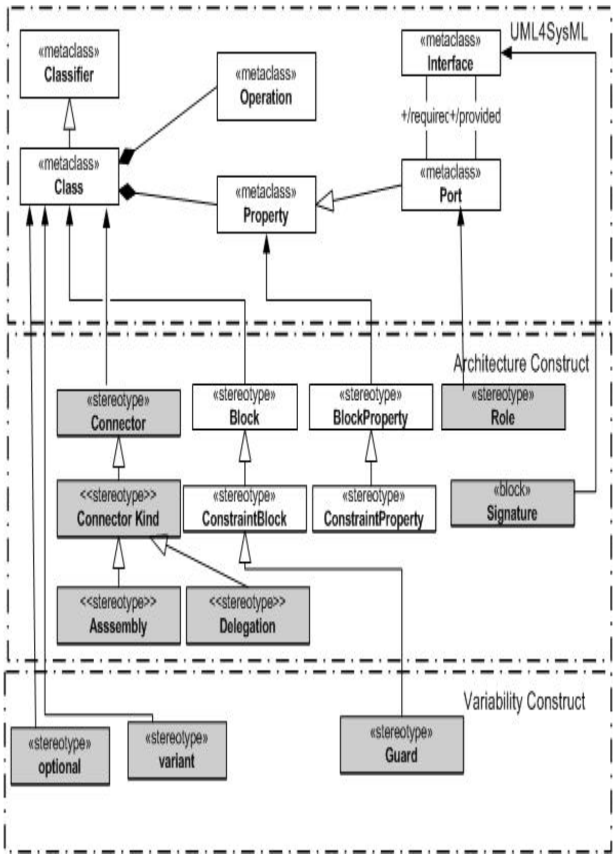

Figure 2. xADLUMLProfile

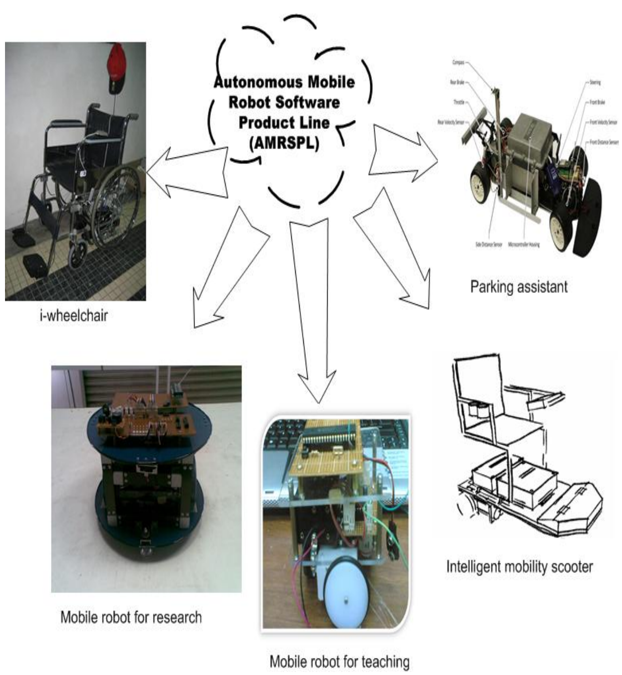

Figure 3. AMR Product Line (AMRPL)

In order to identify the commonality and variability of the AMRPL requirements, approach by Abd Halim, Jawawi and Safaai [14] is used. However, in order to simplify this paper, the common and variable function is represented in use case diagram as shown in Figure 4.

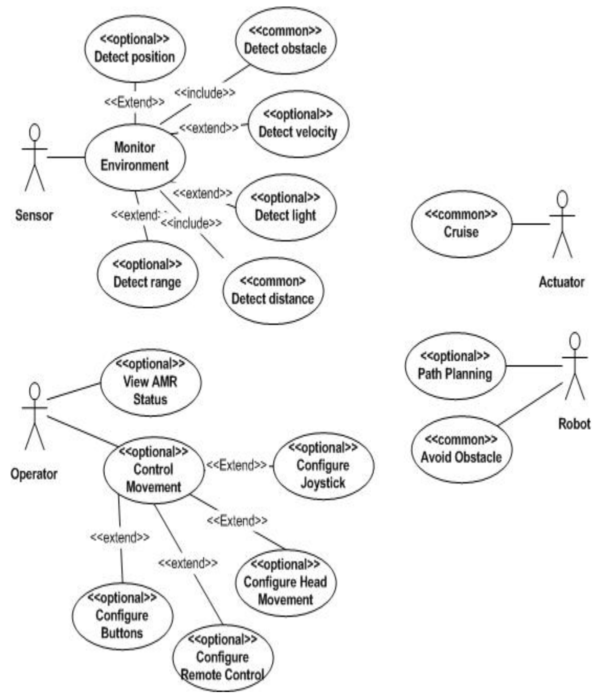

Figure 4. AMRPL Use Case

The proposed profile is used in modelling general architecture, the block definition diagram (**bdd**) in SysML. The bdd diagram shows the structure of the components in the form of *noncomposite* relationships which will explicitly shows the common and variable blocks involved in the system. Other than *noncomposite* relationships, another relationships that can be shown in bdd is the *whole-part* relationships [15]. However, in PLA, a noncomposite relationship is more suitable as the block can either be selected or not selected based on its variability and commonality and it would not affect the block which it related to. The *whole-part* relationships is not chosen as it will affect the relationships between blocks which is not being selected for composition.

Furthermore, the profile will then be used for modelling specific architecture, which is shown in SysML internal block diagram (**ibd**). In this diagram the component which are modelled as having a *part* component in the **bdd** will be elaborated further, which will explicitly show the variability in the connectors and the internal components relationships. Both bdd and ibd diagram can be referred at Figure 5 and Figure 6 respectively.

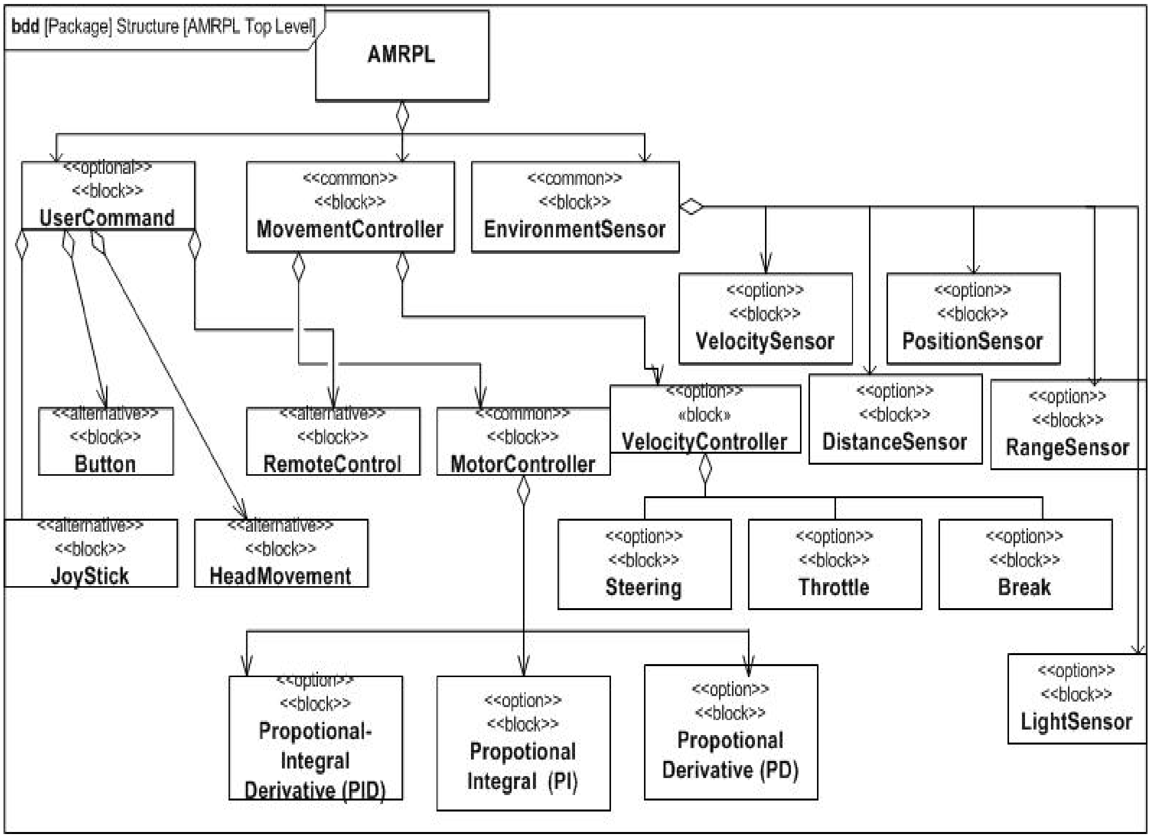

Figure 5. Block Definition Diagram for AMRPL

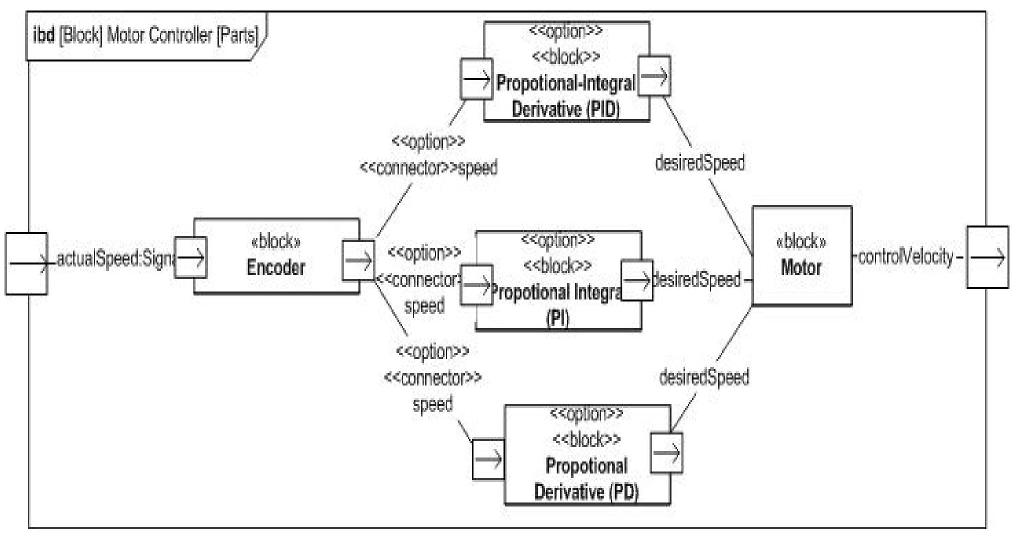

Figure 6. Internal Block Diagram for Motor Controller Part

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V. DISCUSSION

From the case study, PLA modelling can be seen in different granularity based on the SysML bdd and ibd diagram. In both diagrams, the proposed xADLUML profile is used to augment the diagram with commonality and variability stereotypes and also with a more concrete architectural construct. From the case study, bdd diagram in Figure 5 shows common and optional stereotype in the AMRPL such as Motorcontoller block which have the option of using PID, PI or PD as a controller. The Motorcontroller blocks and its parts is further refined in ibd diagram in Figure 6 where the common and variable connectors are clearly shown by the stereotypes. Nonetheless, there are few constructs in the profile that is not being applied to the case study such as the use of delegation and assembly and the use of signature for representing interface. However, the case study did reflect a significant potential in modelling PLA in both bdd and ibd diagram thus helps in the understanding of the PLA for an easier product specific derivation for AMRPL.

According to our experience with this case study, the profile can explicitly show the commonality and variability in the AMRPL. The mapping from xADL to SysML profile further helps in formalising the architectural concepts of the modelling. Nonetheless, rule is essential to ensure consistency between the model elements. Therefore, OCL rule should be added in the profile to constraint metaclasses between the bdd and ibd diagram. The constraint will determine the consistency between the different views of the block diagram. Consequently, it is essential to understand how the rule in xADL Guard can be translated into OCL rule for the purpose.

VI. CONCLUSION

This paper concentrates on how to map architecture concept from xADL to one of UML profile, SysML for an explicit representation of architectural and variability construct for modeling PLA. From the case study, it did show a noteworthy contribution in modelling PLA in terms of its blocks and its connector and also in terms of the granularity of the modelling. A more extensive case study should be done in the future in order to fully validate the proposed profile. Furthermore, rules to infuse consistency of the metaclasses and its instance should be further explored. It is hoped from the explicit modelling of PLA commonality and variability can further help reuser to derive a product specific application in the application engineering phase.

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