AN ONTOLOGY-BASED APPROACH TO REQUIREMENTS REUSE PROBLEM IN SOFTWARE PRODUCT LINES

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ELİF KAMER KARATAŞ

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submitted by **ELİF KAMER KARATAŞ** in partial fulfillment of the requirements for the degree of **Master of Science in Computer Engineering Department, Middle East Technical University** by,

Prof. Dr. Canan Özgen
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. Adnan Yazıcı
Head of Department, **Computer Engineering**

Dr. Ayşenur Birtürk
Supervisor, **Computer Engineering Dept., METU**

Examining Committee Members:

Prof. Dr. Ferda Nur Alpaslan
Computer Engineering Dept., METU

Dr. Ayşenur Birtürk
Computer Engineering Dept., METU

Assoc. Prof. Dr. Ahmet Coşar
Computer Engineering Dept., METU

Dr. Cevat Şener
Computer Engineering Dept., METU

Tolga İpek, M.Sc.
Manager, ASELSAN

Date:

ABSTRACT

AN ONTOLOGY-BASED APPROACH TO REQUIREMENTS REUSE PROBLEM IN SOFTWARE PRODUCT LINES

Karataş, Elif Kamer
M.S., Department of Computer Engineering
Supervisor : Dr. Ayşenur Birtürk

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With new paradigms in software engineering such as Software Product Lines, scope of reuse is enlarged from implementation upto design, requirements, test-cases, etc. In this thesis an ontology-based approach is proposed as a solution to systematic requirement reuse problem in software product lines, and the approach is supported with a reuse automation tool. A case study is performed on the projects of an industrial software product line using hereby proposed solution and then based on the evaluated metrics it's reported that the content of requirements specifications documents can be prepared upto 80% by derivation of reusable requirements.

Keywords: Software Product Lines, Reusable Requirements, Ontology modeling

ÖZ

YAZILIM ÜRÜN HATLARINDA ONTOLOJİ TABANLI GEREKSİNİM YENİDEN KULLANIMI

Karataş, Elif Kamer
Yüksek Lisans, Bilgisayar Mühendisliği Bölümü
Tez Yöneticisi : Dr. Ayşenur Birtürk

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Yazılım mühendisliği dünyasında yeniden kullanım bilindik bir kavram olmakla beraber, güncel paradigmalarla yeniden kullanılabilir kavramların seviyesi kaynak kod yanında tasarım, gereksinim ve testleri de kapsayacak şekilde değişmiştir. Bu tez çalışması kapsamında, yazılım ürün hatlarında gereksinim yeniden kullanımının sistemli bir şekilde sağlanabilmesi için ontoloji tabanlı bir çözüm ortaya konmuş, ayrıca yeniden kullanım sürecini desteklemek amacıyla bir otomasyon aracı geliştirilmiştir. Önerilen yöntem, durum çalışması olarak endüstriyel bir yazılım ürün hattında kullanıma alınmış, bu süreçte elde edilen deneyimler ve alınan ölçümler paylaşılmıştır.

Anahtar Kelimeler: Yazılım ürün hattı, Yeniden kullanılabilir gereksinimler, Ontoloji modelleme

to my dear father Hüseyin Karataş

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CHAPTER 1

INTRODUCTION

Software Product Line approach is popular in software engineering due to its motto of "development with reuse". With this approach the scope of "what is reusable" is enlarged: in addition to implementation, reuse of artifacts like requirements, architecture and test cases are made possible but the effort to enable their reuse is not the same. Requirements reuse is considered to be a higher level reuse and difficult to enable in product line. In this chapter first some background information on SPLs and software requirements is given and then the motivation of this thesis is explained.

1.1 Software Product Lines (SPLs)

Traditional approaches to software development which includes methods such as development from scratch, "clone and own" [1], and development with reuse libraries are no longer feasible alternatives due to market's evolution in which size of software products are increased enormously, thus companies are usually specialized in a core business domain and build similar products [2]. Furthermore increasing customer demand for better quality software causes producers to meet shorter deadlines while minimizing cost and infamous "software crisis" emerges [3]. Software product line (SPL) approach is popular especially in embedded software industry to increase software quality and reduce development and maintenance costs [2]. Definition of the term "product line" is given in [4] as " a set of software-intensive systems sharing a common set of features that satisfy the specific needs of a particular market or mission and that are developed from a common set of core assets in a prescribed way", which introduces the core or domain asset term to denote the reuse repository of a product line [1]. SPL development process consists of two different phases, namely domain engineering and application engineering [5] (See Figure 1.1).

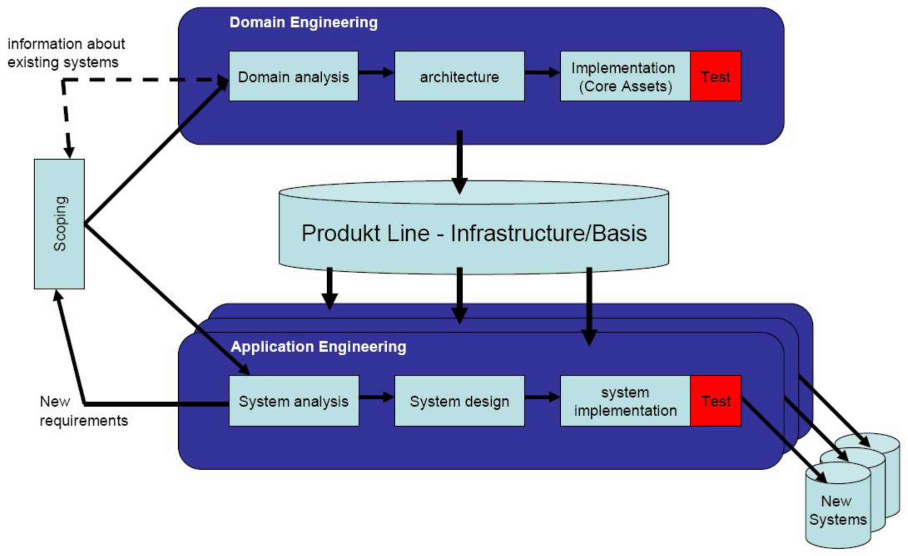


Figure 1.1: SPL Activities [5]

Domain engineering starts with domain analysis step during which product line scope is specified and commonalities and variability among product line members are identified [5]. Based on the commonalities and variations detected at this phase architecture design is performed to provide a common development framework for all members of a product line where product variations are supported at known points. During final step of domain engineering reusable core assets are developed for later use which can be implementation, architecture, requirements, test cases, reports, etc.

Application engineering is the phase during which individual products are developed from reusable core assets. Requirements for individual products are derived from the reference requirements of the product line domain [5] and only the requirements that are valid for that individual product are implemented. As a result of intensive effort put forward during domain analysis phase, effort needed for development, test and management of new systems is largely reduced compared to traditional reuse approaches [1]. Studies in [6, 7, 4] point out that with SPL development, considerable improvement in terms of productivity, quality and time to market is possible.

Essence of SPL lies in the paradigm shift it starts from traditional single system development to product family development whose success is highly dependent on the quality of domain knowledge. Now, opportunistic reuse is replaced with a planned and systematic reuse which requires to be supported by automation tools for efficiency

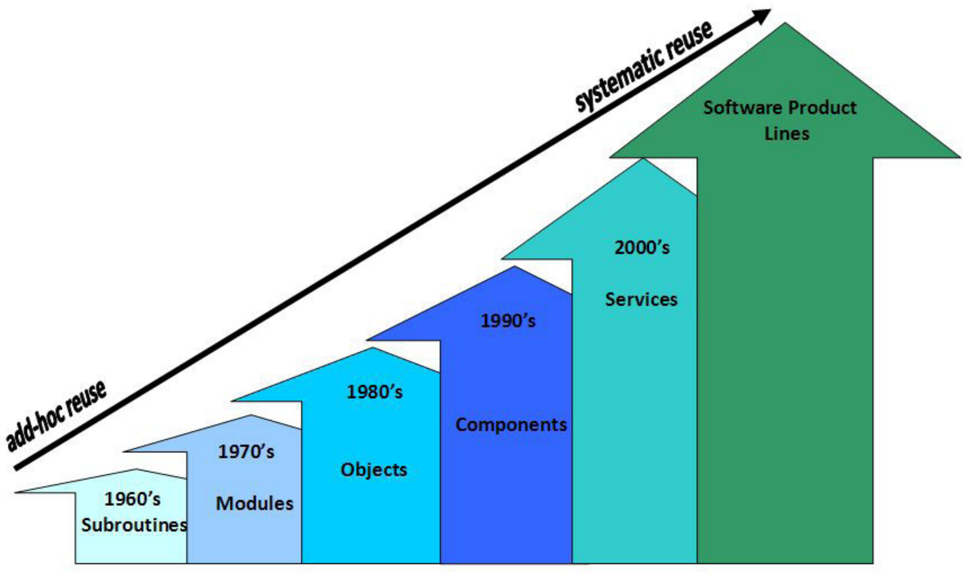


Figure 1.2: History of reuse in software: modified from [8]

1.2 Software Requirements

Software requirements provide the specifications for desired behavior and functionalities of a product. This knowledge constitutes a base for the other phases of software development namely; design, implementation and test, see Figure 1.3.

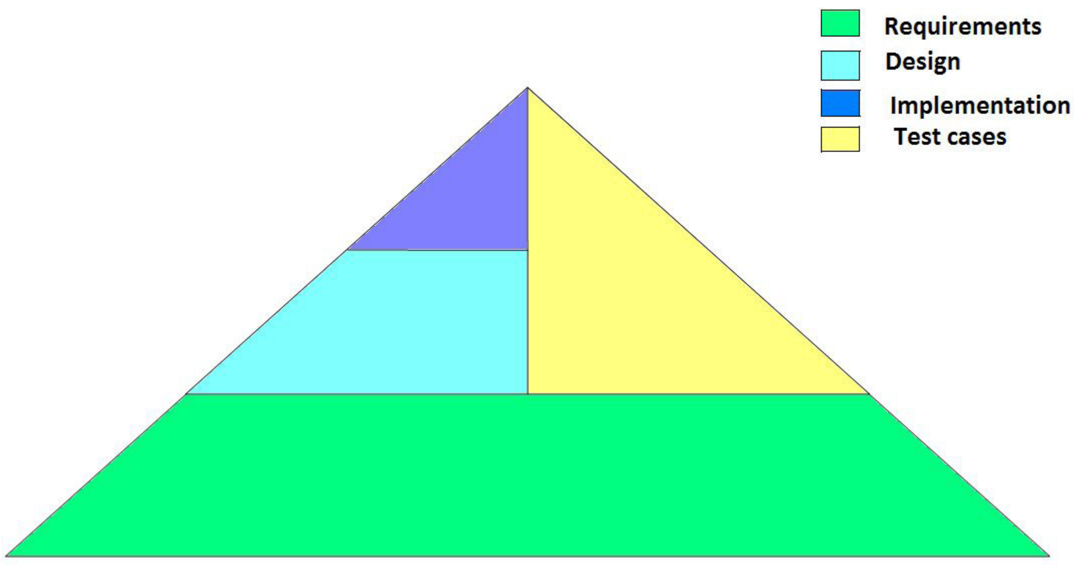


Figure 1.3: Knowledge pyramid of software phases

In our study, the term “ requirement” is used to denote software requirements.
In SPL context, Requirements Engineering (RE) processes have two goals: to define and manage requirements within the product line and to coordinate requirements for the single products [9]. Deployment and management of RE process is difficult especially in large, trans-national organizations which produce complex, long lead products in multi-disciplinary contexts [10]. RE process usually takes longer than planned and is more costly than originally budgeted for [11]. This nature of RE process often leads to immature and low quality requirements which are highly error prone [11, 12] and dynamic and changing nature of requirements have catastrophic effects on the following phases of software lifecycle. Instead of performing RE process from scratch for each project, having stored reusable requirements elements in a repository might highly improve to the development time, cost and quality of the resultant products, which is a promoted idea in SPL development [12].

Requirements reuse has not get as much attention from research community as design and implementation reuse and the proposed solution ideas have been restricted to small-scale academic examples and largely untested for industrial or commercial capacity [13]. Factors that make requirements reuse difficult include the existence of different notations, different formats and different abstraction levels for requirements knowledge [12]. Product line requirements are classified to three different categories (See Figure 1.4) whose reuse handling mechanisms will be different than each other .

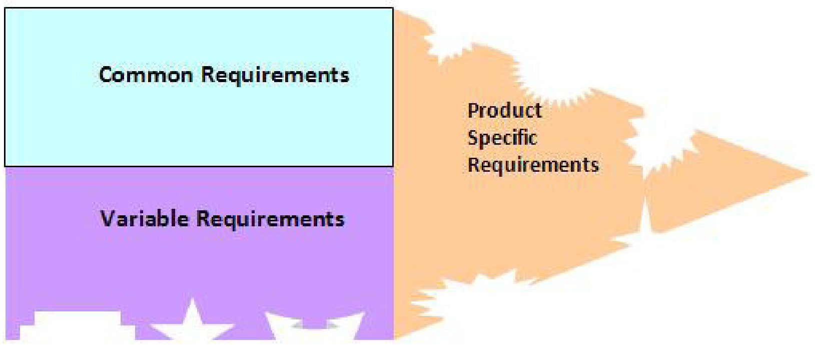


Figure 1.4: Product Line Requirements

- Common requirements originate from the commonalities in a product line and they should be implemented for each member of a product line. Their handling is easier since they are used as it is.

- Variable requirements originate from the variability in a product line. They should be implemented for only the products that are valid for, which make their handling more complicated. The need for an underlying model for variable requirements is mandatory to enable their systematic reuse.

- Product specific requirements originate from scoped out variations in a product line, mostly customer specific and their reuse are not intended because with a well conducted domain analysis phase the percentage of product specific requirements will be so low that the effort to enable their reuse is not affordable anymore.

Study at [12] states that addressing systematic requirements reuse requires a model for reusable requirements elements and three different kinds of requirements representation models are available [12]: $Formal\ models$ are based on rigorous semantic and syntax. $Semiformal\ models$ make the negotiation among producers and customers easier. $Non-formal\ models$ are usually in the form of expressions in natural language. Based on a requirements representation model a mechanism for reuse should be prescribed.

1.3 Motivation

SPL approach enables mass-production of a family of related products in software industry and its proposed systematic reuse strategy can be adopted at any phase of software development but the benefits of systematic reuse at each phase will be different. Consider a product line in which there is no systematic reuse at requirements engineering phase: Requirements specifications should be written for each instance of the product line and these documents are either going to be created from scratch or copied from existing specifications for similar systems and then modified which is inefficient in time aspect and leads to low quality, unstandart specifications.

Similar systems appear to have similar functionalities, thus documenting requirements specifications for similar system from scratch or first copying then manually editing is a time waste in the sense that same work is repeatedly performed by possibly different people, which introduces uncontrolled differences in resultant specification documents. There may be a control list to write good specifications in natural language, but even if the structure of the sentences can be controlled with some little sentence analysis it's not possible to avoid from a vast source of semantic differences and ambiguities. Requirements knowledge is mostly the result of domain expertise and depending on the experience level of the authors and knowledge sharing among them knowledge reflected to specification documents varies. Another problem which is a result of multi-source requirements specifications is that editors may decide to follow different abstraction levels independent from each other which disables the visibility of some knowledge in some of documents and its difficult to be sure of these kind of knowledge supressions do not occur in documents, furthermore there is no formal mechanism to check that the selected abstraction level covers necessary information and consistent throughout the whole document.

Uncontrolled variations among requirements specifications annihilate the potential advantages of domain commonalities and reduces the efficiency of domain variability handling. Starting with these unpredictable requirements its difficult to obtain high quality results at later phases of software development. Incomplete, missing, erroneous or ambiguous requirements are followed by incorrect design solutions, implementation errors or faulty test results. Especially the quality of test phase outputs is directly dependent on the quality of requirements specifications due the fact that for each requirement specification there should be a

corresponding test case and missing information and semantic ambiguity is directly transferred to test case specifications. For example if some domain requirement is not documented its related behavior in the product is not formally tested and test cases written for ambiguous requirements result in false negatives or false positives which decreases the confidence to a software product.
To sum up following problems are identified as a result of not reusing software requirements:

- content and abstraction level diversity in documents of similar products
- textual representation diversity in documents of similar products
- high time costs for preparation of documents for similar products
- less feedback among documents of similar products

It's obvious that not adopting systematic reuse in requirements engineering phase disables the advantages introduced with SPL approach and jeopardize the overall quality of a product line. Although above listed problems can be eliminated by enabling requirements reuse, this subject has not get much attention in research community until recently [13] which means methods proposed for requirements reuse are not mature enough yet and there are two well-known obstacles on the way of systematic requirements reuse: one is the lack of efficient methods for domain commonality/variability modeling and second is the lack of efficient mechanisms for documentation of product line requirements [14]. Motivation of this thesis is to develop a practical solution to efficient requirements documentation problem for SPLs.

CHAPTER 2

RELATED WORK

Related work can be classified into domain modeling approaches, existing applications of requirements reuse, and product configuration problem. Each is discussed in turn.

2.1 Domain Modeling Approaches

The systematic discovery and exploitation of commonality across related software systems is fundamental technical requirement for achieving successful software reuse [15]. For a successful reuse application the commonality and variability of a domain should be identified and modeled appropriately, which increases the importance of selected domain modeling technique. Three different types of representation models can be listed: formal models are built on rigorous semantic and syntax (i.e ontology models), semiformal models make the knowledge sharing easier among users of the knowledge, and non-formal models are usually expressions in natural language [12]. Since pure non-formal models are not suitable for systematic reuse activities they are not mentioned in the following subsections. Feature modeling and ontology modeling are discussed in details as formal knowledge representations.

2.1.1 Feature Modeling

Feature modeling is an increasingly popular technique for commonality and variability modeling in Software Product Line Engineering (SPLE) [16] especially for feature oriented domain analysis (FODA)[17]. The term feature is defined in [18] as "a prominent or distinctive user-visible aspect, quality, or characteristic of a software system or systems ". A feature model is a hierarchy of features with a defined set of relations that hold among them [16]. Figure 2.1 displays an example feature model with the explanation of displayed relations. Commonality is represented via mandatory features whereas variability is originally represented with optional features. The main purpose of creating a hierarchy is to organiz ea large number of features into into different levels with increasing detail [16]. Feature model is a way to represents a set of available configurations and it can be limited only to valid configurations with the guidance of constraint-based facilities[19].

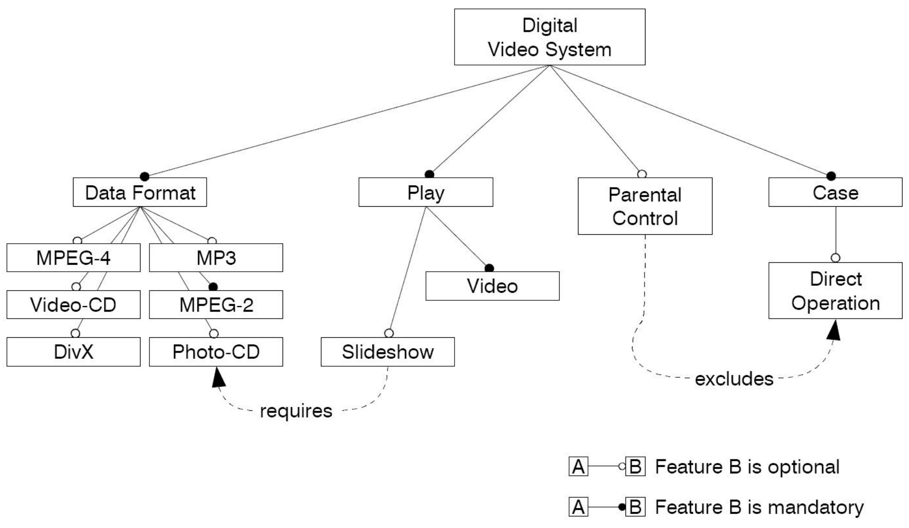


Figure 2.1: An example feature model [20]

Study at [21] report that feature modeling based on the FODA method is advantageous in the following aspects:

- Control over variability
- Reuse of requirements.
- Configuration support.
- Sales and new development support.

2.1.1.1 Limitations of Feature Modeling

Feature models are effective in modeling commonalities of a product line but they are not efficient when used to model product-line instantiations and their management becomes difficult [14]. Basic feature modeling consists of a hierarchy of features and a propositional formula to represent knowledge [16] whose descriptive power is limited. Reported concerns with basic FODA expressions are related on how to express domain knowledge of certain configurations, such as default values, configuration implications and constraints while retaining the simplicity [22], since the strength of basic feature models lies in their simplicity and intuitiveness [16]. There are a number of extensions proposed to basic feature models to handle the above listed problems. Multi-level feature trees [23] are proposed in order to dealt with the complex hierachy generated by the feature model, which are promising but untested solutions to management problem of feature models [14]. Feature attributes of basic types are allowed whereas adding attributes invites complex constraints [16]. Another extension is cloning which enables the existence of features with cardinality greater than one [16] and which potentially invites a new class of constraints, such as constraints over set of clones [16]. Reference attribute is another extension that may point to another feature in a feature configuration and only meaningful in the presence of cloning [16].

Other extensions to feature models are available but they do not influence the configuration or semantics of a feature model [16]. In summary feature models are efficient representations to capture and convey commonality knowledge of a domain. But the basic form is not enough to efficiently represent, reason over and manage variability on a domain, thus some extensions are defined on basic feature models which increases the representation power (See Figure 2.2) while inviting additional complexity to a model whose power lies in its simplicity [16].

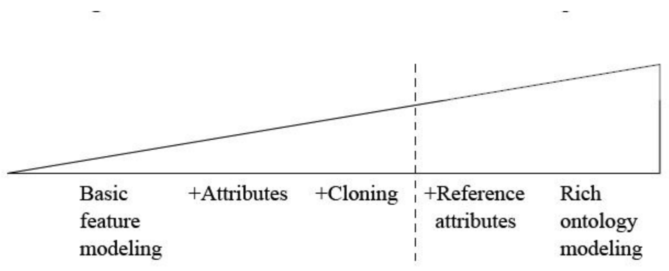


Figure 2.2: Feature model extensions [24]

2.1.2 Ontology Modeling

In computer science, ontology is considered as a formal representational artifact for specifying the semantics of some knowledge in a certain domain [25] and it should represent a shared conceptualization in order to be useful [26]. A common definition of ontology in is given in [27] as “an explicit specification of conceptualization”. “An ontology represents the semantics of classes and their associations using some descriptive language coupled with first-order logic or its decidable fragment ” [16].
Ontology modeling is considered to be advantageous in the following listed aspects [28]:

- Rich descriptive power. Being a formal representation based on first-order logics, makes ontology a powerful knowledge description mechanism. Rich decriptive power enable complex constraint to be defined according to the nature of a domain [16].
- Reasoning. Use of ontologies enable reasoning over existing knowledge to derive facts that are not explicitly expressed in the model. Constraint propagation and constraint solving mechanisms are also supported [16].
- Semantic interoperability. Domain ontologies are the most important part of the Semantic Web [29],they enable knowledge sharing between different knowledge-base applications, without ontologies web is not semantically interoperable because it is originally designed for direct human processing of information presented [29].

Different paradigms for ontology modeling are available, among them two widely used paradigms are OWL and Frames [30]; although they are built on top of constructs such as class, properties, facet, restriction etc. they display differences in their semantics, expressive power and available tool support [30]. Some of the major differences between OWL and Frames are listed in [30] as follows:

- In Frames ontology if truthiness of some knowledge is not explicitly specified it is considered to be false (closed world assumption) where as in OWL if some knowledge is not explicitly specified as false it is considered to be true (open world assumption).
- There is a single minimal model that satisfies each of the assertions in a frame ontology whereas in OWL multiple models that satisfy the assertions in the ontology are possible.

- In Frames constraints on a class define the necessary conditions that must hold for all the instances of that class, whereas in OWL sufficient conditions can also be defined.
- In Frames, reasoner checks if the defined constraints are satisfied, whereas in OWL consistency check of the ontology is done while trying to build a model to satisfy all the assertions in the model. Default reasoning is one f the key strengths of Frames over OWL, since in the former default values are used to fill partial knowledge and exceptions are supported.
- In OWL, set of classes and instances are disjoint and it is not possible to use classes as property values and OWL have a poor representation power of numeric expressions which disables the expression of quantitative relations.
- In OWL, complex expression can be built using intermediate concepts anonymously (without having to name it prior to use), which reduces the number of explicit facts in the model. Frames do not have anonymous concept support.
- In OWL, set operations over class descriptions are allowed and also transitive properties can be modeled, which are non existing features in Frames.

Based on the above characteristics of OWL and Frames, the nature of domain and the application that will run on top of that domain model have a major effect on the selection of suitable ontology modeling paradigm.

2.2 Requirements Reuse Applications

Reuse is not a new concept in software community, traditional reuse techniques that are supported by object oriented programming such as polymorphism, encapsulation and inheritance are used by programmers to write modular and to some extent reusable code [31]. Reuse libraries [32] are another traditional reuse approach which is based on storing any previous solution of the development process for later use. But with the emerge of SPL development, the concept of what is reusable, changed dramatically. In addition to implementation, now it is possible to reuse requirements, design templates, test cases, reports, etc. Effort for enabling reuse of different assets and also benefits gained from their reuse are different from each other.

Although enabling requirements reuse have an overall affect in the performance of a product line [33], there is not much research on the subject until recently [14], thus solution domain is not mature enough. which results in the proposed solutions to be usually restricted to small-scale academic examples and untested in terms of industrial or commercial capacity [13].

Existing research on requirements reuse indicates that RE is a highly knowledge intensive process [11, 28, 14] thus knowledge based solutions become increasingly popular [28]. For example potential uses of ontologies are listed in [28] as:

- representation of requirements model,
- domain knowledge acquisition,
- representation of domain knowledge

In [14] following RE problems, that are related to knowledge intensive activities are listed:

- insufficient requirements traceability,
- lack of systematic requirements reuse,
- lack of integration of RE activities,
- communication problem in distributed development.

Since SPL development is about systematic reuse, lack of systematic requirements reuse is an important problem for product line success. In [34] two key challanges for requirements reuse in product line development is identified as effective techniques for domain analysis, and how to document product line requirements. Also the diversity of representations and the existence of different levels of requirements description are factors that make requirements reuse difficult [12].

Feature oriented and ontology based methods are the two mostly used methods in domain analysis [13, 28]. In [33] an approach to capture and validate software requirements using OWL and reasoning technology is presented. This mentioned approach extends OWL with closed world constraints to check the completeness of requirements model against well established metrics such a ISO/IEC 9126. OntoREM [11] is an ontology-driven requirements engineering methodology, which introduced in order to improve requirements quality while reducing the efforts (ie. development and maintenance) for requirements reuse. Although it is not a study on software requirements reuse, it is important in the sense that it reports evaluation results of the proposed method in a case study on aircraft operability domain, which increases the confidence in ontology based methods in requirements reuse problem. A feature oriented study in [13] proposes a requirements management process in the concept of reuse in product lines and shares the experience with the proposed method in embedded software industry. The findings of the study can be listed as features are efficient mechanisms for reusable requirements and reusable test cases development. In [12] a requirements meta model to define reusable requirement is proposed, contribution of the study is the introduction of a meta model to enable requirement reuse in domains where semiformal representations are used to capture requirements information. Another study that focuses on reusing traditional textual requirements is presented in [35], which proposes a reuse model based on "derived requirements" concept and reports engineering efforts savings with requirements reuse as high as 61

In summary, domain analysis and requirements documentation is two important problems in the way systematic requirements reuse that waits for efficient solutions. Feature oriented and ontology based approaches are available for domain modeling. Successful applications of ontology based solutions have been reported. In addition to development of reusable requirements, methods to define process for reuse and management of reusable requirements are needed. Although the findings in [11, 13, 35] are promising, in general the ideas are either restricted to small-scale academic examples or untested in genuine industrial or commercial capacity [13].

2.3 Product Configuration Problem

"Given a set of customer requirements and a product family description, the configuration task is to find a valid and completely specified product structure among all alternatives that the generic structure describes" [36]. While domain analysis and modeling are the important problems of domain engineering phase of SPL development, product configuration is the major problem of application engineering phase in which software products of a company are configured from a set of components, according to the needs of individual customers. Even after a commonality and variability modeling solution is presented, an industrial scale SPL may include very large number of different instantiations of the underlying model, thus selecting valid product configurations for individual systems is a difficult problem to solve manually [37], thus *product configurators* are needed.

Product configurators are considered to be among the most succesful applications of artificial intelligence technology [36] but usually adopted for the configuration process of non-software products, and product configurators used for non-software products give results as abstract products , but during software product configuration it's also possible to give result as the product's itself [38]. Different configuration approaches are listed in literature such as rule-based, model-based and case-based approaches [36]. Each of these approaches have a different underlying ontology that is used to represent the domain knowledge, domain entities and relations that hold between these entities [36]. Logic-based, resource-based and constraint-based representations are commonly used for the implementation of model-based approaches [36].

In [39],the fact that a configurable product and the configurator software should be developed in parallel is highlighted which makes knowledge acquisition and maintenance of configuration knowledge bases critical. This study [39] states that the existence of different proprietary knowledge representations which are not integrated into standard software development processes makes knowledge based configuration more complicated and proposes UML usage to construct a configuration knowledge base.

In [38] a model-based product derivation methodology for application in software-intensive domains is proposed. A novel aspect of the study is stated as the combination of tool-supported configuration and realization into one process for deriving software products [38]. Experiences gained from the experiments with industrial partners are also reported.

Following important properties for a product cofiguration solution methodology is listed in [40]:

- explanation, product training, and help desk support
- reasoning schemeas that handle incomplete or ambiguous information

- inconsistency detection, error handling and retraction

In [41] an interactive configuration approach is presented which is a combination of configuration and content-based recommendation of product lines. In [42] a model-based framework for automated product derivation is presented relying on an independent model-based design layer. It's proposed that this design bridges the gap between feature models and product implementations.

CHAPTER 3

PROPOSED SOLUTION

Requirements engineering(RE) is considered to be a knowledge intensive process in software lifecycle which encourages the use of knowledge based techniques in this area of software engineering[use], depending on this fact an ontology based approach is proposed for requirements reuse problem in SPLs. In this chapter, the proposed solution, basic information about the problem domain, phases of domain modeling studies and the OntSRDT tool built on this domain knowledge is discussed in detail.

RE and architecting are the two initial phases of software lifecycle whose major outcomes are requirements specifications and architecture documents which contain dense knowledge that has prominent effects on the success of a project and depending on the fact that these two phases have an interweaved relationship and overlapping knowledge [14] with commonalities, some RE problems can be solved by reusing solutions for architectural knowledge (AK) management [14] and in literature proposed methods for reuse of AK are based on formal domain models. Accordingly, this thesis proposes an ontology based domain knowledge formalization for SPLs, ontology modeling is preferred over feature modeling due to their descriptive power and also to overcome management problems of feature models that proliferate with increased variability. Reuse is achieved by a tool support which is based on an interactive product configuration scenario which guides the user to enter required information to instantiate a valid product of the product line and the related requirements with this configuration is enlisted automatically. Requirements formalization and support tool design are performed such that enlisted requirements have unique identifiers to accomplish the management of requirements of the domain ontology. With this feature it is possible to import the outputs of automation tool to a commercial requirements management tool and any changes due to following updates on domain ontology can be reflected upon previously created documents.

Figure 3.1 illustrates the solution architecture:

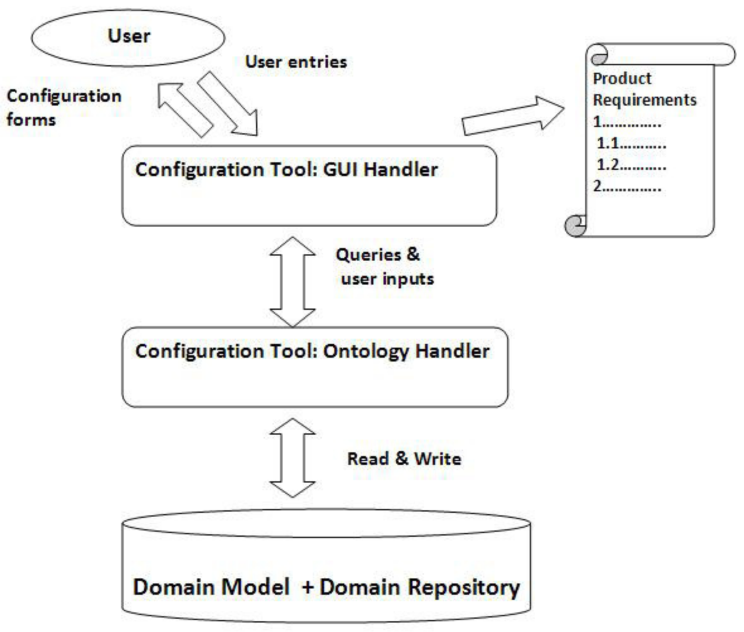


Figure 3.1: Solution architecture

According to this solution architecture, a GUI Handler is developed to provide some forms to user in order to collect information about product configuration and to document the configuration related requirements. GUI Handler is in communication with an Ontology Handler which enables controlled access to underlying domain ontology and provides the information exchange required by GUI Handler. Domain ontology and domain repository is the part where the model and instances of different concepts in the model are stored respectively.

3.1 Domain Knowledge: Fire Control SPLs

Before going into details of domain modeling, it is useful to provide some introductory information about the target domain in this study.“ Fire control in general encompasses all operations required to apply fire on a target” [43] but it can be divided into two as tactical or technical fire control, tactical fire control is responsible for the planning and evaluation part where technical fire control softwares are usually embedded in a weapon system and focus on computational and mechanical operations required for that weapon system to hit a specific target with a specific munition [43]. They operate in real-time and are mission critical,thus for this type of software determinism, system and operator safety are important. These softwares are surrounded with various sensors to obtain information about the target and physical environment of the weapon, accompanied with platforms and actuators to enable motion of the system and also in interaction with a user control panel or tactical fire control systems. Figure 3.2 illustrates the basic concepts in technical fire control software world.

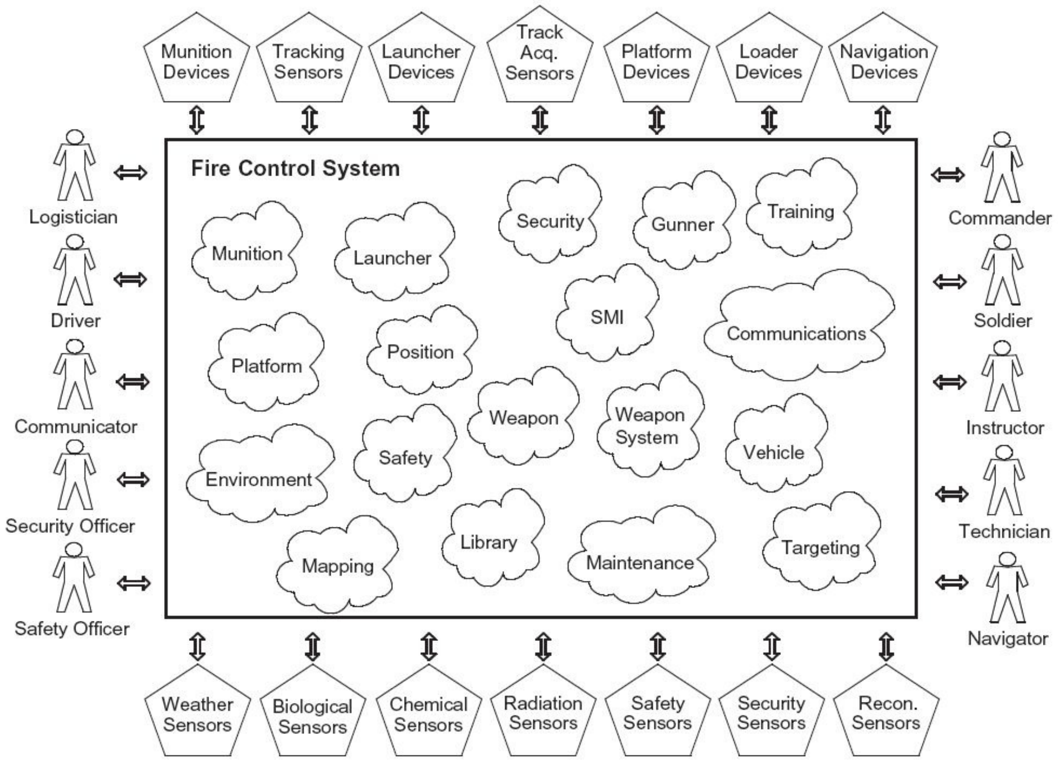


Figure 3.2: Fire control domain and interactions [43]

3.1.1 Fire Control SPL Reference Architecture

According to the previously conducted domain analysis and architecting studies a reference architecture [44] is agreed upon to be adopted in fire control software development. As mentioned in the begining of this chapter, RE and architecting are two interweaved processes whose outputs are feedbacks to each other [14], in that sense when starting to domain modeling for requirements reuse in mind, its not like starting from scratch. Key concepts, relations between them and domain rules are mostly already identified during architecting studies but these knowledge is not formalized in a way to be machine readable and analyzable. Thus existing reference architecture model (See Figure 3.3) and reports constitute as a good starting point for the domain modeling studies and throughout this study domain model is constructed in consistency with reference architecture which means although the structural definitions of the domain concepts are different, the rules that hold between them should not violate the previously defined reference architecture.

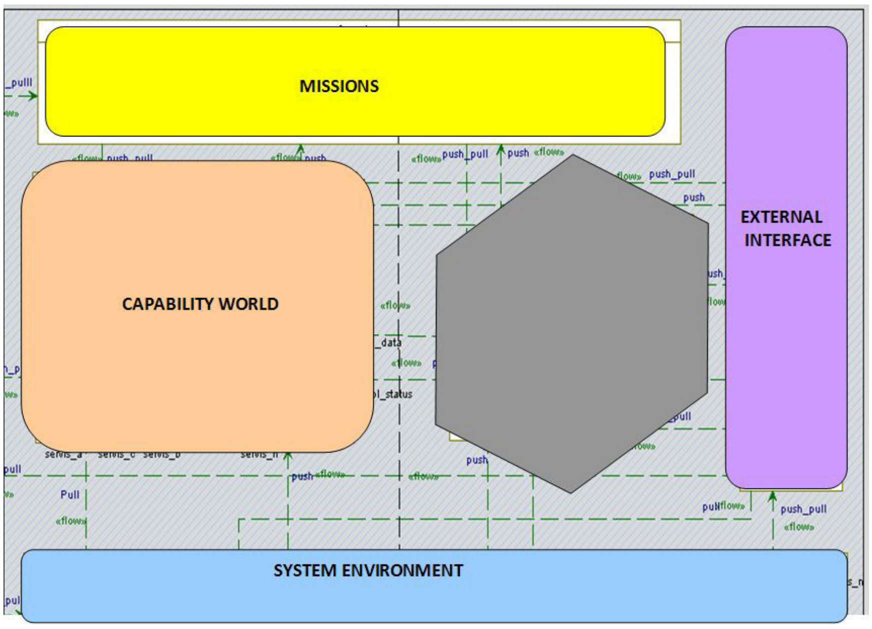


Figure 3.3: Fire Control Reference Architecture [44]

According to the above figure, there are four important main concepts in FCS Product Line:

- *System Environment Concept* corresponds to the various types of sensors and actuators , which will be referred to as units in the rest of this document,that surround a fire control software. Examples to these can be but not limited to inertial navigation systems (INS) for sensing vehicle movement and changes in angular position, reading the current position of the system on earth or power control devices to manage the power distribution of the systems, servo controllers to perform angular positioning of the platforms, gun controllers to perform firing of some munitions with a specified setting, etc. Different kinds of system environment elements are identified, their provided services and information are explored and they are grouped into family of devices. Before our work, this concept was the most exploited one, but their effects to product requirements were not documented explicitly.

- *Capability Concept* correspond to different groups of management operations that are required for centralized management of system environment inputs and services. For example platform management capability handles different angular inputs from different sensors, which can be attached to different platforms, and provides data transformation between different platforms. Capabilities can be seen as guards that prevents direct access to system environment inputs and services. They are also well defined concepts, different groups of capabilities are identified to be used throughout the related product line, in that sense they are similar to system environment concepts but are less open to changes, functionalities and data of capabilities are rarely updated. Before our work, effects of capabilities to product requirements also were not documented explicitly.

- *Mission Concept* is closer to end user due to its higher level of abstraction and can be further divided into different types of missions which are basically the scenario managers in a system, based on what capability world provides to them they are responsible for the conduction of operational scenarios while assuring system safety and user specifications. Although some initial understanding on mission concept exists, it is usually handled in a free format way rather than studying and modeling the commanality and variability throughout the product line. Structure of mission layer and attributes do not exist prior to this study and also their reflection to product requirements are not formally studied. An important difficulty that arises with the mission concept is that most of the domain knowledge on missions are not documented, they are usually embedded to the product via the domain expertise knowledge of the developers and product requirements corresponding to mission concepts are the ones where divergence among requirements specification documents are most visible.

- *External Interface Concept* is the part where user interaction enters the scene of fire control software and also the part where everything goes hand in hand. Different types of external interfaces can be user consoles on which some button, switch, led kind of entities make it possible to start/stop scenarios and alert user, alternatively tactical fire control softwares may have software interface to operate through technical fire control softwares. Results of previous domain research [44] indicates that its difficult to model the behavior and structure of external interface concept in isolation from other concepts that constitutes the fire control software. This part usually includes system specific requirements and thus external interface concept modeling is not among the initial goals of this study but still some effort is used for identification of the structure of external interface related domain requirements.

3.2 Domain Modeling

During this study, ontology modeling approach is chosen over feature modeling due to its richer descriptive power and suitability for formal analysis. Frame ontology paradigm is followed. Ontology model is developed on Protege3.4.7 ontology editor because of its support for frame ontology [45]. Final domain model should include formalizations for domain concepts, constraints and domain requirements; during the modeling process, existing reference architecture documents of the domain is used as initial input to indentify key domain concepts, architecture models and documents are used as input to identify domain rules, previously documented requirements specifications are used as input to identify domain requirements, apart from these codified inputs, expert knowledge is also investigated to be made explicit in the model. We propose a solution model such that, domain requirements and domain concepts are formalized and if some domain concept invokes a set of requirements in real world, in model that concept is also related with these requirements, thus when a fire control software is built up from specified domain concepts, domain requirements related to these configuration are also built up. Figure 3.4 displays the intended solution model.

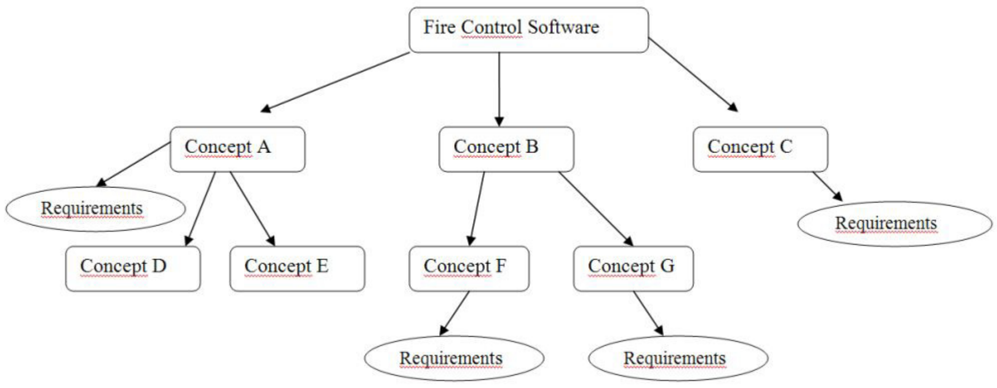


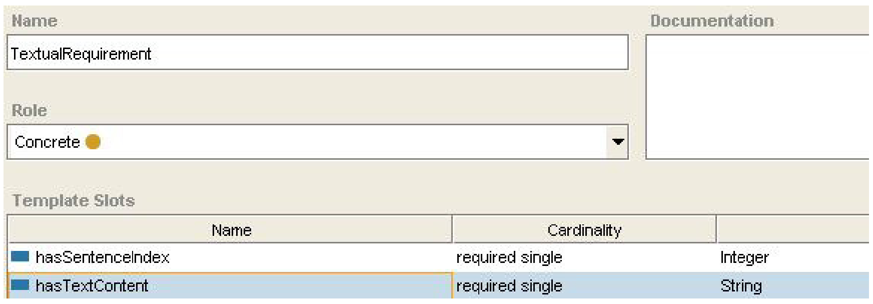
Figure 3.4: An abstraction of proposed solution model

3.2.1 Domain Requirements

After analysis of existing requirements specification documents, two types of requirements are identified:

- constant requirements that do not display variations for different products. Examples:
  - Software should end laying when laying accuracy is achieved.
  - Software should stop firing when ammunition empitied.
- variable requirements, that display some variations according to the product configuration. Examples:
  - Software should check *INS connection error before laying*.
  - Software should check *INS connection error during laying*.
  - Software should check *INS connection error during fire*.
  - Software should check *servo connection error before fire*.

Based on above descriptions about requirements specifications, our aim in this work is to formalize textual requirements specifications such that, both constant and variable requirements can be supported. Constant requirements are trivial but variable requirements needs a mechanism to enable variations, which is the introduction of "requirement parameters". A requirements specification is considered to be "complex requirement" consisting of one or more "textual requirements" and zero or more "parametric requirements". Figure 3.5. and 3.6 displays model snapshots for introduced terms.



Name: TextualRequirement

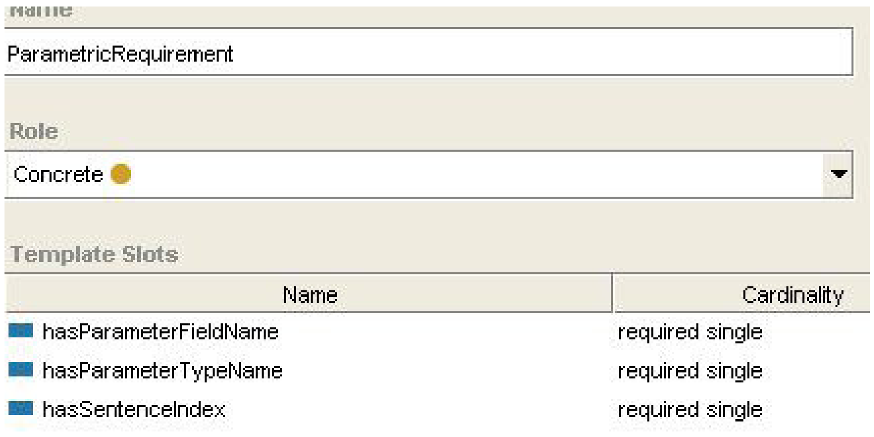
Documentation:

Role: Concrete ●

Template Slots

Name	Cardinality	
hasSentenceIndex	required single	Integer
hasTextContent	required single	String

Figure 3.5: A snapshot from model: Textual Requirement Representation


Name

ParametricRequirement

Role

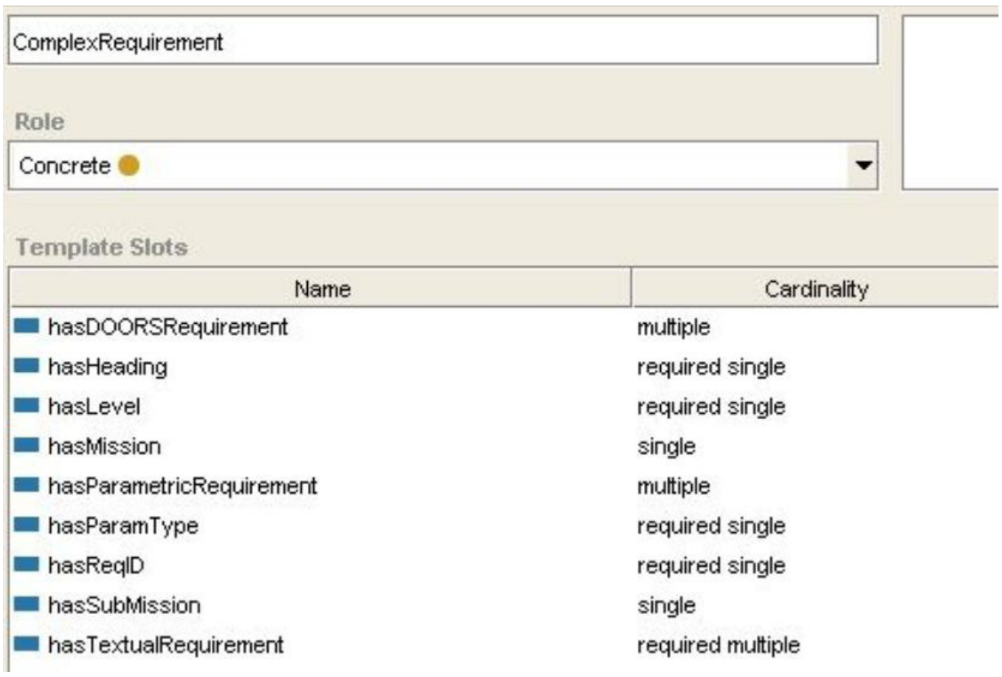
Concrete ●

Template Slots

Name	Cardinality
hasParameterFieldName	required single
hasParameterTypeName	required single
hasSentenceIndex	required single

Figure 3.6: A snapshot from model: Parametric Requirement Representation

Parametric requirements are stored in repository without their actual parameters entered, instead a textual representation is developed as place holders. Parameters will be determined later at reuse time, with some little parsing actual values of parameters will be inserted to the related location. Complex requirements is mainly a combination of textual and parametric requirements, but some more information is added to its definition to also specify a template document structure for resultant requirements specifications. See Figure 3.7 for a snapshot of complex requirement definition. The template document structure is to group requirements to related headings thus introduce a document hierarchy for readability.


ComplexRequirement

Role

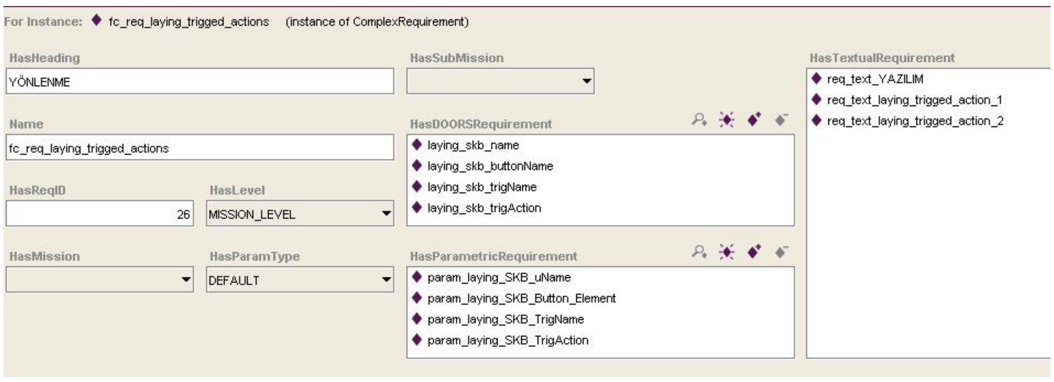
Concrete

Template Slots

Name	Cardinality
hasDOORSRequirement	multiple
hasHeading	required single
hasLevel	required single
hasMission	single
hasParametricRequirement	multiple
hasParamType	required single
hasReqID	required single
hasSubMission	single
hasTextualRequirement	required multiple

Figure 3.7: A snapshot from model: Complex Requirement Representation

After a formalization for requirements specification is developed, construction of repository of domain requirements is started, but since requirements are related with domain concepts, repository construction is performed in parallel to domain modeling, while new concepts are added to the model.


For Instance: fc_req_laying_trigged_actions (instance of ComplexRequirement)

HasHeading: YÖNLENME

Name: fc_req_laying_trigged_actions

HasReqID: 26

HasLevel: MISSION_LEVEL

HasMission:

HasParamType: DEFAULT

HasSubMission:

HasDOORSRequirement:
- laying_skb_name
- laying_skb_buttonName
- laying_skb_trigName
- laying_skb_trigAction

HasParametricRequirement:
- param_laying_SKB_uName
- param_laying_SKB_Button_Element
- param_laying_SKB_TrigName
- param_laying_SKB_TrigAction

HasTextualRequirement:
- req_text_YAZILIM
- req_text_laying_trigged_action_1
- req_text_laying_trigged_action_2

Figure 3.8: A snapshot from model: example complex requirement instance

Figure 3.8 diplays an example complex requirement instance with its assigned slots/attributes. This complex requirement instance is composed of a set of parametric and textual requirements, apart from requirements representation other types of information such as level, heading(to be used in the template),and parameter type are also exist. For example this complex requirement instance will appear under laying requirements heading of mission requirements section in the document.

3.2.2 Domain Concepts

In domain study the initial effort was on answering the question “Which concepts are used to built a fire control software?”. Reference architecture indicates some of these concepts namely system environment, capability, mission, without giving formal definitions. Aim of this study is to provide an ontology model that includes representations of these more general concepts from software requirements perspective. Meaning of a concept can be divided into a number of sub concepts, with the following base condition: if a newly introduced sub concept is not a parameter of some requirement in the repository or has no effect on the evaluation of domain constraints, just don’t introduce it. In this section details of the modeled concepts are given.

- *SystemEnvironmentThing* concept is introduced to model fire control software system environment units. Reference architecture includes unit type enumerations for a number of sensors and actuators, based on this knowledge classification of system environment concept is as in Figure 3.9.

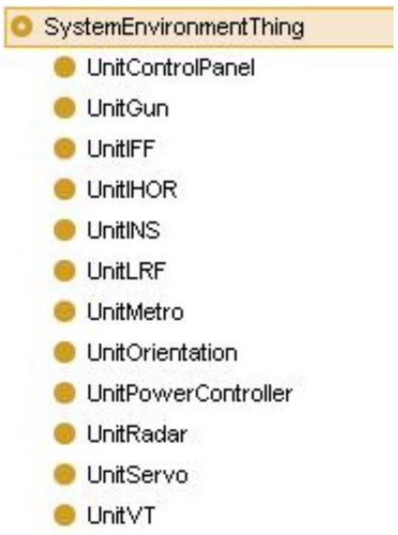
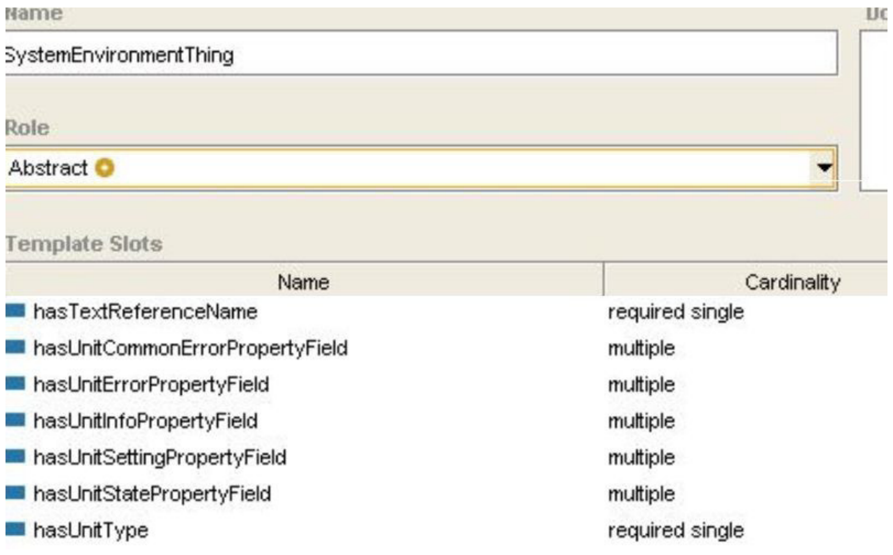

SystemEnvironmentThing
- UnitControlPanel
- UnitGun
- UnitIFF
- UnitIHOR
- UnitINS
- UnitLRF
- UnitMetro
- UnitOrientation
- UnitPowerController
- UnitRadar
- UnitServo
- UnitVT

Figure 3.9: A snapshot from model: Classification of System environment concept

After detailed inspection of interfaces defined for different unit types, there emerged a common representation frame for units as displayed in Figure 3.10 which enlists the attributes of a system environment unit and additional information such as their cardinalities.


Name

SystemEnvironmentThing

Role

Abstract

Template Slots

Name	Cardinality
hasTextReferenceName	required single
hasUnitCommonErrorPropertyField	multiple
hasUnitErrorPropertyField	multiple
hasUnitInfoPropertyField	multiple
hasUnitSettingPropertyField	multiple
hasUnitStatePropertyField	multiple
hasUnitType	required single

Figure 3.10: A snapshot from model: Frame for system environment concept

It's proposed that a unit may provide zero or more services, is related to a set of requirements and provides some information that can be grouped into following 4 categories:

- setting is the information group that specifies some operation configuration, which can be read from and write into a unit
- data/info is the information group that a unit outputs, which is read only for the fire control software
- mode of operation which can be commanded to change(writable) or only readable for some units
- errors are special types of information for a unit to indicate faults occurring during operation,which is read only.

Following example requirements are related with members of system environment concept, meaning for each unit included in the product configuration, its related requirements will be added to document automatically:

- Software should report $UNITXXX\ ERRORYYY$ error.

  - Software should report $UNITXXX\ INFOYYY$ information.
  - Software should read $UNITXXX\ MODEYYY$ mode.
  - Software should write $UNITXXX\ SETTINGYYY$ setting.
  - Software should write $UNITXXX\ SETTINGYYY$ setting.

  An example unit of type INS has the following fields:

  - setting: initialization time, boresight, orientation, shutdown with stored heading, information accuracy, alignment time
  - info: north referenced angle values, GPS data, initial position, vehicle moving, remaining time to complete alignment
  - mode: zero velocity update requested, initial position requested, initialization mode, stored heading alignment mode, gyro compass alignment mode, etc.
  - error: connection error, initialization error, communication error, crtical fault

- $ServiceThing$ concept is introduced while modeling $SytemEnvironmentThing$ concept, it's known that some members of system environment are there to provide some services while supporting information, settings or mode related to these services. A service is modeled with a service name and a supplier instance of system environment. A portion of services introduced to model are listed as follows:

  - Angle Service provides angular information about the platform of the service supporting unit.
  - GPSPosition Service provides the GPS position of the service supporting unit.
  - Stabilization Service provides stabilized motion of a platform
  - Drive with Speed Service provides the motion of a platform with a commanded speed.
  - Drive with Position Service provides the motion of a platform to a commanded position.
  - Drive with Error Service provides the motion of a platform from its current position as the specified error.
  - Drive with Torque Service provides the motion of a platform with commanded torque value.

  - Target Velocity Service provides the velocity information about a detected target.
  - Firing Service provides the firing of some munition.

  During service concept modeling, following feedback to current architecture is given: Current architecture defines a “driveService” which may have the following drive modes as enumerations: move with speed, move with position, move with error, move with torque. This type of encoded usage of different drive services disables the detection of configuration inconsistencies at model level. When a system environment unit arrives its supported services are also known thus instead of encoding different service types as enumerations a different service interface can be defined, which enables the model based check of “each service used should be provided by some unit” rule.

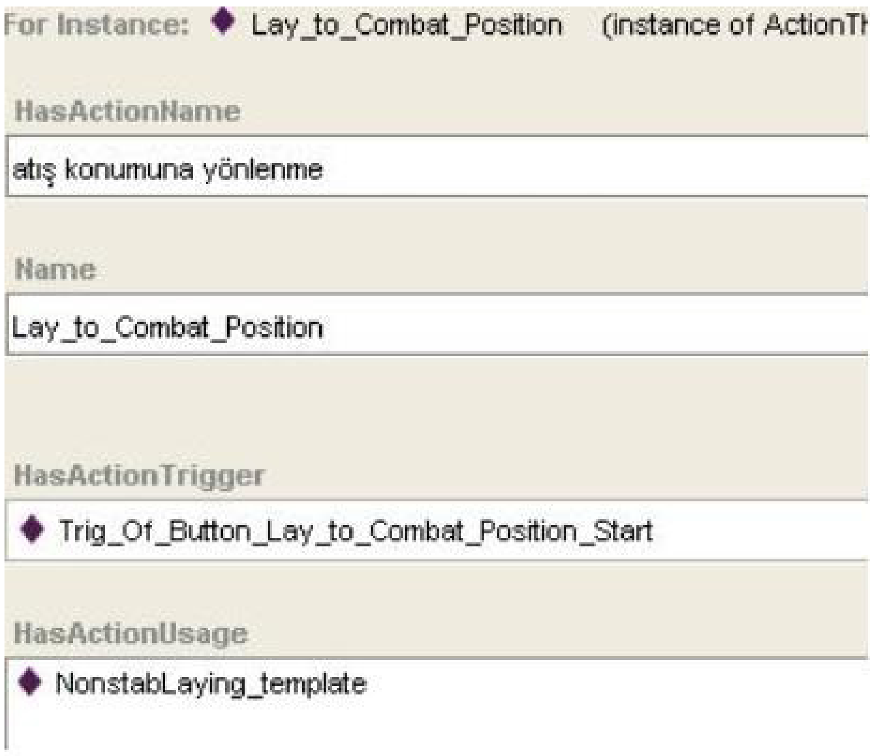
- *ActionThing* concept is introduced to model missions which control different scenarios.(which will also be introduced later). Mission scenarios can be thought as actions and each action is triggered by some external/internal event, and that action is realized by some mission. Figure 3.11 displays an example action instance which is the scenario of laying to combat position, triggered by some button in the system and that action is realized by a sub type of laying mission.

- *TriggerThing* concept is introduced to model different types of scenario starters in a fire control software which is usually an external command from either a control panel or a user interface software. Each trigger trigs an action in the software. Since most of the triggers are caused by external interface events, although initial goal of this study does not include a complete model of fire control software external interface, control panel related part of external interface sub domain is studied to complete the relationhip between a mission, an action and a trigger.

- *UnitControlPanel* is a special member of system environment concept which has some additional concepts other than modes,information, errors, etc. These additional concepts are grouped under a different concept named *ControlPanelElement*, see Figure 3.12.

  A control panel element is either a button, switch, led or joystick that resides on a system environment member of tye UnitControlPanel which has the following additional requirements:

  - Software should set the status of *LEDXXX* on *UNITCTRLPANELYYY*


For Instance: ◆ Lay_to_Combat_Position (instance of ActionTh

HasActionName

atış konumuna yönlenme

Name

Lay_to_Combat_Position

HasActionTrigger

◆ Trig_Of_Button_Lay_to_Combat_Position_Start

HasActionUsage

◆ NonstabLaying_template

Figure 3.11: A snapshot from model: an example ActionThing instance

- Software should read the status of $SWITCHXXX$ on $UNITCTRLPANELYYY$
- Software should read the status of $BUTTONXXX$ on $UNITCTRLPANELYYY$
- Software should set the origin of $JOYSTICKXXX$ on $UNITCTRLPANELYYY$

A switch or button usually have some substates such as ON/OFF, ENABLE/DISABLE, etc. and each state of these control panel elements are triggers of actions in a fire control software.

- $MissionThing$ concept is introduced to model for supported mission scenarios of a fire control software. Reference architecture does not include any specification for mission concept, just indicates the existence of it. Thus depending on the applications in existing projects and including expert knowledge on this subject a number of requirements related to mission concept are enlisted and following classification is introduced (See Figure 3.13).

  Unlike units, mission types do not have much commonality in structure, since information used and operations performed by different missions are usually disjoint. But an underlying mechanism that is modeled with this work is that: each mission type has a

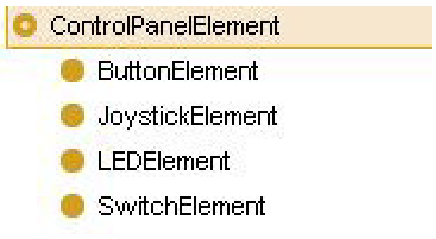


Figure 3.12: A snapshot from model: classification of control panel elements

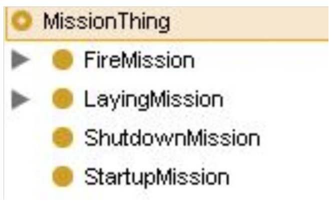


Figure 3.13: A snapshot from model: Classification of Mission concept

set of supported scenarios whose support status depends on the availability of related service suppliers, and each scenario is triggered by some event.

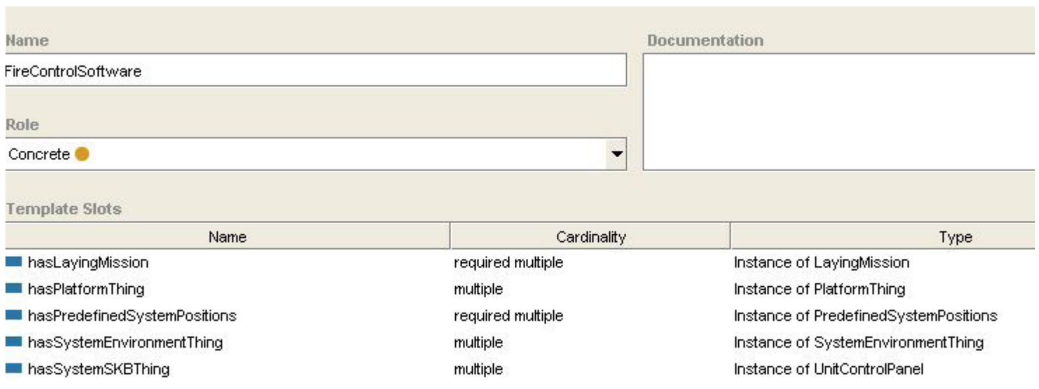
– *Startup Mission* is responsible for the operation of start up scenarios of fire control softwares, these scenarios usually include restoring of parameter values tha are stored in non-volatile memory and managing power up scenario of system environment units included in the system configuration. Types of parameters that are stored on non-volatile memory and the units whose power is controlled by fire control software are variable according to system configuration.

– *Shutdown Mission* for the operation of controlled shutdown of a fire control software, which includes the storing of some parameter values to non-volatile memory and also power down scenario of system environment unis included in the system configuration. Types of parameters that are stored on non-volatile memory and the units whose power is controlled by fire control software are variable according to system configuration.

– *Fire Mission* is mainly responsible for hitting a target with a munition, apart from that some safety requirements are assigned to that concept such that some safety checks are performed before and during a fire mission. Types of safety controls are variable according to system configuration and also according to the controlled firing scenario, for example safety requirements of a stationary firing scenario are different than the safety requirements of a non-stationary firing scenario.

  - *Laying Mission* is mainly responsible for the motion of a platform to some other position or with some specified speed, etc. , apart from that some safety requirements are assigned to that concept such that some safety checks are performed before and during a laying mission. Types of safety controls are variable according to system configuration and also according to the controlled laying scenario, for example safety requirements of a non-stabilized laying scenario are different that the safety requirements of a stabilized laying scenario.

- *FireControlSoftware* concept makes use of other defined concepts in its frame definition to built a fire control software according to the underlying domain model. See Figure 3.14 for the example frame of a *FireCotrolSoftware* concept.



Name: FireControlSoftware

Role: Concrete ●

Documentation:

Template Slots

Name	Cardinality	Type
hasLayingMission	required multiple	Instance of LayingMission
hasPlatformThing	multiple	Instance of PlatformThing
hasPredefinedSystemPositions	required multiple	Instance of PredefinedSystemPositions
hasSystemEnvironmentThing	multiple	Instance of SystemEnvironmentThing
hasSystemSKBThing	multiple	Instance of UnitControlPanel

Figure 3.14: A snapshot from model: a partial view of a fire control software frame

3.3 Reuse Mechanism

At the end of domain modeling phase a reuse repository for requirements and domain concepts is constructed. Reuse mechanism proposed in this study is to handle requirement reuse as a conceptual product configuration problem. Since domain concepts are modeled in a way that if a domain concept introduces a set of requirements to product line, then this concept is related with its requirements on the model. Thus if a concept is included in some conceptual product configuration its requirements are also included. Manual product configuration is a time consuming and error prone task which will endanger the success of reuse. Tool support is required at that point to decrease human errors and increase reuse efficiency.

3.3.1 Ontology-based Requirements Derivation Tool: OntSRDT

During this study an ontology based automation tool for requirements reuse and documentation is developed. OntSRDT is designed to be in interaction with a user via a graphical user interface and ask some questions or give some tasks in order to lead user to valid product configurations of the product line and documenting requirements specifications for that configuration. By valid product configuration, it is mentioned that user should not be able to configure a product which is out of domain scope or violating domain constraints, the tool is responsible for disabling user from making invalid decisions and also for checking the validity of user entered data against domain constraints, this way any configuration will be a valid product and requirements will be valid requirements for that product. This requires an information entry flow to be defined to collect most restricting information from user as soon as possible so that invalid configuration paths are disabled earlier. For that purpose the information flow in Figure 3.15 is adopted during this study.

3.4 Reusable Requirements Management

Being able to automatically derive and document product configuration related requirements is a big improvement, but it is not enough in requirements engineering domain. Requirements repository should be updateable when needed and it will be needed since domain modeling is usually performed in iterations, with each iteration the coverage of the model is increased and possibly new requirements are introduced to the model, or some errors detected at requirements textual representations should be corrected with updates to repository. Without a management policy the outputs of the support tool will only be useful for producing the first version of a product's requirements specifications, and after that point traceability of repository requirements with documented requirements will be lost. Just like repository requirements, requirements specification documents are open to changes and considered to be dynamic in nature. Before a requirements specification document is formally published it's sent for review by other functional participants of the project such as test engineers, system engineers, quality department, etc. According to the review results initial document needs to

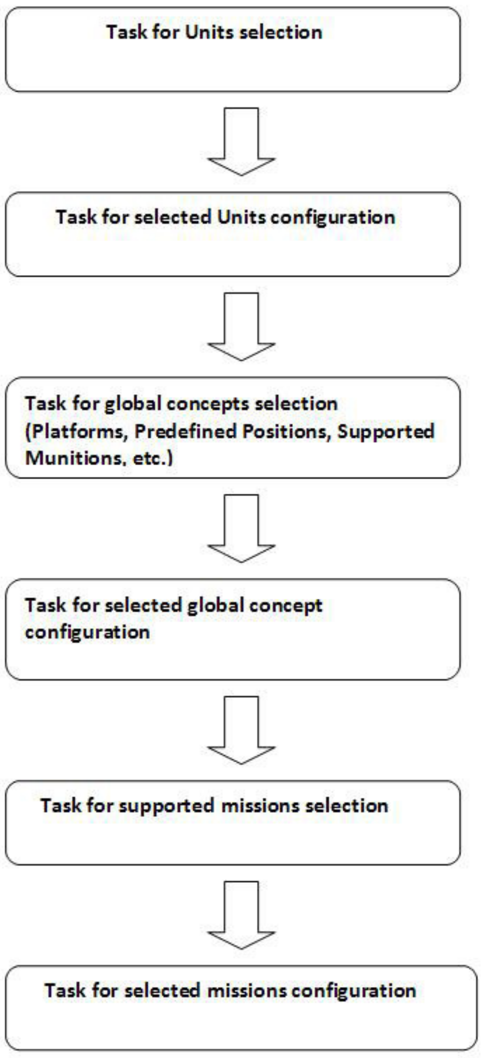

Task for Units selection
Task for selected Units configuration
Task for global concepts selection (Platforms, Predefined Positions, Supported Munitions, etc.)
Task for selected global concept configuration
Task for supported missions selection
Task for selected missions configuration

Figure 3.15: Configuration flow of the tool

be modified and this change proposals may be given for requirements which are derived from requirements repository, if manual change is permitted after documents first release then there is no way to guarantee that systematic requirements reuse is achieved. Another aspect that should be considered is that although product specific requirements are not in scope of any reuse activity, they are also members of requirements specification documents and proposed management solutions should not ignore their existence.

OntSRDT is an automation support tool, not a requirements management tool. Usually there is a generally accepted commercial requirements management tool at companies and using some other management tool independently will lead to more serious synchronization problems with other participants of the project. Our proposal is to implement an add-on for existing commercial requirements management tool in order to import the outputs of the developed support tool in this thesis. One more problem that arises after the output requirements of the tool is migrated to a commercial management tool, is the reflection of changes to the document that resides in that other tool. To handle this problem it's decided that our support tool should include some unique id generation mechanism for repository requirements, which also requires the underlying model to include partial identifiers for concepts and their related requirements. Documenting each requirement specification with a unique identifier solves management problem of reusable requirements management. Even though updates are performed on domain concepts or requirements repository, when related product configuration is applied on support tool and outputs are imported to commercial management tool again, unique id mechanism is enough for that tool to apply changes only to affected requirements and preserves identifiers and specifications for other requirements.

CHAPTER 4

CASE STUDY

One problem with proposed solutions for requirements reuse in software engineering is that they are usually untested for industrial usage [13]. To support the reuse solution proposed in this thesis with results obtained by application of it on an industrial scope product line, a case study on fire control software product lines developed by Aselsan Inc. is planned. Conduction details of case study and results are discussed in detail.

4.1 Conduction of Case Study

In order to evaluate content and coverage of domain ontology and automatically derived requirements specified with this study, the support tool is enabled in RE of two different fire control software projects under development, this projects will be referred to as FCS-P1 and FCS-P2 in this document. FCS-P1 and FCS-P2 have the following general product configurations:

- Servo Controller
- Gun Controller
- INS/Compass
- tracking as a type of laying mission
- fire mission

Requirements specification documents for the above product configurations are documented by the support tool developed in this study. But since meeting the deadlines of the above project was necessary and graphical user interface of the tool was not completed at the time, case study is conducted by performing product configuration manually inside code. Initial goal of the case study was to display the coverage of ontology based requirements specifications thus valid product configurations are supplied to the tool. Output files of the tool are imported to commercial requirements management tool and each document is opened to review of a group of engineers from software engineering, test engineering, systems engineering and software quality engineering departments. The information that some of the requirements are automatically derived from a requirements repository is not shared with the review group. After review process is completed and change proposals are reflected upon the documents some metrics are calculated which are shared in the following section.

4.2 Metrics and Evaluations

During this case study the number of requirements in the repository is noted as 59. Initial versions of requirement specification documents for FCS-P1 and FCS-P2 contain 264 and 304 requirements respectively. During evaluations comparison with existing systems' requirements are not preferred mostly due to their different abstraction levels than the hereby introduced one. Thus some of the requirements documented within this study are almost invisible in existing documents which makes the comparison difficult. Apart from abstraction level, quality and content of existing documents are not standard to be considered as a bases for comparison.

Following metrics are introduced for evaluations, see Table 4.1 and Table 4.2 for computed values of these metrics.

- Ratio of automatically derived requirements to overall requirements, as an indicator of document coverage of automatically derived requirements in terms of percentage.
- Ratio of automatically derived requirements that are manually updated, as an indicator of maturity for used requirements repository. Updated requirements are inspected and different update types are noted, for each update type a different metric is introduced.
- Ratio of syntax updates to overall updates, indicates the ratio of updates to correct typo mistakes and some Turkish natural language corrections about suffixes to derived requirements. Following requirements are extracted from documents as examples:

- *initial requirement*: Software should check that servo controller unit is clear of *H*ardware error ...
- *updated requirement*: Software should check that servo controller unit is clear of *h*ardware error ...

• Ratio of naming updates to overall updates, as an indicator of a need to rename some concepts in the document without imposing any semantic difference. Following requirements are extracted from documents as examples:

  - *initial requirement*: Software should check that "gun controller unit" is clear of not ready to fire error ...
  - *updated requirement*: Software should check that "gun otomation unit" is clear of not ready to fire error ...
  - *initial requirement*: Software should check that mode of "servo controller unit" is ready to move ...
  - *updated requirement*: Software should check that mdoe of "azimuth servo controller unit" is ready to move ...

• Ratio of semantic updates to overall updates, as an indicator of semantically immature requirements. Following examples are extracted from documents as examples:

  - *initial requirement*: Software should propose an ammunition type to be fired.
  - *updated requirement*: Software should propose an ammunition type to be fired according to the result of ammunition proposal calculations.

• Ratio of deletions to overall updates, as an indicator of unwanted requirements due to their irrelevance of configuration or abstraction level. Following requirements are extracted from document as examples to deleted requirements:

  - *deleted requirement*: Software should enable target type entry for an active target.
  - *deleted requirement*: Software should enable target angular position entry for an active target.

Table 4.1: Computed metrics for FCS-P1

Metric	Value(%)
Ratio of derived requirements to overall requirements	81.71
Ratio of manual updates on derived requirements	25.57
Ratio of deletions to overall updates on derived requirements	1.82
Ratio of syntax updates to overall updates on derived requirements	23.52
Ratio of concept renaming updates to overall updates on derived requirements	66.66
Ratio of semantic updates to overall updates on derived requirements	15.68

Table 4.2: Computed metrics for FCS-P2

Metric	Value(%)
Ratio of derived requirements to overall requirements	84.38
Ratio of manual updates on derived requirements	18.50
Ratio of deletions to overall updates on derived requirements	4.76
Ratio of syntax updates to overall updates on derived requirements	19.04
Ratio of concept renaming updates to overall updates on derived requirements	78.57
Ratio of semantic updates to overall updates on derived requirements	7.14

Based on the above metrics, with the proposed solution approach most of the product requirements can be automatically derived (81.71% - 84.38%). As previously stated after reviews some requirements are updated manually, depending on the effects of these update following comments are made:

- The ratio of deletions on derived requirements is less than 5%, this means our approach mostly documents in scope requirements, not causing false positives in measurements.
- The ratio of syntax updates (19.04% - 23.52%) is an indicator of need for review of textual fragment in the requirements repository and sentence compositions for more natural language looking sentences, it's detected that some sentence structures irritates the reviewers.
- Based on the ratio of concept renaming updates (66.66%- 78.57%), depending on the project without changing the semantics, there is a need fro flexibility in our tool design to be able to give proper names especially to system environment units in order to increase documents' understandability.

- Based on the ratio of semantic updates (7.14%-15.68%), it can be said that our domain model and requirements repository are not mature enough, model should be updated in the light of these semantic changes.

CHAPTER 5

DISCUSSION

Results of the case study indicate that document coverage of automatically derived product line requirements is acceptable, thus proposed method is promising and applicable in practice. But during this study it was not possible to perform a comperative study of our method with existing approaches/tools since the success of the method is to a great extent dependent on quality, scope and complexity of underlying domain model. Tools developed for other domains can not be directly applied to the domain studied in this research, thus comparison of our results with the results of other methods evaluated in other domains does not provide significant information because there is no way to compare the complexity and the scope of the underlying domain models used in different research. Since results of existing methods in literature are not suitable for a comperative study with the hereby proposed method, for further evaluation of our method, a set of metrics for continuous evaluation should be defined and evaluated with updates on our approach and/or domain ontology and thus new versions of our method will be compared against previous versions and we will be able to track the improvements with future updates.

Another point is that evaluated metrics in this research do provide information about document coverage of automatically derived product line requirements, but do not provide any information about the quality improvements achieved with the proposed method. A set of metrics should be selected and evaluated on documents created with the method introduced in this thesis and existing documents that are created with traditional approaches, so that a comparison in terms of requirements quality is possible.

CHAPTER 6

CONCLUSION

In this thesis an ontology based solution is proposed to enable requirements reuse in a product line to eliminate the disadvantages of not reusing software requirements. The main contribution of this work is the introduction of a practical mechanism for requirements reuse and management of these reusable requirements. Hereby proposed approach is applied in RE phase of two different fire control software and metrics we obtained from this practice is reported. The benefits of the proposed approach can be listed as follows:

- Requirements whose source are reference architecture or reusable components are made visible in the documents independent from the document owners' decision. Expert knowledge is represented in the model such that even unexperienced engineers working in the domain can prepare a great percentage of requirements specifications documents by just following their knowledge about system configuration.
- Previously domain knowledge was stored in raw text documents such as reports of architecting studies, in UML to represent reference architecture and interface definitions in C++, the accumulated knowledge on fire control domain is not in a machine readable form, which prevents analysis and development of assisting applications on this knowledge. Studies in this thesis started the migration of knowledge from other existing formats to a formal format as domain ontology. During this migration process some useful feedbacks to architectural interfaces are generated. For example current architecture defines a "DriveServiceInterface" which encodes different drive services as enumerations such as drive with torque or drive with speed. When a unit arrives which kind of drive services it support is known in advance based on its interface control documents, but embedding this knowledge as enumerations prevents the detection of improper usage

of the "DriveServiceInterface" on model level. Thus, instead of enumerating different drive services of the domain, "DriveServiceInterface" can be breakdown into sub types.

- One of the main quality indicators of a requirement statement is having one and only one requirement in it. Traditional requirements engineering methods can not detect these types of quality deficiencies before requirements reviewing phase. Since automatically derived requirements are coming from the same source, by controlling requirements in the repository in terms of their language and quality, all of the following documents will be affected from this quality assessment.

- Document prepared by traditional methods may differ in abstraction level, by using automatically derived requirements even if the documents are created by different level except from product specific requirements, abstraction level is consistent throughout a single document and throughout all product line requirements specification document. Product specific requirements will be in minority and there will be enough time for their careful inspection. Reuse of requirements will increase the quality of requirements while decreasing the effort used to documenting them in the long term.

Although the results obtained from the experience gained with this study is very promising, efficiency of the proposed method is directly related to completeness and correctness of the ontology model and quality of the tool support. Thus, following items are listed to be studied in future:

- The coverage of the ontology model is not complete yet, which prevents its efficient usage for some of the product line members. One way to continuously improve the coverage is to apply this approach on the upcoming projects and collect feedbacks from them.

- The conformity of requirements specifications in the repository to quality standards on requirements should be checked by introducing the evaluation of required metrics. Based on this metrics it will be possible to comment on the general quality of prepared documents with this reuse method.

- There is more to do with the support tool, current status of OntSRDT tool is suitable to support the requirements reuse process but it should be improved to be open to public use as a product configurator. Also it should be updated for each new concept that affects a product configuration is introduced into model to get synchronized with the underlying model. Current tool support is only for regular user and do not let any changes to happen to underlying ontology model with user actions. But there is also a need for a special user, who also cannot change the structure of the model but can add new instances of concepts usually for system environment units. It can be enhanced to an expert system in the future and can be used to for human training and optimization for valid product configurations.

Above listed work items are important to keep alive the studies that started with the hereby presented work, but application of knowledge based methods in software engineering are not limited to RE activities. This encourages us to enhance the underlying domain model in future such that on top of requirements, automatic test case derivation can be supported to an extent, furthermore some relation to implementation can be supplied such that the support tool that's currently only used to conceptually configure a product can also be used to configure an implementation for that product in the future.

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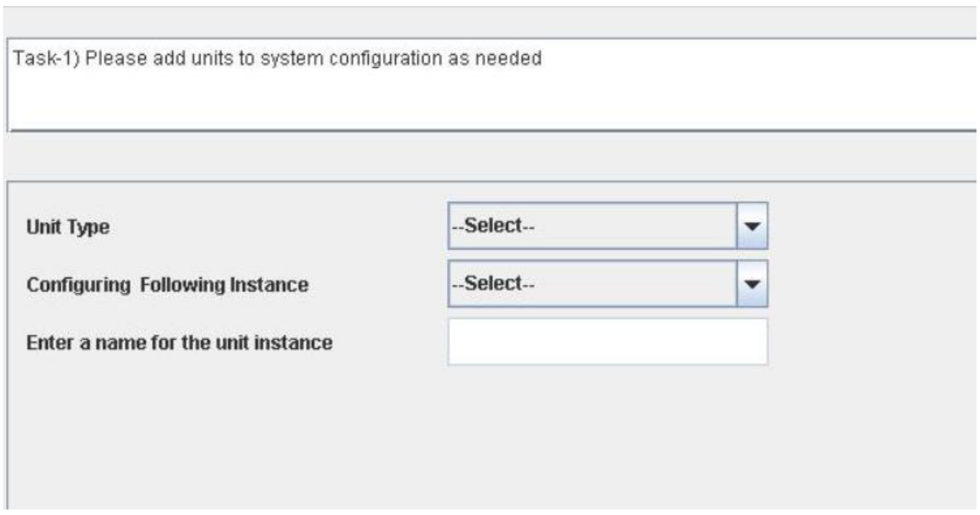
APPENDIX A

EXAMPLES

A.1 A Simple Configuration Example

Following images display the steps for a simple product configuration and resulting requirements specification.



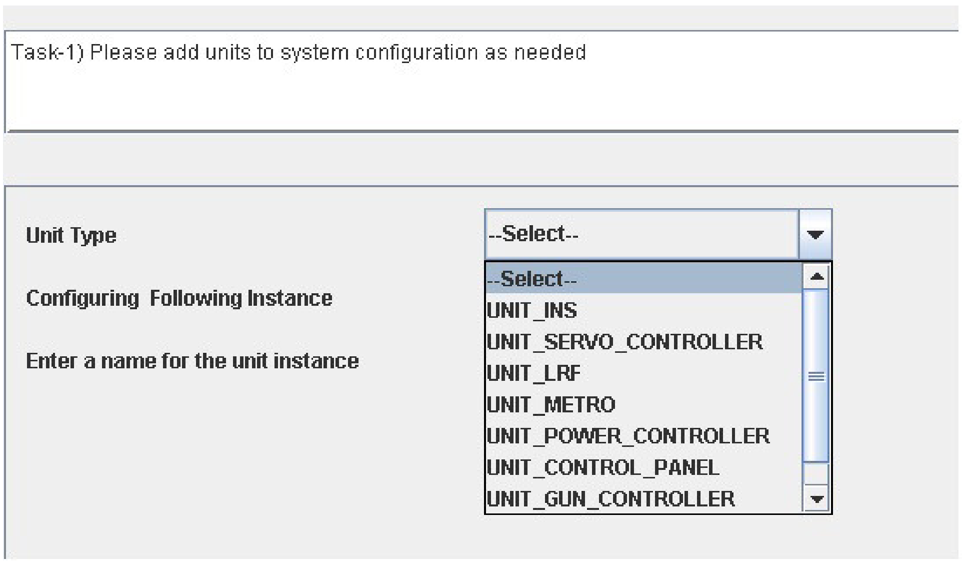
Task-1) Please add units to system configuration as needed

Unit Type: --Select--

Configuring Following Instance: --Select--

Enter a name for the unit instance

Figure A.1: configuration step1

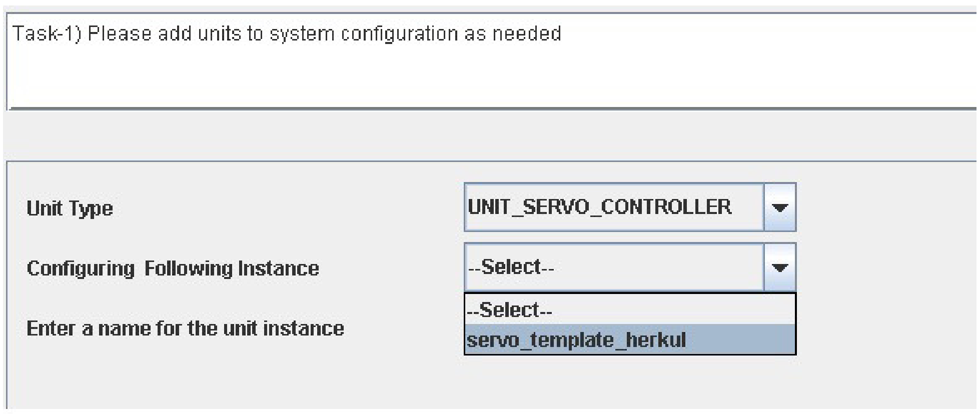

Task-1) Please add units to system configuration as needed

Unit Type

Configuring Following Instance

Enter a name for the unit instance

Figure A.2: configuration step2

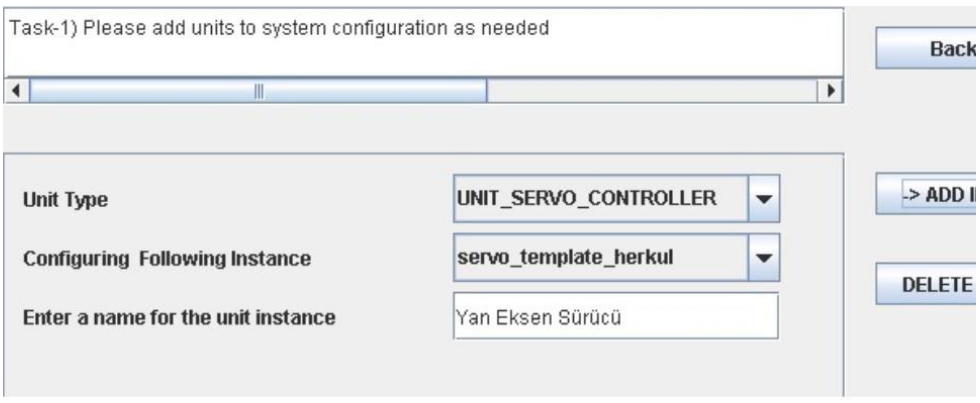

Task-1) Please add units to system configuration as needed

Unit Type: UNIT_SERVO_CONTROLLER

Configuring Following Instance: --Select--

Enter a name for the unit instance

Figure A.3: configuration step3

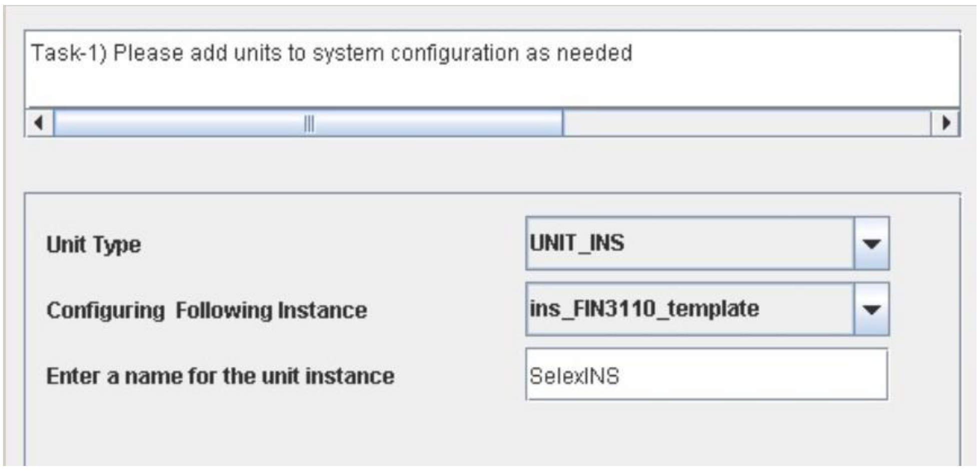

Task-1) Please add units to system configuration as needed

Unit Type: UNIT_SERVO_CONTROLLER

Configuring Following Instance: servo_template_herkul

Enter a name for the unit instance: Yan Eksen Sürücü

Figure A.4: configuration step4


Task-1) Please add units to system configuration as needed

Unit Type: UNIT_INS

Configuring Following Instance: ins_FIN3110_template

Enter a name for the unit instance: SelexINS

Figure A.5: configuration step5

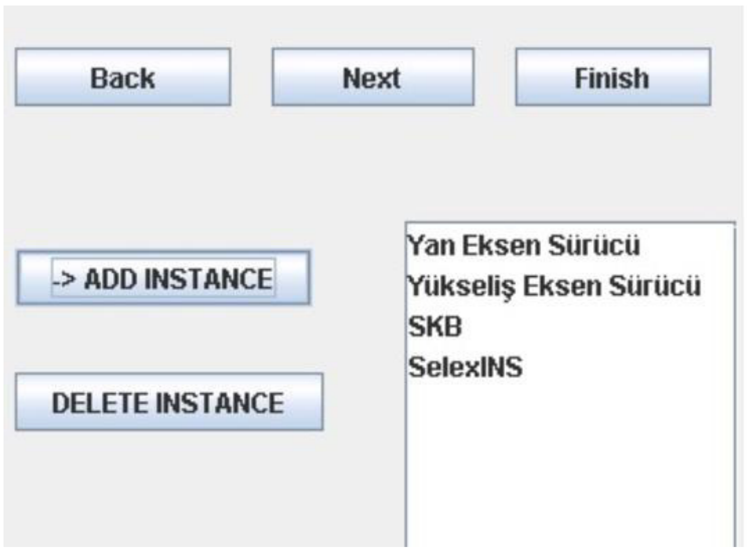
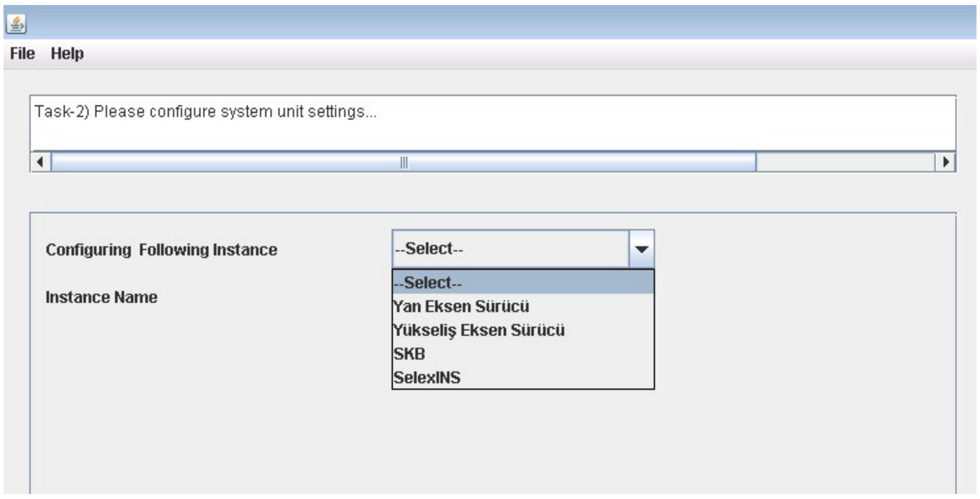


Figure A.6: configuration view after step5



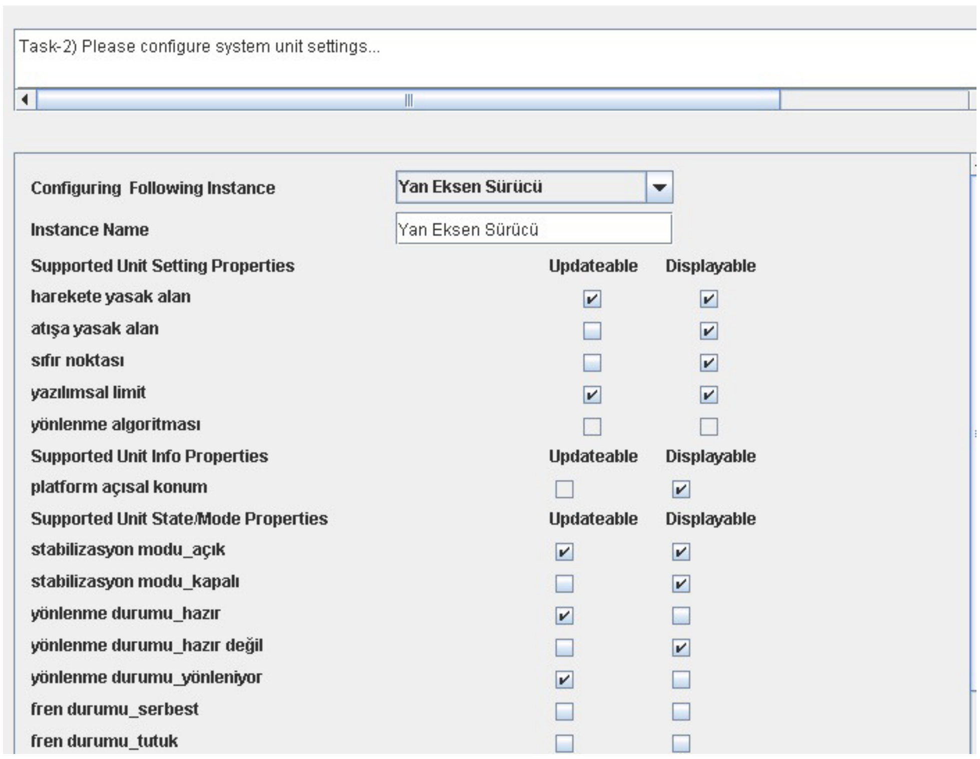
Task-2) Please configure system unit settings...

Configuring Following Instance --Select--

Instance Name

--Select--
Yan Eksen Sürücü
Yükseliş Eksen Sürücü
SKB
SelexINS

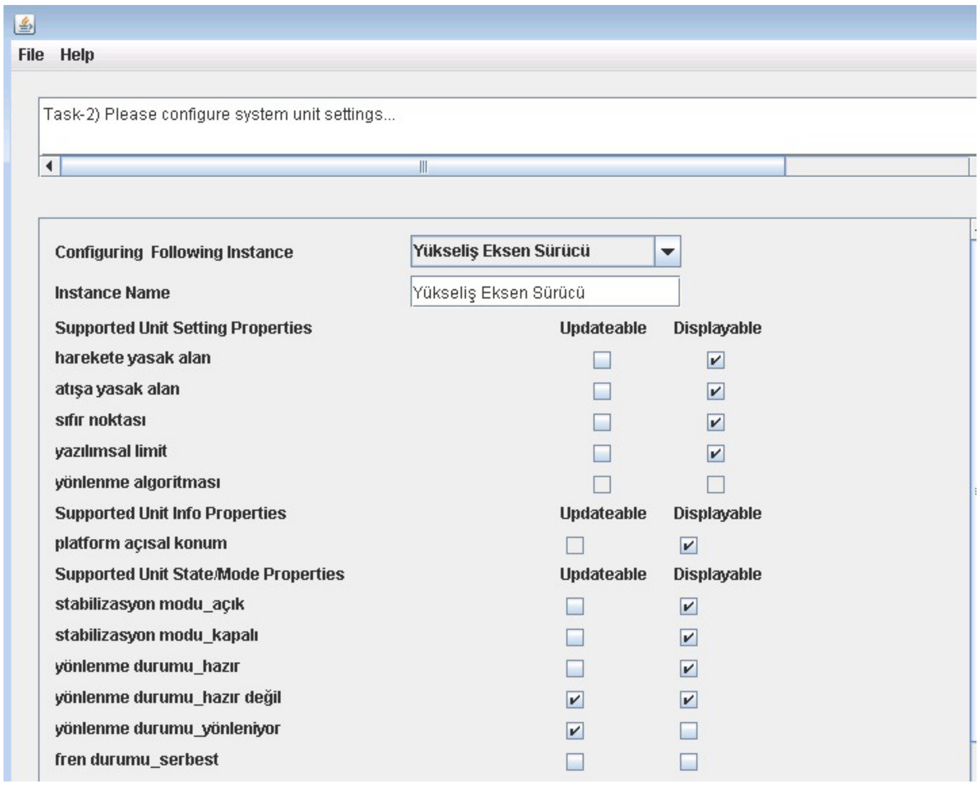
Figure A.7: configuration step6



Task-2) Please configure system unit settings...

Configuring Following Instance	Yan Eksen Sürücü	
Instance Name	Yan Eksen Sürücü	
Supported Unit Setting Properties	**Updateable**	**Displayable**
harekete yasak alan	☑	☑
atışa yasak alan	☐	☑
sıfır noktası	☐	☑
yazılımsal limit	☑	☑
yönlenme algoritması	☐	☐
Supported Unit Info Properties	**Updateable**	**Displayable**
platform açısal konum	☐	☑
Supported Unit State/Mode Properties	**Updateable**	**Displayable**
stabilizasyon modu_açık	☑	☑
stabilizasyon modu_kapalı	☐	☑
yönlenme durumu_hazır	☑	☐
yönlenme durumu_hazır değil	☐	☑
yönlenme durumu_yönleniyor	☑	☐
fren durumu_serbest	☐	☐
fren durumu_tutuk	☐	☐

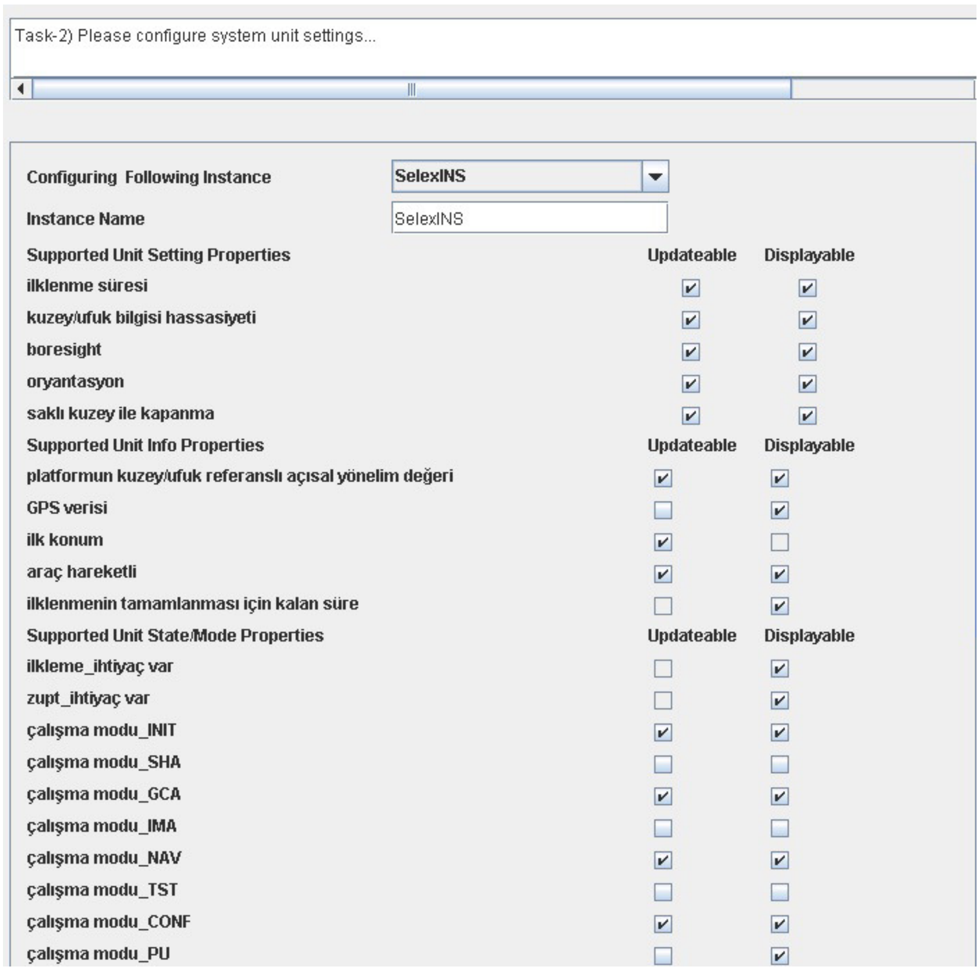
Figure A.8: configuration step7



Task-2) Please configure system unit settings...

Configuring Following Instance	Yükseliş Eksen Sürücü	
Instance Name	Yükseliş Eksen Sürücü	
Supported Unit Setting Properties	Updateable	Displayable
harekete yasak alan	☐	✓
atışa yasak alan	☐	✓
sıfır noktası	☐	✓
yazılımsal limit	☐	✓
yönlenme algoritması	☐	☐
Supported Unit Info Properties	Updateable	Displayable
platform açısal konum	☐	✓
Supported Unit State/Mode Properties	Updateable	Displayable
stabilizasyon modu_açık	☐	✓
stabilizasyon modu_kapalı	☐	✓
yönlenme durumu_hazır	☐	✓
yönlenme durumu_hazır değil	✓	✓
yönlenme durumu_yönleniyor	✓	☐
fren durumu_serbest	☐	☐

Figure A.9: configuration step8

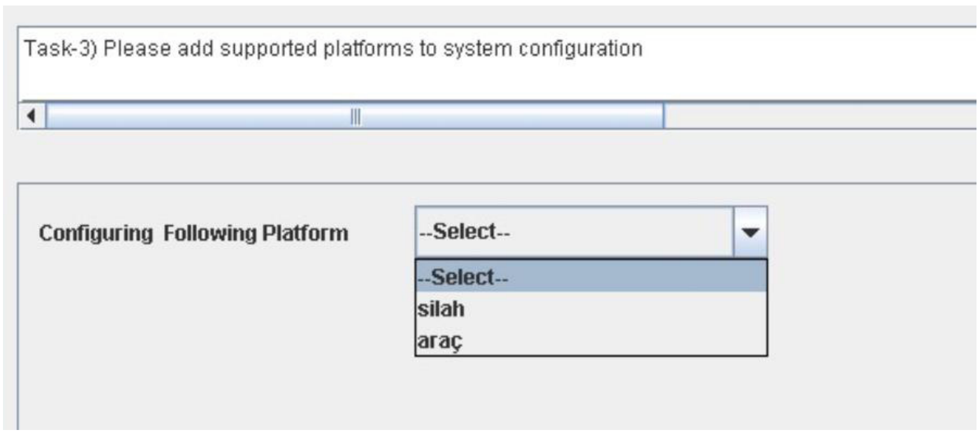

Task-2) Please configure system unit settings...

Configuring Following Instance: SelexINS

Instance Name: SelexINS

Supported Unit Setting Properties	Updateable	Displayable
ilklenme süresi	✓	✓
kuzey/ufuk bilgisi hassasiyeti	✓	✓
boresight	✓	✓
oryantasyon	✓	✓
saklı kuzey ile kapanma	✓	✓
Supported Unit Info Properties	**Updateable**	**Displayable**
platformun kuzey/ufuk referanslı açısal yönelim değeri	✓	✓
GPS verisi	☐	✓
ilk konum	✓	☐
araç hareketli	✓	✓
ilklenmenin tamamlanması için kalan süre	☐	✓
Supported Unit State/Mode Properties	**Updateable**	**Displayable**
ilkleme_ihtiyaç var	☐	✓
zupt_ihtiyaç var	☐	✓
çalışma modu_INIT	✓	✓
çalışma modu_SHA	☐	☐
çalışma modu_GCA	✓	✓
çalışma modu_IMA	☐	☐
çalışma modu_NAV	✓	✓
çalışma modu_TST	☐	☐
çalışma modu_CONF	✓	✓
çalışma modu_PU	☐	✓

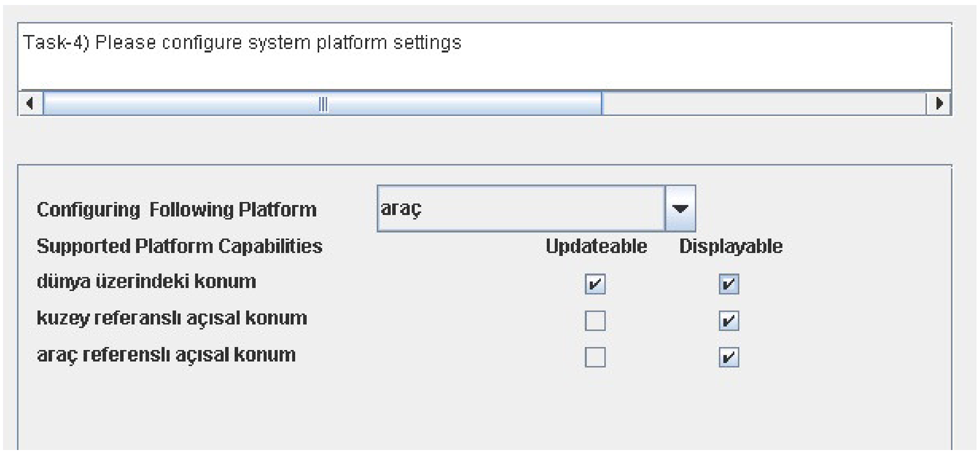
Figure A.10: configuration step9



Task-3) Please add supported platforms to system configuration

Configuring Following Platform: --Select--

step10]configuration step10

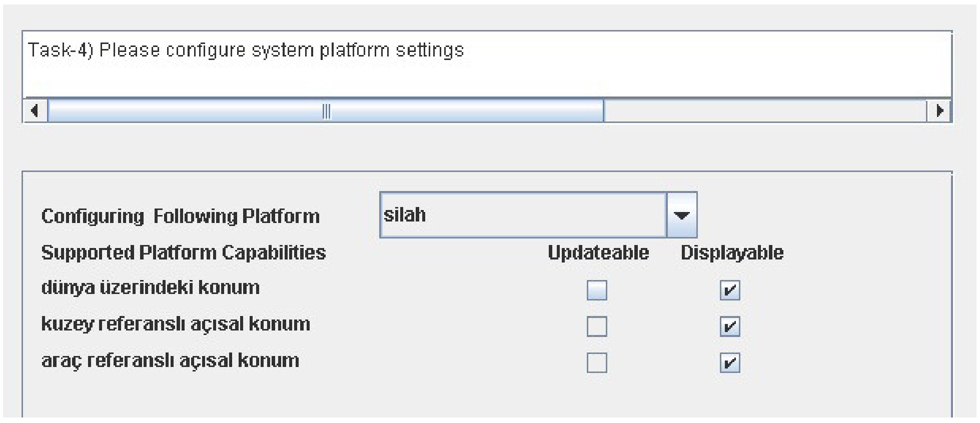


Task-4) Please configure system platform settings

Configuring Following Platform: araç

Supported Platform Capabilities	Updateable	Displayable
dünya üzerindeki konum	✓	✓
kuzey referanslı açısal konum		✓
araç referenslı açısal konum		✓

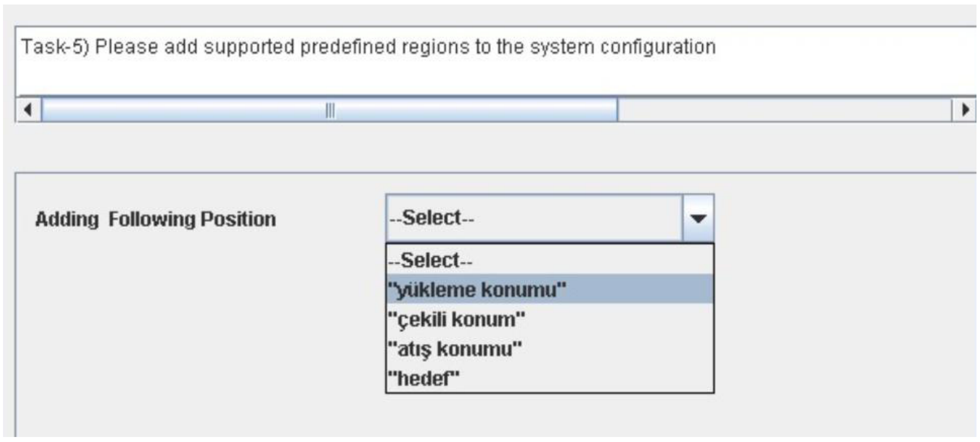
Figure A.11: configuration step11



Task-4) Please configure system platform settings

Configuring Following Platform	silah	
Supported Platform Capabilities	Updateable	Displayable
dünya üzerindeki konum	☐	☑
kuzey referanslı açısal konum	☐	☑
araç referanslı açısal konum	☐	☑

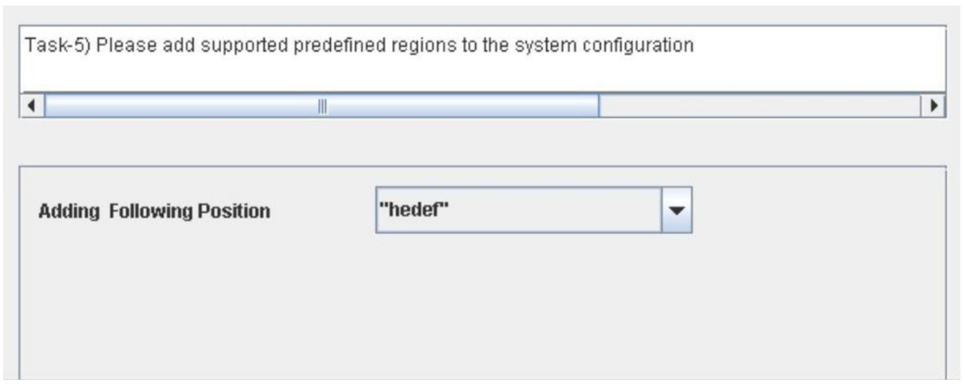
Figure A.12: configuration step12



Task-5) Please add supported predefined regions to the system configuration

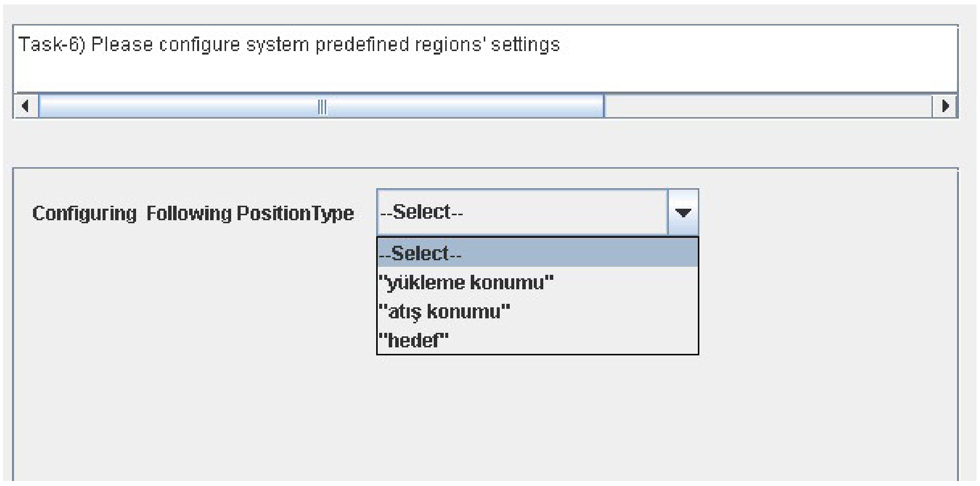
Adding Following Position --Select--

Figure A.13: configuration step13


Task-5) Please add supported predefined regions to the system configuration

Adding Following Position: "hedef"

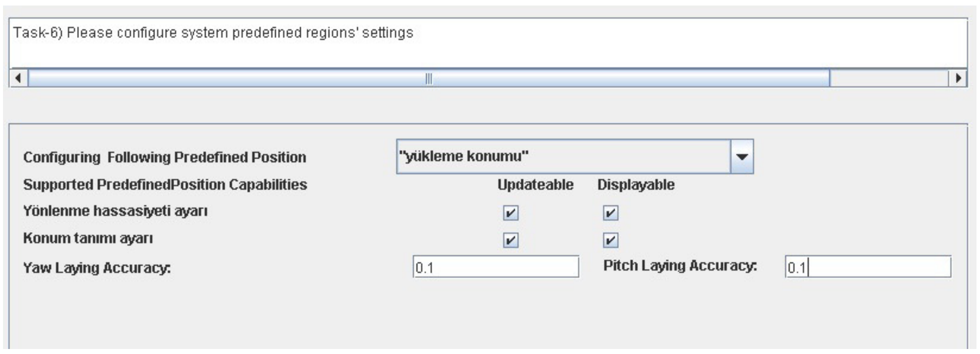
Figure A.14: configuration step14



Task-6) Please configure system predefined regions' settings

Configuring Following PositionType --Select--

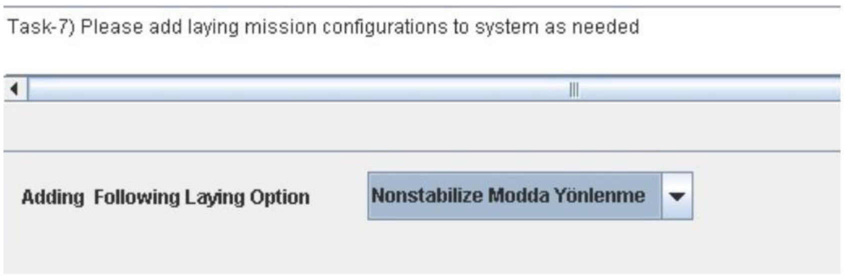
Figure A.15: configuration step15


Task-6) Please configure system predefined regions' settings

Configuring Following Predefined Position	"yükleme konumu"	
Supported PredefinedPosition Capabilities	Updateable	Displayable
Yönlenme hassasiyeti ayarı	✓	✓
Konum tanımı ayarı	✓	✓

Yaw Laying Accuracy: 0.1 Pitch Laying Accuracy: 0.1

Figure A.16: configuration step16


Task-7) Please add laying mission configurations to system as needed

Adding Following Laying Option: Nonstabilize Modda Yönlenme

Figure A.17: configuration step17

A.2 Sample Requirements Specifications

U: BIRIM AYARLARI ILE ILGILI ISLEMLER

U:21-I:1 INS AYARLARI

U:21-I:1-P:1-NP:1 Yazilim, INS baglanti kurulamadi hatasini bildirecektir.

U:21-I:1-P:2-NP:1 Yazilim, INS haberlesme hatasini bildirecektir.

U:21-I:1-P:3-NP:1 Yazilim, INS donanim hatasini bildirecektir.

U:21-I:1-P:4-NP:1 Yazilim, INS acilma hatasini bildirecektir.

U:21-I:1-P:66-NP:2 Yazilim, INS GPS baglanti hatasini bildirecektir.

U:21-I:1-P:67-NP:2 Yazilim, INS VMS baglanti hatasini bildirecektir.

U:21-I:1-P:6-NP:3 Yazilim, INS tarafindan bildirilen platformun kuzey/ufuk referansli acisal yonelim degeri bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:7-NP:3 Yazilim, INS tarafindan bildirilen GPS verisi bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:9-NP:3 Yazilim, INS tarafindan bildirilen arac hareketli bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:10-NP:3 Yazilim, INS tarafindan bildirilen ilklenmenin tamamlanmasi icin kalan sure bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:6-NP:4 Yazilim, platformun kuzey/ufuk referansli acisal yonelim degeri bilgisinin girilebilmesini saglayacaktir.

U:21-I:1-P:8-NP:4 Yazilim, ilk konum bilgisinin girilebilmesini saglayacaktir.

U:21-I:1-P:9-NP:4 Yazilim, arac hareketli bilgisinin girilebilmesini saglayacaktir.

U:21-I:1-P:49-NP:5 Yazilim, INS oryantasyon ayar(lar)inin okunabilmesini saglayacaktir.

U:21-I:1-P:48-NP:5 Yazilim, INS boresight ayar(lar)inin okunabilmesini saglayacaktir.

U:21-I:1-P:46-NP:5 Yazilim, INS ilklenme suresi ayar(lar)inin okunabilmesini saglayacaktir.

U:21-I:1-P:47-NP:5 Yazilim, INS kuzey/ufuk bilgisi hassasiyeti ayar(lar)inin okunabilmesini saglayacaktir.

U:21-I:1-P:49-NP:6 Yazilim, INS oryantasyon ayar(lar)inin yapilabilmesini saglayacaktir.

U:21-I:1-P:48-NP:6 Yazilim, INS boresight ayar(lar)inin yapilabilmesini saglayacaktir.

U:21-I:1-P:46-NP:6 Yazilim, INS ilklenme suresi ayar(lar)inin yapilabilmesini saglayacaktir.

U:21-I:1-P:47-NP:6 Yazilim, INS kuzey/ufuk bilgisi hassasiyeti ayar(lar)inin yapilabilmesini saglayacaktir.

U:21-I:1-P:34-NP:7 Yazilim, INS calisma modu CONF bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:35-NP:7 Yazilim, INS calisma modu PU bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:32-NP:7 Yazilim, INS calisma modu NAV bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:33-NP:7 Yazilim, INS calisma modu TST bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:38-NP:7 Yazilim, INS performans modu INU OK TO MOVE bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:39-NP:7 Yazilim, INS performans modu DEGRADED PERFORMANCE bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:36-NP:7 Yazilim, INS calisma modu PD bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:37-NP:7 Yazilim, INS performans modu ALIGNMENT NOT COMPLETED bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:42-NP:7 Yazilim, INS GPS kullanim modu harici GPS bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:40-NP:7 Yazilim, INS performans modu FULL PERFORMANCE bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:41-NP:7 Yazilim, INS GPS kullanim modu dahili GPS bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:27-NP:7 Yazilim, INS zupt ihtiyac var bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:26-NP:7 Yazilim, INS ilkleme ihtiyac var bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:28-NP:7 Yazilim, INS calisma modu INIT bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:30-NP:7 Yazilim, INS calisma modu GCA bilgisinin okunabilmesini saglayacaktir.

U:21-I:1-P:34-NP:8 Yazilim, INS calisma modu CONF seciminin yapilabilmesini saglayacaktir.

U:21-I:1-P:32-NP:8 Yazilim, INS calisma modu NAV seciminin yapilabilmesini saglayacaktir.

U:21-I:1-P:33-NP:8 Yazilim, INS calisma modu TST seciminin yapilabilmesini saglayacaktir.

U:21-I:1-P:36-NP:8 Yazilim, INS calisma modu PD seciminin yapilabilmesini saglayacaktir.

U:21-I:1-P:42-NP:8 Yazilim, INS GPS kullanim modu harici GPS seciminin yapilabilmesini saglayacaktir.

U:21-I:1-P:41-NP:8 Yazilim, INS GPS kullanim modu dahili GPS seciminin yapilabilmesini saglayacaktir.

U:21-I:1-P:28-NP:8 Yazilim, INS calisma modu INIT seciminin yapilabilmesini saglayacaktir.

U:21-I:1-P:30-NP:8 Yazilim, INS calisma modu GCA seciminin yapilabilmesini saglayacaktir.

U:1-I:2 YUKSELIS EKSEN SURUCU AYARLARI

U:1-I:2-P:1-NP:1 Yazilim, Yukselis Eksen Surucu baglanti kurulamadi hatasini bildirecektir.

U:1-I:2-P:2-NP:1 Yazilim, Yukselis Eksen Surucu haberlesme hatasini bildirecektir.

U:1-I:2-P:3-NP:1 Yazilim, Yukselis Eksen Surucu donanim hatasini bildirecektir.

U:1-I:2-P:4-NP:1 Yazilim, Yukselis Eksen Surucu acilma hatasini bildirecektir.

U:1-I:2-P:68-NP:2 Yazilim, Yukselis Eksen Surucu asiri isinma hatasini bildirecektir.

U:1-I:2-P:70-NP:2 Yazilim, Yukselis Eksen Surucu savas moduna gecilemedi hatasini bildirecektir.

U:1-I:2-P:66-NP:2 Yazilim, Yukselis Eksen Surucu harekete yasak alana girildi hatasini bildirecektir.

U:1-I:2-P:67-NP:2 Yazilim, Yukselis Eksen Surucu atisa yasak alana girildi hatasini bildirecektir.

U:1-I:2-P:6-NP:3 Yazilim, Yukselis Eksen Surucu tarafindan bildirilen platform acisal konum bilgisinin okunabilmesini saglayacaktir.

U:1-I:2-P:48-NP:5 Yazilim, Yukselis Eksen Surucu sifir noktasi ayar(lar)inin okunabilmesini saglayacaktir.

U:1-I:2-P:46-NP:5 Yazilim, Yukselis Eksen Surucu harekete yasak alan ayar(lar)inin okunabilmesini saglayacaktir.

U:1-I:2-P:27-NP:7 Yazilim, Yukselis Eksen Surucu stabilizasyon modu kapali bilgisinin okunabilmesini saglayacaktir.

U:1-I:2-P:26-NP:7 Yazilim, Yukselis Eksen Surucu stabilizasyon modu acik bilgisinin okunabilmesini saglayacaktir.

U:1-I:2-P:29-NP:7 Yazilim, Yukselis Eksen Surucu yonlenme durumu hazir degil bilgisinin okunabilmesini saglayacaktir.

U:1-I:2-P:28-NP:7 Yazilim, Yukselis Eksen Surucu yonlenme durumu hazir bilgisinin okunabilmesini saglayacaktir.

U:1-I:2-P:29-NP:8 Yazilim, Yukselis Eksen Surucu yonlenme durumu hazir degil seciminin yapilabilmesini saglayacaktir.

U:1-I:2-P:30-NP:8 Yazilim, Yukselis Eksen Surucu yonlenme durumu yonleniyor seciminin yapilabilmesini saglayacaktir.

U:1-I:1 YAN EKSEN SURUCU AYARLARI

U:1-I:1-P:1-NP:1 Yazilim, Yan Eksen Surucu baglanti kurulamadi hatasini bildirecektir.

U:1-I:1-P:2-NP:1 Yazilim, Yan Eksen Surucu haberlesme hatasini bildirecektir.

U:1-I:1-P:3-NP:1 Yazilim, Yan Eksen Surucu donanim hatasini bildirecektir.

U:1-I:1-P:4-NP:1 Yazilim, Yan Eksen Surucu acilma hatasini bildirecektir.

U:1-I:1-P:68-NP:2 Yazilim, Yan Eksen Surucu asiri isinma hatasini bildirecektir.

U:1-I:1-P:69-NP:2 Yazilim, Yan Eksen Surucu motor saturasyon degerine ulasildi hatasini bildirecektir.

U:1-I:1-P:70-NP:2 Yazilim, Yan Eksen Surucu savas moduna gecilemedi hatasini bildirecektir.

U:1-I:1-P:66-NP:2 Yazilim, Yan Eksen Surucu harekete yasak alana girildi hatasini bildirecektir.

U:1-I:1-P:67-NP:2 Yazilim, Yan Eksen Surucu atisa yasak alana girildi hatasini bildirecektir.

U:1-I:1-P:6-NP:3 Yazilim, Yan Eksen Surucu tarafindan bildirilen platform acisal konum bilgisinin okunabilmesini saglayacaktir.

U:1-I:1-P:49-NP:5 Yazilim, Yan Eksen Surucu yazilimsal limit ayar(lar)inin okunabilmesini saglayacaktir.

U:1-I:1-P:47-NP:5 Yazilim, Yan Eksen Surucu atisa yasak alan ayar(lar)inin okunabilmesini saglayacaktir.

U:1-I:1-P:49-NP:6 Yazilim, Yan Eksen Surucu yazilimsal limit ayar(lar)inin yapilabilmesini saglayacaktir.

U:1-I:1-P:27-NP:7 Yazilim, Yan Eksen Surucu stabilizasyon modu kapali bilgisinin okunabilmesini saglayacaktir.

U:1-I:1-P:29-NP:7 Yazilim, Yan Eksen Surucu yonlenme durumu hazir degil bilgisinin okunabilmesini saglayacaktir.

U:1-I:1-P:30-NP:8 Yazilim, Yan Eksen Surucu yonlenme durumu yonleniyor seciminin yapilabilmesini saglayacaktir.

U:71-I:1 SKB AYARLARI

U:71-I:1-P:4004-NP:25 Yazilim, SKB hedef konumu anahtari konumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4001-NP:25 Yazilim, SKB nakliye konumu anahtari konumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4002-NP:25 Yazilim, SKB yukleme konumu anahtari konumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4506-NP:23 Yazilim, SKB hedef konumu ledi durumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4504-NP:23 Yazilim, SKB atis konumu ledi durumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4511-NP:23 Yazilim, SKB acil durdur ledi durumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4510-NP:23 Yazilim, SKB servo manuel ledi durumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4509-NP:23 Yazilim, SKB servo otomatik ledi durumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4508-NP:23 Yazilim, SKB atese hazir ledi durumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4512-NP:23 Yazilim, SKB aku dusuk ledi durumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4502-NP:23 Yazilim, SKB durbun acik ledi durumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4501-NP:23 Yazilim, SKB sistem acik ledi durumunun okunabilmesini saglayacaktir.

U:71-I:1-P:4507-NP:24 Yazilim, SKB yukleme konumu ledi durumunun ayarlanabilmesini saglayacaktir.

U:71-I:1-P:4505-NP:24 Yazilim, SKB nakliye konumu ledi durumunun ayarlanabilmesini saglayacaktir.

U:71-I:1-P:4504-NP:24 Yazilim, SKB atis konumu ledi durumunun ayarlanabilmesini saglayacaktir.

U:71-I:1-P:4508-NP:24 Yazilim, SKB atese hazir ledi durumunun ayarlanabilmesini saglayacaktir.

U:71-I:1-P:1-NP:1 Yazilim, SKB baglanti kurulamadi hatasini bildirecektir.

U:71-I:1-P:2-NP:1 Yazilim, SKB haberlesme hatasini bildirecektir.

U:71-I:1-P:3-NP:1 Yazilim, SKB donanim hatasini bildirecektir.

U:71-I:1-P:4-NP:1 Yazilim, SKB acilma hatasini bildirecektir.

P: SiSTEM AYARLARI iLE iLGiLi isLEMLER

P:1-I:0 SILAH PLATFORMU AYARLARI

P:1-I:0-P:1-NP:11 Yazilim, silah platformunun kuzey referansli acisal konum bilgisinin okunabilmesini saglayacaktir.

P:1-I:0-P:1-NP:13 Yazilim, silah platformunun arac referansli acisal konum bilgisinin okunabilmesini saglayacaktir.

P:2-I:0 ARAC PLATFORMU AYARLARI

P:2-I:0-P:2-NP:10 Yazilim, arac platformunun dunya uzerindeki konum degerinin degistirilebilmesini saglayacaktir.

P:2-I:0-P:2-NP:11 Yazilim, arac platformunun kuzey referansli acisal konum bilgisinin okunabilmesini saglayacaktir.

P:2-I:0-P:2-NP:13 Yazilim, arac platformunun arac referensli acisal konum bilgisinin okunabilmesini saglayacaktir.

S:2001-I:0 ATIS KONUMU AYARLARI

S:2001-I:0-P:2001-NP:20 Yazilim, atis konumu tanimli konumu icin yukselis ekseni yonelim hassasiyetinin guncellenebilmesini saglayacaktir.

S:2001-I:0-P:2001-NP:19 Yazilim, atis konumu tanimli konumu icin yan eksen yonelim hassasiyetinin guncellenebilmesini saglayacaktir.

S:2001-I:0-P:2001-NP:15 Yazilim, atis konumu tanimli konumu icin mevcut taniminin okunabilmesini saglayacaktir.

S:2011-I:0 YUKLEME KONUMU AYARLARI

S:2011-I:0-P:2011-NP:18 Yazilim, yukleme konumu tanimli konumu icin yukselis ekseni yonelim hassasiyetinin okunabilmesini saglayacaktir.

S:2011-I:0-P:2011-NP:17 Yazilim, yukleme konumu tanimli konumu icin yan eksen yonelim hassasiyetinin okunabilmesini saglayacaktir.

S:2011-I:0-P:2011-NP:20 Yazilim, yukleme konumu tanimli konumu icin yukselis ekseni yonelim hassasiyetinin guncellenebilmesini saglayacaktir.

S:2011-I:0-P:2011-NP:19 Yazilim, yukleme konumu tanimli konumu icin yan eksen yonelim hassasiyetinin guncellenebilmesini saglayacaktir.

S:2011-I:0-P:2011-NP:15 Yazilim, yukleme konumu tanimli konumu icin mevcut taniminin okunabilmesini saglayacaktir.

S:2011-I:0-P:2011-NP:16 Yazilim, yukleme konumu tanimli konumu icin mevcut taniminin guncellenebilmesini saglayacaktir.

M: GOREVLER iLE iLGiLi isLEMLER

M:11-I:0 Nonstabilize Modda Yonlenme

M:11-I:0-P:2001-NP:22 Yazilim, atis konumu tanimli konumuna yukselis ekseninde 0.15 derece hassasiyet ile yonlenebilecektir.

M:11-I:0-P:2011-NP:22 Yazilim, yukleme konumu tanimli konumuna yukselis ekseninde 0.1 derece hassasiyet ile yonlenebilecektir.

M:11-I:0-P:2031-NP:22 Yazilim, hedef tanimli konumuna yukselis ekseninde 0.056 derece hassasiyet ile yonlenebilecektir.

M:11-I:0-P:2001-NP:21 Yazilim, atis konumu tanimli konumuna yan eksende 0.2 derece hassasiyet ile yonlenebilecektir.

M:11-I:0-P:2011-NP:21 Yazilim, yukleme konumu tanimli konumuna yan eksende 0.1 derece hassasiyet ile yonlenebilecektir.

M:11-I:0-P:2031-NP:21 Yazilim, hedef tanimli konumuna yan eksende 0.056 derece hassasiyet ile yonlenebilecektir.

M:11-I:0-P:71-4005-1-7005-NP:26 Yazilim, SKB acil durdurma butonu basili hale gelmesi ile acil durdurma baslat islemini baslatacaktir.

M:11-I:0-P:71-4005-2-7006-NP:26 Yazilim, SKB acil durdurma butonu serbest hale gelmesi ile acil durdurmadan cikis islemini baslatacaktir.

M:11-I:0-P:71-4003-1-7003-NP:26 Yazilim, SKB atis konumu anahtari basili hale gelmesi ile atis konumuna yonlenme islemini baslatacaktir.

M:11-I:0-P:71-4002-1-7001-NP:26 Yazilim, SKB yukleme konumu anahtari basili hale gelmesi ile yukleme konumuna yonlenme islemini baslatacaktir.

M:11-I:0-P:71-4001-1-7002-NP:26 Yazilim, SKB nakliye konumu anahtari basili hale gelmesi ile nakliye konumuna yonlenme islemini baslatacaktir.

M:11-I:0-P:71-4004-1-7004-NP:26 Yazilim, SKB hedef konumu anahtari basili hale gelmesi ile hedef konumuna yonlenme islemini baslatacaktir.