APPLYING THE COMMONKADS-RT METHODOLOGY TO ANALYSE REAL-TIME ARTIFICIAL INTELLIGENCE SYSTEMS

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Abstract: *Advances in Real-Time Artificial Intelligence facilitate the creation of large AI applications. In order to develop such applications, a methodology that encompasses development techniques, tools and processes is needed. There are several important lines of research in RTAIS, such as architectures, languages, methods and methodologies. All of them provide the necessary information and knowledge to build computers systems to solve real-world problems.*

This paper describes CommonKADS-RT, a methodology to analyse and design Real Time Intelligent Systems. It is based on CommonKADS with the addition of elements necessary to model real-time restrictions. We also present an application of this approach to examine maritime operation problems. On this paper we describe the analysis phase.

1. INTRODUCTION

Current computer systems can be mapped with different research areas of Computer Science. Some researchers have been interested in creating systems that manage the domain knowledge, others are interested in systems where time to carry out their tasks is one of the most important variables and yet others are interested in modeling and representing information systems in general. Intelligent Systems, Real-Time Systems and Software Engineering areas have risen, respectively.

Important advances have been achieved in each one of these areas, but the point has been reached where the techniques of one area can be applied to the others. This has generated the area of the Real-Time Artificial Intelligence Systems - RTAIS which intends to solve complex problems that require intelligence and real-time responses.. In this new area there are three possible ways to achieve the fusion of those areas (VHB, 1998), (MHA+, 1995): a) Integrate intelligent system on real-time systems. This is accomplished by applying AI techniques in real-time systems. b) Integrate real-time systems on intelligent systems where the intelligent system has tasks with temporal restrictions. c) Systems in where one real-time component and one knowledge-based component work in cooperative form.

One of the lines of research in RTAI has been to build large applications or architectures that embody real-time constraints in many components. Almost all these architectures are designed for soft real-time systems (without critical temporal restrictions).

To develop each one of these types of systems, it is important to consider methodologies that define the techniques, tools and, more importantly, the processes to successfully carry out the project. These methodologies should not be ad hoc but widespread to be able to guarantee certain necessary standards to assure the project's success and the quality of the software system.

The objective of this paper is to present CommonKADS-RT, which is based on the CommonKADS and RT-UML methodologies. CommonKADS-RT aids in the development of real-time intelligent systems - RTIS, including intelligent agents and temporary tasks or time restriction modeling. The second part of the article presents some aspects related to this proposal. The third part shows an autonomous physical agent, an analysis phase in maritime operation systems based on CommonKADS-RT. The fourth part presents some conclusions.

2. COMMONKADS-RT

CommonKADS (SAA+, 2000) is a methodology that gathers a set of methods, techniques and tools to develop KBS. It is based on the fact that building a knowledge-based system is essentially a modeling activity. From this point of view, the system is an operational model that exhibits the wanted behavior that has been specified or observed in the real world. The methodology reflects some methods borrowed from structured analysis and design, the object paradigm and some management theories such as strategic planning and reengineering, among others.

CommonKADS offers a structured approach reflecting the knowledge- and software-engineering processes and bringing to the knowledge engineer a series of worksheets or templates to make the system development easier. These worksheets contain some of the most important factors to consider when the knowledge engineer has to model knowledge-based systems.

This methodology is one of the most widely used for the development of knowledge-based systems. It has even been taken as the European standard to develop systems of this type. It has been used in numerous universities and European companies, banks and industries among others.
CommonKADS-RT (Hen, 2001), (BHS, 1999) is based on those methodologies because they are strong and incorporate the most important software engineering concepts following the object oriented and agent oriented paradigms. To model the real time features we selected RT-UML (Dou, 1998), (Dou, 1999) because it has a tool set to apply on the real time analysis and even on knowledge based systems in real time, and the Michael Deutsch (Deu, 1988) proposal.

A real-time intelligent system – RTIS has temporal conditions, reactive responses and has to handle physical devices like sensors and/or actuators. In order to model those characteristics we did added changes to CommonKADS, especially on the models. We claim that these changes can be used to specify and to model this kind of systems.

Fists of all, we have to establish the difference between the task ideas, the one handled in real time and the one in knowledge engineering areas. The CommonKADS task is a complex function that is a relevant part of a business process and it has a method related to how the task is accomplished. The task is composed by other tasks, inferences or transfer functions. In contrast, in Real-Time Systems a task is associated with a temporal execution process, which is in the low-level architecture. It becomes imperative to establish the difference between those task conceptions. We propose the High Level Task – HLT to the complex functions (high level) and a Real-Time Task – RTT to the low-level process (SHB, 2000). HLT includes CommonKADS task considerations such as: process description, components, involved agents, among other particular things. At the same time, to RTT is important to determine the task periodic behavior, a deadline and the worst execution time (Sta, 1988).

CommonKADS-RT includes the following models (figure 1) that allow answering why, what and how to solve a problem with a RTIS throw some templates.

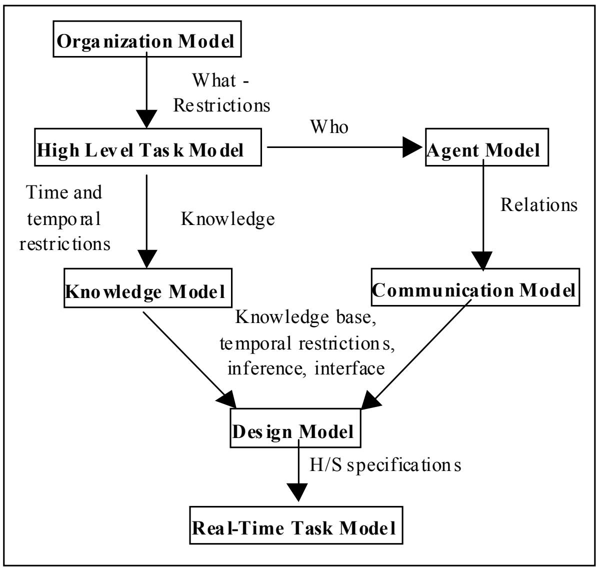

Figure 1: CommonKADS-RT models

- An Organization Model (OM), besides including every CommonKADS item, describes the organization in which the system will be used. It incorporates issues such as priority associated with a process, average time of the computation process, slack time, and specifications of specialized equipment for data acquisition such as sensors or sonars; whether the process is periodic or not. Some OM´s templates represent the problem domain, the others represent the solution domain. Some of the issues addressed by OM are following: weaknesses, strengths, threats and opportunities, lists of problems and knowledge-intensive strategies and real-time; high-level task description and the KBSRT proposed details. Artifacts produced during the OM analysis are templates to describe problems in which temporal and time variable restrictions are as relevant as those based on knowledge, problem requirements and solution requirements.

- A High Level Tasks Model describes processes that are assigned to the system and those related to the organization. For this reason, some of the UML diagrams of (Deu, 1988), (Dou, 1998) and (Dou, 1999) are taken as a reference, specifically the different scenarios of the domain, the sequence diagrams and the transition state diagrams. These templates have to include those factors described above. In an organizational process, it is possible to have HLT with temporal restrictions. In this case, the analyst has to determine and define those constraints from the beginning. Artifacts produced during the HLTM model are templates to describe HLTs, their knowledge and their events, flow and concept charts, activities and states diagrams, and the HLT characterization.

- An Agent Model: an agent is what executes a high level task in the organizational process. It can be a human or an information system or any entity capable of doing the task. This model is used as a link between the Task Model, the Communication Model and the Knowledge Model. Its objective is to reflect the agent capabilities and restrictions involved in the task solution. Therefore, how agents are, what knowledge they have and who they communicate with, are defined in this model. The artifacts produced are use cases to model the human agents and an external event list that contains the environmental events and the expected systems response.

- The Communication Model describes the interaction among the agents working on the process, while they carry out their HLT. Iglesias (Igl, 1998) proposed having an additional model to express the special communication between intelligent agents called the Collaboration Model. Our research group is currently studying this topic because it is very important not only to include it in CommonKADS-RT methodology, but also to include it in the architecture and tools developed (BCJ+, 1999),(GTB+, 1997) and (CJG+, 1997).

- The Knowledge Model shows the knowledge used by the system to solve its HLT, including real-time specifications. The Knowledge Model is developed with a Conceptual Modeling Language – CML2 (CML2,) and it is divided into three main components: a) the domain knowledge composed by the static structures of the domain. b) The inference knowledge that describes how the static structures can be used to do the reasoning. c) The task high level knowledge to define the goals that we are trying to reach by applying the knowledge.

  The real-time variables that have to be involved. A plan should be made – scheduling - in which the order of the execution of the tasks and the important time variables should be determined. First, it is necessary to define the concepts in terms of which the temporary properties of the class are specified (execution period, computational time, ending time, answer time, deadline, etc.). Therefore, it would be necessary to add or change CML2. For example, the real time task and a new primitive type called *time*, which represents an absolute time (determined by the pulses of a clock) or a relative time (the partial order strictly imposed on the groups of all transaction occurrences) (FHL+, 1996) is added.

- A Design Model describes the architecture and the detailed functionality of the RTIS to be implemented. The most important thing to consider in this model is the software (including operating system and computer language) and hardware characteristics (computer architecture issues like memory capacity, processor speed, etc). It must be kept in mind that, in order to develop a real time system, an off-line planning to prove the system integrity and the logical correctness and robustness, *must* be done.

- A Real-Time Task Model to describe the real-time tasks. It is based on the ARTIS architecture (GTB+, 1997). Although ARTIS has a language to define entities, we use CML2 to describe the real time tasks. This model can be considered as part of the Design Model, but the reason for establishing it separately is to emphasize real time aspects.

CommonKADS-RT is based on the spiral life cycle model, widely used in Software Engineering. This paradigm provides a structure for the development of a computational system, dividing it into a group of phases with a predetermined execution order. Inside each phase, a different group of activities should be carried out. At the end of each phase one or more tangible products must be delivered (documents, reports, designs, etc.) usually as input to other phases. In several phases of the life cycle, there are milestones where decisions are made.

Following, we present a real application using CommonKADS-RT. Due to the limitations of this paper, we cannot show every consideration explained in this section, but we will illustrate some relevant aspects.

3. MODELING THE MARITIME OPERATION IN A CONTAINER TERMINAL OF A SEAPORT.

We have been applying our methodology to model a solution to systematize and improve some activities on the container terminal of the Principe Felipe Seaport. We will present some parts of the developed models.

First of all, we have the following items in the Organization Model:

- OM-1: Identifying problems and opportunities oriented to knowledge, with time as important factor. The area defined and identified to improve its existing systems is *Maritime Operations*. We detected some weaknesses, diverse strengths, some threats and many opportunities. The most relevant are:
  - One of the enterprise strengths is its employees. They know their job very well. They understand completely why every task is carried out. This profound knowledge allows the employees to share a common vision, making all processes easier to carry out.
  - The enterprise is growing, it has a strong interest for improving and investing in appropriated technology. It is a great opportunity.
  - The enterprise has a weakness because the knowledge related to some of the processes is only kept in the minds of some employees. Appropriate documentation is missing in these cases, lacking technologic register about the processes.
  - One of the threats is the fact that the enterprise has to compete with other ports which traditionally are better known and bigger. It could be also be seen as an opportunity.
- The maritime operative is one of the activity with highest priority in the port, it has complex processes that are difficult to divide into discrete steps because they have many possibilities in the same situation, and most of the processes demand knowledge based on the experience by the daily work.
- Time to accomplish the tasks is very important. They need to attend the ship as soon as possible in order to reduce time in the pier because productivity rate is related to time.

- OM-2: Describing the organizational aspects affected by the selected problem. The maritime operation chart is formed by RIBA Operations, Planning, Communications, and Serialization. The process activity chart includes land operations (figure 2).

  Additionally, in OM-2 we have defined some factors related to the business, processes and tasks, such as: mission, vision, culture and power, involved areas, involved knowledge, needed resources, priority, associated temporal restrictions.

- OM-3: Describing process through its High Level Tasks (HLT). Maritime operation is made up of some HLT characterized by their implications, they are complete, have well defined objectives and specified outputs. The Maritime Operation Process could be considered as a HLT that has been divided in order to better structure it and to describe every detail about the activities. With the OM-3 template, we can observe the HLT specifications. Parts of final OM-3 are showed in table 1.

- OM-4: Describing knowledge components from the organizational model. The process knowledge was defined in OM-3, but it is important to further classify it depending on its type: data (facts), information (processed data), skills or abilities (from the person), process-specific knowledge. An example:
  - Data: ship history, current pier situation, load and unload ship list, ship characteristics, load characteristics, available resources, etc.
  - Information: Pier situation forecast, shipowner requirements, the time sheet, the ship attention order is depending on the anchoring order and on the machine available to operate, the objective of maritime operation in NOT STOP the ship, etc.
  - Abilities or capabilities related with: communication, problem resolve, make decisions, risk evaluation, information register.
  - Process specific knowledge: load and unload activities planning, activity programming to assign ships in the pier, optimization criteria, etc.

OM-4 template includes specially the following issues, related to process knowledge: knowledge asset, who has the knowledge, HLT where this knowledge is used, ¿knowledge is in the right way, and how is it? ¿Knowledge is in the right place? ¿Knowledge is of the right quality?

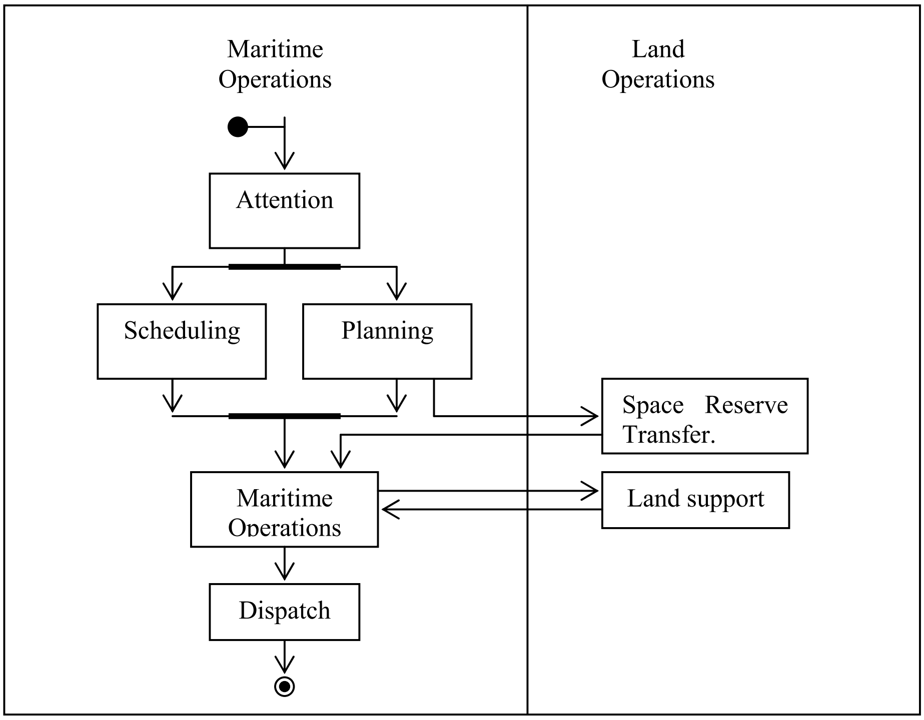

Figure 2. Process activity diagram for Maritime Operations

Table 1. OM-3 TAN for the attention HLT

HLT identifying	**HLT name**	**Objectives**	**¿Knowledge intensive?**	**¿HLT has temporal restrictions?**	**Data, information and knowledge involved**
ATN	Attention ship	Make communication between ship owner and ship to open a service folder	Low	It could be periodic because it is possible to know when the services arrive	- Ship history - New information from the ship owner, from the agent and from the captain. - Communication abilities - Information register abilities
SCHE	Scheduling	Make the ship attention planning in the pier and the resources assignment	High	It has not a fix time but the attention should be fast.	- Ship history - Current situation - Pier situation forecast - Knowledge about ship assignment in the pier - Criteria about ship assignment - Activity and resource programming

					knowledge - Resource optimization - Risk evaluation - Data or information from the process to send to the ship and to the agent
PLAN	Planning	To plan container loading and unloading in or to the ship. It implies the "hands"[1] appropriate assignation	High	There are not.	- History - Loading and unloading list - The layout by destinies - Ship map - Ship characteristics - Load characteristics - Knowledge in loading and unloading activities planning - Criteria about hands, cranes and trucks
MAR-OP	Maritime operation	To carry out loading and unloading of containers	Half	It would have temporal specifications depends on quality criteria. Temporal specification could be fixed in terms of: load type, number of containers, "hands", cranes and trucks	- Current ship state and final ship situation - Available resources - Knowledge in maritime operation - Knowledge about load shipping - Knowledge about incidences - Resolve problem ability - Communication ability
DIS	Dispatch	To record the process information, including the incidences	Low	No. It would be on line	- Information achieved during the process

- OM-5: Describing the organizational aspects will have impact on or will be affected by the chosen solution (knowledge-based system real time - KBSRT). It is a detailed explanation or justification about the KBSRT.
- OM-6: Checklist about the decision feasibility to develop a KBSTR. This list includes the business feasibility, technical feasibility, project feasibility, and the actions proposed.

The High Level Task Model implies breaking the process down into high level tasks (process components that represent an goal oriented activity). Each HLT has an objective, a problem definition and a method or way to solve it. In the maritime operation there are 5 HLT described on the previous Table-1. The items to analyze for each HLT are: where the HLT is located in the organization, goal and significance, flow and dependence relation, objects in the HLT, times and control, agents, knowledge and abilities, resources and temporal restrictions. Additionally, it is important develop flow, event, activities and transition states diagrams by HLT and into HLTs.

[1] "Hands" is port jargon for labor.

For each HLT it is necessary to identify different roles involved on it through the Agent Model. The Agent Model and Communication Model have to describe the specific communications needed on RTIS, too. But, due to the limitations of this paper, those models are not explained here. Role examples in Planning HLT are maritime operation chief, planning chief, sequence personal, and communicators. The software agents are the databases, Wincasp and Ships systems (BRH, 2000).

To model knowledge it is essential to analyze and determine the static and dynamic knowledge sources used on the domain, define a glossary with domain key terms including the domain concepts, scenario list to solve application problems, validation criteria and validation results. Those form the KM-1 template named "knowledge model check list".

Furthermore, it is of fundamental importance to develop a Concept diagram, similar to the Class diagram in Object Oriented Programming and some State diagram, to explain some concepts.

To the maritime application, two important concepts are *machine* and *container* described in the following way:

CONCEPT machine;
ATTRIBUTES:
num-machine: **INTEGER;**
type: **STRING;**
state: **STRING;**
operative: **STRING;**
current-position: **INTEGER** =0;

END CONCEPT machine;

CONCEPT container;
ATTRIBUTES:
num- bulletin: **INTEGER;**
num-container: **STRING;**
state: **STRING;**
class: **INTEGER;**
weight: **INTEGER;**
level: **STRING;**
destiny: **STRING;**
ship: **STRING;**
temperature: **INTEGER;**
maximum-height: **INTEGER;**
END CONCEPT container;

The task knowledge is expressed doing its detailed description and the specification of the task method using CML2. There is a task methods library where many description tasks as Problem Solving Methods (PSM) are described. The *stack* concept state diagram is show in the following figure (figure 3)

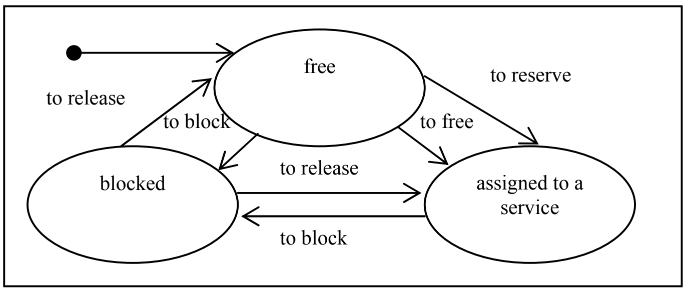

Figure 3. Stack state diagram

To develop the design model and the real-time task model we used the ARTIS agent architecture (BCJ+, 1999), which is an extension of the blackboard model (Nii, 1986), and has been adapted to work in hard real-time environments. According to the usual classification of the agent architectures, the ARTIS Agent architecture could be labeled as a hybrid architecture (Mul, 1994). This architecture provides a hierarchy of abstractions, which organizes the knowledge in order to solve, in a modular and gradual way, the global problem.

The Communication, Design and Real-Time Task Models are not detailed in this paper due to space limitations.

4. CONCLUSIONS

We have used CommonKADS-RT to develop this analysis and we have proved the functionality of this method for modelling real applications about systems based on knowledge and real-time.

No single methodology is used traditionally in this type of application because they are not known by the enterprises. Furthermore, many creators of real-time applications undertake the design and implementation phases, forgetting the analysis phases. But we have been able to observe that the knowledge engineering processes help to elicit, model and document better every type of systems.

In this paper we have presented some of the CommonKADS-RT characteristics through a real situation to propose real-time knowledge-based systems.

Now we are working on adding new features to CommonKADS-RT to support multi-agent system modelling and to introduce some characteristics of the Requirements Engineering. We are also designing, simulating and implementing this application using our own architecture called ARTIS.

5. ACKNOWLEDGMENTS

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