MASVERP: A Multi-agents System for Safety Interventions on SEVESO Sites

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Abstract

Virtual reality and simulation give us today new tools for improving the training or making better decisions in the domain of risk prevention thanks to virtual autonomous characters. In our work, we develop such a tool allowing storyboarding hazardous working situations on Seveso-type sites. Our architecture is based on a multi-agents system MASVERP (Multi-agents System in Virtual Environments for Risk Prevention) including virtual operators represent by our agents (cognitive and reactive) and human operators. The system interprets a cognitive activity and a related risk model resulting from field analyses. In the proposed environment a manager can visualize the risks incurred during an intervention. The emergent risks depend on the cognitive characteristics of the operators (human factors). The difference with classic MAS is that our cognitive agents are enriched with a planner that decides the action to realize according to their objectives, the environment and their personal characteristics (temporal pressure, cautious, tiredness, hunger).

Key-words: virtual reality, multi-agents system, interaction, cognitive agents, virtual environment for risk prevention

1. Introduction

Our research deals with the design of technical and/or methodological tools to support decision-making in the preparation and the management of sub-contractors interventions in the field of high-risk industry. Virtual reality and simulation can offer today the opportunity of developing new tools for improving the training and decision-making in the domain of risk prevention using virtual autonomous characters. Many virtual environments for training and learning have been proposed up to now. In these systems, however, there are still few considerations on the risk factors and on the impact of technical factors associated to the actions and decisions of the operator. This last point is the main axis of our research. In our work, within the context of the V3S project (Virtual Reality for Safe SEVESO Substractors) [1] supported by ANR, we aim at developing such a tool for external maintenance companies that intervene on SEVESO sites. This tool has to allow the industrial users to scenarize customized hazardous working situations on SEVESO sites with avatars and autonomous virtual characters (usual procedures as well as non-nominal working situations, etc.) according to their needs. The working situations are modelled with a high level task description language which is then automatically interpreted together with an associated risk model, both issued from field analysis. The challenge is to associate the technology of virtual reality and artificial intelligence to develop a VERP[1] that support the control of virtual operators represented by artificial cognitive agents in interaction with humans operators represented by avatars. From the perspective of decision-making, the tool would support managers training by providing them with a serious simulation game situation. The manager and his/her are represented in the VERP and have to operate and to achieve their task within the set of constraints. The team has a goal to achieve and the manager is in charge of dispatching the different tasks and roles between the virtual operators. Depending on his choices, he will monitor in the environment the impact of his decisions on the technical, organisational and human dimension of the working system. Our work is based on two assumptions. The first one is that using virtual reality is undoubtedly a priority in the construction of a system dedicated to improve safety during industrial interventions [2][3]. Our

[1] Virtual Environment for Risk Prevention

hypothesis is that the effectiveness of virtual reality in terms of training and decision making for safety management increases when operators and managers see the impact of their decisions. Virtual reality will provide visualization and representation functions that should help the trainee in building an adequate mental representation of the process. Furthermore, interactive virtual environment might favour learning by doing. Indeed the user interactivity in the learning process is essential. Indeed, there is a large literature in psychology, ergonomics, instructional sciences and neurosciences that show how humans build their representation from action [3]. Using virtual reality enable the users (operators and managers) to familiarize with the site by displaying the plant under operation and to learn how to detect the defaults while playing the scenario of an intervention. In the proposed approach, the task assigned to the trainees is mainly to supervise and to verify continuously essential elements related to safety during an exercise. The second assumption is that such an environment can be fruitfully implemented by a multi-agents system. In the system each virtual character is represented by an autonomous cognitive agent able to take decisions and each behavioural object of the environment is represented by a reactive agent. In our project, our goal is neither to reproduce perfect cognitive mechanisms nor to describe the operator's cognition. Instead of that, we want to simulate dynamically the behaviours that could occur with a reasonable level of representativeness. In particular, the virtual operators should adapt to the environment in an autonomous way and learn from their interaction. To give them the necessary cognitive capacities we propose an approach based on the concept of agents [5]. The system will endow the environment (virtual characters and objects) with autonomous decisional capacities. In this paper we present the multi-agents system, how it solves the problem of cooperation, organization and collaboration subjacent in such a system between virtual operators and avatars and how it self-adapts to the specified technical competencies and the human-factors characteristics of the virtual operators.

2. State of the art

2.1. Multi-agents Tools and languages for behavioral modeling

A multi-agents system (MAS) is composed of a number of agents that are interacting, cooperating and belonging to an organisation. We distinguish two kinds of agents: reactive and cognitive. Reactive agents only react to a stimulus (intern and extern) and do not use an internal symbolic representation. Cognitive agents are able to build their own behaviour and have a full representation of the environment. This distinction tends to disappear with hybrid agents, a mix of both species. Multi-agents systems are efficient to build systems where the notions of cooperation, organisation and autonomy are crucial.

- STEVE

STEVE is historically a reference in the domain of behaviour modelling tools [9]. It is an autonomous animated agent that lives in a virtual world with students. It has been designed to help students in learning to perform physical procedural tasks. It can demonstrate tasks explaining his actions, as well as monitor students performing tasks. STEVE has a cognitive mono-agent architecture based on SOAR [10] which allows him to know the state of the environment in real time, to decide what actions to undertake.

- IRISA

IRISA has developed a large number of tools for behavioural modelling like HPTS++ or SLURGH [11]. HPTS++ is a behaviour modelling language for autonomous agents. The agents are organised in a hierarchy of automata. SLURGH is a scenario modelling language. It allows managing the scenario data and also the dialogue between the characters (actors). It creates a determinist scenario in which the actors have to share the resources using HPTS.

- GRIC-GRAAL

This group of researcher developed a training tool for firemen; it aims at keeping them out of danger. A human operator (trainee) drives the virtual firemen in a special mission environment [12]. The system architecture is multi-agent composed of emotional and reactive agents. The agents have a goal to achieve and use a Prolog planner to determine their actions.

- MASCARET (ENIB)

In this project, the physical environment represents a plant where the exercise takes place and also includes physical phenomena that can take place in the plant (fire, smoke, water spreading). The trainees play the role of the different group managers who intervene during an incident and the trainer participates to the simulation as a troublemaker. He can create dysfunctions, help the trainees and also play a role in the team. The system is driven by the MASCARET model proposed in order to organize the interactions between agents (give them reactive, cognitive and social abilities) [13].

- INRS

INRS started a multidisciplinary project in 2002, in order to evaluate the contribution of virtual reality in the domain of training addressing professional risks and the conception of safe system [14]. The INRS group research also developed a virtual environment dedicated to chemical risk prevention (EVICS[2]) [15].

2 French acronym for Virtual Environment for the Design of Safe/reliable Systems

2.2. Positioning of our work

Our approach differs from previous work in the following way. Current approaches rely mostly on architectures based on informatics foundation (automates, Petri network, expert system). Some works propose to build systems while taking into account cognitive behaviour model [16] for virtual human animation for example. From cognitive models in the domain of safety and human behaviour in risky situations, we propose new mechanisms to represent human decisional process and human errors to finally simulate them in a virtual environment. Among others, our added value is to propose tools that make use of artificial intelligence to (i) analyse the human processes in work situations and (ii) to generate errors with the purpose of supporting learning.

3. Our objectives

3.1. Autonomous virtual operator

The tool should allow them to identify observable cues associated to risks during an intervention carried out by virtual and human operators. We propose a generic tool allowing easy scenarization in the virtual environment, of the operator's behaviours on the industrial risk-plant and of the dynamics of the environment. Indeed, the virtual operators should adapt to the environment in an autonomous way, as well as they have to react to the manager orders and to cooperate with the human operators. For that purpose, we have to plan the virtual operator's behaviours in the VERP so that such plan may be used to simulate and to reproduce the possible and probable behaviours of the virtual operators depending on situational constraints which could have three origins: (i) the physical dimensions of the environment like e.g. difficulties related to the geometry of the site, operator morphology, coldness, windy; (ii) the organizational dimensions, like e.g. prescribed procedure, border-line tolerated conditions of use (BTCU) and (iii) the cognitive or mental characteristics of the virtual operators like, e.g. objectives, temporal pressure, cautiousness, tiredness, stress, expertise, etc. Indeed our objective is to model the working environment and the selected operative mode in good and deteriorated (i.e. non-nominal) situations of work.

Here, artificial intelligence permits us to simulate some of the possible deviations of virtual operator's behaviours and operation modes in this constraint situation. In our work the taking into account of human factors is preponderant. Our foundation relies on cognitive models in the domain of safety and human behaviour in risky situations.

3.2. The COCOM model and BTCU

Proposed by Hollnagel [19] the model COCOM enables to describe, what he called, the control mode of an operator depending on the temporal pressure and the operator characteristics. COCOM defines four types of control mode in which an agent can operate. In the (i) strategic control mode, the agent has a wider time horizon and looks ahead at higher-level goals. He has a both large and detailed anticipation of the work system. The (ii) tactical control mode characterise of situations where performance more or less follows a known procedure or rule. The user's time horizon goes somewhat beyond the dominant needs of the present, but planning is of limited range. In the (iii) opportunistic control mode, the next action reflects the salient features of the current context. Only little planning or anticipation is involved, perhaps because the context is not clearly understood by the agent or because the situation is chaotic. Opportunistic control is a heuristic that is applied when the knowledge mismatch is large, either due to inexperience, lack of formal knowledge, or an unusual state of the environment. In the (iv) scrambled control mode, the next action is in practice unpredictable or random. Such performance is typically the case when people act in panic, when cognition is effectively paralysed and there is accordingly little or no correspondence between the situation and the actions. Thus depending on the control mode, the operator will plan widely and choose the actions the more adapted to the situation or plan in a limited range and do compromise on safety aspects to gain in productivity. If the temporal pressure is extremely high, the operator can have irrational behaviours. Among others, control modes will be simulated. However, the first step is to build a detailed description of the activity of the operator.

The notion of border-line tolerated conditions of use (BTCU) comes also from studies in ergonomics and human reliability. This notion highlights the regulations operated on the field which bring the use conditions of the tools and the realization mode of the task to some compromise zones affecting the safety [20]. For example, some tasks are partially or not realized because of a lack of time due to the compromises made between safety and production. This concept is a complement of others elements link to the individual, like those reported to the conscience of the risk, the tiredness effects or the temporal pressure on the performance, etc.

3.3. Description of the human/operators activity

The human activity in natural situations is an important domain of research in ergonomics and psychology. In ergonomics, one's should generally talk about task and/or activity models. These models are constructed on the basis of data collected by the way of ergonomics analysis of work and activity. Functions of these models are threefold: (i) translating and providing a summary the collected data; (ii) reifying the knowledge of a specific domain; finally (iii) guiding the analysis and the collect of information on the field. Among the various existing formalisms, some are well-adapted, generic and have the interesting ability of taking into account the objectives, resources and working process of a subject in relation with his complex environment like HTA, GTA or MAD*. GTA is particularly designed to model collective's tasks. MAD* is more centred on the individual activity even if the latest version tends to integrate this dimension. These formalisms are interesting in two ways. First, they offer a formal basis flexible enough to support the implementation of an internal cognitive model of the operators' activity in the virtual environment (tasks sequences). Secondly, it gives also the opportunity to "program" the behaviour of the operators. As a consequence, the proposed activity model should support (i) the explicit integration of factors affecting the performance at a collective level; (ii) the expression of the operator's activity as it should be; (iii) how the activity may change in deteriorated situations (lack of time, imprudent behaviour, safety behaviour, tiredness, etc.).

4. Architecture of MASVERP

The tool should allow the managers to visualize the risk incurred during an intervention lead by virtual and human operators. It is interesting to propose a generic tool for scenarizing easily in the virtual environment, the operator's behaviours on the industrial plant and any changes of the environment. The virtual operators should adapt to the environment in an autonomous way, response and react to the manager order and cooperate with the human operators. We assume that a MAS is a promising solution to reach this goal in terms of organisation, cooperation and planning [5] and we propose MASVERP aims to model the decisional module of the virtual agents and to give them the required autonomous abilities. According to our model, three types of entities are in interaction within the virtual environment: reactive, cognitive and human ones. The reactive entities correspond to the objects in the environment, the cognitive entities are the virtual workers, and the human is the manager who interacts with the VERP. The objects have different behaviours but they only have to react to a specific action or a stimulus. For example: if the scaffolding is knocked down, then it should fall. They do not need to have a full representation of the environment and therefore they are considered as reactive. The cognitive entities that are representing the virtual operators are more complex (Figure 2) and based on the BDI model [17]. The agents are provided with a capacity of planning according to a high level cognitive activity model in the following fashion:

- Generate a plan (sequence of tasks)

According to the perception skills of the agent, he computes an approximate result of the actions in order to take the next decision.

- Adapt to the environment and do plan repair

The agent evolves in an open and dynamic environment, and obviously it is a complex system. The agent should react to any possible unexpected events considered as relevant to risk prevention like e.g. a fire, a leak or any other incident that could happen. He must achieve the assigned task and find a compromise whenever possible to cope with simultaneous (and sometime not compatible) goals.

- Present a behaviour consistent

The substitution of a human operator by a virtual autonomous character requires obtaining an operational behaviour which permits to represent what a real operator could do. Therefore it is essential to have an effective methodology to collect and to model the workers mode of operations as it is actually performed in the real field.

4.1. Organizational rules and roles

In this project, we want to describe and simulate the cognitive mechanisms of human operators. We will therefore implement the physical behaviours realistically and in particular the cognitive decision. The operators represented by the agents evolve in an organisation, cooperate and aim at reaching a common goal. To reach their goal each agent computes behaviour in rational way. We describe the structural organisation as follows: in the organisation, an agent can play one or more *roles*, to determine which agents typically need to *interact* with others to exchange knowledge and coordinate their activities. These interactions occur according to patterns and protocols constrained by the nature of the role itself. The cognitive mechanisms are reflected by the decisions taken by the agent according to the manager orders and the environment (other agents and resources) state. The virtual environment can be viewed as an organisation to which will be connected the multi-agent system. A trace of the environment is needed. Obviously it is an open and complex environment. The agent manager represents the manager; the agent trainee represents the real operator; the agent operator represents the virtual characters; the reactive agent represents the object and the risk agent is associated with the objects which have special behaviours determinate with rules.

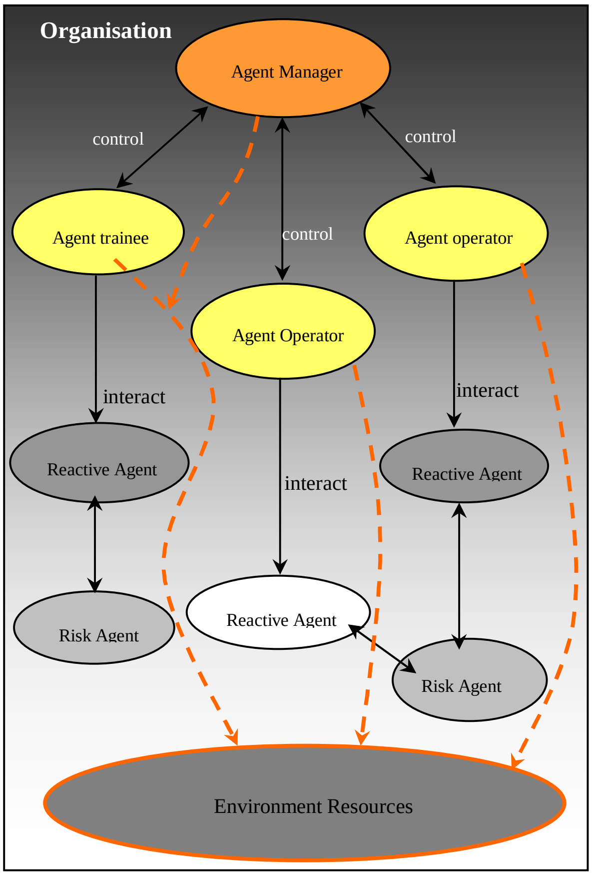

Figure 1 Structural Organisation

4.2. Agent composition

As we have said, the cognitive agents are more complex than the reactive one. On Figure 2 we can see that they are composed with: (i) skills: in this part we specified what the agents can do and how they can do it; (ii) a list of goals: what they have to do. They also have an updater to refresh their goals, for example, if during the exercise they are thirsty their goal will be to quench one's thirst;(iii) knowledge: what the know about the environment and also what they have learned; (iv) environment: this part contains the environment variables and state; (v) address book: all the acquaintances of the agent, who he knows and who he can interact with; (vi) memory : this field regroup all the agent internal states and his characteristics, it could be progressive (pg) or permanent (pm) characteristics as cautiousness (pm), tiredness (pg), temporal pressure (pg), expertise (pm); they are used to determinate in real time the behaviour (control mode) adopted by the agent [22]; the model of the activity is store in the agent memory; (vii) a planner which produce their decisions i.e. their (viii) activity. The planner constitutes their decisional module which settles their behaviours according to their characteristics.

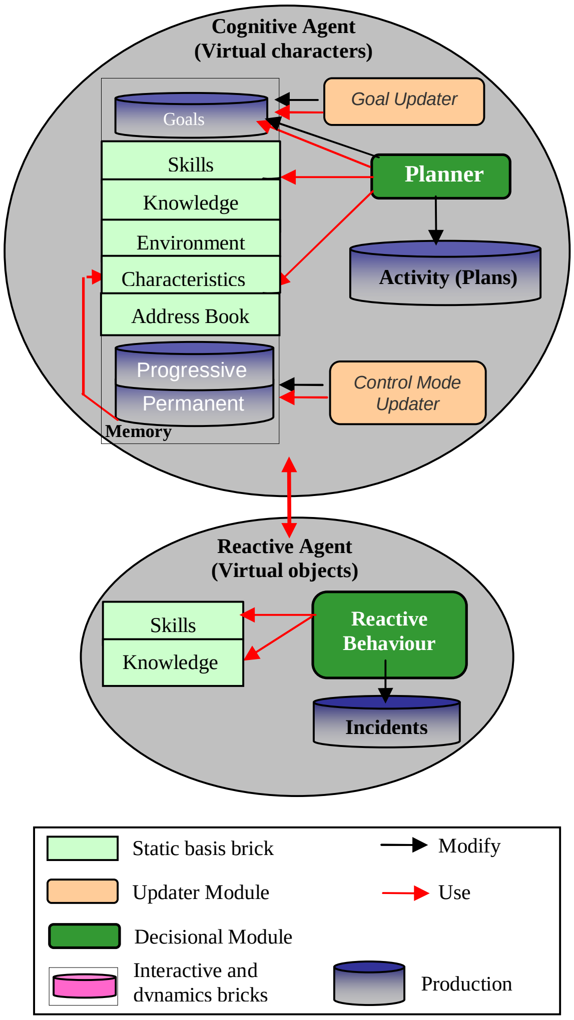

Figure 2 Agent architecture

The Figure 3 presents the model of our architecture concentrated on the agent aspects. We retrieve the components describe previously. We can also see that the agents have a box tools. We are in the domain of maintenance intervention and this component was very useful and necessary for planning. A tool is considered as an object of the environment for example a screwdriver. The objects are included in what we call the world state, the key module for the planning. The agent's planner provides a plan according to their characteristics and control mode. A plan is a list of tasks (section 3.3) issued from their activity model. The agents also have a risk model representing the different risk which could occur according to the situations.

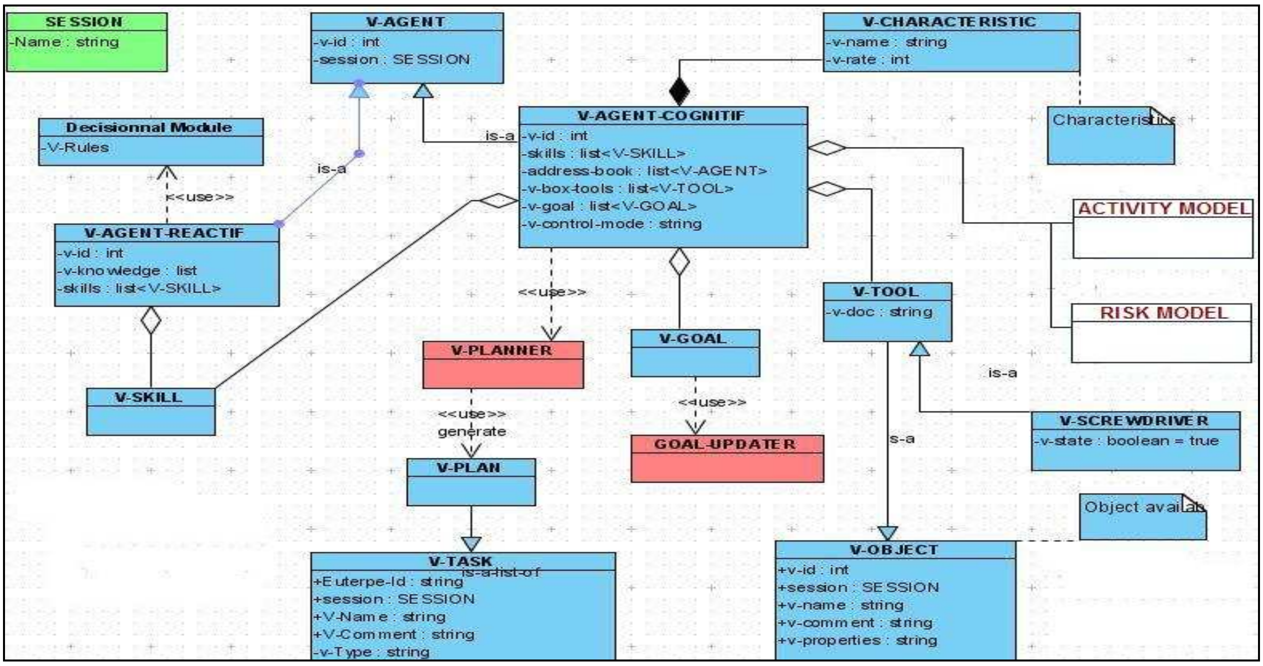

Figure 3 MASVERP Agent Model

5. MASVERP planner

The planning problem is at the intersection of two domains: cognitive modelling/planning and planning agent (robotics). Although the two approaches are quite different we propose to merge them in what we called the "cognitive planning agent". The need of planning is as important for the inexperienced as for the expert. Plan elaboration often comes to improbable situations which are consequently also interesting for the training of experts. We distinguish two phases of planning, (i) a provisional planning or pre-planning and (ii) a real synchronous planning during which it can be necessary to do re-plan or to repair. The first phase imposes to build a flexible plan allowing the adaptation to the unexpected events. At the end of the pre-planning we have a provisional flexible plan and after the execution we have an effective adapted plan. This pre-planning is then used to determine what would have been the correct plan in normal i.e. conditions without parameters influence (low probability). We will also support the addition of statistics on the probability that the agent follow his initial plan. The architecture of the planner is represented on Figure 4. The planner has for entries: (i) the activity model of the operator for the specified intervention described in Section 3.4., (ii) a risk model presenting the possible risk incurred during the intervention, (iii) a scenario and a world model containing the scenario data and the state of the different objects and resources of the environment. To define the plan, (iv) the characteristics of the agent are taking into account by defining in real time the control mode associate and finally the (v) goals. The plan provided by the planner can be also use to do diagnosis on the trainee.

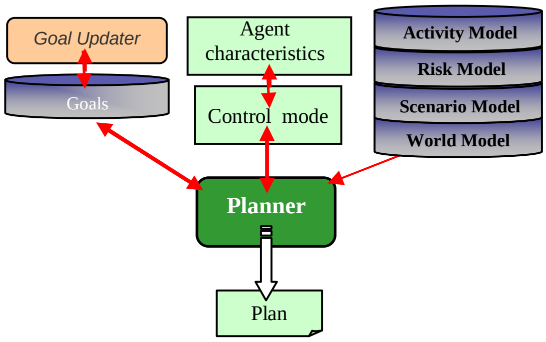

Figure 4 Planner architecture

5.1. Implementation

Multi-agents system

The MAS is developed with the OMAS platform (UTC) [24]. With OMAS the user can define agents, give them skills and goals (programmed as Lisp functions), then run them. Platform options allow tracing agent behaviour or messages. OMAS offers an advanced model of an assistant agent and allows creating local coteries. A coterie is the agent organisation; every agent in the same coterie can communicate, receive and view all messages. Only one such local coterie is allowed on a machine. The name of the local coterie is usually the name of the machine (although this is not required). The agent structure in OMAS is close to our model; this was a criterion for selecting the platform.

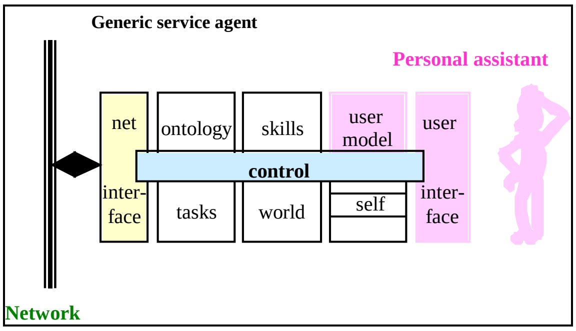

Figure 5 OMAS agent: intern structure

Each OMAS agent is multi-threaded and has a number of attached processes. This number changes during the life of the agent. In particular an agent has two basic persistent processes (Figure 6): (i) scan: continuously watches the input-messages; (ii) mbox: processes messages sent by the scan process that are relevant to the particular agent.

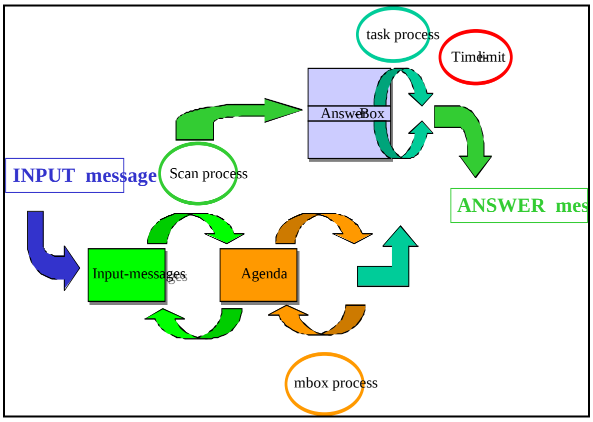

Figure 6 OMAS Processing Messages

During the agent life other transient processes are created as needed. For example timers (timeout for call for bids, timeout on a subcontracted task, time-limit on an executing task). Each task triggers a new process.

In MASVERP each agent are build with OMAS agent template and the have several files representing their environment and containing their skills:

- An ontology file containing their task model in a MOSS format.

```
(defconcept (:en "V-CHARACTERISTIC"
                 :fr "V-CARACTERISTIQUE")
      (:doc "Characteristics of an agent :
            permanent or progressive")
   (:tp (:en "V-NAME" :fr "V-NOM") (:entry))
   (:tp (:en "V-RATE" :fr "V-VALEUR")))

(defconcept (:en "V-AGENT" :fr "V-AGENT")
      (:tp (:en "V-EUTERPE-ID" :fr "V-EUTERPE-ID"))
   (:tp (:en "V-NAME" :fr "V-NOM"))
   (:tp (:en "V-COMMENT" :fr "V-COMMENTAIRE"))
   (:tp (:en "V-AGE" :fr "V-AGE"))
   (:tp (:en "V-AGENTTYPE" :fr "V-AGENTTYPE"))
   (:tp (:en "V-SKILLS" :fr "V-CAPACITES"))
   (:tp (:en "V-ATTITUDE" :fr "V-ATTITUDE"))
   (:rel (:en "V-CHARACTERISTICS" :fr "V-CARACTERISTIQUES"
         "V-CHARACTERISTIC")
   (:rel (:en "SESSION" :fr "SESSION") "V-SESSION")
   )
(defconcept (:en "V-TASK" :fr "V-TASK")
      (:doc "A task with a descriptive language")
   (:tp (:en "V-EUTERPE-ID" :fr "V-EUTERPE-ID"))
   (:tp (:en "V-NAME" :fr "V-NOM"))
   (:tp (:en "V-COMMENT" :fr "V-COMMENTAIRE"))
   (:tp (:en "V-DURATION" :fr "V-DUREE"))
   (:tp (:en "V-FREQUENCY" :fr "V-FREQUENCE"))
   (:tp (:en "V-CONSTRUCTOR" :fr "V-CONSTRUCTEUR"))
   (:tp (:en "V-INITIAL" :fr "V-DEBUT"))
   (:tp (:en "V-FINAL" :fr "V-FIN"))
   (:tp (:en "V-ATTRIBUTE" :fr "V-ATTRIBUT"))
   (:tp (:en "V-GOAL" :fr "V-BUT"))
   (:tp (:en "V-EUTERPE-USER-ACTIONS" :fr
```

Figure 7 Ontology Extract

In this ontology each characteristics of the task is viewed as a concept.

- A file defining the coterie: each agent can communicate and send messages to the entire agent register in the coterie.
- A file in which are declared their skills, their internal states and the different module presented in the architecture

All this files represent the agent environment.

Task model

The task model is the heart of our system (Figure 8). This model describes first the activity of an operator in ideal conditions and distinguish also other possible "deviation paths" due to deteriorated conditions (missing time, imprudent behaviours, safety behaviours, tiredness, etc.).

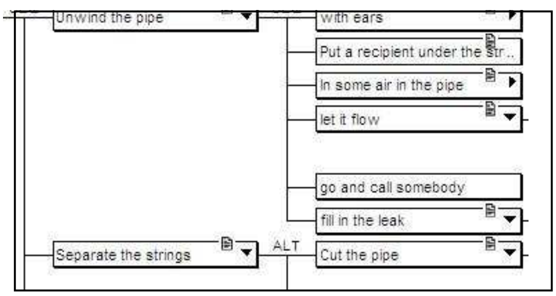

Figure 8 Cognitive Task Model Sample

To include the safety aspect in the planning, we have added the following new properties in the tasks pre-conditions to be described. The tasks are tagged with fields like “BTCU task”, “safety task”, “not allowed to do it”, “allowed to do it”. The expertise is also integrated in the activity model. If the agent is inexperienced he will not take into account the environment conditions. All these parameters are integrated in what we call the task favourable or cool conditions. For example: empty a pipe, the expert agent knows that in a pipe it always remain some product contrary to the inexperienced agent, except if the manager told him before, who don’t known this information. This activity model is translated in a MOSS modelling by a first parser creating all the concepts. A second one is in charge of creating the instances of each tasks of the model (Figure 9). This production represents the agent task ontology. Once the model is loaded, there is two mode functioning. Whether the agent receive a high level order from the manager or from another operator, in this case he looks for a way to achieve his goals; or the agent start an internal goal which specify to do the scenario as defined in his task model.

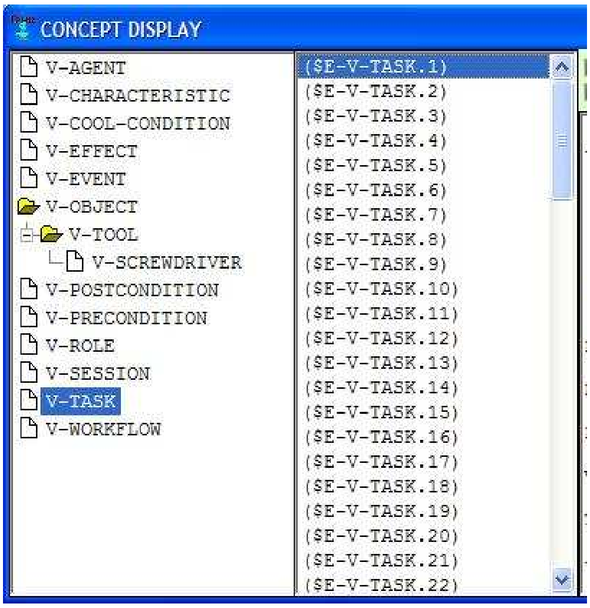

Figure 9 Task Ontology

5.2. Algorithms

Depending on the agent’s personal characteristics and therefore their control mode, they will have a different behaviour and different ways to do the same task without or with risk. By the four modes determinate by Hollnagel [19] we have proposed four type of planning (Figure 10). In the strategic mode (P1), the agent should be able to foresee the result of his actions and take decisions with a large anticipation. He will do a pre-planning by covering the entire task tree. From this pre-planning the agent will prepare his intervention, get the resources needed if possible and move away the task he can’t or don’t have to do. In the tactical mode (P2), the agent will do a pre-planning but in a smaller depth. We have arbitrarily defined this one as the tree depth divided by two plus one. In this mode the agent will plan in a temporal way, and will not do some of the BTCU tasks. For example, normally the agent has to put his harness, but depended on the plants if the agent doesn’t do it, it is tolerated. This permits the agent to gain some time on his task if he his in a hurry. In the mode opportunistic (P3) the agent will do planning and if necessary re-plan. The agent will verify if he has the necessary resources (e.g. tools). In the contrary case, he will evaluate the time necessary to obtain the desired resource and will estimate if it is preferable to go and look for the resource or to do a substitution if possible (e.g. replace a hammer by a screwdriver). In the scramble mode (P4) the choice of the next action is irrational. The behavioural model which determines if the agent can effectively do a task is a rules system from this type: if the agent is expert then he takes into account the task environment conditions. If the task is eligible then she is store in the plans list or she is directly executed.

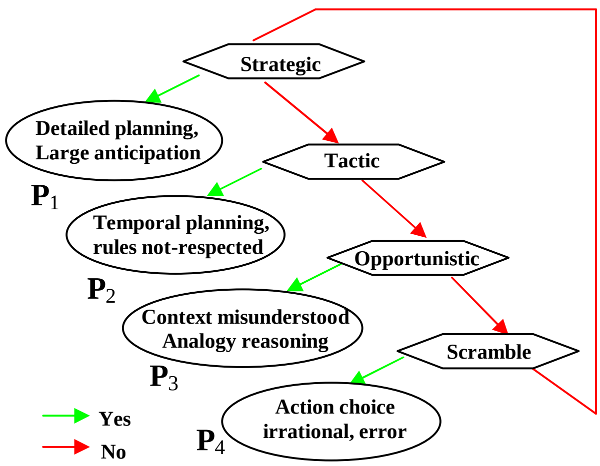

Figure 10 Which planning?

To resume, firstly the agent verify if he can do the task. This implies the recomputation of their control mode by the appropriate module. The module takes into account the environment (temperature, etc), the agent characteristics, and the task effects to finally provide the new value of the control mode. If the task is not applicable the branching is done on the correct planning function. If not, then the agent ensures that the necessary conditions of the task are realized; if he is an expert he will verify the environment conditions. The Figure 11 shows the algorithm which is used to apply a plan.

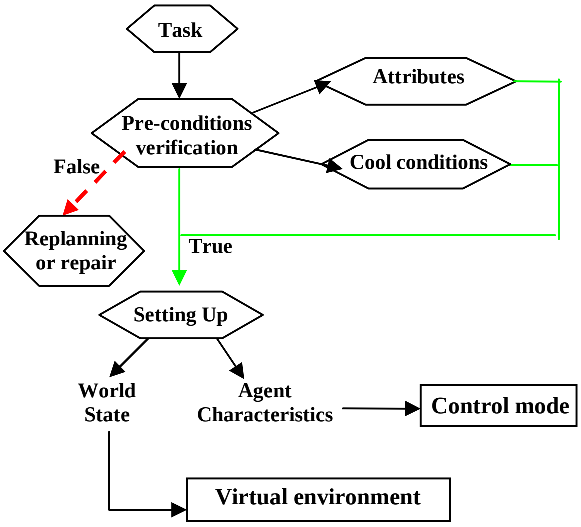

Figure 11 Algorithm of a plan execution

6. Conclusion and further work

In this paper we described the goals and the implementation of a system to simulate the operative mode of operators working at a SEVESO site based on a multi-agents architecture: MASVERP. An interesting part of the project is to work along a new axis: taking a high level model of tasks and a cognitive activity model into account. The next step will be to associate this model to risk models developed by other partners of the project [INERIS]. The functional scenario for the VET developed in this project is to allow managers to visualize the scenario and to view the effects of their decisions in the environment. To achieve this goal we will use a virtual support helping us to give a vision of the process that aim to be the closest as possible to actual field practices. Our environment is not only a training environment (VET); it is a VERP including training and decision making. At present, the system offers the possibility to simulate the operative mode and some risk cases. According to the operators characteristics (safety, imprudent, expert, inexperienced) the system aims to simulate the different associated behaviours. The validation of the system will also be conducted in the next step.

7. Acknowledgement

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