Towards a Distributed Pedagogical Simulator

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Abstract. The use of simulation for a pedagogical purpose is very interesting. One of the essential repercussions of the construction of a pedagogical simulator is the perennisation of the 'know' and especially 'know-how' held by the human experts. This deals with an expert system, ` kernel of the simulator´, able to diagnose and detect faults, as well as to describe scenarios of maintenance. Our major concern is to take into account the diversity of the types of knowledge held by the human expert, because they tend to be procedural (functional) or declarative, founded on a confirmed theory or a simple experience lived by the expert. Unfortunately, the more the structures of knowledge are complex, the more it is difficult to choose one of them. This difficulty still increases with the next setting in œuvre. This is really related to the different interactions of this expert system in the architecture of our pedagogical simulator
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1 Introduction

The project aims at designing and realizing a generator of pedagogical simulators. That we plan to distribute by providing a great importance to modularity, sharing information, interactions. Today, simulation is more and more used in the learning process for reasons regarded as practical (to simulate dangerous or costly situations, …) and affective (its attract for the learner, the best increase in the learner's motivation, ...)[9]. According to [7], in a pedagogical simulator (or a simulator for training), all the problems raised by: training, expertise and its management, have a major importance. Indeed, the simulator must have a perfect knowledge of the expertise on the simulated system. This allows it, through a `special interface´ to feed the expert model with the input data in the form of model describing the state of the system. Moreover, through this interface an anomaly is detected and sent to the expert in order to provide a diagnosis and to plan a scenario of maintenance. Therefore, the simulator has a set of knowledge on the expertise domain. Thanks to it, the simulator can reach its objective of picturesque formal correspondence with the real system.

The other essential element in any pedagogical simulation is the evaluation of the learner. Let us notice initially, that it is the weak element of the majority of current CAI systems. This is generally due to its lack of flexibility, the essential quality of evaluation. For the sake of achieving a reliable evaluation, the evaluator must base mainly on expertise. In order that these three essential components (simulator, evaluator, expert model) could cohabit in total harmony, it would be necessary to have a common knowledge basis.

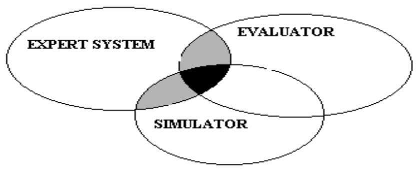

Fig-1-

Thus, the importance of the *expert model* is clearly established. When designing this one, three guidelines helped our work: the diversity of knowledge, re-use and standardization. The following measures have been taken into account:

· Not to dedicate the system to a particular process;

·To Consider the different interactions (expert-simulator, expert-evaluator…) so as to build an open system, Etc.

After having flown over some existing formalisms, we present the one we have chosen and then describe the expert model. Thereafter, the architecture of the system containing this model will be in detail. Finally, we conclude with some interesting points.

2 Knowledge Representation Formalisms

Several formalisms of knowledge representation exist:

- *Logic*: The logical formalism is tempting because it immediately suggests a powerful means of deducing new knowledge from the old ones (the mathematical deduction).
- *Semantic networks:* semantic networks will be appropriate to any classification and simple description of objects, and make possible to memorize various types of semantic relations. However, when the number of nodes and arrows become important, the research space increases exponentially and consequently leads to the combinatory explosion.
- *Production rules*: The production rules have been a real success as a formalism of knowledge representation in the Expert Systems [1]. However, the problem of checking coherence arises during insertions of new rules and mainly when the size of the basis is important, it will slow down the system (in the research) considerably.

- *Structured objects*: This formalism consists in mixing in the same structure, declarative and procedural knowledge, such as frames, objects, Etc.

3 Expert Model:

An expert system is a computer system that emulates the ability of human to take a decision [2]. Our concern is to answer the role assigned to our expert system, that are the diagnosis, the detection and the maintenance of faults while ensuring a certain modularity in the knowledge basis of the system, in order to re-use it by the other agents implied in the pedagogical simulator (simulator, evaluator, pedagogue, …).
Our efforts were focused on the choice of an amalgam of representations to be able to exploit superficial & deep/ declarative & procedural knowledge. To develop such a system, we took as a starting point the cognitive model of R.Case, which explains, within the framework of research known as " néo-piagitiennes ", the learning mechanism in the learner. Whatever the knowledge domain, Case analyses the behaviour of the subject (for us, it is the human expert opposite to fault situation) by regarding it as the execution of a `mental plan´ of problem solving.

The organization of the plan articulates around the 3 following components [5]:

- The representation of problem situation: a set of conditions to which the action plan is relevant (input).
- The representation of the objectives to be reached: a set of new states towards which the plan is directed (output).
- The representation of the strategy to be adopted: a sequence of operations that make it possible to move from the problem-situation to the objective-situation (scenarios).

Our knowledge basis is composed of two essential parts as follows:
The first one contains the experience and the range of the known faults. This part constitutes the superficial knowledge of an empirical exit. The latter can represent a handicap for a new unknown fault or a possible explanation requiring a much finer degree of granularity. In order to enrich the system, as new states of faults appear, we thought of the addition of a second part, which represents the domain theory. Here, we dealt with a zoom on the rules, roles and formulae, which govern the studied field (mechanics, electronics, medicine…).

Then, we ended with the three-dimensional sight of knowledge basis showed in fig-2-

The production rules are the most appropriate to a declarative representation of the accumulated expertise. They make it possible to enjoy the role of selection device for a possible classification of the faults. The scenarios of maintenance are described in terms of a sequence of actions ordered in time. In order to build the second part of the basis, it is necessary to determine, at first, the elements of our system, because the level of refinement is an important factor for the evaluation of the good functioning (time, space) and the reliability of the mapping of the real world.

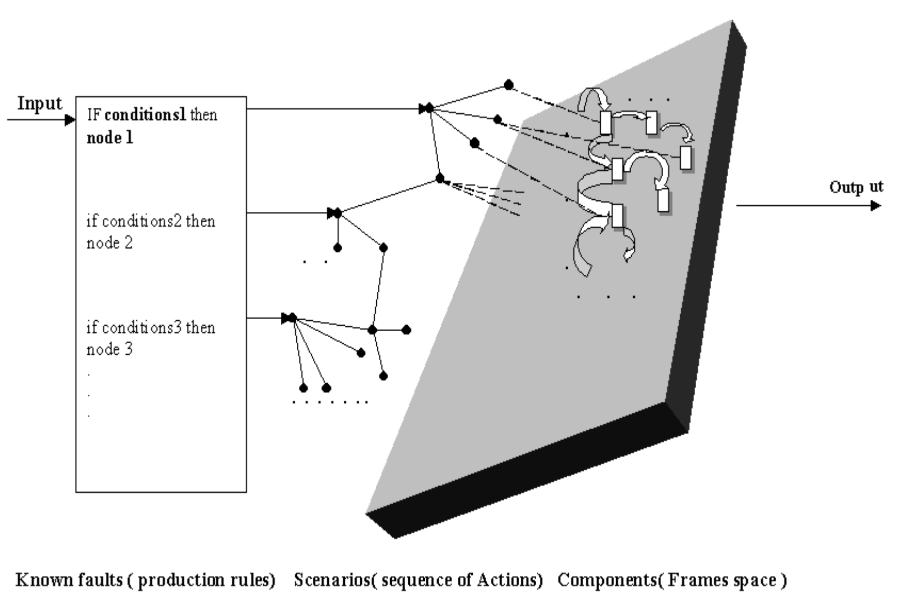

Fig –2-

We admit that the real system consists of:

- *A set of components*: a component represents any material or abstract entity (turbine, gas, switch, bulb, blood, vein, …).
- *A set of actions*: it is any action, which the human expert can carry out on the components joinable in a given state (increase-speed-turbine, support-switch, open-vein).
- *A set of relations*: we consider exclusively the relations between-components. These relations represent the role allocated to each component and can explain the indirect effect of an action (turbine-vary-pressure-gas, switch-control-bulb, blood-runs-in-vein).
- *A set of constraints*: they are the temporal constraints and those of integrity linking the actions.

On the whole, the frames are more suitable to represent this part, because they allow the possibility of integrating the procedural and declarative aspect and organizing the considered entities hierarchically. Since the system is brought to infer on the two parts, the choice of the frames is confirmed, because they facilitate the inference [6] of facts not yet observed starting from new situations.

2.1 Tasks:

Detection of faults:

Following some manoeuvres carried out on the real system, the result could not be, for any reason , one of the results expected. Initially, according to the current state of the system, a research will be made on the level of the known faults. If the research is fruitful, the sequence of corresponding actions will be stated. The system will make use of it, when necessary. In the case of unfruitful research, our system will try to detect the incoherencies, which can be classified as follows:

- Inter-components
- Between-components

Maintenance:

It is a question of facing, when possible, a faulty situation. This task uses the results of the previous one. We are interested in the components of which states are considered to be erroneous, putting in wait the components whose states are unknown. Via the relations between-components and the applicable actions from this state, we seek a sequence of actions to force a change in the current states of the components. For the unknown components state, we use states by default, which can be modified to the profit of other components whose states are known. All this states the system at one or more normal classified cases. At the end of the treatment, the state of the system having caused this fault as well as the sequence of the achieved actions, will be tested and added to the basis of the production rules.

4 Elements of the Model Proposed:

4.1 Component:

Each component is represented by all significant parameters. We will be sensitive to the parameter with real sensor. Attached to these parameters, **procedures** and/or **functions** expected during the significant changes of their values. The component can move by several states along its existence in the system. Each state can include a vector or intervals of values of the parameters. We admit that these states are in mutual exclusion. The equation state=vector of values presents the correspondence between the qualitative (state) and quantitative (vector) level. This decomposition would allow a qualitative reasoning in the case of the lack of information. The state is a set of the possible states of a component, State={E1,E2…Ek }. This is a finite set. We distinguish the final states, from which the component does not admit a change of state (state of uncontrollable failure) as well as two classes of states (normal, abnormal).
This set sight would make possible in a later stage of the project to insert the uncertainty concept in the simple component state diagnosis. The components can be gathered in a hierarchical form (linked by the compound-of relation) and transformed the multidimensional relations into binary relations. Such a classification will be used to graduate the levels of details. This will make possible to express the same situation with different sights.

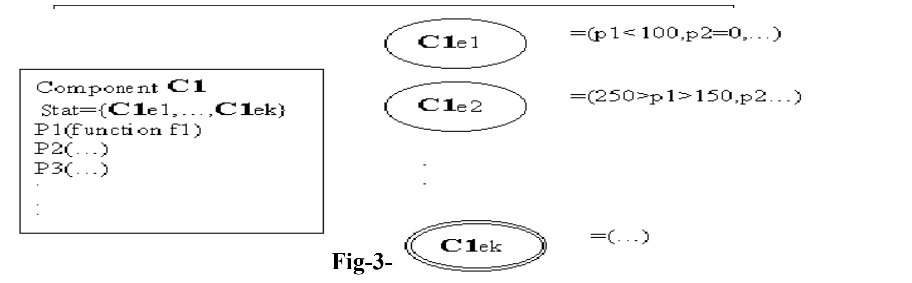

Fig-3-

4.2 Action:

Considering actions for initiating effect, i.e. direct actions carried out in reality on the components. The actions cause directly the change of the components state. Opposite to a system state, only a limited number of actions will be likely applied. Therefore, we define a set of actions of the system, Action={A1, A2, ...}, each one having a set of preconditions. An action is characterized by a **date** of the beginning and a **period** of validity. The latter will influence the good propagation of its effect to the concerned components.

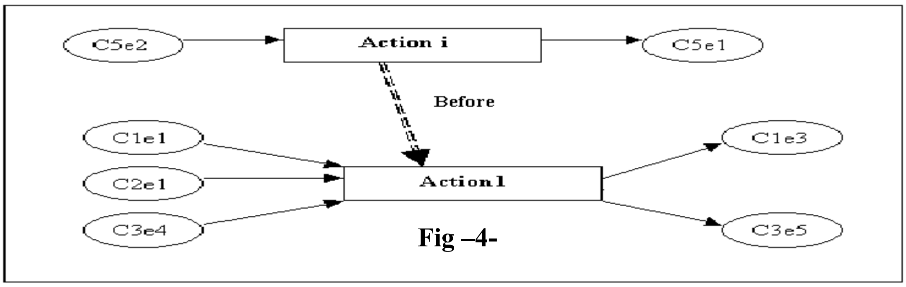

Fig –4-

4.3 Constraints:

The integration of a Meta level for the control and the scheduling of the actions, proved to be essential. Each action is regarded as a variable Xi being able to get value on an interval of the beginning. The temporal constraints may be: in parallel, afterwards, before, Etc. The constraints of integrity will ensure the non-stop of the propagation of effect during an atomic transition of the system. The modeling of the constraints will be made in the form of resolution of linear equations (we will go back to a Constraints Satisfactions Problem (CSP)).

4.4 Relation (role):

Each attribute or set of attributes, which acquires certain values, (constituting a component by state) would force the change of another component. This fact shows the role-played by the first component in comparison with the second one (to transmit a movement, …). These relations can be also connected to the temporal variables: period and the date of the beginning. The period and the date of the started action constitute an important factor in the continuity of the action propagation, because the application of the component role has duration of propagation effects specific to each bond between components. We can say that these relations constitute a channel or communications protocol between components. The relations in the opposite direction will be used to express a reasoning of causality (to explain).

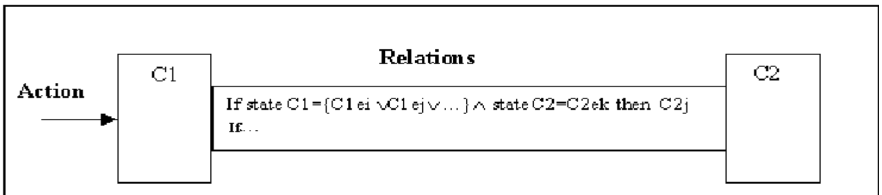

Fig-5-

5 Reasoning

The reasoning is integrated into several levels:

5.1 To reason on the actions:
The reasoning formalisms theory on the actions encounters several problems. The most known one is `ramification´ (the impossibility of describing all the consequences of an action). The traditional way [3] to solve this problem is to describe in the action laws only a part of its effects and to infer the other effects by the use of the domain laws (for us, that is done by the means of the relations between-components and the formulas which control the change of the internal parameters of a component). Noting that time is presented in the form of discrete values.

5.2 The resolution of the system of constraints:
From a set of actions chosen, the techniques suggested by the theory of the CSP will make possible to prune the search space [8]. These techniques will only use the network of constraints concerned with the selected actions, in order to schedule and determine the dates of the beginning of actions.

5.3 The reasoning by default:
For certain parameters whose values cannot be collected all the time, we are obliged to fix default values. These sensors are known in advance. The `default values´ will be useful in the case of lack of information and modified to the profit of the confirmed values, in order to diagnose a fault.

5.4 The qualitative reasoning:
It is a matter of working in close collaboration with the experts of the studied field to specify the relevant states of a component and the bond with the quantitative level.

However, this reasoning can be integrated into the formulae level, which binds the parameters, by the use of a qualitative model [4].

6 Global Architecture of Pedagogical Simulator:

In [9], pedagogical simulation is classified according to the approaches of learning in the category namely discovery-construction of knowledge, which holds the following:

- The environment of training
- Micro worlds, Etc.

The construction of a complete pedagogical simulator was the target result. The complexity of this task made essential the decomposition of the system in cooperative sub-systems in the terms of collaboration by the interaction and the common use of information. After designing the expert model, the architecture of the system was cleared up. In this architecture, we distinguish in particular:

The expert, the evaluator, the simulator, the pedagogue and the interface.

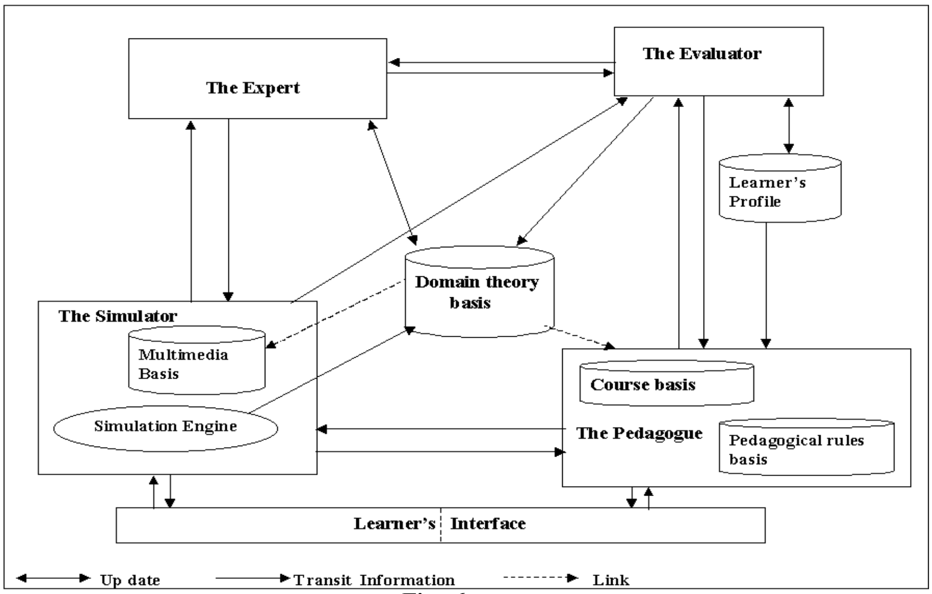

Fig –6-

6.1 The Expert:

The expert is at the same time able to face a faulty situation and to generate a model of reactions (sequences of actions and states) that the evaluator and the simulator will be able to exploit independently. The first one uses it to calculate the distance between two answers and the second one to transmit an emanating behaviour from the expert.

6.2 The Evaluator:

The importance of 'domain theory basis' emerges mainly from the fact that evaluator can build a sketch from it, containing a network of statistical measures. Each element (action, constraint, relation, component) is represented by two counters Nb-correct and Nb-false, which enter into account for the same session (scenarios) of simulation, the number of correct and erroneous uses of each implied element. The calculation of these two numbers takes into account the response of expert model. The evaluator selects a vector of grids of weighting (coefficients). This vector follows the perception of the system in its decomposition (in boxes labeled: component, action, constraint, …). The note is calculated and transmitted to the pedagogue. This note can be replaced where necessary (defuzzification) by an appreciation. In addition to the first sketch, which the evaluator maintains at its level, a second one will be built and maintained on the learner's profile level (more global and personal). The latter will be regularly updated by the evaluator and the pedagogue (using pedagogical parameters).

6.4 The Simulator *:*

The simulator plays a role of pivot. Its first role, through interface, is to simulate the behaviour of the real system. This is done, while cooperating with the expert and basing itself on the domain theory basis (which can be enriched by a multi-media basis). Moreover, the pedagogical aspect is dominant; the simulator integrates an explanatory module. Finally, it deals with conveying certain pedagogical parameters to the pedagogue. Simulation can be used in an autonomous way (free mode) or pursue a goal fixed by the pedagogue (guided mode).

6.5 The Pedagogue:

All the agents intervening in the system strive to offer to the pedagogue, according to its instructions, the reliable and the least noisy possible image of the learner. Its instructions can be of various natures: The choice of the scenario, the choice of the pedagogical objective, … .The pedagogue bases its instructions on suitable pedagogical rules (according to the learner's profile). This confers a great adaptability on the system.

6.6 The Interface:

It constitutes an important pillar in the system. The problems of its design increase, once we aim at a generator of simulators. It presents in this architecture, two working modes: simulation mode and course mode. The system, and more precisely, the pedagogue can switch learner from a mode to another according to its level described by its profile.

We see that a possible distribution can be done at two levels:

- the geographic bursting of the system: system will be (having the same proposed

architecture), decomposed on sub-system in terms of process or installation . The influences caused by the change of their state constitute the natural bonds between them (routing of information, sharing the knowledge basis) .

- co-operative learning: that is carried out within same sub-system and relates to

the learning aspect . The possibility of inter-connecting several learners in the same training can be established. This is done indeed in the case of a strategy strongly recommended by the pedagogue (based on the level of the learner's profile) as their wishes to be within a virtual class.

We agree with [10],in the fact that multi-agent methodology can certainly bring several advantages to the development of educational applications since it deals well with applications where such crucial issues (distance, cooperation among different entities …) are found. As result, multi-agent systems (MAS) together with technologies of networking and telecommunications bring powerful resources to develop pedagogical system.

7 Conclusion:

We have tried to put in œuvre a system for pedagogical simulation. The expert model is a first stone. We intend to pursue that in the near future by:

- The detailed design of a learner model.
- The addition of the fuzzy notion in measures and diagnosis .
- The distribution will open large doors for a cooperative learning.

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