INTELLIGENT AND INTERACTIVE COMPUTER IMAGE OF A NUCLEAR POWER PLANT:
The ImagIn project

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Abstract

The ImagIn project consists in a method and a set of computer tools apt to bring perceptible and assessable improvements in the operational safety of a nuclear plant.

Its aim is to design an information system that would maintain a highly detailed computerised representation of a nuclear plant in its initial state and throughout its in-service life. It is not a tool to drive or help driving the nuclear plant, but a tool that manages concurrent operations that modify the plant configuration in a very general way (maintenance for example).

The configuration of the plant, as well as rules and constraints about it, are described in a object-oriented knowledge database, which is built using a generic ImagIn meta-model based on the semantical network theory. An inference engine works on this database and is connected to reality through interfaces to operators and captors on the installation ; it verifies constantly in real-time the consistency of the database according to its inner rules, and reports eventual problems to concerned operators. A special effort is made on interfaces to provide natural and intuitive tools (using virtual reality, natural language, voice recognition and synthesis).

A laboratory application on a fictive but realistic installation already exists and is used to simulate various tests and scenarii. A real application is being constructed on Siloe, an experimental reactor of the CEA.

This paper describes a research project of the French CEA, concerning evolutions in plant operation apt to bring perceptible and assessable improvement in the operational safety [ref.1].

Many mistakes in plant operations are due to a discrepancy between the "mental representation" of the plant by the operators and the actual plant status : this is often due to lack of information provided to operators, particularly on the modifications of the plant, either temporary or definitive. This can also originate in an inconsistency between the operational procedures and the actual status of the plant, due to these modifications. The maintenance of a coherent and unique representation of the plant for all the actors (human or computerised) of plant operations is the main objective of the ImagIn project [ref.2,3].

1. ELEMENTS OF SPECIFICATION

The aim of ImagIn project is to design an information system that would maintain a highly detailed computerised representation of a nuclear plant in its initial state and throughout its in-service life.

Each actor working around the plant uses his own database (equipment database, documentation, regulations, supplier database for instance), needs information from other actors and has to know current and past status of the plant. Some of them, e.g. operators in the control room and maintenance operators, directly operate on the plant configuration.

The role of the computerised representation system is :

• to provide a unique and accurate description of the whole plant for all the actors.
• to be a central node of communication between these actors.
• to record any modification of the plant.
• to verify the consistency of the plant within respect to regulations.

To reach these objectives an ImagIn system must :

• provide a database containing the specification and the current status of the installation (components, systems, spaces, staff ...), and all the available documentation (drawings, procedures and instructions, regulations...),
• restore, at any time, these informations in a comprehensible and reliable form exempt of any ambiguity,
• follow up each modification occurring on the plant and update the plant database (memorising how, when and what was done), without any unbearable additional constraint on operators,
• always verify the coherence of these modifications with the requirements and regulations, and point out any discrepancy.
• manage although any temporary modification involving a non compliance with requirements, during extraordinary maintenance operations or transient alarm situations for instance.
• take into account changes occurring on regulations,
• always inform actors about modifications of any type that concerned them.

The ImagIn program is based on two main tasks :

• build a prototype which will be a full-size illustration of the ImagIn implementation on the experimental reactor SILOE of the CEA/Grenoble.
• identify a method which will allow us to build such an application on any nuclear installation in an industrial context.

2. TECHNICAL COMPONENTS

An ImagIn application has three main technical components (fig.1) :

• the "Representation" component.
• the "Management" component.
• the "Interfaces" component.

2.1. The "Representation" component

It consists in constructing a database that contains all the information about the real status of a plant at a given moment, still memorising its past history. It is the knowledge model of the plant.

This model has a generic frame, built on the semantic networks theory : the ImagIn Meta-Model (fig.2). The IIMM describes the types of objects of a plant that an ImagIn application can represent and manage. Its concerns materials, spaces, activities, procedures and regulations, staff organisation, language of the domain and documentation. So this very wide model allows us to describe the tangible reality of the installation, as well as the way to modify it, and the way to control it. It is implemented in an Object Oriented Data Base System.

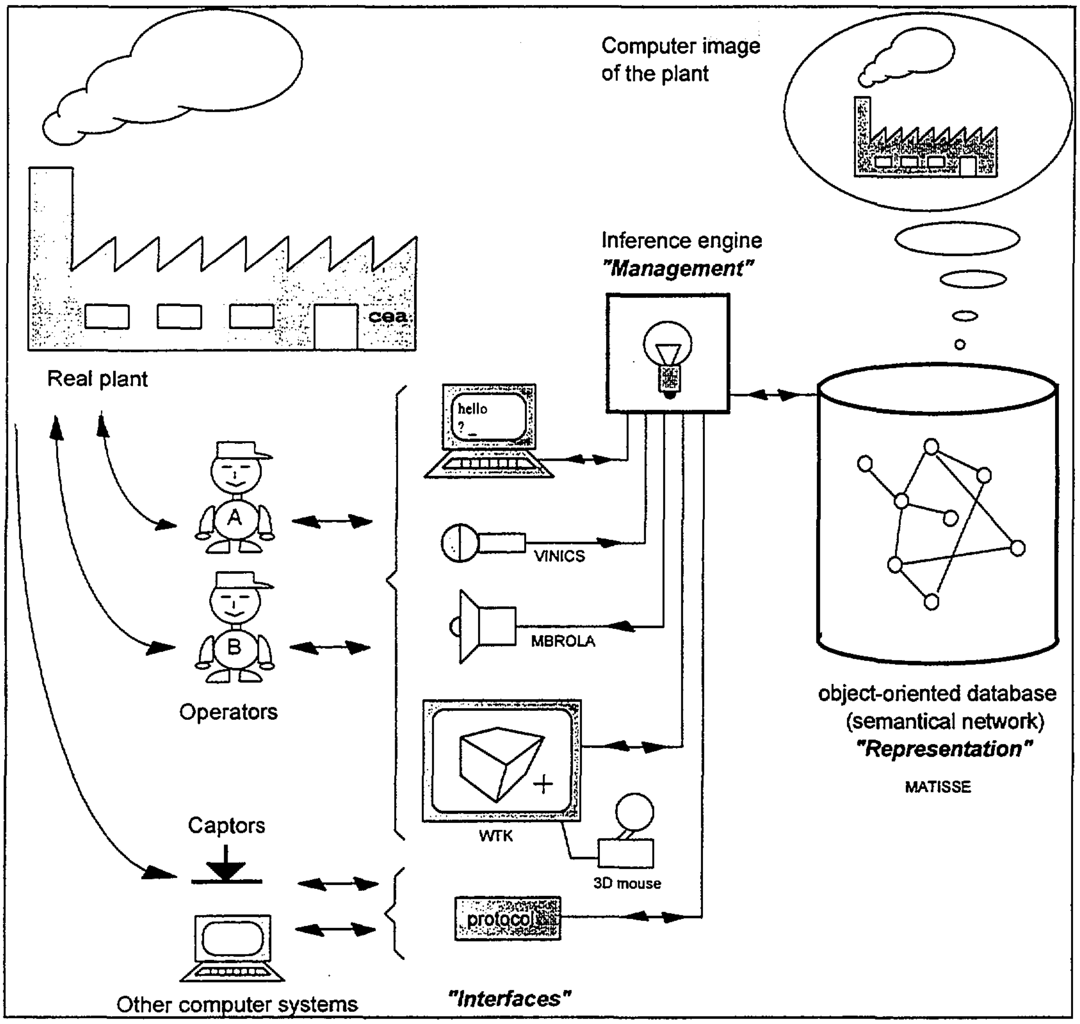

Figure 1. Overview of ImagIn system's components .

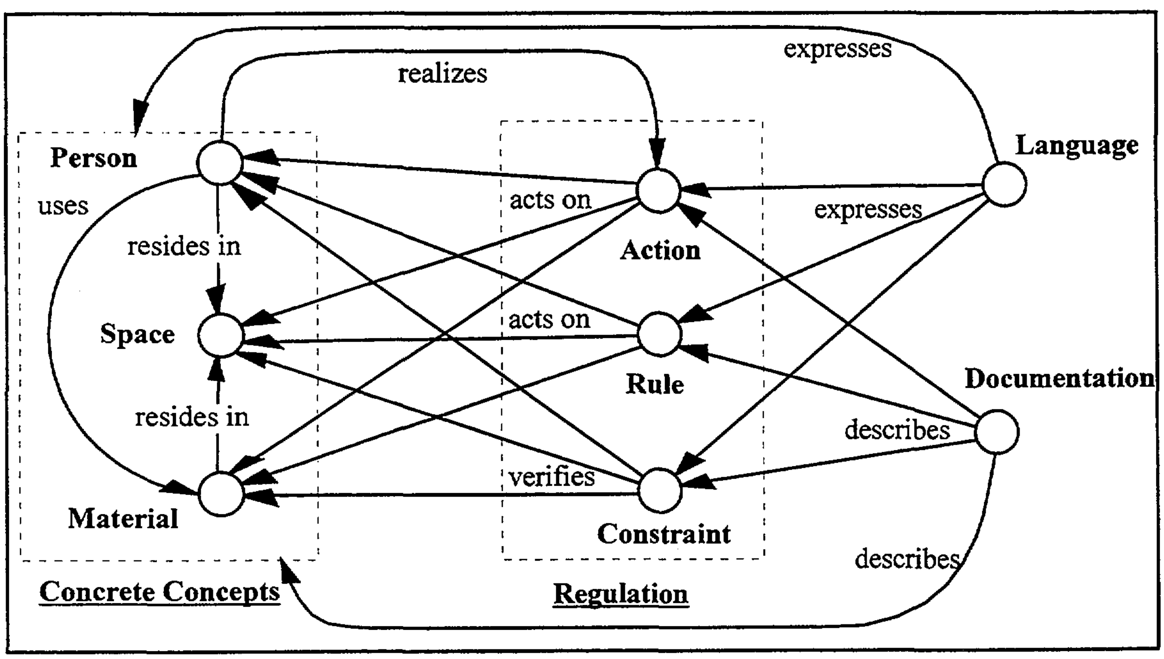

Figure 2. Simplified ImagIn Meta-Model (IIMM) .

The whole representation is based on information extracted from the documentation of the plant. To describe more precisely a given installation, an specialised Application Model is derived from the original Meta-Model by declining every concept into sub-families. This intermediate level of abstraction helps us reducing the « growing in size » effect, and allows us to stick specialised attributes on derived concepts (fig.3).

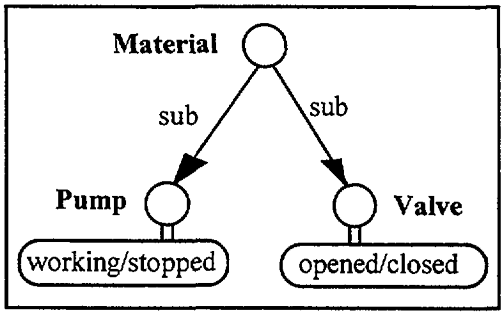

Figure 3. Application model .

The application model is then instanciated into final objets that describes the reality. In the following example (fig.4), a person P is localised in a space E and uses a valve V.

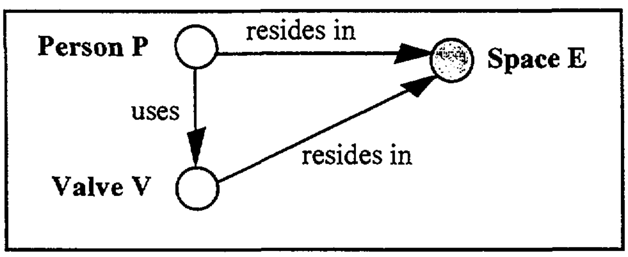

Figure 4. Example of representation .

A dating relation and attribute, and Modification objets are used to memorise completed operations and to provide a full tracability. On the following example (fig.5), a person P moves a pump O from a space E to a space F on date D.

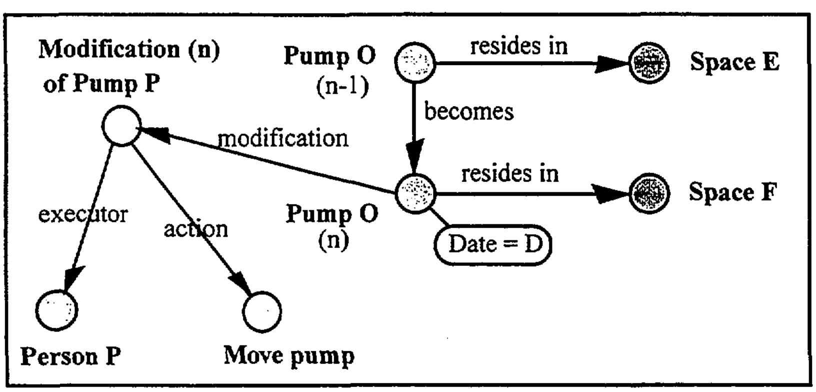

Figure 5. Example of dating .

2.2. The "Management" component

It consists in making the database evolve at the same time as the real plant while checking its inner coherence.

In the plant, every activity (maintenance, operation, handling, ...) has its own restricted point of view. For each point of view, there is an agent which is a computer process working on its specific knowledge database built on the same generic ImagIn meta-model. This agent can communicate with its dedicated human actors, involved in the same activity. All agents work independently at the same time and communicate with each other through a blackboard [ref.4] (fig.6).

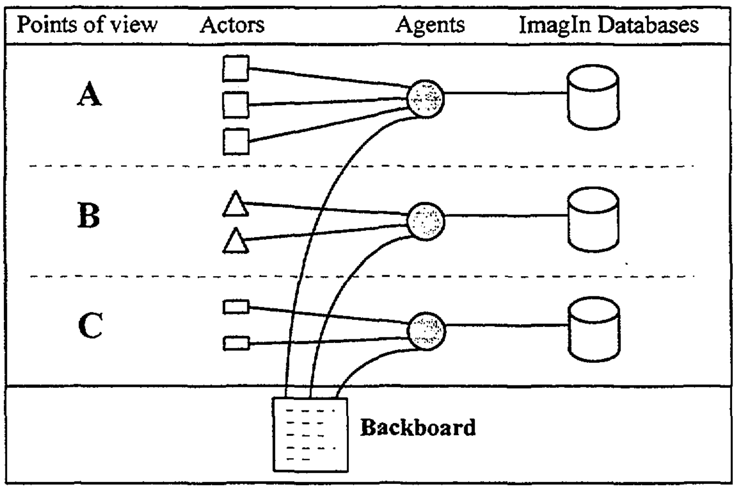

Figure 6. Communication between agents .

As soon as a human actor makes a modification on the plant, and tells it through an interface to his agent, this one reacts :

• it identifies the action and directly implied objects, trying to resolve any ambiguity (using the « Actions » part of the IIMM),
• it deduces any direct or indirect following modifications and updates its database (using the « Rules » part of the IIMM),
• it verifies the inner coherence of the database (using the « Constraints » part of the IIMM). In case of incoherence, it returns a warning message to the human actor who made the initial modification and to all its human actors concerned (according to their current work).
• it writes to the blackboard any modification recorded.

Simultaneously, any agent reads the blackboard and integrates any modification message it can understand. Then, as above, it verifies the coherence of the database and, in case of incoherence, informs all its human actors concerned, according to their current work.

An important point is that ImagIn must be as much as possible a preventive tool rather than a corrective one. That is why it works on a « intention/permission/action » basis : the actor declares his intention, waits for a permission, and then realises the action. But as ImagIn should just be an adviser, the actor should be the only one able to take the final decision (fig.7). These features raise an important theoretical problem : the introduction of « possible » or pending actions (in a multi-user environment). This problem is quite similar with a more general time problem : we are working on the possibility to declare *a priori* a action planned in the future, and to declare *a posteriori* an action realised in the past.

actor	intention of action			
ImagIn	verification in every point of view ⇔ consistency of the action ?			
🕒 delay...				
ImagIn	permission		action denied	
🕒 delay...				
actor	action 👍	*cancel...* ✋	*action !* 💣 *(⇔ warnings)*	no action 👍

Figure 7. The « intention/permission/action » cycle .

2.3. The "Interfaces" component

Two original interfaces have been developed : a bi-directional vocal interface and a 3D interface.

2.3.1. The vocal interface

The input of the vocal interface is supplied by a continuous speech recognition system developed using the VINICS system of the CRIN/Nancy/France [ref.5,6]. This system is speaker-dependant and needs a learning stage. It is based on a new approach to phoneme-based continuous speech recognition, in which a time function of the plausibility of observing each phoneme is given. To improve the recognition, it also uses a phonetical grammar that describes the language of the domain. One of its advantage for industrial applications is that it can work in a noisy environment.

The grammar needed by the system is built using the « Language » part of the IIMM. As we are using one grammar per point of view, the recognition bandwidth is shortened and results should satisfied our requirements. As an example, VINICS average results are better than 98% success, on a word basis. Its only drawback for the moment is the calculation time (about 30 seconds), but we demonstrated at least that such a system is feasible, and we think it would be possible to use it efficiently in 10 years.

The output of the vocal interface is supplied by a speech synthesis software, called MBROLA and developed by TCTS/University of Mons/Belgium [ref.7]. This synthesiser can generate various intonations : this can be used to express different levels of urgency. It also permits a feedback in case of misunderstanding in the recognition step. Current work of TCTS is based on prosody (automatic intonation generation).

But both systems only convert analog voice signal to ASCII sentences : we developed natural language understanding and synthesis systems to change an ASCII sentence into an ImagIn understandable action and vice-versa.

2.3.2. The 3D interface

A virtual reality interface provides a 3D realistic but synoptical image of the plant, in which a user can navigate with a 3D input device in order to consult from a terminal the status of any parts of the plant (fig.8). On such a display, results of any action can be followed in real-time.

This interface is implemented with the World Tool Kit library [ref.8]. This library can support virtual reality devices. The background of the image displayed on the screen is built up using the « Space » part of the ImagIn model and will show buildings, rooms, doors, ground and stairs. Movable objects are issued from the « Material » part of the model and can be selected in the 3D view using the 3D pointer.

This interface can also be used as a simulator and various menus are provided to select actions to execute on objects selected in the 3D view.

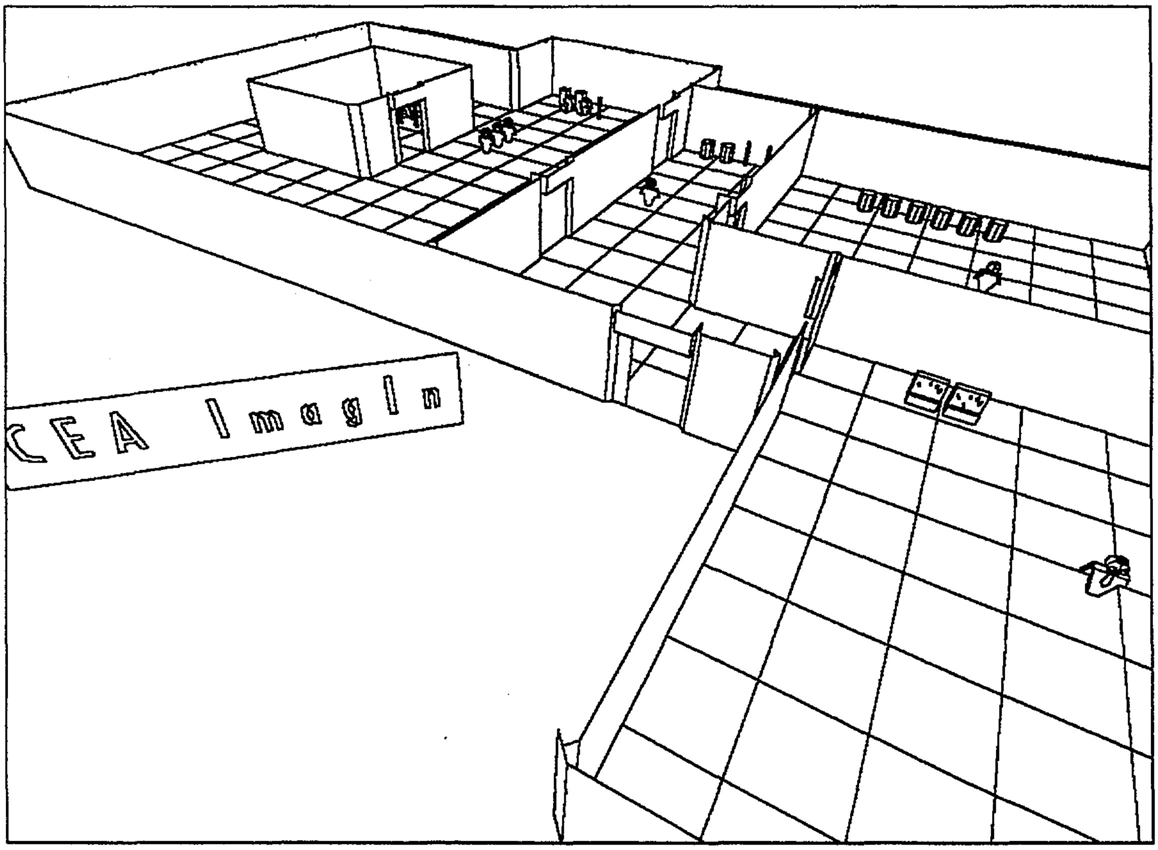

Figure 8. 3D overview of an installation .

3. CURRENT WORK

A laboratory application called ImaLab has already been developed, for purpose of tests and demonstrations. It represents a simple fictitious installation and demonstrates all the features of ImagIn using several possible scenarios, without having to manage the whole mass of information attached to a real nuclear installation.

The main goal of the ImagIn project is now to build up a prototype application on the experimental nuclear reactor SILOE located at CEA Nuclear Research Center of Grenoble. This application should be installed on the site at the very beginning of 1997. During this first real-sized experience, we will learn how to built a large ImagIn database, and write down the ImagIn Method.

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