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A Mobile Agent-based Architecture for Distributed Program Supervision Systems

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Abstract: - Program Supervision aims at automating the use of complex programs, independently of any particular application domain. Program Supervision Knowledge-Based Systems (KBS) offer original techniques to plan and control program processing activities. The distribution of such systems becomes essential because real applications imply more and more participants on various sites. It allows either to simply consult existing distant knowledge bases on the use of programs, or to collaboratively construct new knowledge bases, or to launch a request on a distant KBS with local data. Our current application concerns assistance to physicians in the use of medical imagery programs and more precisely osteoporosis detection in bone radiographies. The image processing request management based on several distant programs is transparent to physicians. In this paper, we propose a distributed architecture based on mobile agents for program supervision systems and we show why and how to use mobile agents for such systems. A simple scenario illustrates the functioning of the distributed system when solving a user-request in medical imagery domain.

Key-Words: - Program Supervision, Distributed Program Supervision, Mobile Agents, Grid Computing, Medical Imagery, Osteoporosis detection.

1 Introduction

Many libraries of programs have been developed by specialists in various domains, but the end-users of these libraries do not necessarily master the programs and thus cannot use them in the most effective way. So programs and knowledge on their use must be accessible to non computer specialists and especially to specialists in the application domains of the programs. A solution is to develop systems able to manage the use of these libraries, freeing users from this know-how and allowing them to focus on the interpretation of the results. We thus propose to design program supervision systems which automate intelligent use of programs. Such systems meet well the needs for service sharing which is necessary in several areas like Medical Imagery (e.g. chemotherapy follow-up based on Factorial Analysis of Medical Image Sequences [3]), Astronomical Imagery (e.g. automatic galaxy classification [12]) and Vehicle Driving Assistance (e.g. obstacle detection [9]). Our current application is related to assist physicians in the use of medical imagery programs, more precisely for osteoporosis detection in bone radiographies.

A program supervision system allows end-users (physicians in our case) to run programs, to check the consistency of image analysis methods, to compare algorithms, to evaluate results, to reconsider some parameters, and to readjust them.

Physicians can be in different locations, programs and knowledge on their use can be written by different persons and thus located on distant machines. That is why distributing program supervision systems is interesting. It allows either to simply consult existing distant knowledge bases, or to collaboratively construct new knowledge bases, or to launch a request on a distant KBS with local data. Our goal is to propose solutions for cooperation and sharing that allow teams to share medical imagery programs and knowledge on their use, and thus to benefit from the work of other teams without revealing the source code. In this paper, we start by defining program supervision systems and discuss the interest of their distribution. In section 4, we propose a distributed architecture based on mobile agents for a program supervision system, followed by its illustration for a medical request resolution in section 5.

2 Program Supervision Systems

Supervision environments were born [11] in order to automate the use of various program libraries. A Program Supervision System (Fig.1) is a Knowledge-Based System which ensures the selection and sequencing of programs in various configurations, thanks to the reasoning strategy of its engine and to the knowledge contained in its base. This allows an

"intelligent" reuse [7, 8] of programs and makes them accessible to users who are not specialists of the techniques and algorithms coded in these programs. Such a system is composed, as any KBS, of a knowledge base which contains the know-how on the use of the programs and of a supervision engine which uses this know-how to build an execution plan of the programs and to run it in order to obtain the results. The engine must have all knowledge to plan the programs, to run them automatically, to launch their execution, to produce results, to evaluate them, and to know which corrective actions to undertake (re-planning or re-execution of the current stage) in the event of bad quality results. Moreover, a program supervision KBS also involves a set of programs to be planned and adapted to a precise application domain, a set of data (images) to be processed, and a graphic interface making it possible for users to express their objectives, to follow executions and to see results.

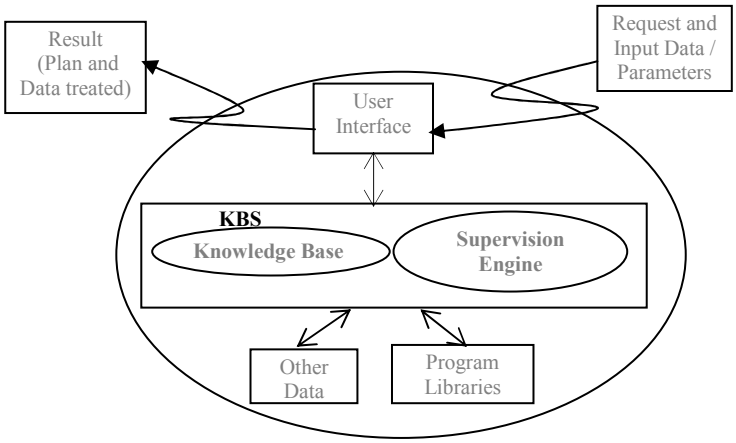

Fig. 1. Components of a Program Supervision System

3 Distributed Program Supervision

Distributed Program Supervision Systems (DPSS) should offer services, on the one hand, to distant users who wish to process their data using program supervision facilities and, on the other hand, to experts and designers who wish to share programs and knowledge. The latter must work in a collaborative way, i.e. must be able to consult information on existing programs, to create new common knowledge bases or to update existing ones by introducing new programs or new knowledge. Supervision environments were originally conceived to be mono-site. However, the components of a supervision environment (see § 2) can be located on various sites. Not only codes and/or data can be on different sites, but parts of the engine itself can be delocalized, for performance reasons, for hardware characteristics, etc. [7]. A mono-site environment is no longer sufficient, because it implies to install all the components, in particular the programs and the complete knowledge base, on a single site, which is not always possible or desirable. On the one hand, installing and maintaining codes remain a heavy problem which requires time and competence. In addition, programs are sometimes not very portable and difficult to install (because they require other utilities or they depend on development environments or compilers). On the other hand, when users on various sites create (parts of) knowledge bases, they in fact develop a competence that should be easily accessible to a user community using similar techniques. The repatriation of this knowledge on all the user sites would induce coherence and maintenance problems. The setup of architectures and services for distributed resolution of program supervision problems can be done by installing knowledge servers which allows to share and to disseminate knowledge on multiple client sites. Each site can allow the use of the resources (programs and knowledge) of other sites in a transparent way. Each site thus becomes a client of the competence of others and a server of its own competence. Consequently, if programs related to the same problems are developed in disseminated teams, distributed supervision can allow a cooperative resolution of problems, in which each stage represents the know-how of a team. It also allows researchers to confront their experiments and to enrich their results. For that purpose, we started studying various distribution methods for program supervision systems. Each form of distribution generates different problems due to the size of the data to be transferred, to the heterogeneity of the languages and development environments, to the specific needs of resources for the execution of some programs, to the management of knowledge coherence, etc.

4 Distributed Program Supervision System Architecture

During former work, we developed a supervision server via the Web, named SPI, which allows the remote consultation and modification of knowledge bases and provides an authenticated access to different users. It manages their requests, repatriates data, delegates processing, recovers the results and returns them to the user. SPI is currently under development to improve the management of concurrent accesses and to maintain the coherence of the knowledge bases.

The architecture we proposed for a Distributed Program Supervision System (Fig.2) includes a set of program servers, a set of knowledge servers, a supervision engine called *Pegase* [10] and the supervision server SPI. This latter plays the role of an interface between the supervision system and end-users by allowing the

communication with the other components of the distributed system.

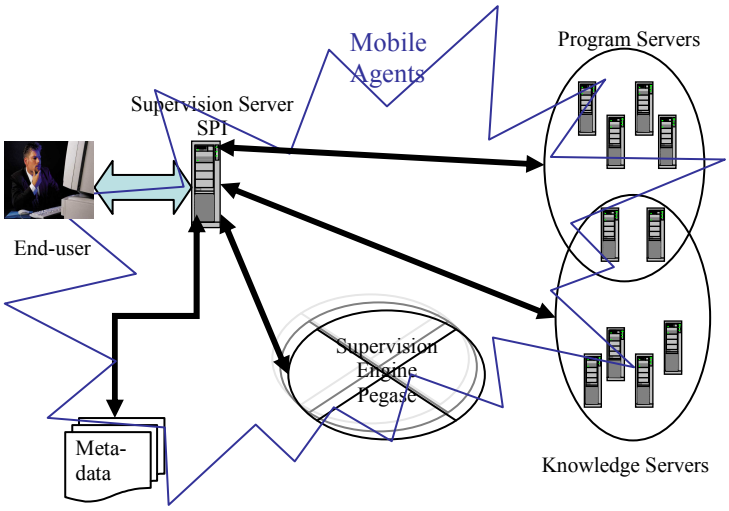

Fig. 2. Distributed Program Supervision System Architecture

This architecture is also equipped with a metadata warehouse (used to locate the various resources, to define access permissions, etc.) and is managed by mobile agents which are responsible for updating the previous components and for performing requests.

4.1 Why Mobile Agents?

Any distributed application implies a multi-localization of the handled entities and requires the mobility of certain of them. The choice of the entities to be moved raises problems of technology (how to carry out mobility?) and requires a size/time compromise (moving too large entities involves a time penalty). The Multi-Agent Systems and particularly Mobile Agents can be adequate solutions to this problem.

Lange and al. [6] defined seven good reasons for using mobile agents. All these reasons apply in Distributed Program Supervision:

- Solving a supervision request requires multiple interactions between the supervision engine and the different servers. The result is a lot of network traffic. Mobile agents allow these interactions to take place locally and no via the network.
- Our system deals with large size data (images), so it will be better to process these images locally because it is generally less expensive to move programs than images.
- Our distributed system must allow the sharing of heterogeneous resources (programs, data and knowledge) by facing hardware and software heterogeneity (interaction mechanisms with the servers, data format). In this case, mobile agents which are only dependent on their execution environment (generally computer-independent and transport-layer-independent) are a suitable solution.
- If a distant host (involved in the supervision process) is being shut down while our system is solving a supervision request, we risk that the treatment will be stopped and the request will never be solved. Mobile agents are able to react dynamically to this unfavorable event (and others) and dispatch themselves to continue their operation on another host if possible.

4.2 Mobile Agents Model

To communicate between the different components of the architecture, when performing a request, our system needs different classes of agents: a *Supervisor* agent, several *Solver* agents and possibly *Evaluator* agents. Only the two last ones are mobile. Each class of agent is characterized by its behaviour and its knowledge.

4.2.1 Agents Behaviour

The *Supervisor* agent is associated to the supervision engine *Pegase*. It has a triple role:

- Determine the number of necessary *Solver* agents to solve the user request and create them. This is possible if we have independent or parallel treatments, if not, only one *Solver* is necessary.
- Plan their itinerary.
- Facilitate the communication and the interaction between the mobile agents (*Solver*s and *Evaluators*), the engine and the supervision server.

Solver agents are created by the *Supervisor* and have to execute distant programs planned by the supervision engine and communicated by the *Supervisor*. For the migration of these agents from a machine to another, different policies can be considered:

- Leave the programs where they are, make the data migrate towards program sites and recover results to transmit them to the end-user.
- Take the programs (sometimes lighter than data) and execute them on the data hosts.

For example, for the first case, when migrating, a *Solver* agent brings necessary data and parameters for the execution of a planned program, performs this program and stores in its context the result and the execution parameters for the next programs.

Evaluator agents are created on the program sites (by *Solver* agents) when needed, i.e. when a program requires evaluation of its results. They are interested in the evaluation phase of the supervision process. For their migration, they move from a program server to the supervision engine, if the evaluation is automatic or from

a program server to the user site if the evaluation requires user interaction (manual evaluation). They store the result to evaluate in their context. If the evaluation is manual, the user assessment has to be sent to the *Supervisor* to allow it to decide of the next step.

4.2.2 Agents Knowledge

The *Supervisor* agent is characterized by a local memory containing a dynamic list of its acquaintances (*Solvers* and *Evaluators* with whom it communicates), a request to be solved (a functionality), a list of the knowledge files involved in the supervision process and the generated plan (or part of plan).
In each stage of the supervision process, a *Solver* agent is characterized by a local memory containing a dynamic list of distant programs to carry out and their respective arguments, a dynamic list of hosts to visit (itinerary) and a list of its acquaintances, namely its *Evaluator* agents with which it communicates, the *Supervisor* agent and other *Solvers* if they exist. Moreover, it has the input data for the next step and the result of the previous one.
An *Evaluator* agent is characterized by a local memory containing a result to evaluate, the kind of the evaluation (automatic or manual). Moreover, it is capable of deciding the site to which it must migrate (engine or user site) and a list of its acquaintances, namely the *Solver* agents with which it communicates and the *Supervisor*.

4.3 Extension of the Architecture

As an enhancement of the presented architecture, we can propose its integration in a larger one to allow the participation of a large number of disseminated concerned persons (physicians, for example).
In order to establish an adequate larger architecture for distributed supervision systems, we studied some network techniques such as Peer-to-Peer technology [5] and Grid Computing technology [4, 5]. Grids offer relatively sophisticated services and applications; they usually connect a few sites collaborating for complex scientific applications. On the other hand, P2P systems involve much more participants and offer unsophisticated, limited and specialized services such as file sharing. In our case, distributed supervision systems must be powerful, do not have to be limited to simple operations of file exchange but must rather offer complex functionalities such as execution of distant programs and access in various modes to data and knowledge files; it must also be able to parallelize processing for time reasons, as for example, when we want to apply the same algorithm to the various segments extracted in a radio image, given that an image can include between 2000 and 4000 segments. Consequently and contrary to [1] which proposes a Peer-to-Peer architecture for the distributed knowledge management, we prefer a Grid one since it offers richer strategies making it possible to accelerate processing and to increase collaboration.
As chosen by Cao and al. [2], we suggest also an architecture combining Grid and Agents. But, we will not use agents for the resource management only (knowledge bases, programs, etc.), but also for performing some complex tasks like the execution of distant programs.

5 Scenario for a Medical Request Resolution

Let us first define two major concepts the *Pegase* engine is based on: operators and criteria.

- Operators are of two types: primitive and composite. A primitive operator represents a particular program and a composite operator represents a combination of programs. Combinations of programs correspond to decompositions into more concrete operators at various levels of abstraction, either by specialization (alternatives), or by composition (sequences, parallels, etc.).
- Criteria represent decisional information, they are implemented by sets of inference rules which play an important role during the reasoning, i.e. choosing between various alternatives (choice criteria), adapting the programs execution (initialization criteria), diagnosing the results quality (evaluation criteria), and repairing a bad execution (repair criteria and adjustment criteria). These rules are written by experts on the use of the programs.

The following scenario describes the way a request is solved by a DPSS. Let us consider for example a request OSTEO for osteoporosis detection in bone radiographies by a mathematical morphology approach.
Once connected to the SPI supervision server (after authentication), a physician can launch a request by first selecting the knowledge base to be questioned from a list and specifying the input data that he/she wants to be processed. Receiving the request, the server transforms it into a program supervision purpose i.e. in a functionality manageable by *Pegase*. Referring to the metadata contents, the server deduces that OSTEO can be solved thanks to the "Morphology" functionality carried out by the composite operator "OsteoMorpho". Finally, the server creates a *Supervisor* agent and gives him all necessary information (functionality to achieve and input data).
Since the *Supervisor* agent is an interface between *Pegase* and the future agents, it has to forward the previous information to the engine. Now and thanks to the metadata, *Pegase* becomes able to locate all the necessary knowledge to use for OSTEO resolution.

Then, the supervision engine can start the planning phase of the execution of the various distant programs, i.e. build a plan or a part of plan for executing these programs.

To this end, *Pegase* begins by decomposing operator "OsteoMorpho" in other more concrete operators (composite or primitive). Fig.3 presents a graph of the osteoporosis detection base, showing the decomposition of operators. "OsteoMorpho" breaks up into a sequence of operators: *lecture, squelettisation* and *analyse*. To be able to decide the number of *Solver* agents and the triggering of the planned operators, we take into account, during the planning phase, the dependencies between programs i.e. whether the results of a program are inputs to some further programs.

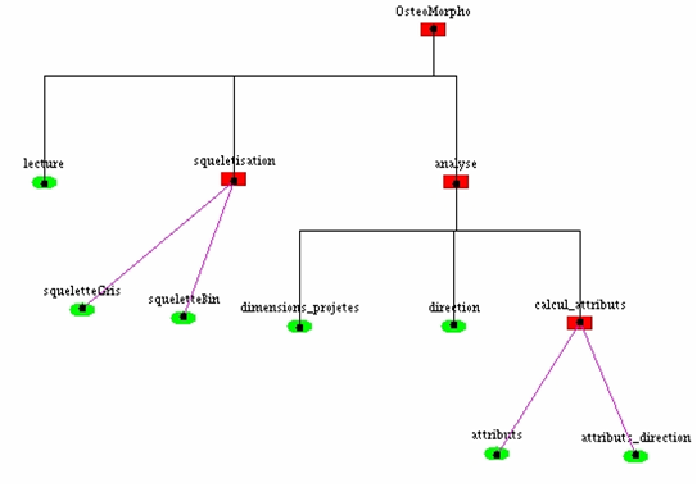

Fig. 3. Osteoporosis Detection Base

The first operator "*lecture"* is primitive, so it has to be executed. Thus, a *Solver* agent will be created by the *Supervisor* and informed of the following parameters: the program name, its location and the evaluation. The evaluation parameter can be *No* if there is no evaluation for this program, *Man* if the evaluation is manual and *Auto* if it is automatic. Note that "lecture" needs no evaluation. The agent migrates to the distant host of program "*lecture*" having in its context, in addition to the preceding parameters, the input data to be treated.

While the *Solver* is running, *Pegase* continues by breaking up *"squelettisation"* into two alternative operators: *squeletteBin* or *squeletteGris*. The choice between these two operators can be carried out by the user or by *Pegase* itself, according to existing choice rules.

- If the choice is automatic, *Pegase* uses choice criteria to decide the operator to plan.
- If the choice must be carried out by the user, the engine sends to the server (via the *Supervisor* agent) a request for choice which can be in the form of a question "Do you want to carry out a binary skeletonization or a skeletonization in grey levels?". The answer of the user will be read by *Supervisor* and transmitted to the engine so that it takes into account this choice in its planning.

Let us suppose that according to the last choice, the *squeletteBin* program is planned.

At this level, the skeletonization requires an evaluation; therefore, the *Supervisor* agent sends the name of the program to be carried out (*squeletteBin*), its location, and the evaluation parameter to the distant *Solver*.

Receiving these parameters, the *Solver* agent migrates (Fig.4) towards the *squeletteBin* site bringing with him the result of "*lecture*" execution. Once the execution of the program is finished, it is time to pass to the evaluation phase of the results, which is the role of *Evaluator* agents. Such an agent will be created by the *Solver* and informed of the result and the type of the evaluation so that it may decide where to migrate next (Fig.4):

- If the evaluation is automatic, it migrates towards the site of the supervision engine;
- If the evaluation is manual, it migrates to the user site to ask for an answer. The *Evaluator* finishes by sending this opinion (assessment) to the engine.

If the assessment is positive, the engine continues its planning with the composite operator "*Analyse*" and transmits its plan to the *Solver* via the *Supervisor*.

If the assessment is negative, the engine will use repair or parameter adjustment criteria to decide to start planning again or to re-execute the same plan with different parameters.

If it has repair criteria, the engine will repair the previous plan, for example, by adding an optional operator not previously considered or by choosing another operator if there were a choice. In this case, re-planning takes place and the *Solver* will be informed of the new plan and will behave in the same way as with the previous plan.

If it has adjustment criteria, and according to them, the engine readjusts some parameter values of the current program. This readjustment can be automatic (made by the engine) or manual. In case of manual readjustment, the engine transmits a request for parameter adjustment to the supervision server, such as for example: "To repair the plan, do you want to change the parameter *P* from 10 to 9 or to 8?". The server forwards this request to the user, gets the answer and then gives the adjusted parameter value to the *Solver* via the *Supervisor*. The *Solver* runs its program again with the updated value(s) of parameter(s).

This process is repeated until the last program (*attributs* or *attributs_direction*) is executed. The *Solver* agent carries out the chosen operator (we suppose "*attributs*") while being informed that it is the last program so that it can go back to the *Supervisor* site bringing with it the

final result (the response to the request). Finally, the *Supervisor* transmits this result and the generated plan (*lecture – squeletteBin – dimensions_projetes – direction – attributs*) to the end-user.

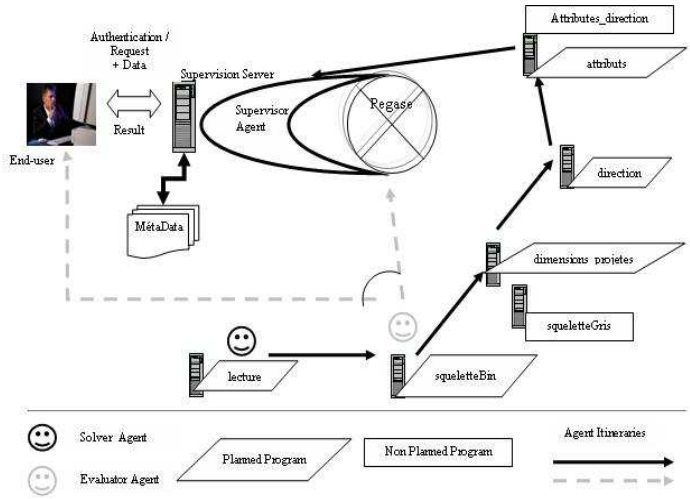

Fig. 4. Example of Agent Dispatching for Osteoporosis Detection

Thus, and thanks to the DPSS, we could assist physician in his osteoporosis detection diagnosis by sequencing and executing a set of programs which use a mathematical morphology approach and about the contents of which the physician has no idea.

6 Conclusion

Supervision environments were originally conceived to be mono-site. However, their interest and the nature of their components made their distribution necessary in order to offer services to different distant users: specialists in image processing who can try out and compare their programs, knowledge base designers who can describe the use of these programs and physicians who can use these programs through the WEB and thus improve their means of diagnosis.

Moreover, the interest of this work was felt by various teams in different domains and especially in medical imagery.

In this article, we proposed a distributed architecture for a program supervision system based on mobile agents. We showed how such a system behaves to solve a request of osteoporosis detection.

To extend our architecture, we intend to integrate it in a Grid architecture and thus to combine a network technology for distribution (Grid computing) and an artificial intelligence technology for distributed processing (mobile agents). Forthcoming work will concern the integration of new programs from different teams in our distributed system and the use of ontologies to simplify the search for resources in the distributed supervision system.

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