

Dynamic task allocation and A.I systems for the maintain of the air-traffic controller in the supervision loop

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Summary

The air traffic increase and the air controller's workload heaviness lead to give assistance to the controller.

The purpose of our research is to propose and validate a new organization of the air-traffic control which allows controllers to stay active in the supervisory loop of the process, in order to maintain the present safety level and to improve the global system performances.

Our studies are directed towards an horizontal cooperation which consists in a dynamic allocation of control tasks between controllers and assistance tool implemented on a calculator.

Keyword:

ATC, Dynamic Task allocation, A.I

Introduction

The immediate consequence of the air traffic constant increase is to influence the traffic safety and to constraint the air traffic controllers to a too important workload. In order to face the rise, a increase in tools is needed in order to enable an optimal control for keeping the same security level and to reduce the workload of the air-traffic controllers (Debbache and al., 1990a). The variation of workload may lead on one hand, to an overload which brings about the degradation of the system performance, and on the other hand to an underload which causes a loss in vigilance. Consequently, the rising workload of the air traffic controllers, linked with the traffic evolution justifies researchs which concern, on one hand, the implementation of new decision support tools for controllers and other hand, a new organization of the controller-tool system. The proposed organization relies on a dynamic task allocation between man and this tools in order to regulate the human workload, and also to improve the performance and the reliability of the controller-calculator team.

1-Dynamic task allocation principle.

The dynamic task allocation principle consists in inserting in the control and supervision loop, a task allocator which shares tasks between the operator and the calculator's decisional stage, figure 1 (Milot and al. 1985). The calculator is responsible for some tasks when the human operator workload is too high. The expected advantages of such a system are, firstly to optimize the process performances, and secondly to maintain the op-

rator active in the supervisory loop by avoiding him a permanent underload and also by helping him in case of overload, (Milot, 1988).

For that purpose, Rieger and Greenstein (1982) quoted two types of dynamic allocation structures:

- The first structure concerns an "explicit" task allocation performed by human operator through a dialogue interface. The operator is his own estimator of performance and workload, and allocates tasks himself. The implementation is rather easy, but the major drawback is the extra workload for the man due to the allocation organization and the commands he has to send to the task allocator. In order to minimize this extra load, Greenstein and Lam (1985), propose to optimize the ergonomic quality of the dialogue interface.

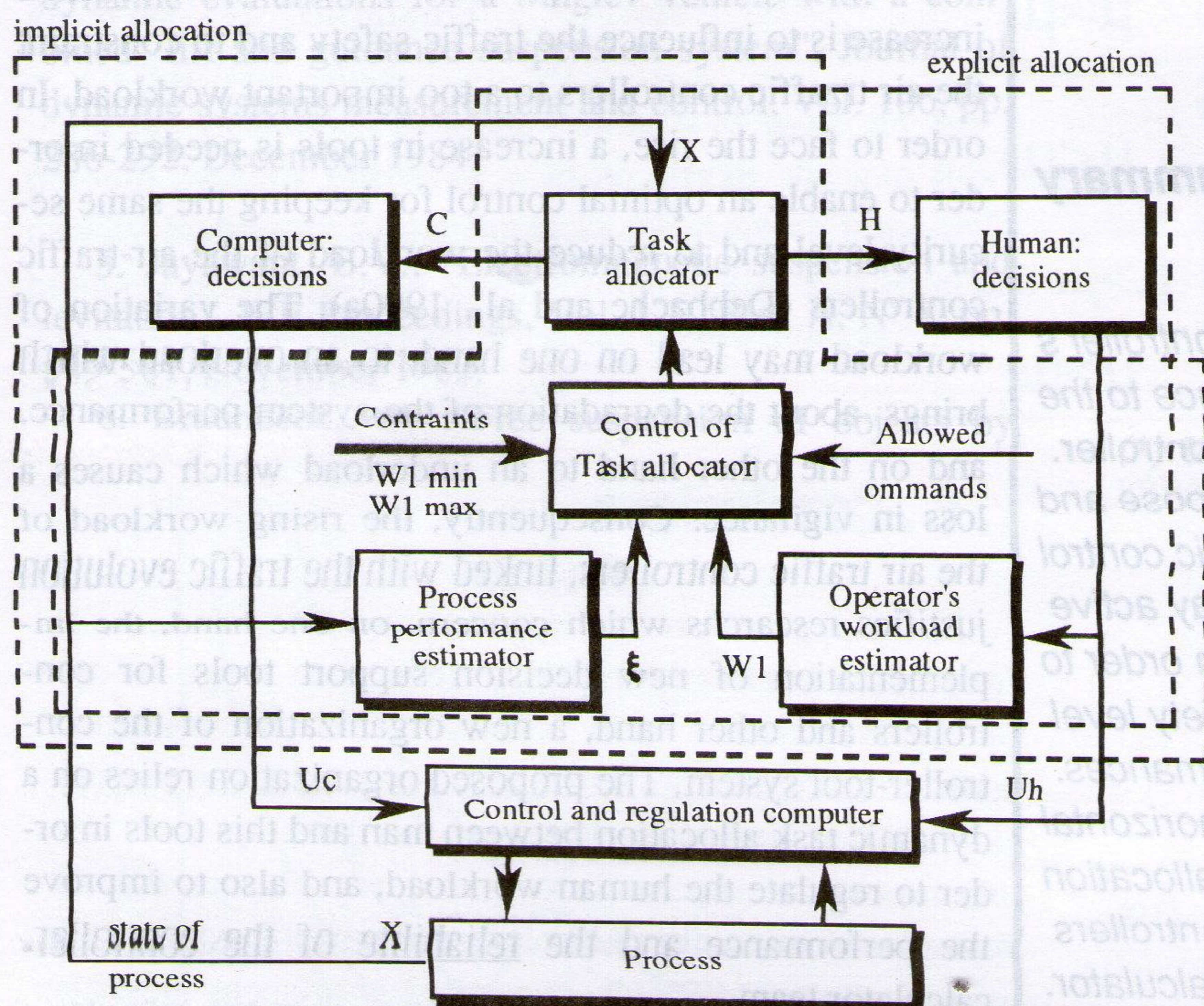


Figure 1 : Principles for Dynamic Allocation of Supervision Tasks

- In the second structure, called "implicit" task allocation, the tasks sharing is controlled by the calculator. The principle consists in searching an optimal share, which improves the global performances of the man-machine system, by modifying iteratively the number of tasks allocated to each decision-maker. Nevertheless, the human operator workload must be kept between two workload

thresholds respectively maximum, WL_{max} , and minimum, WL_{min} , (Milot, 1988). For these reasons, the calculator must estimate on line, the system's performance and the human operator workload.

A previous research carried out in a laboratory context on an experimental platform, enabled us to validate these principles especially for continuous processes (Milot, 1988). The numerous experimentations realised on this platform in implicit and explicit modes have allowed:

- To validate an estimator of the operator workload. This estimation method follows from the formalism of Tulga and Sheridan (1980) who consider the workload as the ratio between the required time to realize the tasks and the effective available time. Our method is based on

an observer model which determines, firstly the functional and temporal requirements of the tasks to be realised (related to the available time), and secondly the occupational rate of the operator (related to the required time). Then, the requirements and the occupational rate aggregated to deliver, in real time, the workload of the operator (Milot, Kamoun, 88).

- To develop, in the implicit mode, an algorithm for the task allocation based on a predictive model of the process performances which allowed to reach process global performances near-optimal (Kamoun, and al., 88).

2- Transposition to air-traffic control.

Our present research aims at extending our methodology to the concrete domain of air-traffic control (ATC), in which the controller's workload is highly varying along the day and for which a flexible assistance in decision and action should be very helpful.

The research objectives concern :

- the implementation of both the dynamic task allocation (either implicit or explicit),
- the evaluation of these principles according to technical and human criterion (performance, workload), and the choice of most adapted dynamic allocation mode.

In order to carry on the volume and the air-traffic con-

troller work dimension, a general idea of the ATC and the main controller's activities is presented.

Air-traffic controller's activities.

The air space is divided into geographical sectors and the management of which is insured by two controllers. The first one is a tactical controller (radar controller) who looks after the good progress of the traffic in the sector. The radar controller activities are then, the supervision of the traffic and the dialogue with the aircraft's pilots. The supervision of the traffic is made through a radar screen, and consists in detecting possible conflicts between planes (e.i. predicting if the separation norms between two or several planes are going to be transgressed) and solving them. The dialogue with the pilots aims at informing them about traffic or forecast for instance, or at asking them to modify their flight level, or cape or speed, in order to avoid a conflict.

The second one is a strategic controller (organic controller) who is principally in charge of planes transit between two sectors so as to, firstly avoid the conflicts at the sectors borders which are impossible to solve (this activity is called coordination between sectors), and secondly regulate the workload of the radar controller by anticipating at best the traffic density. For that purpose, he manages the flight strips which contain the main parameters of the aircraft which will enter the sector (fig. 3). At present, these strips are typed on paper sheets from the computed flight plan and must be manually ordered on a board. But in a near future, they will be displayed on a screen. The organic controller activities are then, the input coordinations (i.e. when a plane enters the sector), the output coordinations (i.e. when a plane gets out the sector), and the phone calls with the controllers of the others sectors to insure these coordinations.

Specific problems with the ATC for the application of a dynamic allocation.

The application of a dynamic allocation method to the air-traffic control leads to several difficulties.

-The workload assesment method developped in laboratory (LAIH) gives a workload index in a multitasks situation. It requires, for each task, the available time and real-time measurement of task operator computing duration. This evaluation of the control task available time is not easy in the air-traffic context case. Indeed, these tasks are random and highly cognitive.

-The set of shareable tasks (which can be performed by the controller and the AI system as well) evolve dynamically, (Debbache and al. 1990b). Therefore, an intelligent module for the recognition of the shareable tasks is necessary.

-The main aim of the implicit dynamic allocation method is to optimize the process performance. For that, the criterion of process performance assesment must be realistic, representative and feasible.

With regards to air-traffic control complexity, previously outlined, the implementation and the tests of such a new organization of flexible task allocation cannot be made directly in a real control room without a sufficient validation in a simulated context. For these reasons, we have build a simulated platform of air-traffic control.

3- The experimental platform.

Study context.

The experimental platform we have developped is slightly futuristic. It is composed of the only radar controller for a given sector (the second controller will be added afterwards). The paper strips generally used by the controller are replaced by an electronic stripping on a screen on which the information concerning a plane (flight, level, characteristics) which are necessary for the controller are displayed. The radio is replaced by an appropriate computer interface, permitting to send orders to planes (level, cape, speed, climb or descent rate). This interface allows us to modelize the controller activities more easily.

These modifications allow us to eliminate some tasks and to keep only those which are the most important ones concerning the traffic safety: the conflict resolution, the input coordination and output coordination.

Description of the experimental platform SPECTRA (Système de Partage Expérimental des tâches de CONTRôle Aérien)

This platform (figure 2) is build around a realistic air traffic simulator called OLIVE. It is also composed of two 19' colour graphic screens used by the controller ; on the first one, a radar view of the sector is displayed which allows the controller to supervise the traffic; the other one displays the electronic stripping and allows the controller to gives orders to the pilot by means of a mouse (operator dialogue).

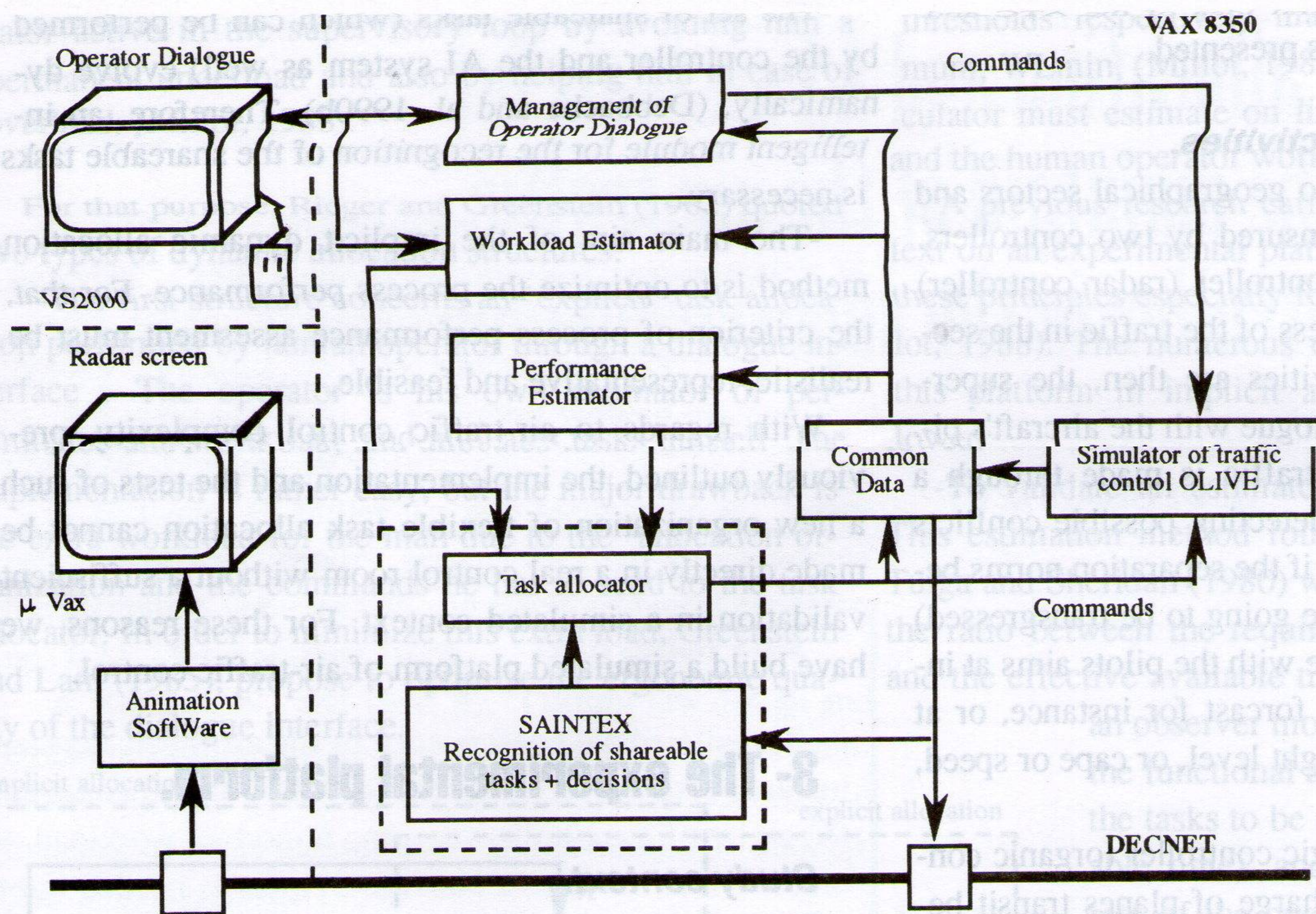


Figure 2 : Experimental Platform Structure.

The SPECTRA's structure is distributed through three calculators linked by a DECNET network. The first calculator is a μ VAX which controls the radar view display and its dynamic animation on a color graphic screen. The second one is a VS2000 station used for the operator dialogue. The other component modules are implemented on a VAX 8350 computer and consist in:

- The air-traffic simulator "OLIVE" simulates, in a realistic way, the evolutions of the aircrafts in a given geographic sector according to their flight plan and to the instructions given by the air-traffic controller or by the decisional stage of the calculator.

- The decisional stage is an expert system (SAINTEX) whose knowledge based. It is able to resolve conflicts between two planes in rather simple conditions (Debbache and al. 1980b). It is composed of different modules:

- * A detection module for conflicts between two or more planes.

- * A conflicts classification module which determines whether a conflict can be resolved entirely by it or not and consequently, determines the shareable tasks between it and the human controller.

- * A calculation module of the order which must be sent to one or two planes so as to resolve the conflict (at

only realised by modification of the cape). At the same time, the effective sending date of the order to then air traffic simulator is calculated.

*A supervisory module which sends orders at the indicated date if the conflict is allocated to saintex itself, and which replaces also the plane in its previous trajectory when the conflict is over.

- The radar view displays on line the evolution of the aircrafts, and enables the controller to supervise the traffic and to detect possible conflicts between aircrafts. By request, the controller can apply successive zooms on the view and display the speed vectors of planes. In relation to the reality, different ergonomic modifications have been done to this radar view so as to warn the controller about the state of a plane. The four existing distinct states are :
 (blue) : plane to take in charge (entering the sector)
 (orange): plane taken in charge by the human controller.
 (orange): plane that SAINTEX is able to deal with.
 (white) : plane taken in charge by SAINTEX.

- The operator dialogue interface contains the electronic stripping and a generator piloting module (figure 3). The human controller knows from the electronic stripping featuring, every plane concerned by the sector,

The screen is divided on three parts. The upper one (area A) contains possible commands for managing the radar view (figure 3-1). The central part (area B) contains all the strips taken in charge. By using a mouse, the controller can order the strips as he wants on the screen. The left bottom part (area C) displays automatically a new plane to be taken in charge when entering the sector. Therefore, the controller must move this strip to the area B as soon as he affectively takes it in charge. The right bottom part (area D) consists of the two commands for

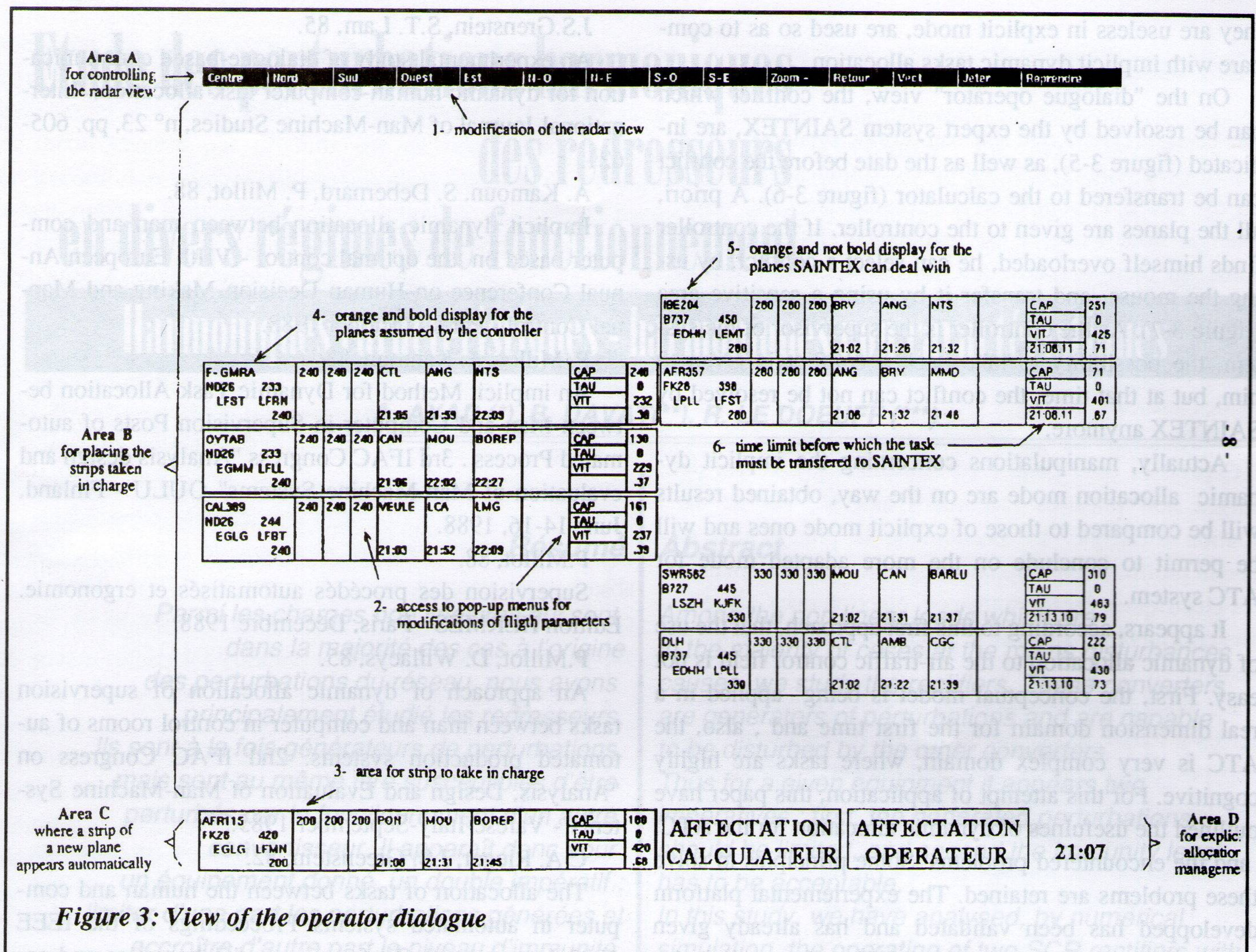


Figure 3: View of the operator dialogue

transferring the shareable tasks from one decision-maker to the other one in the explicit mode.

On each strip, four sensitive areas permit the access to pop-up menus in order to modify the level, the cape, the speed of the climb rate (figure 3-2). As for the radar view, the display characteristics of the strips show a particular state of the plane - Blue for the strip of a new flight to take in charge (figure 3-3)- White for the flights taken by SAINTEX - Orange and bold for the flights taken in charge by the human controller (figure 3-4) - Orange and not bold for the flights taken in charge by the controller but which SAINTEX can deal with (figure 3-5). For these last ones, the time after which it will be impossible to transfer the conflict to SAINTEX, is displayed on the strips (figure 3-6). This case particularly exists only in the explicit dynamic task allocation mode.

-A task allocator is integrated in the decisional stage, and aims at sharing the control tasks between the con-

troller and SAINTEX according to the workload and performance criterions. This module is only effective for implicit dynamic tasks allocation.

-A performance estimator based on a calculation of kerosene consumption and takes into account the deviations between actual level and cape of each flight and the level and cape corresponding to the initial flight plan.

-A tasks demands stimator. These demands are only functional and take into account the difficulties encountered when assuming a plane, detecting the conflicts, correcting and supervising a conflict, and replacing a plane on its original trajectory.

4- First results and conclusion

Nowadays, we have validated from a technical point of view, the explicit dynamic tasks allocation on SPECTRA. Performances and workload estimators, even if

they are useless in explicit mode, are used so as to compare with implicit dynamic tasks allocation.

On the "dialogue operator" view, the conflict which can be resolved by the expert system SAINTEX, are indicated (figure 3-5), as well as the date before the conflict can be transferred to the calculator (figure 3-6). A priori, all the planes are given to the controller. If the controller finds himself overloaded, he can select a conflict, by using the mouse, and transfer it by using a sensitive area (figure 3-7). As the controller is the supervisor of the system, the possibility to take back a conflict is given to him, but at that time, the conflict can not be resolved by SAINTEX anymore.

Actually, manipulations concerning the implicit dynamic allocation mode are on the way, obtained results will be compared to those of explicit mode ones and will be permit to conclude on the more adapted mode for ATC system.

It appears, according to this first approach, that the use of dynamic allocation to the air-traffic control field is not easy. First, the conceptual model is being applied in a real dimension domain for the first time and, also, the ATC is very complex domain, where tasks are highly cognitive. For this attempt of application, this paper have outlined the usefulness of dynamic allocation for the ATC, and the encountered problems. Some principles to solve these problems are retained. The experimental platform developed has been validated and has already given some results. It has allowed to validate the explicit dynamic allocation principle.

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