Task allocation between man and computer for an electronic appointement book

Alain Michard

IRIA
CENTRE DE ROCQUENCOURT

Institut National
de Recherche
en Informatique
et en Automatique

Domaine de Voluceau
Rocquencourt
B.P. 105
78153 Le Chesnay Cedex
France
Tél. 954 90 20

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RESUME

Une méthode d'analyse du travail inspirée du concept de "fermeture de la tâche" proposée par EASON, peut fonder sur des bases empiriques solides les critères de partage des tâches entre opérateur et ordinateur.

Une tâche étant caractérisée par la stabilité des contraintes qui président à son exécution, on s'attache à montrer que le traitement automatisé d'une contrainte suppose la connaissance du domaine de variabilité de celle-ci et de ses interactions avec les autres contraintes. Cette analyse est développée sur un exemple d'agenda informatique.

SUMMARY

A method of work analysis inspired by the concept of "closeness of the task" proposed by EASON, can give a solid empirical basis to allocate tasks between operator and computer. Characterizing a task by the stability of the constraints that direct its execution, we try to show that to treat a constraint automatically, supposes the knowledge of its range of variability and its interactions with the other constraints. This analysis is developed using the example of a computerized appointment book.

I - INTRODUCTION

During the conception of a man-computer system, two broad options are often considered. The first consists of defining the appropriate algorithms and automizing as far as possible the execution of the task. This option leads to the realization of man-machine systems in which typically, the operator's role is to survey the process and perhaps to inform the machine.

The second option, however, gives the operator a leading role-the computer system being conceived as a tool to aid the process and not undertake its execution.

Many compromises are possible between these two extremes : in particular, the automation is often limited to parts of the process. Here, the criteria of choice are often unclear or purely empirical : that which can be programmed and have been valided on more or less related systems, is automised. It is widely admitted that this practice has its risks : a possible automation may not necessarily be desirable, even in strict terms of efficiency.

To encourage systematic reflection on the criteria of choice in task allocation between man and computer, EASON (1980) recently proposed to characterise a task by its degree of openess or closeness. A task is said to be closed if :

- the objectives remain identical during each realization of the task;
- the operator always goes through the same steps (algorithmic behaviour)
- the parameters that define each realization vary in predictable and relatively narrow limits (such that they do not change the nature of the task).

In a closed task, the constraints (conditions of realization) being known a priori, can be taken into account by the software : the task can be automated, the operator's role being to initiate, apply the parameters and control the system.

Inversely, in an open task, the computer system must leave the operator the freedom to find a satisfactory procedure in order to define a mode of operation for each realization.

We have tried to verify experimentally the soundness of this principle of characterization to define task allocation between man and computer, using a computerized appointment book. Two types of appointment book were composed : in the first, the finding of dates and times was undertaken by the operator who had complete freedom to "flip through" the pages of a graphic representation of the traditional appointment book and total responsibility in choosing a solution which respected the constraints demanded : delay between two appointments, order of several appointments, uniformisation of workload, etc.

The second system completely automated this finding, the operator's role being limited to introducing the request and choosing a date from three offered by the system. These two types of software were compared for problems of appointment -making which differed in the number and type of constraints demanded.

II - EXPERIMENTAL PROCEDURE

II-1 The task studied and its analysis in terms of constraints

We simulated the keeping of a hospital appointment book. The hospital had eight departments. The experimenter offered requests for appointments for consultations in these departments, the subjects had to find a date and time which satisfied the constraints that were indicated for each appointment problem.

Four problems were defined. The first was to make an appointment in only one department (simple appointment). The three others were to make two succesive appointments in two different departments (coupled appointments).

The following constraints had to be respected in order to obtain a satisfactory solution for this type of task :

- Precision or length of delay. The constraint for the operator was to minimise the interval between the date of the appointment requested (by the "patient") and the date finally fixed. This constraint is stable in the sense that it is a permanent requirement inherent in the task, but its set of possible values is impossible to fix in advance.

- Order of the appointments. In the problems of coupled-appointments the order of passing from one department to another is liable to be imposed. It concerns a constraint of ternary value (A-B,B-A, no order).

- Minimum interval between two coupled appointments. This is at least equal to the length of time for the first consultation, plus the time needed by the "patient" to pass from one department to one other. It can be increased by a variable value in terms of constraints peculiar to the department concerned (e.g. medical constraints). It is a variable constraint, stable at minimum value and theoretically predictible at maximum value.

- Maximum interval between two coupled appointments. In our example, the origin of this constraint may be medical. The interval can be requested as an imperative or indicative value. It is a variable constraint having its value in a theoretically predictable set.

- The availability of the patient. This is a variable constraint, peculiar to each case.

- The interests of the patient. Each "good solution" must minimise the patient's wait between two appointments and the number of his visits to the hospital, in the case where there is no precise constraint of connection between the two appointments. It is a permanent constraint, but each realization of which is a separate case.

- The workload of the departments. This stable constraint can be expressed at different levels of complexity. At its most simple it is only taking care to not make two appointments for the same time in the same department. At a more complex level it can mean a standardization of average workload for different days, etc. In own problems this constraint was only considered at its most elementary level.

- The length of a consultation. In reality this varies from one department to another. In our problems we fixed it at half an hour in each case making it, for us, a stable constraint of known value.

II-2 The problems

For all the problems the appointment book offered to the subjects was already sufficiently filled in so as to give no obvious, immediate solution. The four problems posed were the following :

Pb 1 : One appointment requested. Two months in the future (delay = 2 months). Availability of the patient was limited to certain times of the day. The optimum date to be found was in the week preceeding the date requested.

Pb 2 : Two, coupled appointments with imposed minimum and maximum intervals and an imposed order of passing from one department to the other. The patient was only available on certain days of the week. The request was for one month later. The optimum solution was for two weeks after the date requested.

Pb 3 : The same as problem 2 but with no imposed maximum interval.

Pb 4 : Two appointments in two different departments but with no order of departments and no imposed limits on the interval. The patient was only available in the afternoon. The request was for two months in the future. The optimum solution for one order of passing from one department to the other was a week later. A less good solution (a larger interval between the two appointments) was possible for the other order of departments.

II-3 The systems used

II-3.1. The "open" system. In this system the treatment of the different constraints which characterize the task is not

internalized : the operator must look for free times and identify them as being suitable or not within the constraints included in the problem. It is an "open" system in that theorically it makes it possible to solve any appointment problem.

For the practical functioning, a traditional paper appointment book was simulated :

- the subject begins by selecting the department(s) requested from a list which is presented to him on a screen.

- then a calendar is shown on which the subject chooses the date that the patient wants.

- finally, the system presents the subject with the workload of the department(s) requested for the week which includes the day chosen. This grid looks like a page of a paper appointment book and the appointments which have already been made are represented on the screen by a cross. If the subject does not find a solution on this grid, he may consult the grids representing the preceeding and following weeks, as if he were turning the pages of an appointment book.

In this system, the subject does not enter information, but it is selected by a menu technique by moving the cursor. The other operations (making an appointment, changing the week in the workload grids...) are made by function keys.

II-3.2. The automatic system. In this system the following constaints are taken into account automatically :

- Precision of the delay : the algorithm searches for the free dates which are the nearest to that requested ;

- The order of coupled appointments. The order requested by the operator is taken into account to find a pair of times;

- The minimum and maximum interval. There are by default two values which may be modified for each problem ;

- The interest of the patient. In the case of coupled appointments the program seeks to minimise the waiting time when other constraints make this possible;

- Workload of the departments. The system only offers free dates.

However, it can be seen that the availability of the patient is not taken into account in this system.

To use the system, the subject, using a keyboard, enters

the name of the department(s) and the date which is requested for the appointment. On the screen appear three possible times at once (or three pairs of times for the problems of coupled appointments) which satisfy the internalized constraints. The operator can then choose a date/time that is suitable to the external constraints. If none of the proposals is suitable, he can ask the system to offer him three different ones until a solution is found. He can also "hold" one of the three proposals which will be represented with two new ones on the following grid.

II-4 Subjects

Twenty subjects (office clerks) divided into two independant groups, took part in this experiment (each group working on one of the systems).

These subjects were inexperienced in that none of them knew the two systems.

II-5 Procedure

The subjects worked individually and went through a training phase before undergoing the experiment itself.

a) The training phase

This was carried out in short steps, following the chronological order of the operations to be made : the subject was given a written explanation of an operation, after which he was asked to apply it to a specific example. This continued until the whole task had been explained.

Then the subject had to effectuate the second training problem without the help of the written explanations, but if necessary with guidance from the experimenter.

If the subject had difficulty or made mistakes, he was given the problem to do again in order that he knew the handling of the system very thoroughly, which was indispensable knowkledge for the next part of the experiment.

b) The experimentation phase

This was begun by making the subject read the instruction, making clear what was expected of him, after which the terms of the first problem to be solved were given to him. When he had finished he received the terms of the second problem, etc. in a random order, which was different for each subject.

During the experiment all the subject's operations and the time needed for each were automatically recorded.

III - RESULTS

III-1 Time taken to choose an appointment

For the "open" system the timing began with the appearance of the timetable grid corresponding to the week requested. For the automatic system the timing began with the first proposal of three dates and times which satisfied the internal constraints.

For both systems, the timing stopped with a final choice of date and time (or pair of dates/times) by the subject.

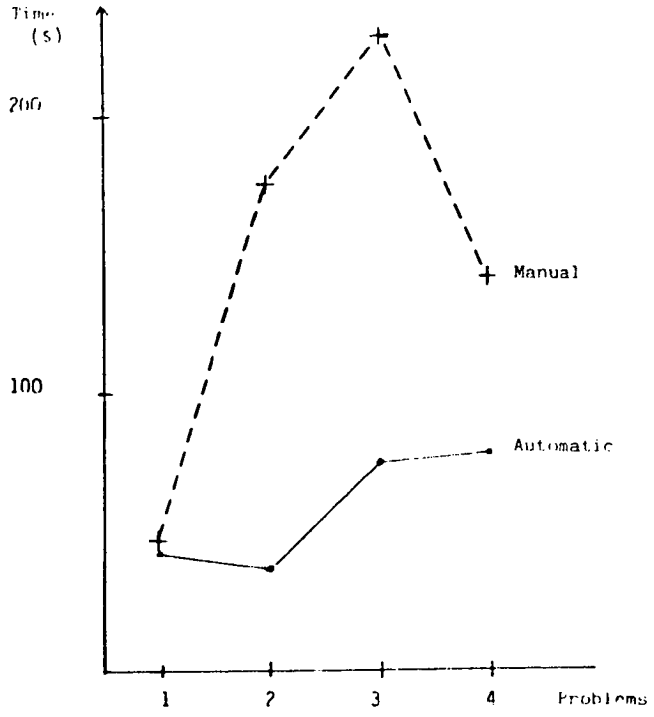

Fig. 1 :Average times taken to choose an appointment

An important difference can be seen between the times taken to solve a problem on the two types of appointment book (statistically significant difference) and an interaction between the "problem" and "type of appointment book" factors (statistical significant .01), the two systems being equivalent for problem 1 and the automatic system being the faster for problems 2,3 and 4.

Moreover, with the "open" system, the discovery time is longer for problems with numerous and strict constraints (2 and 3) than for problem 4, for which there were fewer constraints. With this system, the time spent looking for a solution thus seems to be a good indication of the subjective complexity of the problem.

III-2 Analysis of the errors

subjects and was proposed on the next grid.

It will be noticed that the system gave preference to the precision constraint by presenting firstly the possibilities nearest the date requested, even if they were not the optimum ones from the point of view of the patient's interests. It thus seems as though half the sample of subjects had "confidence" in the machine and accepted the first offer which satisfied the external constraints without looking any further by asking the system for other alternatives.

With the "open" system, the neglected constraints were : precision of the delay (2 subjects) ; maximum interval (one subject) ; order of passing from one appointment to another and the interest's of the patient (one subject).

III-2.3. Errors in problem 3. With the automatic system, one subject rejected the optimum offer, subsequently keeping another which was less satisfactory for the constaints "precision" and "patient's interests".

III-2.4. Errors in problem 4. Almost all the errors observed for this problem arose from the fact that the subjects considered only one order of passing from one department to another. With the open system, four subjects thus imposed upon themselves a supplementary constraint which led them to choose non-optimum solutions for the precision of delay (2) or for the interests of the patient (2). We can point out that nothing in this system gave preference to one order rather than another and the instructions clearly specified that the two appointments could be made in any order. The two appointment books being laid out side by side on the two right-left halves of the screen, the subjects gave preference to the reading order looking for the first appointment in the left-hand appointment book, then another acceptable appointment (not too great an interval) in the right-hand appointment book.

With the automatic system all the subjects made the same error. However, in this case the error was to a greater extent induced by the system : which at the start of the task imposed that either an order is fixed, corresponds to a real constaint (problems 2 and 3) or is arbitrary. To solve problem 4 correctly, it was necessary to seek using the A-B order, then to seek using the B-A order and keep the best solution. This is not a classic type of automatic system manipulation and had not been described during the training phase. None of the subjects thought of this possibility spontaneously.

This error could have been entirely attributed to an imperfect adaptation of the system to solve this problem if it had not appeared with such noticeable frequency in the group using the "open" system. This leads one to think that it concerns a more general phenomenon : it seems as if the subjects, faced with this problem, adopted an arbitrary order

from the start and stuck to it without considering looking for a better solution using the opposite order.

IV - CONCLUSION

The results presented, as concerns observed times, are closely connected to the particular softwares used and to some extent, the specific problems that the subjects were given. They show the general principle that certain softwares are well adapted to the treatment of certain problems and less effective in solving similar problems of the same class. Explained as such this principle is so general and obvious that it is of no use to systems-design . What is necessary then, is a tool to describe the task and the system's characteristics which will make it possible to design an efficient system for all the possible realizations of the task.

It seems that the analysis of constraints partially satisfies this need. During the realization of a task (the making of an appointment) the operator or the man-machine system must satisfy a certain number of constraints. Certain of these are stable throughout each realization of the task, or vary within narrow and predictible limits for the functioning of the machine. Others are characterized with each occurence of the problem and can take very diverse values : they are "external" in the sense that they must be taken into account by the human operator.

The design of a "good" system must thus begin by an analysis of the task in order to identify the different possible constraints that are likely to arise during a particular realization.

In this case of an appointment book, the analysis makes it possible to distinguish :

- Stable constraints :
  -- an appointment cannot be made outside certain hours.
  -- two appointments cannot be made for the same time.
  -- etc.

These constraints were internalized in the "automatic" software without giving rise to errors.

- Constraints present in most realizations and varying only within narrow limits : this is the case in particular of the minimum interval to be respected between two appointments for the same person in two different departments and corresponds to the necessary time forseen for the first appointment, plus the time necessary to go from one department the other.

Our results show the advantage of internalizing this type of constraint in the system : when they are relevent to the

problem (problems 2,3,4) the time taken by man-machine system to reach the solution is much longer than if the treatment of these conditions is undertaken by the operator.

- Constraints which vary greatly from one situation to another. This is the case of the unavailability of the "patient" at certain times or days. It can be supposed that these constaints can be handled by the operator, their automatic treatment implying a parametrisation of the seeking algorithm which is likely to be much longer and more painstaking than a straightforward selection or rejection of the dates offered by the machine.

The example of an appointment book also illustrates several types of error which can be made during this analysis of constraints, and bring to light an important omission that is shown by the analysis of errors.

The following are the errors in design of the appointment book systems which we studied and can be explained by the analysis of the task's constraints :

- Non-internalization of stable constraints into the system. This, in the "open" system, is the case of minimum and maximum intervals and the order between coupled appointments, and the precision of the delay requested. We have seen that these constraints were not always respected by the subjects. In particular the internalization of the order avoids for using the seeking on later dates as shown in problem 1.

- A too narrow limitation in the range of a constraint's variation. This concerns the "order between two appointments" constraint, which in the automatic system could only take the values A-B and B-A. If the system had taken into account the value "absence of order" a more systematic seeking would have been provoked and the errors made in problem 4 would have been avoided.

The omission which appears in the analysis of the constraints is the failure to take into account an explicit hierarchy among the constraints. Many errors would have been avoided with the automatic system if we had taken the relative priorities between constraints as a stable constraint which was internalized in the system. In particular the relative priorities between the "precision" and "interests of the patient" constraints could have been treated by an algorithm, thus avoiding several errors.

In conclusion, it can be maintained that analysis of the task in terms of its constraints taking into account their degree of stability and set of possible values, appears to be afruitful method of fixing the functional specifications of an interactive system. Its use in real situations will demonstrate the possibility of usefully describing tasks more complicated than the making of an appointment for the design of a computer system.

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