A Modelization Of The Task Allocation Problem For Prescribing Activity In An ICU.

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Abstract

The improvement of coordination between Health Care Professionals belonging different specialities and who are extremely mobile, is a crucial problem in Medicine. A workflow System is one example of the new informatics tools which facilitate the transfer of information and responsibility between health care providers. Medical informatics systems in particular should be reactive enough to cope with the flexibility of real work situations: in this paper, we present the task allocation problem. We distinguish between the workflow control process and the notifying process, which concerns the sharing out of the tasks between the actors concerned. We focus on the impact of strategies of notification on the progress of coordinated work. We propose a simulator to model and study the different ways of sharing tasks between actors in an Intensive Care Unit's activity of prescription.

Introduction

The emergence of new tools in relation to the development of new computers technologies brings about changes in the work environment. Computer applications are increasingly being considered as a medium for communication and for human interaction. In Medicine, the dimension of coordination is very crucial but the pertinent tools are still rare. This could partly be due to the complexity of coordination in medical activities. Nevertheless, it is important to know more about the organization of coordination in medical activities. Health cost, professional stress and the risk of breakdowns in the health care process could be reduced by improving the distribution of work load, and also by promoting good communication between health care actors.

In Intensive Care Units (ICU), the need for good coordination is particularly important due to the urgency and the difficulties of care in such units. While studying the activity of prescription in such services, we have previously shown that breakdowns could occur, and these were often due to a lack of good communication between the different health care professionals 1.

Some tools identified from studies in Computer Supported Cooperative Systems are able to solve part of the coordination problem. We aim to use a conversation-oriented workflow inspired from the Winograd and Flores’ workflow 2 to model the activity process of the global prescription in ICU. A cycle of prescription, planification, dispensation and evaluation could then represent such an activity².

But even with such sophisticated tools allowing for a good control of the flow of information and of the succession of tasks to perform, a difficulty persists concerning the notification of the actors or the tasks to perform when a complex activity is involved. In such complex situations as those encountered in ICU, a rigid system is inappropriate. We propose to study the impact of task notification on the activity of the service.

The task allocation problem

The dynamic association between role and actors, which takes the context into account by notifying one or several actors in normal or crisis situation is a major factor for improving the ability of the whole System.

The problem is to determine at each moment which actors are to be notified of the tasks to perform. If the system does it in an overly restrictive way, it would be too rigorous and wouldn't take into account the natural flexibility of a work where several persons can perform the same task; if it does it in overly
flexible way, it would give so much information that it would be impossible to have a good visibility on the problem to solve.

Our system is built on two different modules distinguishing explicitly between: (fig. 1)
- the Placo-Flow System (PFS), which is a workflow strictly in charge of organizing and coordinating the tasks to perform, relative to theoretical competence (responsibility, qualification, experience...) needed to perform the actions, and
- the Task Routing System (TRS) whose action is to identify the actors available to perform the tasks and share out the notification of the tasks to perform between the identified actors.

The model has to take these two principles into account to be useful and accepted in real care units. A sophisticated Task Routing System should be able to adjust its comportment to the contextual environment of care.

Model

Principle

The goal of the TRS is to link the tasks to the actors in the most efficient way. We base the strength of the system on the two following points:

1. **Distinguishing between the theoretical and pragmatic roles of actors.** The theoretical role describes the precise qualification required to perform a task. Such primary roles in our application are *prescriptor, planificator, dispensator and evaluator* roles, which correspond to the four different types of action to perform in our system. But a role could be more complex, integrating some qualifying criteria like "expert" for a particularly delicate prescription or "indifferent" for a usual prescription. The pragmatic role is deduced from the state of the whole system and reduces the constraints if need be and if acceptable.

   Let's take the example of a difficult intubation. The theoretical role required is that of a prescriptor+expert. Before affecting actors to this role, a pragmatic role is defined depending on the state of the system. Normally, only the health actors whose qualification allows them to intubate and who are experts would be notified of this tasks. The pragmatic role is the same as the theoretical one: a prescriptor+expert. In a critical situation, however, the pragmatic role is that of a "prescriptor" and the whole team of prescriptors could be notified.

2. **Using strategies for task allocation.** Beyond the necessity of a dynamic repartition of tasks on the different actors, it is important to identify the consequences of the strategies used in task allocation. Effectively, if it is possible to distribute tasks dynamically to actors, it is also possible to elaborate strategies to guide this distribution. It then remains to be seen how the use of these different strategies on the work distribution of health care actors impacts on the functioning of the entire unit.
In computer science, the problem of resource allocation is well-known. Parallel algorithms are used to design resource allocation so that the system will be sufficiently high-performance. The two principal types of algorithm are: static ones when process affecation is statically made during the compilation, and dynamic ones when the affecation is dynamic and depends on the contextual charge of the system. In ICU, it is necessary to know about changes in the health care process and to consider dynamic affections. The difficulty with such systems has to do with finding the optimum ratio between the advantage of having a more high-performance repartition of charge and the inconvenience of evaluating this performance (evaluation of the charge, cost of the change of affecation...).

Simulation

Testing some of the solutions envisaged in a real ICU is not feasible:

Firstly, given that several solutions for this dynamic linkage between providers and tasks, we are not certain that it is safe to try them directly in ICU.

Secondly, problems arising from system acceptance, due to the use of an inappropriate interface, for example, could mask the problem being studied, that of work distribution. We therefore opted to test our routing algorithms by simulation.

Task Management

One cycle of simulation represents a unit of time. Given that there are several patients, for whom several workflows are associated, the system can manage a large number of tasks. In one cycle the Task Routing System splits the work into three phases which are at the core of the routing principle: extraction, presentation and choice.

1. The first phase (extraction) allows for selecting among the tasks those the system will propose to the actors.
2. The second phase (presentation) manages the notifying of actors that certain tasks have to be performed,
3. The third phase (choice) is to determine which task an actor will carry out.

Strategies

The three decision phases of task management contain strategies for refining the comportment of the system. So, the system manages Extraction strategies, Presentation strategies and Choice strategies.

1. Extraction strategies are in charge of deciding those tasks which will be presented to the actors: the entire list of tasks, the highest priority tasks or randomly chosen tasks.
2. Presentation strategies are more complex, they decide on which tasks would be presented to which actor. Two steps are used to achieve the presentation: the first step defines the pragmatic role required, the second step decides which actors - amongst those who could endorse the pragmatic role - will be notified of the task.
3. Choice strategies compose the last step of control and allow an actor to chose a task: the highest priority task, the oldest task, or a random task.

Fig. 2 mentions these strategies.

![Fig. 2: Each step of the TRS contains strategies to refine the routing comportment](image)

**Simulator**

By using a simple representation of actors and tasks, the simulation describes the ability of an organization to execute a number of coordinated tasks. It could help us to assess the ability of the chosen strategies to support an increase in the number of tasks to be performed. The main criterion is the possibility to perform a task in an specific time interval. Other criteria are the number of actors and patients as well as the repartition between nurses and physicians. Firstly, we are interested in a specific situation: one in which the simulation begins with a lot of tasks. When a workflow cycle is run, it ends and there is no further generation of new tasks. The decrease in work charge allows us to test the ability of the system to take extra work into account.
Two major indicators are defined to evaluate the ability of a simulation to manage the allocation of tasks to actors efficiently.

1. The Average Priority Level of the tasks when they are chosen by the actors: an efficient combination of TRS strategies must reduce this level. This indicator is important for knowing more about the behavior of the system: if too many tasks are urgent, the situation could become unsafe for the patients.

2. The Average Workload of the actors which gives information about the feasibility of the tasks: a heavy workload could lead the system to a bottleneck situation with too many waiting tasks. The Load Balance between the actors of the unit is also very important: an efficient dynamic task allocation must balance the load (i.e., the presented tasks) between actors.

The simulation is based on the representation of actors, patients, workflow and tasks and has three functioning phases: initialization, coordination and aging.

During the initialization phase the system creates the patients and the health care providers (nurses or physician), and creates a workflow whose first phase generates the initial tasks of the system. Each workflow represents one medical care associated to a patient.

For example patient1 is associated with a first workflow: WFL1 (1 prescription, 1 planification, 3 dispensations, 1 evaluation) and a second one: WFL2 (1 prescription, 1 planification, 1 dispensation, 1 evaluation)

In the coordination phase, the system makes actors choose some tasks, which are then marked as done. Each time a task is done, the associated workflow gives information on the next task. During this phase the TRS is used to route the tasks to the actors by managing the task lists.

Example: Prescription of WFL1 is done, planification of WFL1 is then to perform, the TRS would add this task to the list of tasks of nurse3 and nurse4.

The aging phase allows us to induce an evolution of the system context. In a real situation, the parameters of the system are naturally and dynamically modified: the patient fever increases, time is going and the urgent nature of care becomes very high... In order to have an evolving situation in the simulation system, an aging module is defined which principally increases the priority of tasks.

The simulator output consists in statistical data:

- The initial state of the simulator: number of patients, number of actors, actors' roles, specification of the initial tasks and of the initial workflow cycles on patients.
- In running mode, output contains information on extraction, presentation, action and aging.
- At the end of simulation, output displays a summary of actions performed: task distribution and statistics on the time needed to execute the tasks.

### Materials and Methods

The simulation model is developed under Java which allows an object-oriented programming and a distributed system. The architecture of the system is modular so that it will be easy to add or modify some parts of the system. The strategies are adapted from the design patterns described by Gamma. Four classes of generic strategies are defined: extraction, defining role, presentation to the actors, choice. Each of them is instantiated by one effective strategy when running the simulator.

### Results of Simulations

The simulations depend on about 14 characteristics (from the number of nurses to the Load Threshold). The load threshold determines the constraints maintained from the theoretical role to the pragmatic role: above this threshold the constraint of the respect of the actor's status disappears (i.e., a physician can be led to make a dispensation). These characteristics are the simulation parameters. The simulator is able to model prescriptions activities in an ICU. We are now studying the effect of combined strategies on task realization.

We illustrate below the effect of the presentation strategy, based on the definition of the pragmatic role. The two graphs show the difference between the physicians' workload (usually represented by prescriptions and evaluations) and the nurses' workload (usually represented by planifications and dispensations), using a diminishing global workload. In figure three we can see an important gap between the two workloads, which can be explained by a high load threshold (i.e., pragmatic role is as constrained as theoretical role: tasks are presented strictly to the
appropriate actors). In figure four, on the contrary, this gap is reduced as a result of the use of a lower load threshold, which leads to the participation of actors in the realization of tasks that they usually do not have to manage.

![Figure 3](image1.png)

**Fig. 3. Load balancing between roles – High load threshold - Decreasing global workload.** The work is strictly done in function of the required status: physicians and nurses. Physicians have slack period after doing the prescriptions and before the evaluations while the nurses work a lot in between.

![Figure 4](image2.png)

**Fig. 4. Load balancing between roles – Low Load Threshold - Decreasing global workload-** The low load threshold allow a better repartition of work charge. The global work charge of physicians and nurses is more constant, the global work is done quickly.

**References**


**Conclusion**

Even if coordination is a crucial problem in medicine, where the mobility of actors and the number of specialists involved in care are very important, coordination tools are still rare in medical units. The improvement of such a coordination could further improve the global quality of care. With our simulator, we dispose of a tool for studying the impact of the care organization on the workload of the health providers. The results show that such a modeling of prescription activities is possible. The next step in this research deals with the refinement of the elements of simulation and on a precise study of the impact of combined strategies on the actors' activity. Further perspectives lie in the use of such information to build new coordination tools for use in medical units.