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MIXING MANUAL AND COMPUTER-SUPPORTED INITIATIVE FOR SCHEDULING AND NEGOTIATION ACROSS DISTRIBUTED ORGANIZATIONS

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ABSTRACT

Several user studies have shown that in many cases electronic planning and scheduling tools are perceived by the users as disruptive with respect to their actual work practices often based on physical tools. This can result in rejecting such electronic tools without fully appreciating the long-term benefits of their adoption. As a part of a larger effort for providing support along scheduling and negotiation processes across distributed organizations, we have designed a solution to allow manual and computer-supported mixed initiative that aims at letting the users continue working according to their work practices leveraging the benefit of an automated support.
In this paper, we describe our solution also motivating the design choises we made. We show how our solution allows users interact with a manual editing facility to schedule and manage their work activities and, when appropriate, to select and publish scheduling information for triggering negotiations on services with other, possibly remote, users. We illustrate our approach in the context of a business-to-business scenario where users are decision-makers in print centers scheduling and negotiating print jobs.

INTRODUCTION

Users for several reasons may reject planning and scheduling tools. In many cases the main reason is that the tool is not adapted to the actual work practices or, even worse, the users perceive it as totally disruptive, even if they are very interested in the functionality the tool provides them with.
Let's take as an example a workplace where people managing tasks schedule are used to work on a paper support. They may be reluctant to change this practice for adopting a fully computer-supported scheduler, even if the scheduler is very flexible and powerful. They would feel forced to make a choice between the two approaches. On one side there is a consolidated work practice that they know and that is more or less satisfactory. On the other side, there is a new work environment, that they do not know and that after a given time period would (probably) prove to be more effective.
Several field studies and surveys have shown that a number of people prefer to work on physical supports more than with on-line tools (Whittaker and Schwartz 1995). This seems to be due to a general lack of confidence in non-physical objects and also the greater commitment a physical interface imposes. However, without providing electronic information, users loose the benefit of an automated support.
For many years, research has been undertaken on how to bridge the gap between the physical and the electronic worlds. For instance, in the case of a paper-based physical world, existing approaches to this problem can be classified into two groups as described in (Karsenty et al. 2000). The first group includes systems linking the paper to the electronic world; a typical example of this category are barcodes. The second group includes paper-based applications, namely systems that take a specific existing paper object, e.g. a print coversheet or a flyer, and extend its capabilities. See (Karsenty et al. 2000) for examples of systems belonging to one of the two groups.
In this paper we propose a solution, consisting of an architecture and a protocol, enabling a mixed human and computer-supported initiative along distributed scheduling and negotiation processes. We assume a distributed setting with autonomous workplaces offering similar and/or complementary competencies and abilities. Each workplace collaborates, but also competes, with other workplaces to improve its own ability to accomplish customer requests. Moreover, each workplace is very much or completely responsible for managing its schedule.
Users work on a manual editing facility. Our solution encapsulates methods allowing: (1) Users to express scheduling decisions by manually selecting and moving scheduling information slots; (2) Translation of scheduling information to negotiation information; (3) Activation of task negotiation across distributed sites; and (4) Translation of negotiation information back to scheduling information.
In order to show our approach we use a scenario where workplaces are print centers (called printshops in the sequel) and users are printshops decision-makers scheduling and negotiating print jobs. However, the kind of interactions we consider is very generic and can be applied to other contexts involving scheduling activities.
The paper is organized as follows. We first show the design choices for the solution we propose and the printshops scenario. Then, we describe the architecture and the protocol of our solution and a paper-based instance of it, called PaperSchedule. Finally, we discuss related work.

OBSERVING THE SCHEDULING ACTIVITY

Several case studies have been conducted to observe the impact of the introduction of electronic schedule tools and to compare them with practices based on physical artifacts. We

have based our design choices on two of such studies: the first one comparing the usage of electronic tools with large visible planning board in the context of project activities, the second one studying the more specific setting of factory production printing.
The authors of the first study (Whittaker and Schwartz 1995) have observed two groups of approximately twenty people in size, one using a commercial scheduling tool, the other one using pen-and-paper manual procedures on large wall boards. The results coming from the qualitative observation has provided us with insights regarding the different phases of the scheduling activity, that have informed the design of our system:

- *Initial planning.* A key feature of the initial planning is to be accurate and credible, because it impacts heavily all the starting decisions. What has been observed is that the **physical manipulation** required by the paper artifacts resulted in a higher degree of engagement. Moreover, the **public** nature of schedule encouraged a collaborative effort in creating it and awareness of the decisions.
- *Updating.* The activity of keeping the planning accurate and reflecting the current situation that other people can rely on to take appropriate decisions. Therefore easiness in updating is a key feature to achieve collaboration. The **public** nature of the schedule provides a way to acknowledge individual contributions (or lack of those), is therefore an incentive. However, they observed as well the drawback that the updates are more costly on a physical artifacts and this can have a counter effect decreasing accuracy of updates.
- *Replanning.* Replanning is a typical frequent activity on schedules and of course all the advantages of the planning phase are present in this one. Additionally the physical artifact has been proved to provide more **flexibility**, by allowing the allocation of a neutral area where to keep tasks not yet allocated.

We agree with the authors of this study that electronic shared scheduling tools have to be designed taking into account the above-observed benefits. In particular they should "be public, to promote commitment and conversation; material in affording engagement and reflective use of the tools; and they need to simulate the dimensions of size and visibility in supporting ready access to complex information" (Whittaker et al.1995).
The second case study is about the observation of how the order of production printing activity is carried on in one of the major UK factory. This case study provided us not only the observation of the usage of physical artifacts, but also a more complex setting, because the possibility for the factory to work as part of a network of autonomous printshops. We were interested here in the nature of the physical artifacts used in that organization and the perceived affordances they presented. Several paper-based artifacts have been observed to store information about the incoming requests, their current schedule and the resulting current activities. Among those the artifact specifically supporting the scheduling activities is the "forward-loading-board". The forward-loading-board is a scheduling artifact used to work up the daily array of jobs into a rational production order, such that the administrative manager can perform calculation and take decisions for example about accepting an incoming order or a negotiation with another manager for a given print job. In this setting, as a previous one, a key feature of these artifacts has been observed: they were visible "at-a-glance", because they were publicly available and on public display. In this setting this aspect was observed as to be a crucial one to see which jobs have to be shifted and which delays in production can be detected. Additionally, because of the willingness to work in a network of printshops, being therefore able not only to manage locally the schedule, but to exploit resources of other printshops if possible, this observation suggested that an ideal solution would be a system being able to keep all the benefits provided by existing physical artifacts, while being able to publish to the network information on the current status for negotiation purposes.
Building upon these case studies (Button and Sharrock 1997, Pycock et al. 1998, Whittaker and Schwartz 1995) and the description of a variety of print work processes (Eliezer and Zwang 1997), we have defined a model describing printshop activities (Andreoli et al. 2000) as illustrated in next section.

SCENARIO

We assume a distributed setting with autonomous printshops offering similar and/or complementary competencies and abilities. Each printshop collaborates, but also competes, with other printshops to improve its own ability to accomplish customer requests. Moreover, a printshop is very much or completely responsible for managing its schedule. In a printshop, users use manual supports (e.g. paper sheets) to manage their planning/scheduling activities.
The planning/scheduling can be represented in several ways. For example, a representation of the schedule on a paper sheet could be a Gantt chart with print machines along one dimension and the time units along the other dimension. Users allocate jobs trying to optimize the workload of the machines and respecting the time constraints. Jobs may be represented as rectangles whose length is proportional to the estimated duration of the job on a given printer machine. Additionally, unallocated jobs can be listed outside the Gantt chart. Figure 1 shows a simplified example of a schedule, with several jobs allocated to machines on the vertical axis.

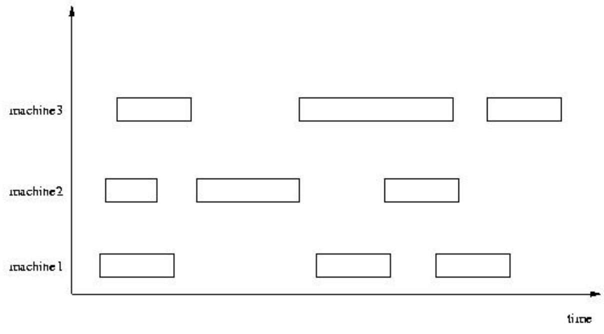

Figure 1: A Sample Schedule

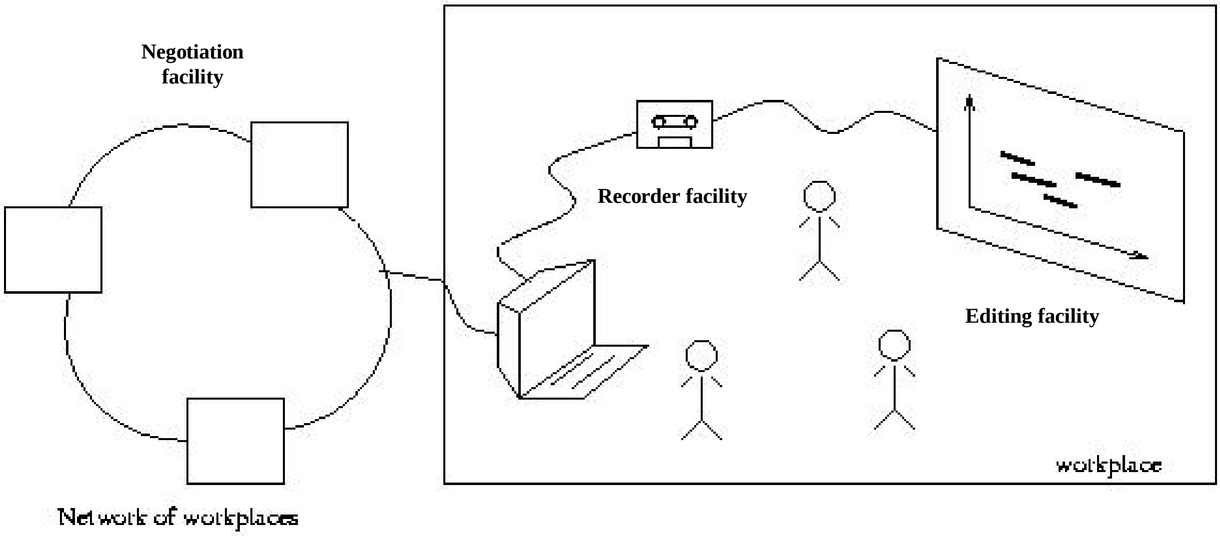

Figure 2: The architecture including an editing facility, a recorder facility and a negotiation facility

From time to time the printshop decision-maker may make the decision to "***insource"*** a print job from another printshop, using a free time slot on a given machine, or to "***outsource"*** a given print job (part of the Gantt chart or of the unallocated jobs list) to another printshop. She will make those decisions basing upon information on the current job schedule and the printshop's technical capabilities, leveraging her knowledge of the customers. She may then start to negotiate with the decision-makers of other printshops for example to outsource a print job trying to find a satisfactory solution in terms of time and price.
This model attempts to capture significant kinds of behaviors even if it can be further enriched. Moreover, the kind of activities and interactions we consider here are quite general. Then, our approach could apply to other kind of organizations, wherever scheduling activities occur to manage work activities.
Next section describes the design of our solution for supporting this scenario, with a more detailed description of the user interactions with the scheduling and negotiation facilities.

OUR SOLUTION

Our solution comprises three facilities: a manual **editing facility**, a **recorder facility**, and a **negotiation facility**. Figure 2 shows in a simplified way the architecture including the three facilities.
Users use a manual editing facility to manage their planning/scheduling activities in a workplace, e.g. a printshop. When the user(s) (e.g. the decision-maker) make(s) decisions (e.g. *outsourcing* a print job), the editing facility will allow to manually express those decisions. A recorder facility (e.g. a camera) will recognize the scheduling decisions and translate them into negotiation information. The negotiation information will be used by a negotiation facility to manage negotiations with other workplaces. Finally, the negotiation facility will provide the results of the negotiations, if any, that will be presented to the users.

The architecture is such that several user interfaces can be adopted. It only requires the capture of selected scheduling information at a site and at specific points in time. The manual editing facility can range from being totally non-electronic (e.g. a whiteboard) through to totally electronic (e.g. a large screen display). The planning/scheduling can be represented in several ways.
Let's see more in details the interactions among the users and the three components of our architecture, in the context of our printshop example.
Users use an editing facility to manage their planning/scheduling activities allocating jobs trying to optimize the workload of the machines and respecting the time constraints. Decision-makers will express their decisions as interactions with the editing facility. When the decision-maker makes the decision to try to insource a job from another printshop, using a free time slot, she will delimitate it with an *insource shape*, e.g. a rectangle, and put an *insource mark*, e.g. a checker on it. When the decision-maker makes the decision to try to outsource a job, denoted by an *identifier*, to another printshop, she will put on it an *outsource mark*, e.g. an asterisk.
The recorder facility will capture these decisions from the editing facility capturing the marks and recording other information. Information captured by the recorder facility will be propagated to a negotiation facility thus triggering the appropriate negotiations with other printshops.
For the interactions among the user, the editing facility and the recorder facility there are at least three modalities. In the first modality, the recorder facility is active all the time; it records the information displayed by the editing facility and reacts immediately to the actions of the decision-maker. In the second modality, the recorder facility becomes active upon a decision-maker request.
The editing facility would contain a **control region** enabling the decision-maker to trigger the actions of the recorder facility. When the decision-maker puts an *activation sign* into the control region, the recorder facility collects the information and sends them to the negotiation facility. When the decision-maker puts a *stop sign* into the control region,

the recorder facility stops recording. In a third modality, the recorder facility records information displayed by the editing facility and sends this information, from time to time, to the negotiation facility as an “exploratory” information. In the first two modalities, when the recorder facility is triggered, it collects a number of time and technical information. For example if the decision-maker has selected a free time slot with an *insource mark*, the left end and the right end of the rectangle corresponding to the slot will provide respectively the earliest possible start time and the latest possible end time for it. This time information combined with the description of the machine technical capabilities will be the negotiation information sent to the negotiation facility. On the other side, if the decision-maker has selected a job (with a given identifier *id*) by marking it with an *outsource sign*, then the left end and the right end of the rectangle corresponding to the *id* job will provide the earliest possible start time and the latest possible end time for it to be performed. This time information combined with the description of the job technical requirements (which is entered in the electronic system when the job is accepted) will be the negotiation information sent to the negotiation facility. In the third modality, the recorder facility will collect information about empty spaces and tasks that will be sent to the negotiation facility for exploratory purposes.

When the negotiation facility receives the negotiation information, it starts the appropriate negotiations with the other workplaces. A number of negotiations schemes can be adopted. When the negotiation facility receives exploratory information, it will use it to search for matching requests from other printshops. For each negotiation, the negotiation facility will collect answers and possibly select solutions, if any, and provide them back to the recorder facility or to the wall editing facility. The recorder facility or the editing facility will show the negotiation results. One possibility, among others, for showing the negotiation results is to list the solution(s) found in a menu, when the user selects the item associated to the negotiation. Moreover, the negotiation facility will provide the results of its explorations, if the exploration mode is allowed.

Also, the decision-maker may want to stop some of the ongoing negotiations because in the meanwhile she has found a solution for the allocation of some of the jobs and the time slots. In that case she could mark the jobs and the time slots for which she wants the negotiation to be stopped with an *end mark* and then put an *end sign* into the control region.

IMPLEMENTATION

As a negotiation facility for implementing our solution we have adopted AllianceNet (Andreoli et al. 2000), a framework allowing users, belonging to organizations grouped into an alliance, to flexibly negotiate items or services. When negotiation succeeds, results are shown back to the user and consequent actions are performed, where appropriate. For example, if the negotiation is about a job outsourcing and the negotiation succeeds, the physical job is automatically transferred to the appropriate printshop. For the editing and the recorder facilities we have considered three possibilities.

One possibility was to use a whiteboard as the editing facility and the ZombieBoard as a recorder system (Moran et al. 1999), given the the techniques for image processing offered by the ZombieBoard (segmentation and grouping rules, symbol recognition, text recognition). Users could draw schedules and control marks with a pen and/or by using magnets. The control region could be a square delimited region at the left-hand corner of the whiteboard. The ZombieBoard allows the user to identify a specific region to be selected. This feature would allow the elaboration of specific areas of the schedule starting/stopping negotiations corresponding to jobs and time slots in those specific areas and letting the decision-maker continue working on the rest of the schedule. The negotiation facility may provide the results of the negotiations (if any) to users on the whiteboard. A projector may project different colored lights on the work items for which negotiations succeeded or explorations succeeded (if the exploration mode is allowed).

Another possibility was to use a large screen display as an editing facility. The Tivoli application (Moran et al. 1998) simulates whiteboard functionality on large screen displays. It provides basic pen-based scribbling and editing with pen-based gesturing and wiping techniques and a scripting language to tailor “domain objects” to specific applications. This layer allows the bi-directional exchange of data between the whiteboard-like display and the actual application behind it. Tivoli provides the ability to script special domain objects (imported/exported from external databases) that users can interact with on the board. In this case the domain objects would be jobs and machines and users could draw their schedules manipulating these objects through a graphical editor. The control region could be a square delimited region at the left-hand corner of the large screen display. The negotiation facility may show the negotiations results to the users on the large screen display. For example, the screen could display colored rectangles in correspondence of the work items for which negotiations have succeeded or explorations have succeeded (if the exploration mode is allowed). Multiple negotiation results could be displayed in a menu when selecting the item associated to the negotiation.

Finally, there was also the possibility to use paper for editing and a scanner device as a recorder system. We created an instance of our solution adopting this option where jobs are represented and identified on “planning sheets” and users schedule and negotiate jobs interacting with the paper. Ideally, the user will be able to walk around the printshop with the paper sheet, making decisions on the fly observing the situation and then scanning the schedule when decisions are mature. Next section shows into details this paper-based instance of our solution, called PaperSchedule.

A PAPER-BASED PROTOTYPE

Before describing PaperSchedule, we recall the principles that have driven our design:

- Physical artifact to support a bigger degree of engagement in the decision
- Public nature of the artifact to support collaborative activities.

- Public nature to support peripheral awareness of the current state of the schedule.
- Support to transient state (i.e. activities existing, but not yet allocated.)
- Possibility to publish to a network selected information about the current state of the schedule.

Jobs Representation and Recognition

Jobs are represented using cardboards with a unique identifier, associating to them DataGlyph™. DataGlyphs (or glyphs for short) are a 2-D data encoding technology, similar to bar codes (Hecht 1994), see Figure 3.

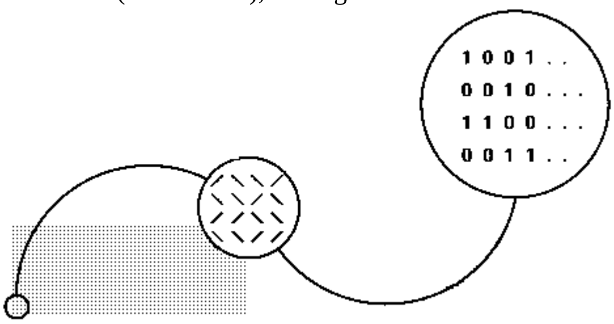

Figure 3: Xerox DataGlyphs

A DataGlyph contains an array of \'s and /'s, and within this array, any data can be coded on paper documents scanned at a resolution of 300 dpi. Figure 4 shows an example of a job glyph (close to real size) like used in our solution. It includes a 16*16 glyph encoding 12 bytes. Below the glyph, information associated to the job is displayed to allow the user recognizing the job: the name of the customer (e.g. **`client1`**) and the name of the job (e.g. **`job3`**). That information is recorded when entering the job into the system (as described later). The user attaches glyph stickers to cardboards for uniquely representing the corresponding jobs. Cardboards are one inch high, and they are precut so that they can be cut appropriately to represent jobs.

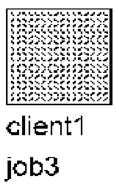

Figure 4: An Example of a Job Glyph

Analogously, free time slots where the user wants to insource a job are represented with specially tagged cardboards delimiting the time region to insource.

Planning Sheets

Users create and manage their schedules on "planning sheets", by placing cardboards on them. Figure 5 shows an example of a planning sheet.

Planning sheets are instances of interactive paper containing scheduling information in a format that can be captured when scanning them. The interpreter of the scanned images has been built on top of the FlowPort™ toolkit (Hecht 1994). FlowPort is a server application that processes scanned images and provides to our application two main set of services: location of the DataGlyphs areas (and their decoding) and image segmentation to locate the jobs and their length. Planning sheets are now described in details.

In the top left corner, there is a 16*23 glyph that identifies the sheet, including information about the layout of the week. The two black squares printed at the bottom of the page are called the registration marks and make it easier to identify the location of rectangles by using relative position to the marks. The registration marks are used for determining the corresponding time span and to which machine each of the jobs is scheduled. They are also used for determining the orientation of the image. This means that even if the image is scanned upside-down or with a 90, the program will interpret it correctly.

To identify himself as the "owner" of the schedule when scanning the schedule in, the user will use a FlowPort™ Cover Sheet as shown in Figure 6. Next section describes in details the interaction possible with the planning sheets.

Scheduling and Negotiation

The main actions the user can perform interacting with a planning sheet are to:

- Allocate a job to a machine local to a printshop.
- Ask for outsourcing a job.
- Mark an area as suitable for insourcing
- Change job schedule.
- Withdraw outsource or insource requests.
- See negotiation results, if any.
- Fixing some constraints as definitive.

The user can allocate a job to a machine local to the printshop by placing the cardboard on the position corresponding to the machine in the planning sheet. If the user wants to outsource a job, she will put it on the "outsource area" below the chart on the planning sheet (see Figure 5). If there is any free time slot where the user wants to insource a job, she puts there a cardboard with an insourcing sticker.

The extension to FlowPort™ handling specific PaperSchedule needs is the "Interpreter" servlet. When the user scans the schedule in, the interpreter observers it and recognizes the information based on position, size and identifiers. In particular, it detects the differences between the new version of the schedule and the current one, if any. It captures then the changes performed by the user on the schedule, e.g. a change in the start time of a job allocated to a given machine or the withdrawal of an insourcing request. The interpreter translates, if necessary, the captured decisions into negotiations requests. Negotiation requests are URL encoded method calls to the representant of the printshop in AllianceNet. Those requests are then propagated to the other printshops. Figure 7 describes the architecture of the PaperSchedule solution.

A job or a region can also be simply drawn directly on the planning sheet, but inaccuracy in drawing the rectangles may prevent a good interpretation.

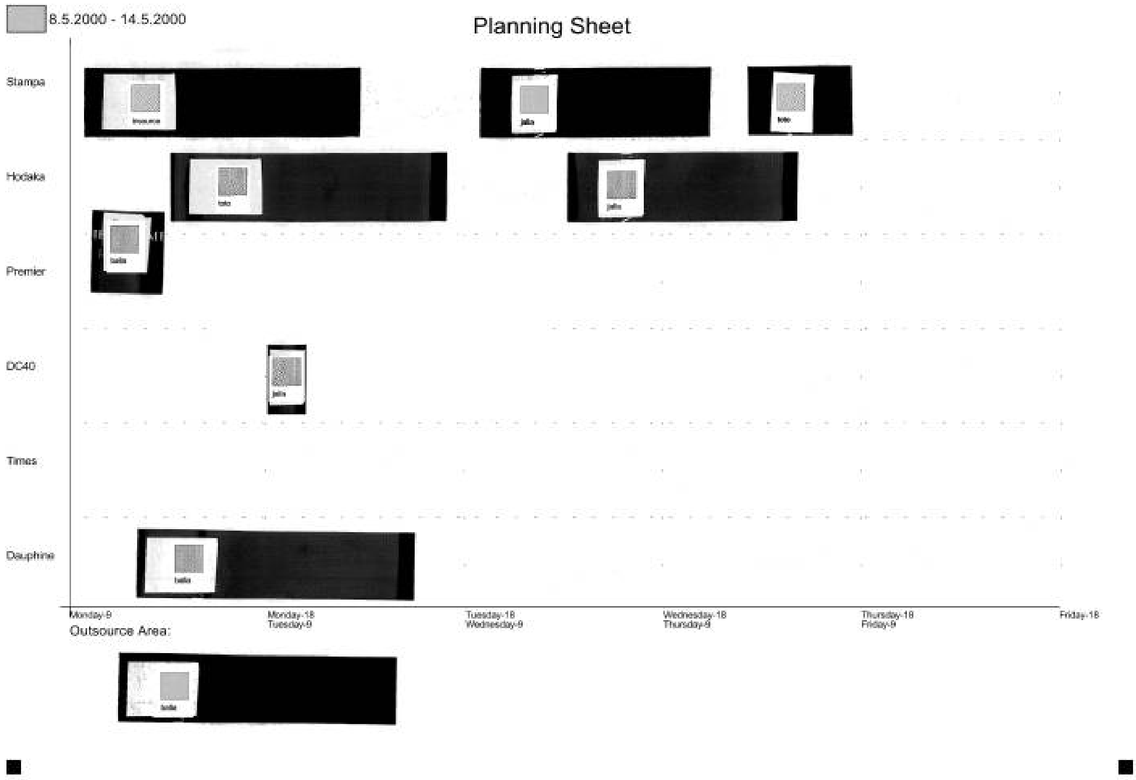

Figure 5: A Planning Sheet

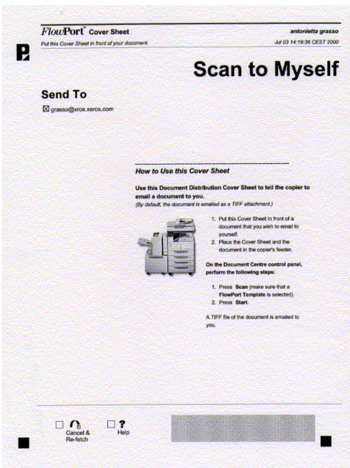

Figure 6: A FlowPort™ Cover Sheet

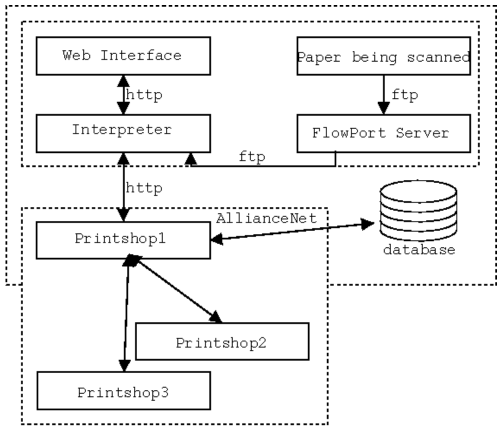

Figure 7: The Architecture of the Prototype

In the current version of the prototype, feedback is presented to the user partly through a paper and partly through a web interface. Next section will describe more in details the web interface. If a job has been found for being allocated to a given insource area, only screen feedback is provided. However, if there is a job that has been outsourced, a new schedule with a name generated as a function of the date is created. On this schedule the job that was outsourced will have a blurred appearance. For example, Figure 8 shows the sample schedule after the negotiation for the job in the outsource area in Figure 5 has succeeded. The user can then continue working on the current planning sheet or print out the new version with the negotiation results and using it as the new basis.

In the latter case, he will have to report the cardboards on the new planning sheet, except the ones he wants to fix. More precisely, if the user wants to definitively allocate a job to a machine he will not report the corresponding cardboard and then this allocation will never be changed in the future.

Browsing Jobs and Planning Sheets

As already mentioned, in the current prototype a part of the feedback is provided by a web interface. Also, this interface allows the user to: enter new jobs, browse the list of the existing jobs and the current and older versions of the planning sheets; print planning sheets; print insource stickers; check changes in the status of a job. The user can create a new job specifying its name, the estimated workload, resources needed, deadline, name of the customer, etc.

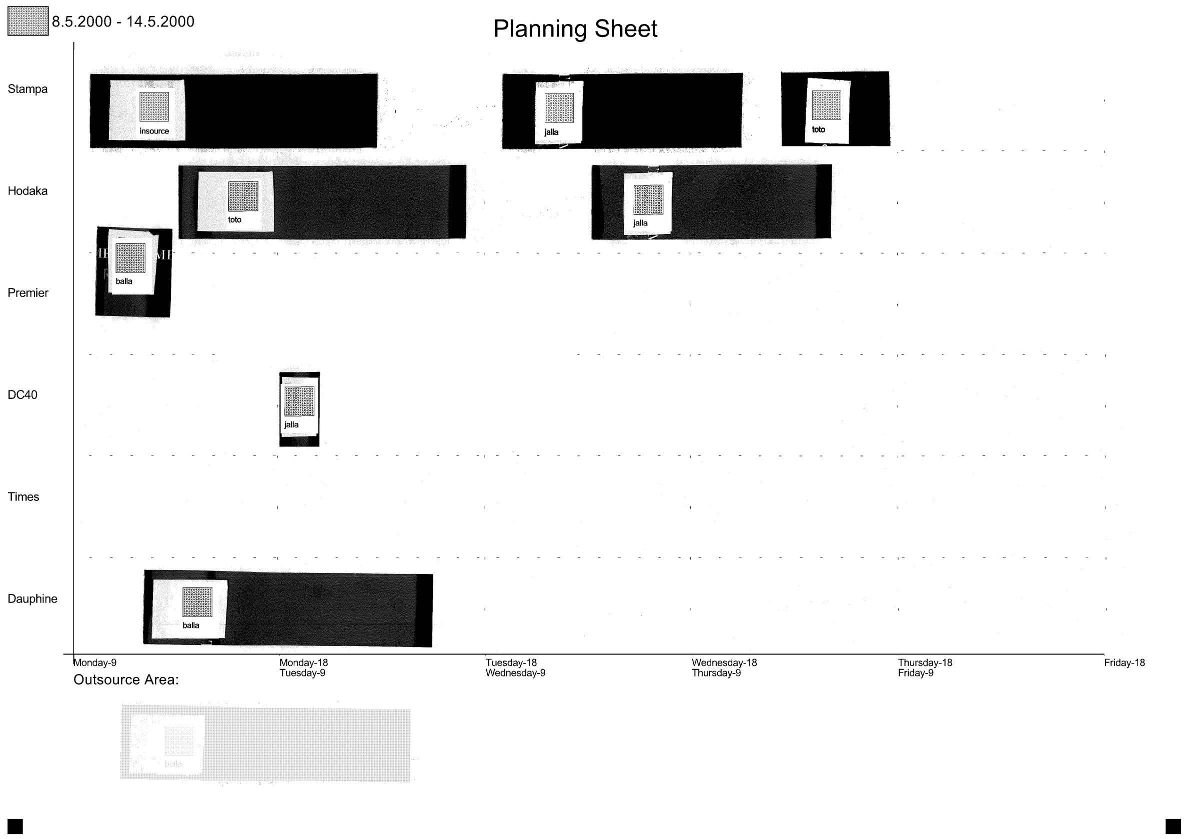

Figure 8: The Planning Sheet after negotiation succeeded

When the user is ready to schedule the jobs, he prints the planning sheet.
The user can see the list of the current jobs (see Figure 9 for an example) and print the glyphs stickers for the jobs cardboards ("PrintAllStickers").

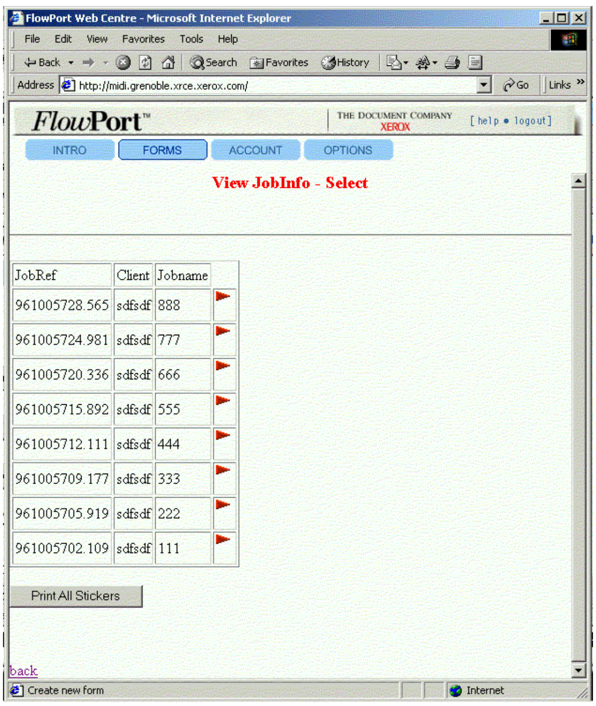

Figure 9: A List of Current Jobs

The user can check changes in the status of the jobs. If there are changes, a new image of the schedule is created, and it is given a name reflecting the time it was created. There will also be feedback on the screen.
The user may also see and print out the latest planning sheet that was generated. Also, he will be able to browse previous versions of the schedules.

RELATED WORK

As already mentioned, several field studies and surveys have observed the affordances of physical supports with respect to on-line scheduling tools, for example (Whittaker and Schwarz 1995) provides an interesting summary of benefits of using physical artifacts to collaborate around scheduling activities. On the base of observations like such, the area of work has recently addressed the design of systems connecting and bridging the physical with the electronic world. In particular other examples of paper-based applications can be found in (Karsenty et al. 2000).
Tagging technologies are widely used. Without talking about bar codes, largely used in our everyday life, we can give a couple of examples of projects that use DataGlyphs: Campiello (Karsenty et al. 2000) and Collaborage (Moran et al. 1998). Campiello supports tourist and local community sharing. In the Campiello Paper User Interface, DataGlyphs are used to identify tourists and flyers. The Collaborage system consists of a board with a collage of tagged items. In Collaborage, DataGlyphs are used to identify items on the board. The content of the board is continuously monitored and the information on it exported and interpreted in correspondence of specific tags being put on the board.

The Collaborage project has designed and implemented an architecture (using and extending the ZombieBoard functions) for physically representing information on a board and connecting it with electronic information. The connection is achieved by tracking the board and applying image analysis techniques on it. Collaborage has also proposed three applications: "In/Out and Away", "Project Task Wall" and "Whiteboard".

The "Project Task Wall" allows to describe tasks on a "wall" representation. However the way the users interact with the board and the architecture behind are different. In particular in the "Project Task Wall" all the tasks are retrieved to produce their electronic representation, while the proposed protocol allows to "retrieve decisions" made by the users. Moreover the "Project Task Wall" doesn't provide an architecture to support distributed negotiation of schedules.

The other application, "Whiteboard", provides features for whiteboard writing and selective command specification on parts of the board. "Whiteboard" would be a possible user interface to be used to implement our solution for mixed human and automated distributed scheduling.

CONCLUSIONS

In this work we have addressed the design of tools to support distributed scheduling and negotiation activities, and in doing so we have first analyzed user studies drawing from them design principles arguing for a mixed reality support system. We have presented a general architecture where several editing facilities could be used and we have then described in detail one of such possibility, that have been prototyped: PaperSchedule. We have illustrated our approach in the context of a business-to-business scenario where users are decision-makers in print centers scheduling and negotiating print jobs. We have shown how PaperSchedule is a possible mixed reality implementation that complies to the design principles we have drawn from the user studies.

On the other side we are aware of some limitations of the current implementation and current and future work includes enriching the degree of interaction both between the user and the paper and between the paper and the negotiation system. In particular we are aware that the current implementations can be cumbersome from the point of view of the required effort to create tasks (cutting cardboards and gluing them). While the physical manipulation has been proved to stimulate more engagement in taking appropriate decisions, we believe that lighter interaction ways could be provided. For example the cardboards could be cut from a continuous semi-adhesive tape similar to PostIts. Similarly, the unique identifiers coded in the DataGlyphs could be provided in preprinted adhesive sheets alleviating the users from the task of producing them.

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