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# Adaptive task sharing in collaborative robotics

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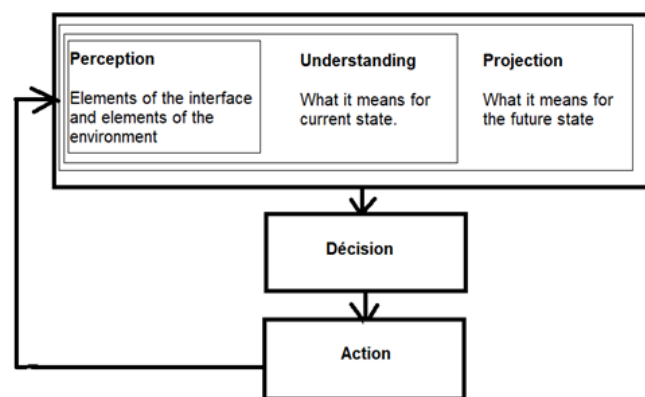
**Abstract**— In a flexible collaborative task sharing framework, it is necessary to take situation awareness issues into account. A robot must be able to “understand” the context of the collaboration, especially the difficulty of the task, the willingness of the human to collaborate or his availability. We propose to implement a robotic decision process based on the situation awareness model defined by Endsley. An experiment has been carried out to illustrate an adaptive collaboration in which the robot takes the initiative and fulfill the task that was assigned to the human.

## I. INTRODUCTION

We propose to study the collaboration between a human and a robot and to set up an experiment highlighting the performance of this collaboration, in terms of adaptation of the robot to the actions of the human. In the context of collaborative robotics for industrial applications, several dynamic teaming methods have been proposed for organizing joint task execution [1-7]. The category and difficulty of the task as well as the competency of each partner and the human availability are generally considered. For instance, Riedelbbauch and Henrich proposed a trust measure and an active vision system to determine the list of stored objects, which are then used in an algorithm for the selection of the action [13]. These studies are in general focused on computational issues, such as observing and updating the representation of the world. In several other studies, it was shown that the degradation of situation awareness is a major cause of errors and accidents, especially in the domains of aviation and robotics, where human systems interactions are complex [8-12]. An important issue is therefore to consider the “demons” that degrade the situation awareness in the design of the teaming method. It is proposed here a new paradigm, where situation awareness is the central concept of the decision model. The architecture of the decision process is based on Endsley’s situation awareness model and it is used to command a Universal Robot (UR3) robotic arm [10]. See Fig. 1.

In this model, the decision is based on 3 levels of analysis in order to optimize situation awareness: 1) the perception of the environment, 2) the understanding of the current state and 3) the projection of this state into the future. In the context of human-robot collaboration with flexible task sharing, situation awareness is especially important as it allows the robot to minimize human errors and to adapt the collaboration to its understanding of the physical and psychological state of the human. For instance, if the robot understands that the

human is not available, he can take the initiative and perform the task that the human was supposed to do, providing it has the resources and skill to do so.



**Fig. 1.** Endsley’s situation awareness model. The three levels are the perception, the understanding of the current state and the prediction of the future state.

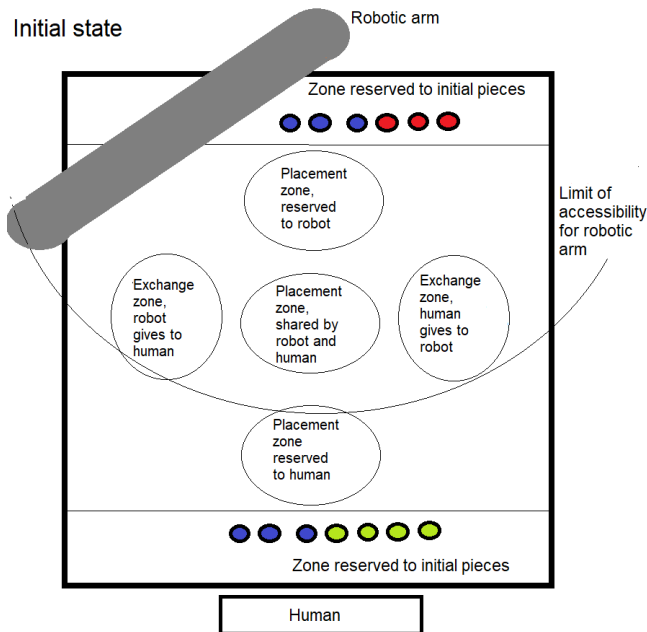
## II. EXPERIMENTAL PROTOCOL

An experiment has been designed to assess the implementation of the model and the quality of the collaboration between a robot and a human in the context of a flexible task sharing. In order to avoid the option of a full assignment of the task to a single participant, human or robot, important constraints have been specified: A subtask assigned to the human must exist, such that its achievement requires the help of the robot. A subtask assigned to the robot must exist, such that its achievement requires the help of the human and finally, another unassigned subtask must exist, which can be achieved by the human, the robot or altogether. In the proposed experiment (see Fig. 2 for the concept and Fig.3 for images of the experiment), a human faces a robotic arm and the objective of the task is sorting colored parts on a tray. Different zones exist. They are divided into two personal zones, one for each participant (human or robot) where he or it is the only one who can place pieces, a common zone where both can stack and finally two exchange zones, from the robot to the human and vice versa. The aim is to stack the pieces with appropriate colors in the personal and common zones, each participant being able to advance at its own pace, in real time and in parallel with what the other is doing.

Noticeably, the UR3 robot needs a green piece given by the human and the human needs a red piece given by the robot. An interesting collaborative issue is when the human is not working at the same speed, for instance if he is distracted by another task. Two strategies have therefore been explored,

the first one without constraint, with instruction to the human to be as fast as possible, and the second one with the instruction to calculate the result of an addition between each piece movement.

For the sake of simplicity, a fake camera has been used. Participants could thus imagine that it was used for object detection, but it was not. The detection of the human moves and the position of the pieces were therefore simulated (Wizard of Oz method): During the experiment, an operator controlled the robotic arm using a tablet. Different positions corresponding to the pieces or to the positions where the pieces have to be sent have been recorded and each one was assigned a distinct number. The operator just had to enter the number of the initial position and the number of the final position to command the move of the effector of the arm. The trajectory was automatically calculated using standard command functions.

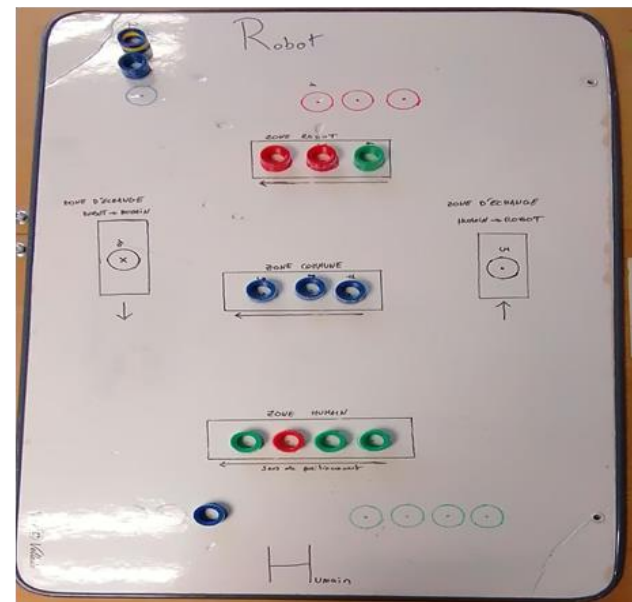
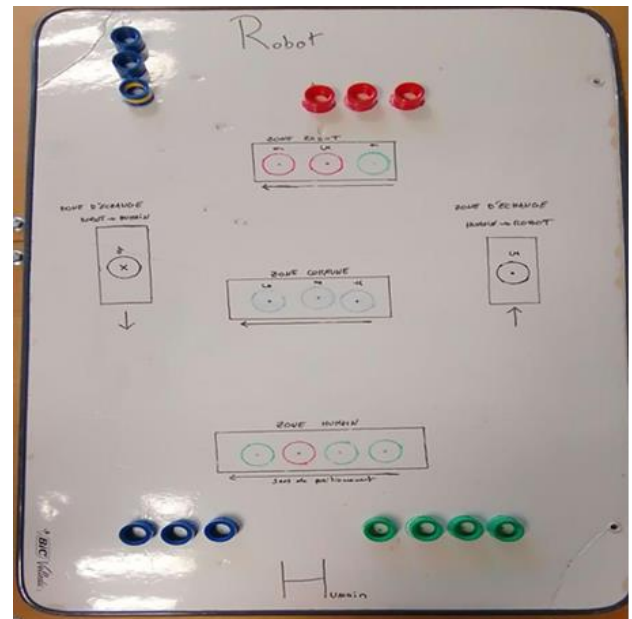


**Fig. 2.** Initial state, concept view. At the beginning, there are 3 blue pieces and 3 red pieces in the zone reserved to the robot, and there are 3 blue pieces and 4 green pieces in the zone reserved to the human.

A specific procedure was used for the decision process. As the human is generally faster at taking and placing the pieces, in normal conditions the priority of the robot is to work first on the row of pieces that has been assigned to it. However, if the human does not provide the green piece in the exchange zone, which suggests that the human may be busy on another task and there is a loss of efficiency (understanding of the current state and prediction of the future state according to Endsley’s model), the planning is modified: The robot tries to put pieces in the shared zone. The person in charge of the robotic arm carried out a training period to make sure that the same algorithmic procedure was followed.

An observational matrix has been elaborated with quantitative variables (duration, mistakes count, zone placements count) and qualitative ones, gathered from a survey which gives a feedback on humans’ experience during the collaboration. The experiment took place in the ENSC

premises from February 6th to February 10th 2023 with 20 subjects total.



**Fig. 3.** Images of the experiment. Top view: Initial state. Bottom view: final state. Only the robot has to fill in the positions close to it, only the human has to fill in the positions close to him and both can access the central zone. See fig.2 for the organization of the different zones.

### III. RESULTS

#### A. Quantitative

Monitoring each exercise duration highlighted two main factors that are affecting the task realization time: The human's first move and the calculus constraint. As the human must effectuate some additions on top of the main task, the length of his task is almost doubled. When the human does not have any constraint, the robot places in average less than a piece on the shared zone, whereas when the human is slowed

down, it adapts and sets in average almost all the pieces. This illustrates the robot's adaptation to the efficiency of the human partner. Without adaptation, the robot would have waited a long time the green piece and the global task would have been completed in a greater time.

### B. Qualitative

For the survey answers to be considered valid, we had to make sure that the subjects perceived the experiment as a collaboration with a robot following a fully automated procedure (and not commanded by a human operator). Hence to the question "If you had to guess how the robot works, which one of these solutions would seem the most plausible?", only 20% of the subjects answered "a human was controlling the robot".

When asked "Do you think the robot is as efficient as a human in the realization of the task?", 65% of participants found it as efficient or more, proving its efficiency in this context. In addition, for the question "Did you feel like the robot was adapting to your actions?", the answer was 85% "Every time" or "Sometimes". To the question "Did you adapt to the robot's action?" 75% answered "Every time" or "Sometimes". This shows how most of the subjects assessed the robot's adaptability similarly to theirs proving once more the robot's adaptability is satisfactory.

Moreover, 95% of the subjects never doubted the robot's ability to complete the task, which highlights their confidence in the robot. At last, another 95% of the subjects felt that they could properly guess the robot's intentions, pointing out its transparency.

See also Fig.4 for the results of two important questions.

## IV. CONCLUSION

A new programmable decision-making technique based on Endsley's model has been proposed. It allows a robot to work and anticipate in real time the availability of the human collaborator and act accordingly. We also set up an experimental protocol in order to assess its performance in a collaborative task with a human with variable availability.

The observed variables highlight the robot's adaptation to the contingencies of the collaboration, ensuring a minimal efficiency even when the attention of the human partner is limited. Finally, as previously suggested by other authors, it is shown that a cognitive model based on situation awareness for decision making is important and allows an efficient collaboration, while keeping the human operator confident towards his safety and the usefulness of the robot [2,3]. Importantly, even if other dynamic teaming methods would probably obtain the same results for the proposed experiment, the initiative taken by the robot is based on a situation awareness model, which can be extended in various ways to take for instance human errors probabilities into account.

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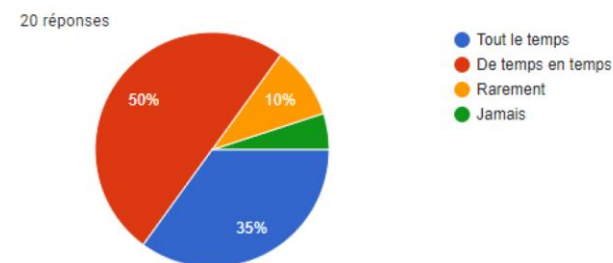
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Main questions and responses (French):

Avez-vous eu l'impression que le robot s'adaptait à vos actions ?



Le robot choisissait les actions les plus adaptées à la complétion de la tâche :

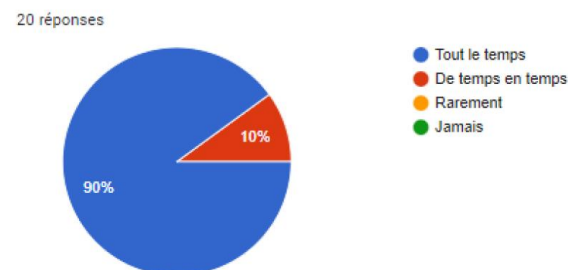


Fig.4. Responses to two important questions (French).