Internship Proposal

This project is financially supported by the Dassault Aviation Patronage Chair *

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Application deadline : Mars 1^{st}, 2018

Title : Human-Robots Interaction : Integrating the Human Operator's Physiological State into the Supervisory Control Loop

Context

The actual ratio factor between UAV operators (O) and UAVs units (N) is O≥N. For example, in the US army, UAVs are managed by several operators : one is in charge of following the flight parameters, another in charge of the payload, and the last one is responsible of the mission supervision. In the next future this ratio should be inverted (O<N) (Gangl et al., 2013). Indeed, UAVs are getting more and more automated, taking decisions by themselves, which lightens the need of such a number of operators. The idea is that UAVs could explore safety automations to ensure a completely autonomous navigation and even a completely autonomous mission planning. However, the human operator is still considered as a providential agent (Casper and Murphy, 2003; Schurr et al., 2009), who gets over the autonomous or automatic system when some hazardous event occurs. But, it is known that, in UAV operations, Human Factors represents the most important part of operation accidents (Williams, 2004). A promising research topic is to consider that automated planning and execution should include, in particular, actions to balance the operators' workload (Gangl et al., 2013; de Souza et al., 2015a). In this sense, one could chose to consider the human operator no more as a providential agent, but rather as an integral part of the human-robot team, i.e. as an agent that can fails (de Souza et al., 2015a). Recently, researchers have addressed this delicate point. For example, (Donath et al., 2010) propose a framework in which a cognitive assistant cooperates with the fighter pilot to help him in his mission's management and balance his workload. (Gateau et al., 2016) proposed a decisional framework in which UAVs take into account the human's non-deterministic behavior and availability during the mission before launching requests to him. A reasonable key point could be to try to infer the human's cognitive state (de Souza et al., 2015a), via physiological sensors, in order to ensure safety constraints or even the respect of operational guidelines accepting that autonomous systems could take over human operators when necessary.

State-of-the-art

Multi-robots or multi-UAV applications are more and more studied by different research communities. On the one hand, the robotic community addresses multi-agent cooperative or coordinated issues (Durfee, 2001; Saber et al., 2003; Nigam et al., 2012; de Souza et al., 2015b) in order to find robust algorithms to drive robots or UAVs joint actions to fullfil, for instance, exploring, search and rescue or surveillance missions. On another hand, the Human Factors' researches globally study and evaluate the conditions in which the human reaches the limits of engagement during the operation task (Pope et al., 1995; Régis et al., 2014; **?**; Dehais et al., 2015), with a special attention on workload or fatigue (Cummings et al., 2013; Roy et al., 2016a,b). A recent report of the U.S. Army, Navy, and Air Force stated that human factors are responsible for 80% of UAVs operation accidents (Williams, 2004) involving human errors. Some researches are now trying to explore physiological measurements and behavioral data to infer the human's cognitive state in such multi-UAVs or multiple-robots operational contexts (Roy et al., 2016a; Senoussi et al., 2017; Drougard et al., 2017a) in order to predict performance for adapting the human-robots interaction.

The integration of such inferred human's cognitive states, based on physiological measurements and behavioral data, in the control loop of a Human-Robot team is a novel topic for both communities (Drougard et al., 2017a), (Gateau et al., 2016). Recently, works of our lab have addressed this issue (de Souza, 2017; Drougard et al., 2017a; Gateau et al., 2016; Senoussi et al., 2017; Roy

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et al., 2016a). In the context of the Dassault Aviation chair [1], we have proposed an human-robotic cooperative mission (Drougard et al., 2017b), in which the human operator and robot must extinguish fires, and for that the human operator has to manage the water tank while paying attention to which operation mode the robot is active (automatic or manual) to possibly take over the robot if necessary. We are currently acquiring physiological data (ECG based) from human operators. This problem is challenging because we need to learn all transitions and observation probabilities (Drougard et al., 2017a) in order to define a probabilistic planning domain to apply a MOMDP (Mixed-Observability Markov Decision Process) solver (de Souza et al., 2015a) in order to find a policy that will drive the human-robot interaction.

The relatively recent field of physiological computing proposes metrics derived from the electroencephalography (EEG) to assess the operator's mental state (e.g. fatigue, workload, stress, engagement, etc). These cerebral measures can be processed through a signal processing pipeline which encompasses a machine learning step in order to automatically estimate a given mental state and close the loop. This kind of system is called a passive brain-computer interface (pBCI) (Roy and Frey, 2016). Additional peripheral measures such as the electrocardiography (ECG) and eye-tracking can also provide relevant metrics. Of course modality fusion can help better assess the operator's state and therefore improve the human-robot interaction.

In this sense, this internship subject would propose a framework in where an artificial agent, that is able to continuously estimate the human's cognitive and UAVs states, should be in charge of driving the mission and should chose which agent would be more apt, in a given decision time step, to perform high level decisions. This work is a continuation of studies already conducted in our lab (de Souza et al., 2015a; Gateau et al., 2016; Drougard et al., 2017a), but should this time *take into account physiological measurements and perform an online estimatation of the human's cognitive state to adapt the human-robots interaction in an ecological mission context*.

Work proposition :

A first research track should help to define the mission scenario, in which a human operator (pilot) has to cooperate and to coordinate UAVs while piloting his plane (Gangl et al., 2013). This human operator would be in charge of taking difficult decisions, such as to recognize targets (Gateau et al., 2016), or to decide to rescue possible victims (de Souza et al., 2016). Previous studies demonstrated that an artificial agent, able to infer the availability of the operator during the mission, could help the latter to better perform while decreasing his/her workload (Donath et al., 2010; Gateau et al., 2016). Another previous study has demonstrated that this artificial agent can also predict the operator's performance when he/she needs to take a decision within a small amount of time (de Souza, 2017). Choosing how to present the information to the human operator allows to maximize the chances that he/she takes an aligned decision considering the operational guidelines. A second research point should better define what kind of physiological means could be explored. Based on previous studies (Roy et al., 2016a; Senoussi et al., 2017; Poussot-Vassal et al., 2017), we believe that the use of EEG and ECG data combined with eye-tracking data could increase the human's state estimator precision to better predict human operator's performance. The last issue is the integration of this psychophysiological information into the decision framework.

Candidate's profile :

— Applied Mathematics, Artifical Intelligence or Automatic Control background ;
— Strong skills in programming ;
— Autonomous, hard-working, problem-solver ;
— Interested in Human Factors research

Candidates are invited to apply by e-mail to **caroline.chanel@isae-supaero.fr** and to **raphaelle.roy@isae-supaero.fr** sending **CV, motivation and recommendation letters and grades**.

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