Human-Centered Design in Synthetic Teammates for Aviation: The Challenge for Artificial Intelligence

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Abstract

Synthetic teammates are a special class of artificial intelligence that is intended to replace the human operator in some special capacity. This proposal outlines some guidelines for effective synthetic teammates in aviation from a human-centered design philosophy.

Introduction

Psychology and artificial intelligence have long held a unique relationship in that each hopes to learn something about the operation of the mind and brain through an examination of each other's domains. This effort is most pronounced in the creation of artificial entities such as synthetic teammates in which abilities considered to be uniquely human such as thinking or problem solving are granted to artificial systems.

Synthetic Teammates

Synthetic teammates are not a new or novel idea. They are a special class of artificial agents that are intended to replace a human operator in some special capacity. Synthetic teammates are different from decision-aids or expert systems in that these agents are intended to provide additional context for action beyond recommendations for decisions or, in some limited cases, direct action on information.

For example, a recent conference (46th Annual Meeting of the Human Factors and Ergonomics Society) included an entire session devoted to synthetic teammates in the training arena (MacMillan & Lyons, 2002). In a number of these papers the concept was to provide training through the use of synthetic instructors or populate a virtual battlefield with synthetic teammates that could take action in the same way a real agent might. In essence, these synthetic teammates are intended to replace the requirement for having human teammates under particular circumstances.

In one report, Zachary, Weiland, Scolaro, Scolaro, and Santarelli (2002) described the architecture of a synthetic trainer that combined intelligent tutoring and synthetic cognition to allow a trainee to practice real-life skills under the tutelage of an artificial system, thus providing an alternative for trainees when a real trainer could not be present.

The applications for synthetic teammates to aviation are numerous. The most obvious application is to have a virtual co-pilot that can react to pilots' voice communications and data from instruments to perform actions. Other applications could include teammates in air traffic control, maintenance, dispatch, or flight operations. The issue, however, is in how to design these synthetic teammates.

Human-Centered Design

One design philosophy that provides guidance for the creation of artificial intelligence in synthetic teammates is human-centered design. Billings (1997) argues that in order for automation or, by implication, artificial systems to support a user, certain principles must be followed. These principles are intended to guide the design of automation but can be adapted to the development of artificial intelligence. While an overview of all of these principles is beyond the scope of this article, a select number of these are provided as a starting point for its application to artificial intelligence. These principles include:

Pilots Must Be In Command

This principle states that the synthetic teammate should not reduce the pilot's authority. There may be instances under which the teammate may be required to protect the operator from harm such as with envelope protection (bounds beyond which the aircraft stalls) but the operator should remain in authority, able to override the artificial intelligence if needed.

Pilots Must Be Informed

This principle states that the synthetic teammate must provide feedback to the pilot indicating what the teammate is doing. Only if this feedback is generated will the pilot be able to take adequate action based on what the synthetic teammate is doing. In the absence of this feedback, pilots may experience automation surprises (Sarter & Woods, 1995) when the synthetic teammate does something the pilot does not anticipate.

Automation Must Be Predictable

A corollary to the previous principle is that the actions of the synthetic teammate must be predictable. Even if the synthetic teammate provides adequate feedback, the teammate's actions need to be predictable enough that the pilot can anticipate the synthetic teammate and take appropriate action. Without a certain level of predictability, even if there is sufficient feedback the pilot may not have enough time to prepare a coordinated response with actions performed by the synthetic teammate.

Automation Must Support the Pilot

Perhaps the most important principle, this principle states that automation should support the pilot. The purpose of a synthetic teammate should be to provide cognitive support, either in areas of decision-making, problem-solving, information collection and integration, or automatic data processing.

The Challenge

So what is the implication for artificial intelligence? Numerous efforts have been made to create artificial intelligence in different scales ranging from full-fledged artificial humans to, more recently, artificial agents that are specialized for particular functions such as internet searches (web-bots).

So the challenge to artificial intelligence is in how these synthetic teammates can be created to support the operator.

Pilots Must Be In Command

The challenge to artificial intelligence is in the creation of an artificial intelligence that does not override the operator. While this challenge may seem trivial in concept, automation systems have a long track record of trumping the authority of the pilot. This tendency may become more pronounced when developing a human-like synthetic teammate. If the teammate is intended to perform more like a real human in order to coordinate actions in the cockpit, the risk of enabling the synthetic teammate to supercede the true pilot increases.

Pilots Must Be Informed

The challenge of keeping the pilot informed about the actions of the synthetic teammate is more than merely providing verbal or textual feedback from the artificial system. This feedback must be meaningful to the pilot. If a synthetic teammate is intended to replace the copilot in an aircraft, the synthetic system should be able to provide information in a manner that is consistent with the actions and operations of a real copilot. This concern does not mean that the synthetic teammate requires high fidelity of response compared to a human copilot, but rather than the actions and information provided by the system are in meaningful terms for the aviation context.

Automation Must Be Predictable

While this principle may be clear in computing terms by detailing all possible states of the synthetic teammate or completely mapping out the synthetic teammate's possibilities for action, this mapping does not mean that those system states may not surprise the human pilot if there are large transitions between those states. If a human teammate requests information from the synthetic teammate on one aspect of information in the cockpit and the synthetic teammate responds with different response patterns each time it is requested, it may not be clear what ties those differences in actions or states in the synthetic teammate together for the pilot for the same request. This issue becomes especially challenging as the complexity and the number of possible system states or responses increases in the synthetic teammate.

Automation Must Support the Pilot

Pilot support should be the ultimate goal of synthetic teammates. In the case of synthetic teammates, they should still remain a tool to support the actions of the pilot, not replace them. This support can emerge from information gathering, integration, or providing expert information that the pilot requires. If, however, the synthetic teammate doesn't support the pilot due to lack of feedback, unpredictability, or excess authority, performance in the pilot may decrease because the pilot has to either counteract the synthetic teammate or spend precious time trying to decipher the actions of the teammate (Bainbridge, 1981).

Notice, also, that synthetic teammates may support the operator in certain domains more easily than others. For example, synthetic teammates may make more sense in the training domain where they can guide the trainee through tasks but may make less sense in the cockpit where lack of support via the synthetic teammate may interfere with the pilot.

The Appeal to Artificial Intelligence

While this document might not provide insight into the exact underlying architecture of how these synthetic systems should operate, it does provide direction and guidelines in the creation of artificial synthetic teammates. Human-centered design addresses concerns for the boundaries of synthetic teammates and some of the global characteristics of these teammates that need to be present in order to be effective.

However, more specific characteristics also need to be addressed to answer in the design of such a teammate, such as what the personality of a synthetic teammate might be (cf: Vallence, Litzinger, & Wise, 2001), the level of emotion or politeness that should be exhibited by a synthetic teammate, or the method of interaction of the synthetic teammate with the pilot. All of these concepts are other aspects of design that collaboration of psychology or human factors with artificial intelligence can address to make these systems more effective.

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