The Effect of Similarity Between Human and Machine Action Choices on Adaptive Automation Performance

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Abstract

One of the defining characteristics of an adaptive automation system is the hand-off from machine to human–and vice versa. This research seeks to improve system control hand-offs, by investigating how the manner in which the automation completes its task affects the overall performance of the human-machine team. Specifically, the research will explore how the level of similarity of action choices between the automation and the human operator affects the resulting system's performance. A design process model for creating adaptive automation systems is complete, and was used to design an adaptive automation research environment. Data gathered using this system will be used to automate user task performance in the system, and allow for research into the effects of that automation.

Motivation and Research Question

One focus of current automation research is the control of multiple unmanned vehicles (UVs) by one human operator. When a user controls multiple UVs in concert with an automation system, it is only possible for him to consciously act on one UV at a time. The automated system controls all UVs upon which a human is not acting at a given time. Therefore, the system must hand-off control of specific UVs from automation to human operator and back again. Problems arise at these control switches. Operators who are not engaged with a specific UV will lack situational awareness to operate on that UV when control is switch from the automation to the human, while involving the human operator in too many aspects of the automated UV control can lead to cognitive overload with excessive control switches.

We start to address this problem by investigating how the manner in which a task is automated affects performance of the overall system. Using a tablet game designed as an adaptive automation test environment, we are currently collecting a game-play database that will enable a player profiling system to predict the reaction of a user to a specific situation. Using this information, we will create an adaptive automation system that helps the user play the game by recommending or taking actions that are predicted as either similar or dissimilar to what the user would have done in the given situation. Specifically, when presented with the same scenario within a task environment an operator acts similarly to another when he performs a similar action to that of the latter–with measures of action similarity depending on the specific environment.

To achieve this, we set up the game as a task environment where all sub-tasks are controlled solely by human operators, and then automate a specific sub-task. The system will either perform the sub-task similarly to the specific user or dissimilarly. We then use the operators' performances to answer the question, "How does the similarity or dissimilarity of the automated aid's task performance to that of the operator affect the overall human-machine team's performance?"

Background and Completed Work

Since a dynamic approach to automated decision-making was proposed by (Rouse 1977), the field has adopted the term *adaptive automation* to define the idea of an automated system that can adapt to a changing environment. In many adaptive automation systems, the onus of determining the current automation state is placed on the system. However, others have shown that even the determination of who (e.g. the human operator or automation) 'adapts' the system can fall on a sliding scale (Parasuraman and Wickens 2008). When determining where to adaptively automate a system, the 'task load' and 'workload' of a specific task have ramifications on the design of an adaptive automation system.

A *task load* is the number and difficulty of tasks assigned to human operators, to which they must respond; and *workload* refers to the perceived impact of the task demand placed upon the operator's mental or physical resources and corresponds to the utilization of these resources. A variability in the task load imposed upon an operator–and the workload the operator experiences–affects performance. In addition to performance variance due to explicitly defined task load, the performance of the human operator may vary due to inherent factors such as fatigue, stress level, motivation, and training level (MacDonald 2003). As such, workload and the ability of a human operator to respond to tasks imposed upon them varies over time (Colombi et al. 2012).

Our preliminary work has aimed to address the problems posed by task load and workload in the system design process (Bindewald, Miller, and Peterson 2014). We investigate the impact of inherent tasks that arise due to the allocation of a task to either a human or a machine to create a process

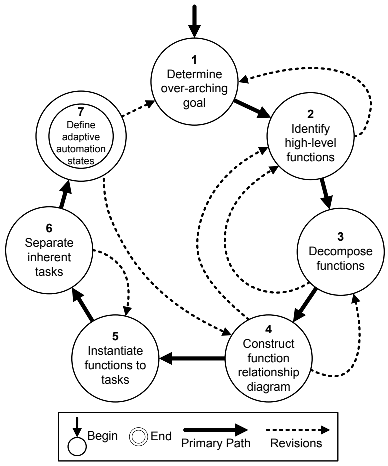

Figure 1: The Function-to-Task Design Process Model for adaptive automation system design (Bindewald, Miller, and Peterson 2014).

for designing adaptive automation. The resulting function-to-task design process model (see Figure 1) utilizes a set of visual diagrams to identify areas for adaptive automation within a human-machine system. This is achieved through a seven-step process allowing designers to identify points within a function network where the transitions between human and machine entities can facilitate adaptive automation.

Using the function-to-task design process model, we created an environment for investigating adaptive automation. The resulting system is a tablet-based game called *Space Navigator* where the operator draws trajectories on the screen in order to interact with the system. One of the goals of the designed system was to simplify the data collection process by "gamifying" the system (Hamari, Koivisto, and Sarsa 2014), using a portable tablet computer for gathering data, and writing an open-source system that can be easily ported to different types of devices.

Current Work

A recently completed data-collection experiment has facilitated the creation of a game-play database. The next step in determining how similarity of action affects human-machine system performance is to create a computational system to mimic human game-play patterns. The objective of this study is to see to what extent we can distinguish between specific players of the game. Presently, we are working to take the game-play database and use it to create a player profiling system.

Preliminary results have shown us that a player-by-player discernment is not feasible, but that player profiles can be created to discern between larger groups of players with specific tendencies. An unsupervised learning system will be used to cluster users according to a k-means clustering algorithm, and a Fisher score supervised feature selection algorithm is applied to determine what defines different clusters of users. The efforts to complete the player profiling system will be completed over the summer of 2014.

Future Work and Expected Contribution

A similarity measure similar to Modified Hausdorff Distance (Atev, Masoud, and Papanikolopoulos 2006), called Windowed Hausdorff Distance, has been developed in order to compare trajectories of different lengths. Coupling this similarity measure with the player profiling system will form the base of an adaptive automation system to play Space Navigator. Other researchers at the Air Force Institute of Technology (AFIT) are working on creating workload-based adaptive automation triggers specific to the environment. This research, combined with the function-to-task design process model results will allow the creation of an adaptive automated version of Space Navigator that aids human performers on one specific sub-task within the environment.

The resultant system and experiments based on it will allow us to answer the research question. Our research has already provided a new adaptive automation design model, allowing system designers the ability to visually and systematically evaluate the placement of adaptive automation within a system network. The Space Navigator platform designed using the model, has allowed us (and future researchers) to simplify the data gathering process. The resulting automation system will allow for research into how similarity and difference of actions between a human-machine team affect the overall performance of the system. The final experimental data will provide several areas of further research including trust in automation, training improvement, workload reduction (actual and perceived), and task load switching.

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