The Development and Testing of a Semi-Automated Hierarchical Task Analysis Process

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1. Introduction

HTA has been described as one of the most popular and widely used Human Factors methods, partly owing to its flexibility and scope for further analysis that it offers (Stanton et al., 2013). HTA was developed in the 1960s to understand the skills required in complex, non-repetitive operator tasks. The basic premise behind HTA is that tasks are explored through a hierarchy of goals indicating what a person is expected to do and plans indicate the conditions when subordinate goals should be carried out, which is akin to the decision making process of an operator. Each goal and the means of achieving them are represented as an operation. Due to its flexible nature HTA has seen many applications across a variety of domains, including interface design and evaluation, manual design, job description, training, allocation of function, job aid design, error prediction and analysis, team task analysis, workload assessment and procedure design (Stanton, 2006). However, one of the biggest limitations of the method is that it can be laborious and time consuming to conduct. Previous research sought to address this with the development of a HTA software tool. The software tool provided structure and expedited the documentation and presentation of the analysis results, allowing for quick edits to be made that propagated through to the rest of the analysis. However, this tool is still a desktop version of the pen and paper method and therefore requires a high proportion of manual input from a Human Factors analyst. As part of the EU funded i-VISION (Immersive Semantics-based Virtual Environments for the Design and Validation of Human-centred Aircraft Cockpits) project work has been undertaken to automate the HTA process in a virtual reality (VR) environment.

2. Development of semi-automated HTA

As an initial case study a procedure from the manufacturing industry was selected (differential gear assembly in automotive manufacturing), subsequent research efforts will develop this work within the context of the aviation domain. This task was selected due to its simplicity and because it offers the opportunity of multiple abstraction levels once the basic HTA is done. A manual HTA was constructed for the task under analysis by two Human Factors experts and three systems manufacturing experts (this will be referred to as the 'reference HTA'). This enabled the identification of verbs to describe the physical tasks that were performed in this assembly of the differential gear. Rules based on the VR principle of collision detection were written for each verb and implemented into the VR system, along with tagging objects, tools used and changes of object states. Verb definitions were determined by the Human Factors and Systems Manufacturing domain experts and task time literature was utilised where relevant. Examples of verbs include: touch, press, move, insert.

A virtual platform was used in order to program the HTA. The VR method produced uses an algorithm developed to generate each task based on the human user's motion and their interactions (i.e. collisions) with several elements of the virtual product (Rentzos et al., 2014). The main virtual environment interaction principle that was used in this development is collision detection. Collision detection identifies whether or not two or more virtual elements are 'colliding' each other. Additionally, a principle called "magnets" was used in order to simplify the virtual task for the user. The working principle of the magnets method lies in identifying the proximity of an object with another in order to position them. Every time the users hand (which is defined an object) collides with a virtual object a verb-task is generated which corresponds to the action performed by the user. This way a readable sentence with correct grammar is created for each user interaction (corresponding to the task step terminology that would be recorded by the HTA expert in the manual method if the task had been observed). By utilizing all of the above information in combination with the Hierarchy Manager of the VR platform we are able to clarify levels of abstraction for each task. This way a complete HTA tree was automatically extracted without any intervention from the VR expert, although they can monitor the process and correct faults that the machine cannot detect.

3. Comparing i-VISION HTA with manual HTA

A study has been conducted in which HTAs generated from the i-VISION tool (semi-automated) and traditional HTAs (manual) were compared. In the semi-automated study 10 participants completed the differential gear assembly task in the VR environment. In the manual study 14 participants completed a HTA of the differential gear assembly task by watching a video of the procedure filmed in the VR environment. In both studies, HTAs were generated at Time 1 and Time 2 (4 weeks apart). The HTAs will be compared using the principles of signal detection theory to establish the similarities and differences with the reference HTA. Time to complete will be also be considered as a metric of comparison. Current efforts are focused on applying the principles to the aviation environment so that the tool can be used in the rapid prototyping of aircraft cockpits. During the initial development, only physical interaction monitoring was used. For example, when a user grasped an object, it was assumed that the object had previously been identified among the other objects. It is intended that other modalities (including visual and auditory) will be included in future iterations with the integration of relevant technologies such as eye tracking and audio devices. The conference presentation will provide an overview of the tool development, present the results of the comparison study, and detail the current research efforts within the i-VISION aviation project.

References

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