

Use of role games in automation assessment

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ABSTRACT

In this paper, the use of the role-based game technique to assess the impact of automation in humans is proposed. The results and outputs of this assessment can be obtained using different types of role-based games.

To do this, firstly human factors in automation and role-based games are described proposing a process to explore the impact of systems automation on the actors involved, and also presenting the role-based games and their use in other studies.

Next, role-based games in the automation assessment is addressed, taking advantage of the strong points of this technique which are the adaptability in the scenarios to be studied and the improvement of the situation awareness of the experts during the games execution, increasing their confidence on the collected results.

Keywords

Automation, human-computer interaction, human factors, role-based game.

INTRODUCTION

One of the main areas under development these last years in R&D projects is the study and involvement of Human Factors in Systems Engineering processes. This is clearly illustrated by the interest of the Single European Sky ATM Research (SESAR) Joint Undertaking (JU) with the consideration of human factors issues in the definition and implementation of the new concept of Single European Sky through the definition of a Human Performance transversal area in its programme [1]. Additionally, a progressive increase on the automation degree of Air Traffic Management (ATM) systems is expected to be accomplished within SESAR objectives for 2020.

Nowadays, there is plenty of literature about automation in ATM, but not so much about the impact of humans when higher level of automation is introduced in the systems

development.

This proposal aims at fulfilling this gap taking into account the literature about automation and human factors (see references [1] and [2]). Role-based games are presented as a proper technique to support the assessment of the automation impact in human factors.

AUTOMATION AND HUMAN FACTORS

One of the definitions for “automation” is the technique, method, or system of operating or controlling a process by highly automatic means, as by electronic devices, reducing human intervention to a minimum [2].

There are different studies which assess the fields of human factors and automation as for example in terms of workload assessment. Different methods have been developed such as SWAT (Subjective Workload Assessment Technique), NASA-TLX (NASA Task Load Index) and WP (Workload Profile) as stated in the work “*Evaluation of Subjective Workload: A comparison between SWAT, NASA-TLX and Work Profiles methods*”[18].

There are other studies [3], and [4] which address the impact of automation in humans. In these studies, it is described how automation is not always the ‘perfect’ solution to improve one specific process in which a human operator is acting. For example, in ATM environment, an Air Traffic Control (ATC) process leaded to a high level of automation can suppose an important reduction of the human involvement in the process and then, in case of technical failure in the system, time of response of this operator could dangerously be increased. So, safety could result impaired and changes in the human operations should be done to prevent unsafe situations.

From the work “*A Model for Types and Levels of Human Interaction with Automation*” [3] a method to assess the level of automation in design systems is summarised next.

This study describes the following aspects to take into account in the assessment process:

The first aspect is the human information processing in a human-machine system, which is described using a simple model. This model structures a general process of the human information management in four stages: Sensory Processing, Perception/Working Memory, Decision making

and Response selection. From this simplification and applied to the type of functions developed in systems, a classification for automation is proposed. It consists of four stages:

- Information acquisition regarding to the registration of input data.
- Information analysis which involves cognitive functions like prediction supporting the decision-making processes.
- Decision and action selection which implies the choice process among decision alternatives
- Action implementation which implies the execution of the selected decision alternative.

Another aspect is the level of automation. This characteristic is needed to assess the degree of automation to be applied in the systems design from the lower level of automation (fully manual performance) to the highest (fully automatic performance without human intervention).

Finally, several validation criteria must be defined to support the assessment of each particular level of automation assumed for each stage of the human information process (e.g. Human Performance Consequences).

This method described in [¡Error! No se encuentra el origen de la referencia.] is used as baseline to study the impact of automation in humans. Figure 2 shows the phases of the proposed process to be performed in combination with role-base games.

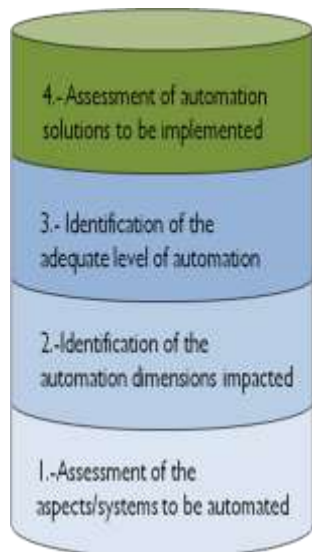


Figure 1 Phases to assess the impact of automation on human factors

The application of this process, using the role-based games to address the different phases, will allow obtaining results typical from the human behaviour, having a complete set of outputs provided by the participants in the games and the

external observers, giving more objectiveness to the answers given by the participants. More details about the performance of role-based games are given in the following section.

This proposal will serve to envisage how the role-based gaming technique provides an added value using it together with the current techniques that assess the impact of automation on humans.

ROLE-BASED GAMES IN RESEARCH AND DEVELOPMENT

In research and development the role-based games are used as a Human-in-the-loop (HIL) simulation that focuses in the decision making and the interaction between characters. Role-based gaming allows exploring the concept in a structured way through people (usually expert on the theme) acting under the assigned roles. The use of role-based games in the early phases of the concept enables to:

- Understand the information flow and the users' needs of information;
- Explore and clarify the responsibilities assigned to each role;
- Identify no-go issues and their possible solutions;
- Explore supporting tools requirements, especially those related to Human Factors;
- Capture motivations, strategies and behaviours.
- It also forces the designers to think about the use that will be given to their design, and the context in which will be executed.

Role games place the experts in a situation with specific problems that they have to face through the use of available tools. A Game Director or Master has to ensure that the simulation follows the applicable concept and answers the questions of the developers without guiding the experts to the desired results. As in other HIL techniques, there must be an initial training session to allow the participants to familiarise with the dynamic of the experiment, and the use of the game tool.

Experience in ATM assessment has probed that the combination of role-based games using paper with role-based games using hardware-platforms provides a good quality assessment of the process involved in the concept under test [6]. Furthermore, different role-based gaming platforms offer different levels of information reliability depending on the status of the assessment process with a good cost-efficiency response:

- Paper-based platform could be adequate for a preliminary assessment of the issues/risks/gaps identification. Although the scenarios must be described and presented to the experts playing, the tools (usually limited to paper and pencils) provide a high degree of flexibility that enables the game director to adapt to

situations that may not have been previously foreseen, by just updating the description of the game. It provides qualitative assessment through a cost-effective simulation. Nevertheless, this platform is not adequate for detailed requirement gathering or quantitative assessment.

- Hardware-based platforms consist of experts/end-users using mock-ups or low fidelity prototypes. It usually follows a modular development to allow the use of the platform in other projects with similar environments. It should give a good enough approach to reality, allowing sometimes to fast-forward the scenario to see the consequences of the decisions taken. It provides qualitative assessment and initial quantitative data. The scenarios to be played must be modelled in the platform which limits the number of scenarios that can be played and the flexibility to address them. The simulations are more expensive than paper based and although they provide initial data assessment, they are not good for quantitative assessment.
- Web-based platforms could be useful to obtain a massive confirmation in the results (given access to the proposed solutions to a big amount of people avoiding travels and saving time of the experts) or new proposed improvements. There is a need to record the game sessions to be able to analyse them off-line. It can be a tool to ensure independence of results as it broadens the background of the players. It could also be used as a dissemination vehicle of the new outcomes or as a training tool if updated at the end of the design process. As hardware-based platforms scenarios must be modelled before the execution of the games which limits the number of scenario and its flexibility. Another limitation is that as people involved are no longer located in the same place the feedback is more limited.

Role games place the experts in a situation with specific problems that they have to face through the use of available tools. As in other HIL techniques, there must be an initial training session to allow the participants to familiarise with the dynamic of the experiment, and the use of the game tool.

Besides, subjective aspects of the human behaviour can be assessed from two different sides, from the players' perspective who are directly involved in the game and from the perspective of the observers and managers of the game who can be focused on the interactions between players and other particular behaviours not perceived by the players. All this information is compiled through the performance of a pseudo-real environment in which actors are invited to act as in the real world to reach a specific objective. This allows complementing the information collected from questionnaires which only reflects the opinion of the participants. This aspect is especially useful to assess some evaluation criteria as for example the players' acceptance or the human performance.

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- Paper-based platform could be adequate for a preliminary assessment of the issues/risks/gaps identification;
- Hardware-based platforms could be adequate for a final assessment in which very-high confidence on the results and approach to the reality are crucial;
- Web-based platforms could be useful to obtain a massive confirmation in the results (given access to the proposed solutions to a big amount of people avoiding travels and saving time of the experts) or new proposed improvements.

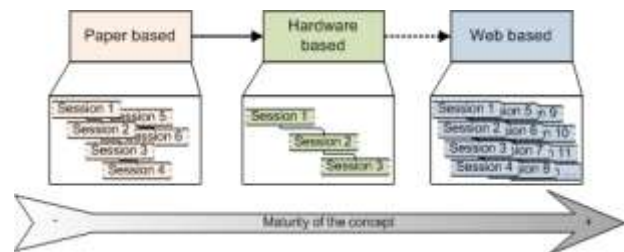


Figure 2 Combination of sessions in different platforms

The successive use of the three approaches enables the early detection of issues in the design, through an increase in the investment, without having to develop a complete system before having a good assessment on the acceptability of the automation approach. Figure 1 illustrates the successive use of the three approaches. The number of sessions in each approach will be driven by the investment need to develop new scenarios, and the availability of the experts to be involved.

Quick review of role-based games in ATM projects

The role-based games have demonstrated its usefulness in the assessment of the interactions between Human-Human and Human-Machine as in Episode 3, addressing the description of new ATM concepts and also the roles involved in the concept:

In airspace organization and management role-based games were used in combination with expert group techniques [9]. First, paper-based games were used to collect preliminary results that support the concept development, and requirements for the platform configuration that was used in following sessions (hardware-based). The main outcomes of the exercise were the identification and detail of several Collaborative Decision Making processes when a military reservation area is requested, the information needs of the

different users involved in these processes (partly implemented in the hardware platform), and the definition of responsibilities for an airline negotiation facilitator.

In [10], hardware-based role-based session was used to deploy dynamic demand and capacity balancing (DCB) measures. One of the outcomes of the exercise, together with the concept refinement, was the need identified by the experts of advanced tools in support of real-time network management and monitoring. The game provided high level requirements for these tools.

In [11], several paper-based gaming exercises were used to establish the impact on queue, trajectory and separation management of medium-long term monitoring and solutions tools in the controller environment. Outcomes of the exercise were responsibilities distribution and requirements for support tools. Also in this exercise, the web-based approach was tested although not implemented.

Using a role-based game

The experiment should start defining a simple scenario to be played by experts 'around a table'. The material to be used are the rule set, the scenario, tools and roles description, and, depending on the platform selected, a paper and pencil, a personal computer or a hardware platform.

During the first session a quite basic scenario should be played as a training session answering all questions related to the game dynamic and tool.

Next sessions will be played using scenario specifically designed according to the issues to be solved. Paper scenarios should be designed to answer high-level questions, but information processes and flows should be the same as in the web/hardware-based scenarios, e.g. if you are a air traffic controller you do not need the same type of information if there is only one aircraft flying in your airspace than if there are two. In this second case, you will need information on the possible interaction between both aircraft which is not necessary if you only have one flight.

Questionnaires should be used before and after the execution of role-based game sessions, and debriefings are also essential to capture improvements that may be lost otherwise. During the on-site sessions (paper and hardware-based platforms) there will be observers who should note down the processes executed, the strategies shown, and the needs expressed.

The feedback from paper sessions should be used to enhance the hardware-based and/or web-based games. The use of these platforms allows having more complex scenarios and rules, executing the game in a more realistic context, providing more reliable and accurate results and increase the number of people exposed to the problem, making the evaluation more independent of the personality of the experts performing the role game.

In summary, role-based games suppose a new method to be used in place or in conjunction of other techniques such as questionnaires, personal interviews or brainstorming, because this technique improves the situation awareness of the actors. This improvement is reached through the actual execution of the processes in the game; this ensures a high confidence on the results. Finally, the flexibility of this technique would allow exploring different situations and approaches with a good cost-effectiveness result.

As introduced previously, role-based games could be useful to support the assessment of the impact of automation in human factors. One specific process to perform this assessment was presented to envisage how these games could be applied together with a specific method. Designing and executing role-based gaming sessions with experts would help identify the most suitable option early in the process, before actually implementing it.

The role-based games have been used to investigate new institutional structures [5], [8]. They have been defined by Torvinen in "*Investigating Institutional Structures: A role-based design game as source of innovations*" [5] as having three levels.

"A first level where everything is taken as it seems to be. At a second level the solution, e.g. the work process, is questioned. At the third level the problem, e.g. the object or outcome of work, is questioned"

NOTE: To avoid misunderstanding with the level of automation we will call the game levels described by Torvinen, game steps from now on.

Applicability of the role-based technique in assessment of automation impact in humans

Our proposal is to use the role-based game and the different game steps in conjunction with the process in 4-phases previously described in this document to study the impact of automation in humans (see "Automation and Human Factors" section). The first step will be used to identify which is the current problem (or structure) and how it is solved currently. This step would cover the phases 1 and 2 of the process in which functions to be automated and the human information processes impacted will be identified. The second step of the game will be used to identify possible applications of automation. This step would address the phase 3 in which the level of automation is assigned for each human information process and the phase 4 for assessing each level of automation proposed. Finally, the third step is used to seek solutions to the new problems that may appear because of the application of this automation.

The first step is used to engage the attention of the experts to the problem(s) that we want to solve through the use of automation, and to present the dynamic of the role game. The use of a familiar scenario will help in the understanding of the rules of the game. Although scenario might not be a

current one but a futuristic scenario with the problems that we know there would be (e.g. an overcrowded sky) and the current solutions applied. This step could be explored using only paper platforms because it is the situation we want to change, so a cost-effective platform should be used.

The second step will introduce the type of automation we want to try in the scenario as solution to the problem(s). As already mentioned, usually there is not one unique and ideal automation approach previously identified. Different scenarios will be used to try the different combination and identify which one is better valued by the experts. Each scenario will have several sessions to support the definition of the new responsibilities, the redistribution of tasks, and the requirement that the tools must have. No-go issues and strategies will appear, and the observers of the development of the game must capture them. It is quite important that the successive sessions are adapted according to outcomes of the previous ones.

This step should be played initially using paper-based platforms, once the automation approach is clear enough a hardware platform should be updated with the outcomes of the paper-based sessions. Expert will then play on the hardware scenarios similar to the finally selected, with the main difference of being in a more realistic environment.

Ideally no-go issues should be addressed in the paper-based sessions to save costs.

Big issues envisaged during the second step would lead to the execution of the third step of the game where maybe completely new scenarios with structure changes should be defined. It can be used to address situations where the actual structure of the work is found to be obsolete due to the new introduction of the automation.

The proposal previously detailed is depicted in the Figure 3 where game steps and phases are represented as an information flow together with the recommended platform that should be used, paper or hardware. Web-based platform (not depicted) should be used after the hardware platform or instead of it.



Figure 3 Proposal to perform the assessment using role-based games

The web-based platforms will be used as a way to confirm the outcomes of the hardware platforms or to refine a closed set of requirements. The use of web-based platforms is a way to expose the solution to a broader audience, thus it will be especially useful if a new issue has appeared and an innovative solution has been proposed by the experts.

Thus, defining the proper scenarios and focusing on each of the four-phases of the process described in the “Automation and Human Factors” section of this paper, an assessment of the automation impact in roles can be performed, highlighting the human factors issues and then, possible solutions for them. The results obtained by the experts could be identified (less effort for the experts involved in the gaming) with a higher confidence on the results [9].

The use of the role-based technique is useful when there is interaction between different actors, thus it should not be used to assess the higher levels of automation where human intervention is no longer needed or it is of marginal impact.

ROLE-BASED APPROACH AND OTHER DESIGN METHODS

Approaches that have also been used to address the impact of automation include:

Expert groups: An expert group is a group of people used as a pool of knowledge that provide feedback to questions from the developers/designers. Expert groups are not a validation technique by its own and usually are used to address concrete questions. Role-based games involves the experts and/or end-users in the execution of the actions and could be used together with expert groups to clarify scenarios design.

Expert panel: An expert panel is a specially constituted work group that meets for evaluation of a situation or artefact. Although it is constituted by expert they are created for a specific task. The background of the experts usually is very similar. In role-based games, although the environment is common (e.g. ATM) the background of each of the actors usually is quite different (e.g pilot and controller).

Brainstorming: is a group creativity technique by which a group tries to find a solution to a specific problem by spontaneously contribution of its members. Role-based games are more structured, although both techniques are good for ice-breaking.

Real-time simulations: are human in the loop simulations that use a physical system that can execute the main features of the final system. The prototype behind a real-time simulation is usually very complete while the hardware platforms used in role-based games are centred in the presentation of information to the users, and the calculation of parameters behind does not correspond to the specifications of the real system.

Two of the most popular tendencies in design are participatory design and Personas method. Role-based games can be used with both approaches.

Participatory design is an approach to the assessment, design, and development of technological and organizational systems that places a premium on the active involvement of workplace practitioners (usually potential or current users of the system) in design and decision-making process [16]. The fields of application of participatory design are broad as well as the techniques to engage the participation of end-users [17]. The role-based technique is based in the importance of involving end-users and experts in the identification of problems and solutions. Therefore, it follows the participatory design main principles and can be used as a technique to promote end-users participation. The role-based game also allows exchanging the roles among participants, enabling them not only to express their needs but to understand the needs of other people interacting with them [11].

The personas method [13] enhances software and product design through a description of end-users and what they want to achieve. Archetypical characters are detailed through the data collected in interviews, mass surveys, market and user research, and/or ethnographic field studies [14]. This method is used as a mean of communication and to engage designers to think about the users' needs and goals instead of being focused on the tasks. The method is applied usually when the group of end-users is broad [13] and not always accessible.

Role-games can be used complementary to this method when end users are accessible: the Personas method would be used to describe the goals and environment where the automation is applied, and the feasibility of the proposed solution(s) would be tested through the use of role-based games. In this case, as the group of end users is broad, web-based games would be the most relevant tool.

CONCLUSIONS:

Role-based games can be an adequate technique to study the impact of automation in humans due to the appropriateness of this technique for the human-human and human-machine interactions assessment. They can provide other alternative to be applied in isolation or with other techniques to get results in these types of assessments taking advantage of their strong points. The use of the role-based games for the automation systems design will be explored in the "Assessment of Degree of Automation on Human Roles" (ADAHR) project inside the framework of SESAR Work Package E [12].

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