A Framework for Risk Assessment in Augmented Reality-equipped Socio-technical Systems*

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***Abstract*—New technologies, such as augmented reality (AR) are used to enhance human capabilities and extend human functioning; nevertheless they may cause distraction and incorrect human functioning. Systems including socio entities (such as human) and technical entities (such as augmented reality) are called socio-technical systems. In order to do risk assessment in such systems, considering new dependability threats caused by augmented reality is essential, for example failure of an extended human function is a new type of dependability threat introduced to the system because of new technologies. In particular, it is required to identify these new dependability threats and extend modeling and analyzing techniques to be able to uncover their potential impacts. This research aims at providing a framework for risk assessment in AR-equipped socio-technical systems by identifying AR-extended human failures and AR-caused faults leading to human failures. Our work also extends modeling elements in an existing metamodel for modeling socio-technical systems, to enable AR-relevant dependability threats modeling. This extended metamodel is expected to be used for extending analysis techniques to analyze AR-equipped socio-technical systems.**

***Index Terms*—augmented reality, immersive visual technology, socio-technical systems, risk assessment, safety modeling.**

I. Introduction

Augmented reality enhances human performance by expanding human capabilities and upgrading human to an AR-extended human. For instance, via the usage of visual augmented reality, human vision capabilities may be extended. An example in the automotive domain is the extended situational awareness enabled by adding safety alerts about blind spots of a car on the windshield [1].

While the aim of using augmented reality is improving human performance, new types of dependability threats might be introduced to the system because of these new technologies. In the context of the EU ImmerSAFE project [2], immersive vision-oriented augmented reality, used within safety critical systems, is in focus. Safety critical systems equipped with such augmented reality can be considered as example of socio-technical systems since not only the risk of technical entities has to be assessed in order to ensure safety, but also the risk of non-technical entities such as humans and organizations and effect of augmented reality on them has to be assessed.

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If we consider a socio-technical system as a component-based system, then the behavior of the socio-technical system would be the result of the concertation of the various components composing the system: humans, organizations, hardware and software. Based on Avizienis et al. [3] terminology, any deviation in human functioning from correct functioning is called human failure. Human error is the reason for human failure, which is defined as deviation in internal human state from correct human state and since it can not be detected unless it leads to human failure, we do not consider human error. Fault is the reason for human error.

Based on ISO 31000: 2018 [4] standard, risk means "effect of uncertainty on objectives" and effect is "deviation from the expected". Risk is "usually expressed in terms of risk sources, potential events, their consequences and their likelihood". In most situations it is not possible to provide risk likelihood, because there is not enough experience about those situations for likelihood calculation. Because of this difficulty in quantitative analysis, we work on qualitative methods using risk sources, potential events and their consequences.

II. Problem and Research Goals

There are various human failure taxonomies and taxonomies of influencing factors on human failures that can be used as the basis in analysis tools. However, there are no data on effect of augmented reality and the new types of human failures and faults leading to human failures that would be introduced to the system because of augmented reality. We consider three steps for risk assessment that are identification of risk, modelling entities' behavior and analyzing system behavior. To do the risk assessment in AR-equipped socio-technical systems, we need to have extension in each of the steps, because effect of augmented reality is not considered in current risk assessment techniques. The first step to do the risk assessment, is to identify risk, which is expressed by risk sources and potential events. Second step to do the risk assessment is to model the entities' behavior, which means to identify the relationship between the entities' behavior and their consequences. Finally, the last step is to analyze the system behavior, which means studying system behavior based on components behavior and their interactions. After identifying system behavior, risk control and risk treatment should be done, which is beyond the scope of this research and we consider as future work. For example, based on modeling failure behavior and effect of failures on system behavior, changes in UI or system design would be required.

The main research goal of this thesis is assessing risk in augmented reality-equipped socio-technical systems. In order to address the overall research goal, we define concrete sub-goals as follows:

1) Identify and classify the common and variable human-related dependability threats in relation to the technological and organizational changes.
2) Develop representation means for capturing the behavior of the involved entities and the behavioral result of their interactions within AR-equipped socio-technical systems.
3) Analyze the behavior of AR-equipped socio-technical systems such that risk can be assessed.

III. Methods

An overview of the adapted research method used in this research, which is based on [5], is as follows: First, we identify the research problem and define the main goal. Then, we divide the research problem to sub-problems and identify the subgoals. After that, we propose a solution for the gap identified on the study. Next, we implement the solution and evaluate on an academic example. After this step, the results can be published as a paper. Integration and communication with industry can also be considered as a step after academic evaluation of the proposed solution, to enable evaluating the solution on real world problem. Finally, if the result is accepted for the real world problem, it will provide the possibility of publishing a paper, otherwise problem should be identified to repeat the iterative task for the new research problem. In order to identity research problem and sub-problems we used state of the art review. In order to define main goal and sub-goals we used literature review. To propose solutions we used qualitative data analysis and to implement them we used classification and tabulation, to make it possible to have an overview of the collected data. Finally, for evaluation and integration, we used case study methodology.

IV. Preliminary Results

Hitherto we have achieved some technical contributions. First contribution is a taxonomy of AR-extended human functions based on state-of-the-art human failure taxonomies. This taxonomy is obtained by extracting human functions from human failure taxonomies, organizing and harmonizing them and then extending by adding AR-extended human functions extracted from experiments and studies on augmented reality. We named this taxonomy AREXTax [6]. Second contribution is a taxonomy of faults leading to human failures including AR-caused faults based on state-of-the-art fault taxonomies. This taxonomy is also obtained by organizing and harmonizing faults from various fault taxonomies and then extending them by adding faults stemmed from AR. These AR-caused faults are extracted from experiments and studies on augmented reality. We named this taxonomy AREFTax [7]. Our third contribution is proposing representation means [8] by extending modeling elements in SafeConcert [9], which is a metamodel for modeling socio-technical systems in order to enable modeling of effect of augmented reality based on identified risks. Using proposed modeling elements provides modeling capabilities required for modeling new types of dependability threats caused by AR. We used SafeConcert as the basis of our modeling extensions, because it is a tool-supported metamodel for modeling socio-technical systems and it is included in open-source AMASS platform [10]. Using the extended modeling elements provides the possibility of analyzing system behavior by considering AR effects.

V. Next Steps

As future work, we aim at implementing our conceptual proposed extension of SafeConcert within CHESSML (CHESS Modeling Language) [11]. In addition, we aim at extending current compositional analysis techniques to be able to assess risk at system level. Specifically, our starting point will be Concerto-FLA (Failure Logic Analysis) [12], which is a plugin within the CHESS toolset, part of the open-source AMASS platform. By extending this plugin based on our proposed extended modeling elements, it is possible to analyze the failure propagations at system level and provide analysis results.

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