A Sustainable GIS-Based Serious Game Approach to Improve Railways Resilience

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Abstract

Railway Infrastructures have been globally emphasized due to their crucial role in supporting everyday life by providing the flow of supplies, and services across the world. Therefore, considerable efforts have been devoted widely to improve the aforesaid systems' efficiency, resilience, and long-term viability. Being increasingly at risk from cyber-physical threats and natural disasters, as well as the interrelationships between critical infrastructures especially in smart cities, have made the situation more complex and highly challenging for urban planners to manage the impacts of cascading effects, develop mitigation plans and rapid recovery. Previous studies indicate that a promising approach to provide a valid environment for the elicitation of expert knowledge to tackle those challenges is Serious Games. Not only this method, but also GIS techniques are commonly tasked with solving and tracking spatial problems because of their great capabilities to meet the Spatial-based requirements of serious games. This paper presents a new integrative framework using GIS-based serious game to address the challenging issue of railways resilience. The serious game concept presented in this paper is being developed as part of the H2020 funded PRECINCT project (www.precinct.info).

Keywords: sustainability, serious game, GIS, infrastructure resilience.

1 Introduction

Structural Health Monitoring (SHM) of critical infrastructures such as bridges, tunnels, rail tracks, and transition zones is crucial for smooth functioning of our

modern cities to minimize maintenance costs and to increase the human safety. This is due to the fact that the aforesaid infrastructures, which are known as the foundation of our today's world, may experience damage or threat induced by different reasons such as common weakening of material properties, fatigue, aging, delamination, corrosion, creep, micro structural defects, environmental influences, overloading, changes in loading patterns or various unexpected causes such as wind excitations, fires, earthquakes, floods, disastrous consequences of global warming, and intentional cyber or physical attacks (e.g. malware, and terrorist driven exploits) during their service life which can critically disturb their integrity and safety [1, 2]. Therefore, improving resilience of critical infrastructures has become a priority for many countries e.g. the European Union authorities which not only requires knowledge about the threat, but also about the area and infrastructures that can be affected. In this direction, according to PRECINCT [1], which is an on-going project funded by the European Union's Horizon 2020 research and innovation programme, Serious Game (SG) and Geographic Information System (GIS) are able to identify the unanticipated combinations of threats or cascading effects in critical infrastructures [3, 4].G is a computer-based simulation that merges knowledge and skills development with video game-playing aspects to enable active, experiential, situated, and problem-based learning. In other words, SG is a simplified version of reality that can enable players to experience decision-making and evaluate the results [5]. GIS has also been defined as "a fundamental and universally applicable set of value-added tools for capturing, transforming, managing, analysing, and presenting information that are geographically referenced" [6]. With rapid growth of cutting-edge technologies, various researchers have successfully integrated the GIS into their methods for different purposes, i.e. storing, retrieving, analysing, and reporting information needed to support knowledge-related decision making. Likewise, this paper presents a novel approach to explore the capability as well as efficiency of GIS technology in integration with SGs for enhancing the resilience of transportation infrastructures with the emphasize on railways to understand and quantify for any damage resulting from the threats. This is because SG is capable to combine game technology with science in real-world applications. To the best of our knowledge, current research is the first attempt to illustrate the feasibly of GIS-based SG procedure in railways.

2 Methods

In this article, a SG in infrastructure management is proposed including a GIS component to provide spatial awareness in the serious gaming scenarios. The extensive capability of GIS to present maps and set contexts for the scenarios as well as spatial planning are all practical examples of spatial awareness in a serious gaming context [7]. The significant advantage of GIS for sustainable infrastructure comprising railways is that a user may sit at a remote computer and get streams of integrated spatial data from various sources, enabling them to perceive the city as a whole and make data-driven decisions [8]. The use of geo-visualizations provides ways to display geospatial data other than what is connected and regulated by cartographic principles. The geo-visualizations of data in this situation go beyond maps, which have long been the standard expression of geospatial data [9]. Urban

planning often uses methods of evaluating resilience by analysing data in quantifiable ways, such as using GIS [10-12]. Although it is possible to store and manage qualitative data within GIS, it has traditionally been associated with the quantitative revolution in geography through the usage of spatial models and statistics [13, 14]. The point of SG combined with GIS is primarily to facilitate more effective discussions/training and knowledge sharing between stakeholders. The GIS component allows to bring the spatial element in the discussion as well as using visualisation techniques, and spatial analytical tools to extract more insights for the discussion. The result of this enhanced discussion through GIS based SG is a more informed management of the resilience of critical infrastructure. Therefore, in this paper, a SG design concept is proposed to improve railway infrastructure resilience which is outlined in six main steps, i.e. (1) fit player's data to train machine learning, (2) generate clusters, (3) create prediction models, (4) identify vulnerabilities, (5) discover trends, and (6) create visualizations. In order to conduct the aforesaid approach, it is required to feed various key contributors/inputs (See Figure 1). As it can be seen from this figure, the inputs of the proposed serious game include player attributes, different threats, resilience indicators, threshold levels, attack and defence strategies, and available budget. Game play records will be analyzed, and data will be mined to produce training material and understanding of how interventions can change the resilience index.

3 Results

The final model of the GIS-based SG system is presented in Figure 2. Spatial data will feed the information required to be visualized in the serious game and will be utilized in the back end of the serious game. The back-end database will be configured for a variety of different spatial formats and/or geodatabases and arranged in pre-symbolized layers. Datasets contain key attribute data to assist in querying/filtering of data spatially or non-spatial databases via SQL and a geospatial server with standardized Web services (OGC standards). The GIS system has data filtering features required to simulate conditional cascading effect probabilities in specific scenarios, including compromised physical and cyber infrastructure, based on the Resilience Methodological Framework. Through the front end, the GIS-based SG offers an interactive decision support and scenario specification/building user interface that the player interacts with during the game play, which integrates and communicates with back-end simulations. The game client development activity (as shown in Figure 2) entails programming of the serious gaming front-end based on the Game Design as well as backend for user management, storing and analyzing the interactions of individual users in the system. The Unity Engine and the respective libraries and frameworks for game programming will be used for client development and providing a development architecture.

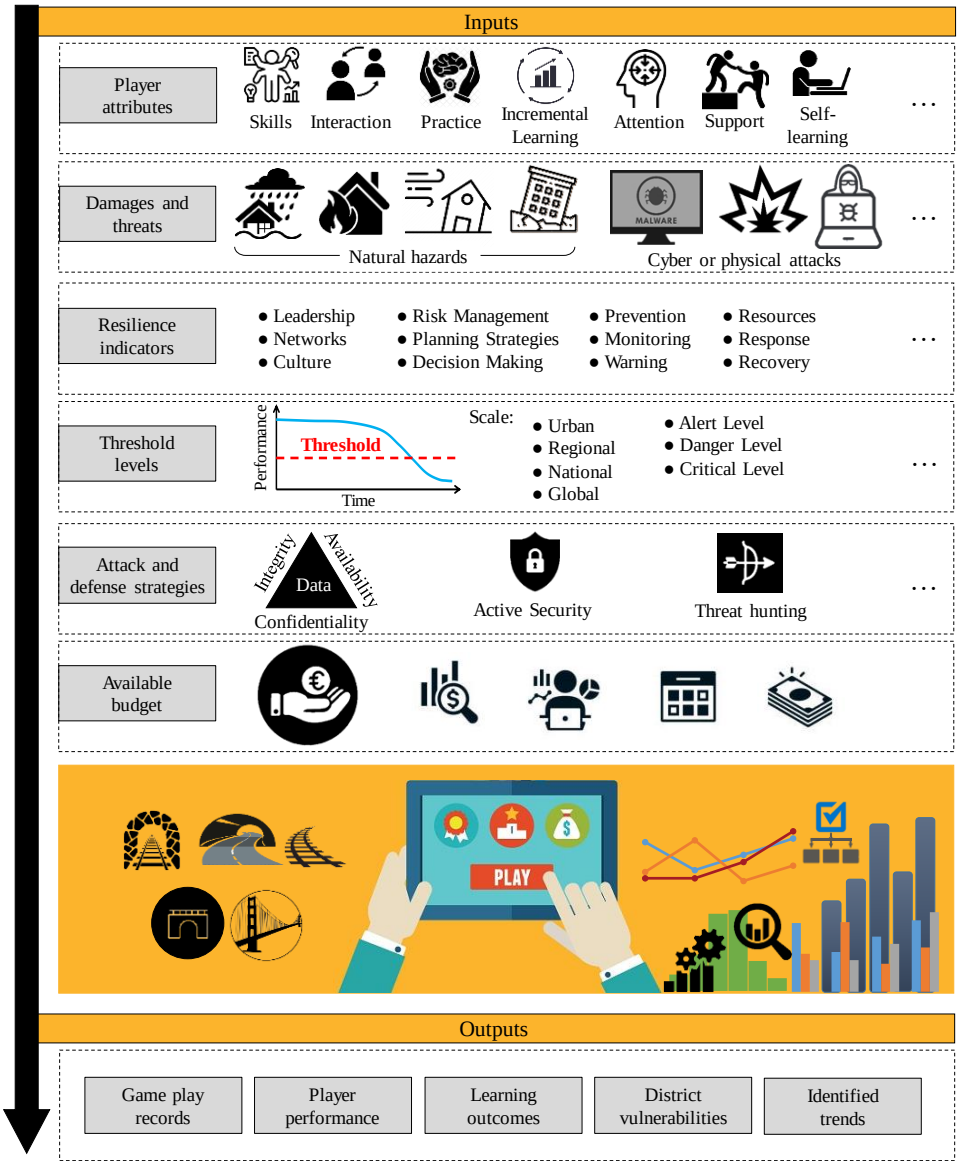

Figure 1: Serious game design concept.

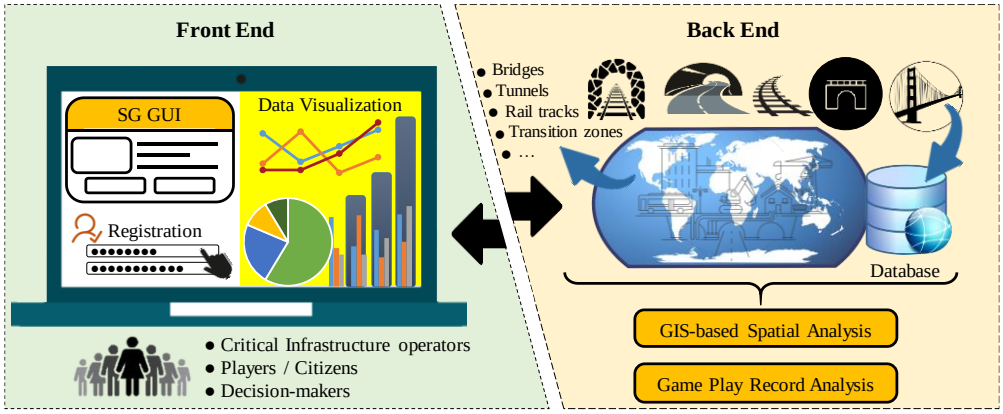

Figure 2: The final model of the proposed approach.

4 Conclusions and Contributions

The focus on threat detection systems has been on the rise for engineering applications in order to evaluate the structural integrity. Therefore, effective and reliable damage detection approaches are very significant to monitor engineering assets (e.g. railway structures) for the occurrence of any threat or damage. In the same line and based on the literature review, it is crucially required to enhance the smartification of threat detection systems using emerging technologies due to the high impact nature of railways. In this regard, this study attempts to employ the integration of GIS and serious game technologies inspired by the H2020 funded PRECINCT project as a novel risk estimation strategy to improve the resilience of railways. The proposed GIS-based SG is greatly capable of reproducing certain circumstances and leveraging gaming elements, i.e. scoring, game narrative, and realism to facilitate a game player's learning procedure. Besides, spatial awareness is a particularly topical theme within critical infrastructure management. Since serious games are closely being linked to spatial analysis, it seems that serious games with a spatial emphasis are set to be increased, considerably. GIS will be required to help with data management, monitoring, and quality control. Data from the data management system will be queried, converted to a map, and then displayed on the online user interface. Moreover, data visualization in combination with geographical analysis has also received increasing attention to display data with GIS through 3D representations. Thus, the proposed gaming approach can provide a powerful experiential learning and training tool for staff involved in the defence of railway infrastructure. The serious game simulation is able to present desired learning objectives via prompting the player to make various decisions based on cyber-physical threat scenarios.

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