PACAS: A Gamified Platform for Participatory Change Management in ATM Systems

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Abstract. In this paper, we report on the development of a web-based platform for Participatory Architectural Change Management in Air Traffic Management Systems (ATM) as part of the SESAR H2020 project PACAS. The platform is the result of an iterative requirements engineering process that actively involves ATM domain experts, starting from stakeholder analysis, to requirements elicitation, scenario definition, and validation.

Key words: Requirements Engineering, Gamification, Automated Reasoning, Air Traffic Management.

1 Introduction

Most of today's software systems are part of larger complex systems, that include not only technical components, but also humans and organizations. These larger systems are otherwise known as socio-technical systems [10] and they stand at the core of how people work and collaborate with others while using the technical systems to get things done. Examples include healthcare systems, e-commerce sites, and air traffic management to mention a few.

Change is inevitable, and socio-technical systems make no exception to the rule. Therefore, they are continuously evolving due to various possible changes: (i) system and subsystems changes, (ii) organizational and domain changes, (iii) normative and regulatory changes, and/or (iii) assets changes. Any of these changes may affect the ability of the socio-technical system to satisfy its intended requirements and function well.

Dealing with change is an important activity in order to understand the implications of change, how it affects the rest of the system, whether it introduces new requirements, and so on. In order to build a Change Management Platform, which will facilitate understanding, modeling and analyzing changes at different layers of abstraction, it is important to have the active participation of domain

experts who can analyze the impact of change from different perspectives. Most importantly, this should be done in an iterative fashion in reingineering an already running system, so that new requirements dictated by a given change issue do not conflict with existing ones or cause problems on the rest of the system.

In this paper, we report on the development of a web-based platform for Participatory Architectural Change MAnagement which is triggered by a real case concerning the evolution of Air Traffic Management (ATM) Systems as part of the SESAR H2020 project PACAS [1]. Given that decision-making involves the consideration of more high-level objectives, such as safety, performance, economic efficiency, etc., the change management process should involve multiple ATM domain stakeholders, one for each given objective, in order to explore a vast space of alternatives and agreeing on optimal solutions. It becomes, thus, crucial the active participation of stakeholders. Indeed, in ATM different experts from different companies across Europe collaborate to design the future European ATM which is intended to improve safety, while cutting down costs and environmental impacts. However, given the variety of experts, their different areas of expertise, as well as their geographical distribution, participatory change management requires user engagement and tools to support and facilitate the work of experts along their interaction. To address the first concern, in recent years, gamification is broadly used as a tool to engage participation with the help of game elements, such as leader-boards or challenges between users. On the other hand, a multi-perspective, model-based approach provides important benefits in that: (i) it allows analyzing individual perspectives without the need of a holistic representation; (ii) it handles complexity through automated reasoning techniques in a transparent way to find optimal solutions as a trade-off among different objectives.

Therefore, the platform we present is a gamified one, and relies on the work of experts that capture the implications of change with the help of a multi-view modelling environment, which supports four default languages to allows the analysis of these four perspectives: safety, security, economic and organizational. The collaboration of experts and decision-making, on the other hand, are supported by automated reasoning techniques within each model and across models with the help of natural language processing.

The paper is structured as follows. We briefly describe the PACAS project in Section 2, while in Section 3 we describe the change management process, while Section 4 presents the platform. Section 5 discusses related work and concludes.

2 PACAS

Air Traffic Management (ATM) systems are complex systems of systems. Participatory Architectural Change MAnagement in ATM Systems (PACAS) is a Horizon 2020 project in the framework of the SESAR Research and Innovation Action (RIA). The main objective is to better understand, model and analyze

[1] `http://www.pacasproject.eu/`

changes at different layers of the Air Traffic Management (ATM) system to support change management, while capturing how architectural and design choices influence the overall system. Understanding all possible consequences of a design decision in an ATM system is a challenge due to the complexity of ATM systems and the existence of tight interdependencies within the ATM architecture. Knowing the implications of change(s) over the whole system is crucial to support decision-making, while making sure that the ATM system does not suffer from any issues with respect to functionality, safety, security, performance, cost efficiency, or other desired characteristics of a well-functioning ATM system. The project aims at developing an innovative participatory change management process wherein heterogeneous stakeholders actively participate in the architectural evolution of the ATM system.

We provide an overview of the participatory change management process, emphasizing the importance of active stakeholder participation. We describe the two main support tools, i.e. gamification for stakeholder engagement, and automated reasoning techniques for handling complexity.

During the demo, we will introduce the PACAS approach, expressly created for architectural change management in ATM systems, and we briefly describe an ATM example case study dealing with the Sectorless change issue, and conclude with a demo of the framework.

In dealing with change, we use the following terminology:

- *Change Issue*: refers to a planned change under evaluation. For instance, Sectorless is an ongoing change in ATM that considers moving to a sectorless approach ATM is a novel way to tackle air traffic management in upper airspace without conventional sectors that has already been proved feasible. This change is expected to improve performance and organizational aspects, with significant increase in capacity and controller efficiency, although safety and security issues require more investigation.
- *Decision point* - we analyze a given change issue splitting it into several decision points. For instance, in Sectorless there are several questions one needs to answer, such as *How many aircrafts should be assigned to each air traffic controller (ATC)?*, or *What criteria should be used to assign an aircraft to a controller?*, and so on. The first question is captured by the decision point *Number of flights per ATC* as opposed to the existing *Handover of aircrafts*.
- *Solution* - within each decision point, we analyze different options, aka solutions. In Sectorless, *automatic assignment* is envisioned.
- *View* - each solution is analyzed from a given expert perspective, aka view. In PACAS we support these four views: safety, organizational, security and economic.
- *Contribution* - in order to assess how well a given solution fares with respect to already set objectives, we capture how a solution contributes to overall validation targets laid down by Eurocontrol and SESAR. Example validation targets include *Increased safety* and *Triple capacity*.
- *Model* - For each view, we support default modeling notations to allow experts to represent but also analyze a given solution from their perspective,

alongside the possibility to upload files should different languages or notations be used by the experts. The default languages in PACAS are: Fault Tree [5] for safety, STS-ml [2] for security, BIM [4] for the organizational, and an income statement (costs/revenues) for the economic view.

3 The Change Management Process

The change management of complex systems, such as ATM systems, cannot be handled by a single person. For each change issue, i.e., for each planned change to be done in an ATM system from the implementation of a single component in the cocKPIt to a new way of managing traffic in the airspace, teams of experts need to collaborate in order to specify the best modifications of the system.

As such, we support the interaction of these main types of users, namely experts, team leaders, builders, company representatives and a game master.

The *Game Master* has the power to start a change issue, i.e., ask different companies to study how to apply the change and propose the best modifications (solutions). The *Company Representatives* serve as contact points in the various companies involved in the analysis of a change issue. Thus, they deal with the creation of teams. In PACAS teams are created per area of expertise (view).

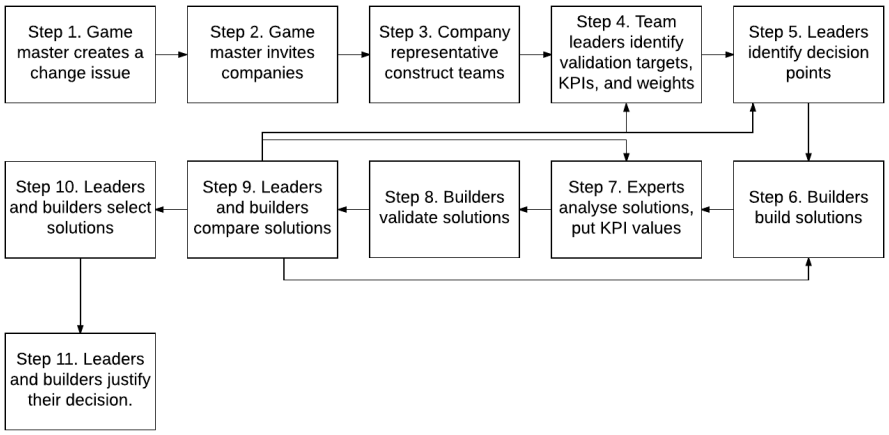

Fig. 1: The Pacas process for change management

Team Leaders will choose the best modification(s) of the ATM system for a change issue. They will study the diagrams/models developed or adopted by the *Experts*, who represent domain experts that know at least one of the modeling languages used to specify and analyze changes and their implications. Team leaders interact with experts, and decide which solution provided by Builders (see below) is the best for the change issue. Similarly to Experts, they are experienced

in at least one of the perspectives supported by the PACAS web platform, and have a good knowledge on the part of the ATM system involved in the change issue. Thus, a Team Leader could be an expert too. Finally, *Builders* are not only domain experts, but have also a wide knowledge of the overall system. They specify the solutions that are to be analyzed by Team Leaders and Experts.

They all interact following the process in Fig. 1 to make a decision.

4 The PACAS Platform

The novelty of the PACAS platform (Fig. 2) relies on these three main pillars:

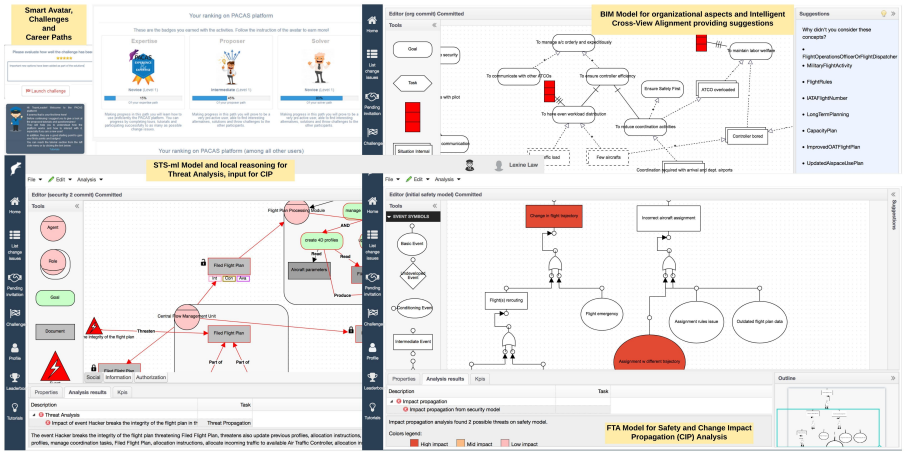

Fig. 2: PACAS gamification, multi-view modelling, and automated reasoning

Gamification. In order to drive collaboration and keep users engaged, PACAS makes use of psychological and social drivers for interaction [7]. In designing the gamification solution for PACAS, we have performed stakeholder characterization in better understanding the motivations of the PACAS end users. Additionally, we have performed a deep study of the context, in order to understand the ATM change management process, and most importantly the roles involved, their tasks, goals, social structure and the nature of good being produced following the MAF framework [8]. From our analysis as well as through interviews, workshops and questionnaires filled out by ATM domain stakeholders, we have identified a number of requirements for the PACAS gamification solution, including *Coverage* of all aspects supported in PACAS, *Collaboration*, *Participation*, *Stakeholder identification*, and *Communication*, among others. At the same time, we have identified two important anti-requirements, namely *Competition*, which can lead to conflicts among participants obstructing collaboration, and *Time pressure*, which can lead to rushing work and poor

quality to meet deadlines. As a result the PACAS gamification solutions builds around three paths, that, while orchestrating the other gamification elements, foster user progression along the three paths reaching different levels while using the platform. Specifically, we have defined mechanisms of challenges among different roles, at the completion of which and after reciprocal evaluation they gain badges to further progress. A smart avatar is used to display messages and suggestions to users, providing timely information at all times. Finally, we support gamified tutorials for users to follow and improve their level of knowledge and expertise regarding the PACAS platform.

Multi-view modeling. Integration of the refined modeling notations and an automatically generated shared model for decision-making, in which contribution links from solutions to validation targets are drawn taking into account the result of the automated reasoning on multi-criteria decision analysis. The platform is modular, in the sense that new modeling environments can be integrated to support experts using different languages in representing and further analysing aspects related to their area of expertise.

Automated reasoning techniques. PACAS supports local reasoning techniques for the security view, namely well-formedness, security and threat analysis for STS-ml [6]. In addition, to aid decision-making, the platform integrates two reasoning services: (i) intelligent cross-view alignment (ICVA) [1], which with the help of NLP provides suggestions to experts in verifying whether changes in one view impact other models and views, and (ii) multi-criteria decision-making analysis (MCDA), which allows identifying first the best solutions per validation target to then propose the best overall solution, which is a trade-off among various aspects, in order to support making an informed decision.

5 Conclusions

In this paper we have reported on a gamified collaborative platform for participatory change management in ATM system. The resulting platform is the result of the end-to-end inclusion of ATM domain stakeholders, who have actively participated starting from early requirements the final release of the platform, through a number of iterations where we have presented mockups and performed prototype validations.

As far as our knowledge goes, there is little work that reports on such gamified platform, the creation of which involves stakeholders active participation. REfine (Snijders et al. [9]) is a gamified online platform for requirements elicitation and refinement by involving a crowd of stakeholders: users, developers, analysts, etc. Similarly to our approach, this is tailored to promote the long-term, sustainable collaboration among stakeholders. However, while REfine is specifically thought for requirements engineering for software products, the PACAS platform is concerned with supporting change management in large-scale socio-technical systems. Helms et al. [3], on the other hand, explore how class or computer-based trainings can be (re)designed using gamification to increase student engagement and motivation. They propose a method for the design of gamified training for

Dutsch railways. The method is based on design science research, and extends the instructional design model ADDIE and uses a database of educational game elements to select the latter. The PACAS gamified solution on the other hand is based on goal models created in the context of the AGON [7] framework while capturing acceptance and gamification knowledge.

In developing the PACAS platform we have faced several challenges, such as the need for vast amount of domain specific knowledge to tailor a customized platform for the ATM domain, identifying the right domain stakeholders, terminology alignment, and last but not least characterizing stakeholders for the gamification solution starting from a small representative set.

Future work considers the application of the PACAS platform in other domains and scenarios requiring collaborative decision-making among different stakeholders, studying the impact of new solutions on the strategic layer considered by PACAS, considering not only economic, organizational, security, and safety aspects, but also integrating new ones. Potential domains include healthcare where privacy issues need to be dealt with and supported by already running systems, especially after the latest General Data Privacy Regulation [2].

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[2] `https://www.eugdpr.org/`