Intelligent environments with entangled quality properties

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1 Introduction

Intelligent environments (IEs) [1], and other very close disciplines, such as Ambient Intelligence (AmI) [2], Smart Environments (SmEs) [3], and even Internet of Things (IoT) [4–6], are intended to proactively improve human lifestyle in many aspects, like healthcare, social inclusion, people assistance, quality of life, lifelong learning, and intelligent and adapted transport, among others. The development of an IE that can be successfully delivered to the society is a complex challenge. So much so that it requires a multidisciplinary team that has to be not only capable of applying a combination of techniques and methods coming from Software Engineering to improve its reliability [7], but also from other Computer Science disciplines, such as artificial intelligence, ubiquitous/pervasive computing and human—computer interaction, among others, that make the resulting IE less intrusive, while being smarter, more proactive and usable for the user. All this with the ultimate goal of increasing user confidence in the IE developed [8, 9].

Therefore, IE development not only involves deploying large scale sensor/actuator networks and the use of a middleware, communication protocols, location/positioning methods, artificial intelligence techniques, smart applications, etc., but also achieving a high level of reliability, performance, usability, security, and many other quality properties. However, these quality properties are entangled, that is, achieving one of them usually involves either fulfilling or decreasing the level of achievement of others. For instance, developing a highly usable IE will probably mean to also develop a high-performance responsive system. However, developing a high-performance system may require reducing security checks and, therefore, the reliability of the whole system.

Those inter-relationships and balances between quality properties are difficult to address. It is particularly difficult to decide which are the most important quality properties to be fulfilled in an IE. In this last decade, some researchers of the IE field have focussed their contributions on addressing specific quality goals [10–18]. However, there are fewer contributions analyzing the interactions between those quality properties, and how they should be balanced with others in real consumer-oriented developments.

This is the reason why we have proposed this Special Issue (SI) on Intelligent Environments with Entangled Quality Properties. This SI was specially conceived so that the authors of papers selected from among those accepted to be presented in the 10th International Workshop on the Reliability of Intelligent Environments (WoRIE 2021)1 could submit extended versions of their works. Nonetheless, an open call was made for other researchers who were working on topics related to the general theme addressed on this SI, even if they had not participated in the workshop, could also submit their manuscripts to it. In fact, only one of the articles included in this SI is an extension of a paper presented at WoRIE 2021. This is a pre-conference workshop held within the 17th International Conference on Intelligent Environments (IE 2021)2 and offered as a forum to discuss not only the state of the art, trends and novel methods and techniques to improve the reliability of IE, but also other quality properties like performance, security, safety or usability. This workshop, which is gradually consolidating and covers a broad range of topics, intends to build solid bridges of collaboration between the different communities involved in IE research and development.

1 https://www.ugr.es/~worie/2021.
2 https://www.mdx.ac.ae/ie2021.
Consequently, this SI, which aims to expand the discussion of such exciting and challenging topics beyond the workshop, is focussed on presenting IEs that have to consider entangled quality properties and balance their degree of fulfilment to produce a quality consumer-oriented solution.

2 Contents of this special issue

Bearing in mind what is indicated in the previous section, this section contains a summary of each of the five articles that have been selected to be published in this SI from among those submitted to it. Our intention is to present here a compendium of its contents, which serves to briefly present the work addressed in each of them, as well as to encourage readers interested in the topics covered in these articles to read them and obtain more information about the research works described in them.

In the first paper, entitled *A survey on reliability and availability modeling on Edge, Fog and Cloud Computing*, Maciel et al. present the differences between these three concepts and address the modelling of certain properties (reliability and availability) on them. Cloud computing is a model that promotes ubiquitous, on-demand network access to shared computing resources [19]. Fog computing intends to bring the services intended to process data as close as possible to the devices generating those data [20], thus decreasing network latency and processing load of Cloud services. Finally, Edge computing intends to further decrease network latency and processing load by moving as many processing tasks as possible to the devices themselves [21]. Consequently, each of those computing paradigms promote a set of entangled quality properties that need to be balanced in any IE, such as flexibility, processing power, efficiency, network latency, etc. In fact, the need of balancing those properties has led most recent IEs to integrate Edge, Fog and Cloud computing paradigms within their system architectures. In that sense, the authors highlight reliability and availability as two crucial, interlinked properties that can be pursued in most systems through the integration of those paradigms. The outcomes of this paper also point out some important open challenges related to the entanglement of reliability and availability with other properties. For instance, the authors mention that Edge devices (such as those found in IoT environments) promote reliability and availability, but it is still necessary to explore how to promote security and privacy on those resource-constrained devices or how to balance those attributes with energy consumption.

In the second paper, entitled *EFSUTE: a novel efficient and survivable traffic engineering for software defined networks*, Mohammadi and Javidan propose a traffic engineering model, called EFSUTE, which intends to promote a good balance between efficiency and survivability in software defined networks (SDNs). EFSUTE monitors working and backup paths on the relevant switches of an SDN. If a link failure occurs, then the working path is declared unavailable, and the backup path is considered to manage the traffic flows. To compute the optimal paths, EFSUTE considers low congested links with shorter delays. The authors have shown through a set of simulations that EFSUTE is very efficient in comparison with other solutions, while, at the same time, it reduces the packet loss ratio, thus improving survivability. Therefore, EFSUTE is able to tackle with QoS issues, which are challenging to address in most IEs. Moreover, efficiency and survivability are a good example of entangled properties, since increasing survivability commonly involves setting up constraints and mechanisms that usually decrease efficiency.

In the third paper, entitled *Helping novice developers harness security issues in cloud-IoT systems*, Corno, De Russis and Mannella investigate security features that two popular cloud-IoT platforms offer to developers for implementing IoT-based systems, given that developing high quality and secure IoT systems are inherently challenging, due to these are complex systems with strict requirements, especially if their developers are novices. The problem is further exacerbated if these systems are designed, developed and deployed on open networks without adequate consideration for privacy and security quality properties, which should be entangled with the rest of quality properties. This study, which is inspired by a survey administered to a small group of novice developers by the researchers, finds out that novice developers often tend to overlook security considerations during the design and implementation phases of the development of IoT systems. This is due to their lack of knowledge and understanding on the features provided by cloud IoT platforms.

In the fourth paper, entitled *Feature selection and human arm activity classification using a wristband*, Zhang et al. present a research work that investigates the potential for improving strategies and algorithms used in data pre-processing and model training/testing for wrist-worn accelerometer sensing. Recent advances in technology have facilitated the development of unobtrusive, lightweight, low-cost and power-efficient mobile wristbands which incorporate accelerometers [22, 23]. A salient feature of these devices is that they capture human activity data which necessitates classification algorithms to analyze the data. However, these are small devices with low computational power and therefore it is imperative to choose the right strategies to manage quality properties, such as accuracy and performance. Consequently, Zhang et al. claim that data pre-processing methods and optimal model selection algorithms are crucial for human
activity recognition. To begin with, they argue that it is crucial to select the feature which will contribute most to the performance of the model from a given dataset. They not only provide a list of potential benefits of feature selection [24] to maximise the classification accuracy and minimize the number of features but also critically compare feature selection and normalisation techniques. The authors investigated different techniques for data sampling frequency, feature ranking, feature scaling and sub-feature sets selection, as well as model selection strategies based on Neural Networks, Support Vector Machines, and Bayes classification algorithms. They recommend a novel plurality voting mechanism to adjust the prediction result during the model testing stage. The paper concludes that the most robust and reliable performance for human activity classification can be obtained from a combination of an individual data model together with a plurality voting mechanism.

Finally, in the fifth paper, entitled Securing future healthcare environments in a post-COVID-19 world: Moving from frameworks to prototypes, Vithanwattana et al. investigate pertinent security vulnerabilities and examines several existing security frameworks for eHealth and mHealth. As healthcare systems around the world have been under tremendous pressure during the COVID-19 pandemic, many healthcare services need to be moved to video, telephone or online sessions, while face-to-face sessions were significantly reduced to cater for medical emergencies or surgeries. In this scenario, it is undeniable that eHealth and mHealth systems could pave the way by offering basic medical services online in the future, given that medical devices have also been increasingly developed and deployed to monitor and record patients’ health parameters. This would help medical facilities streamline their services more efficiently. However, this transformation will depend upon how successfully some of the impending security challenges are met. Consequently, the authors argue that security should be embedded from when healthcare data is collected, then transferred over the network, and stored in both on-site storage and cloud storage. This reinforces the notion that a quality framework should also support all necessary security quality properties, which are entangled, such as confidentiality, integrity, availability, non-repudiation, authentication, authorisation, accountability, auditability, and reliability [25, 26]. Thus, they propose a novel comprehensive implementation framework based on their literature review, which demonstrated that no existing framework caters for all the security requirements and healthcare environments [26]. In the end, a prototype is developed to validate and demonstrate application of their implementation framework. This study also consolidates the notion that development of reliable and secure applications depends on how successfully security properties, among other quality properties, are embedded and entangled during the development process as well as the importance of clear development guidelines.

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