A Principle-Based Transparency Framework for Intelligent Environments

Mohsen Amiribesheli
Faculty of Science and Technology
Bournemouth University
Pool, Dorset, BH12 5BB
UK
www.bournemouth.ac.uk
mamiribesheli@bournemouth.ac.uk

Mahmood Hosseini
Faculty of Science and Technology
Bournemouth University
Pool, Dorset, BH12 5BB
UK
www.bournemouth.ac.uk
mhosseini@bournemouth.ac.uk

Abdelhamid Bouchachia
Faculty of Science and Technology
Bournemouth University
Pool, Dorset, BH12 5BB
UK
www.bournemouth.ac.uk
abouchachia@bournemouth.ac.uk

Intelligent Environments (IEs) can enhance the experiences of their users in a variety of contexts, such as healthcare, energy management, and education. Despite these enhancements, some people do not accept IE technologies to be embedded in their living environments. Numerous studies link this lack of acceptability to users' trust and attempt to address the trust issue by considering users' requirements such as privacy, security and reliability. In this paper, we address the concept of trust from the perspective of transparency by adopting the existing transparency reference models designed for software requirements engineering in the context of IEs. Based on the outcome of applying these reference models, we propose a human-centred principle-based transparency framework for IEs. We hope that this framework aids the researchers and developers in the IE community, and that the suggested transparency principles provide a solid foundation for transparent IE systems.

Intelligent Environments, Transparency, Principle-based Framework

1. INTRODUCTION

An Intelligent Environment (IE) is defined as a space that is equipped with seamless computing technologies for the purpose of empowering its residents to perform their regular living activities with fewer complications and in an improved manner (Steventon and Wright 2010). As a predominant paradigm in computing, applications of IE systems are extended to a variety of settings, such as houses, hospitals, and schools. They are utilised in a range of innovative applications, such as healthcare monitoring, energy management, and educational tools (Amiribesheli et al. 2015; Coronato et al. 2009; Huang et al. 2015).

In general, an IE system consists of the following principal components:

- *Sensors* (e.g., video cameras, passive infrared sensors, and microphones) that collect the data from the residents and the environment.
- *Communication platforms* (e.g., wireless networking protocols such as ZigBee and Bluetooth) that transfer the collected data to the decision-making component.
- *Decision-making component* (e.g., an expert system) that processes the data and determines the appropriate system reactions.
- *Interfaces* (e.g., web applications, Smart TVs) that communicate with the IE residents and other stakeholders through visualising data and receiving data from them.
- *Actuators* (e.g., controlled light switches) that apply the system responses to the environment.

Numerous studies outline the benefits of employing IEs and their potential role in increasing the quality of their users' lives (Saha and Mukherjee 2003; Corchado et al. 2008). Nevertheless, because of technological and design obstacles, IE applications are not utilised to their full extent. For instance, elderly care puts an immense financial burden on healthcare systems around the world and many studies suggest that the cost can be decreased by employing IE technologies, such as smart homes (Coughlin et al. 2007). However, a rather thin portion of elderly care environments is equipped with IE applications (Amiribesheli and Bouchachia 2015, 2016).

This lack of interest is partly rooted in users' concerns, such as reliability, security, and privacy of IE systems (Courtney 2008; Wild et al. 2008). Such concerns may lead to users' lack of trust in IE systems. This, in turn, makes users unwilling to accept IE systems in their living environment. There is a comprehensive body of literature on the approaches addressing the trust issue (Coughlin et al. 2007; Skubic et al. 2009; Mikuleckỳ 2009). Many existing studies focus on privacy as a fundamental basis for the existing distrust. Acknowledging that, we advocate that transparency is another significant factor on users' trust in IE systems. In this context, we define transparency as the open flow of information amongst different stakeholders (Holzner and Holzner 2006).

In several cases, IE residents are not concerned with disclosing their personal information to the IE system, as they are aware that the data is used to enhance their living quality. The distrust results from the fact that they are unaware of *who* accesses the data, *what* data they access, and *how* and *why* they access the data. Transparency, as a mechanism for addressing residents' concerns on the aforementioned questions, attempts to guarantee that the interaction between IEs and their residents is based on informed consent and it can lead to trust (Rawlins 2008). It is worth mentioning that informed consent does not imply that all information should be disclosed to the residents, as in some cases, such as healthcare monitoring, positive secrecy is essential (Derouaux 2007).

In this paper, we present transparency as one of the fundamental aspects of IE quality, an aspect that should be managed in order to increase the residents' trust. To achieve that, we benefit from research studies that attempt to identify transparency facets (Hosseini et al. 2016b), and the reference models for considering transparency for software systems (Hosseini et al. 2016a). In this paper, we will utilise these reference models to produce a human-centred principle-based framework for transparency in IEs, which helps IE researchers and developers to address residents' transparency concerns.

The rest of the paper is structured as follows. In Section 2, we briefly introduce four reference models for transparency in software requirements engineering. In Section 3, we apply these transparency models in the context of IEs. In Section 4, we propose our transparency framework for IEs and discuss some key issues which hinder transparency to be fully implemented in IEs. We conclude the paper in Section 5.

2. TRANSPARENCY REFERENCE MODELS IN SOFTWARE REQUIREMENTS ENGINEERING

In this paper, four reference models for transparency requirements are applied (Hosseini et al. 2016a). In the following, we will provide their summaries.

- Transparency Stakeholders' Wheel: This reference model mainly categorises different roles of social and technical stakeholders during transparency provision. These stakeholders are information providers, information receivers, information medium through which the information is channeled, and the information entity which is the entity about whom or which information is given or requested. The significance of this reference model lies in the fact that trust should be investigated not only between the information provider and information receiver, but also between other elements is this model, e.g., between the information receiver and the information medium.

- Transparency Depth Pyramid: This reference model classifies the information based on their depth. It illustrates whether the information contains data (i.e., answering "who", "when", "what", and "where"), processes (i.e., answering "how"), or policies (i.e., answering "why"). The importance of this reference model lies in the fact that trust relations might increase when stakeholders are provided with process information and reasons behind data collections, and in other words, by increasing the meaningfulness of transparency.

- Transparency Achievement Spectrum: This reference model discusses seven steps to take for ensuring transparency usefulness for its intended stakeholders. These steps are, information availability, information interpretation, information accessibility, information perception, information understandability, information acceptance, and information actionability. This reference model helps information providers to highlight where transparency provision has failed, and therefore to take measures to eliminate the obstacles to transparency provision.

- Information Quality in Transparency (Kahn et al. 2002): This reference model lists 16 different information quality dimensions. As information is core to transparency, and to minimise the chances of disinformation or misinformation, these quality attributes must be ensured for every piece of information which is meant to convey transparency.

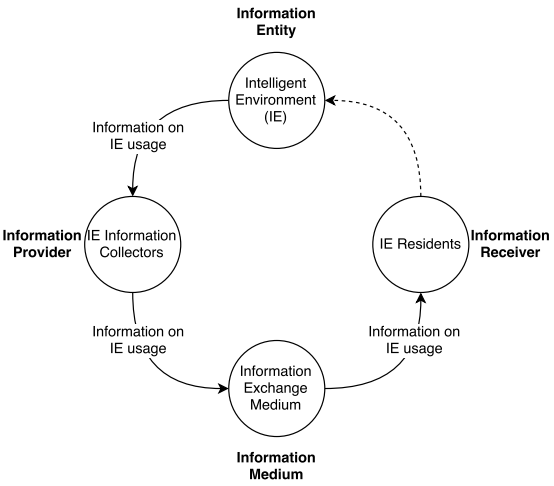

Figure 1: *Applying Transparency Stakeholders' Wheel in the context of IEs*

3. APPLYING TRANSPARENCY REFERENCE MODELS IN THE CONTEXT OF IES

In this section, the concept of trust in IEs will be investigated by applying transparency reference models.

3.1. Transparency Stakeholders' Wheel

As mentioned earlier, this model attempts to study the effects of the transparency on the users' trust based on stakeholders' categories and their interactions. Fig. 1 illustrates different stakeholders involved in IEs and their mapping to the elements of the wheel.

- Trusting the IE System: IEs comprise of a variety of components. Lack of transparency in outlining the ways those components are operating can cause mistrust in IE residents. IE designers should make the information regarding the types of hardware and software arrangements that are used in the system available to the users. For instance, the residents should be informed of the applied security method for the communication platform and the type of sensors used in IEs.
- Trusting the Information Providers: Assuming that the users already trust the IE system, informing the residents who can access the collected data can drastically improve the residents' trust in IEs. For instance, the residents of an energy management IE should know who can access their energy consumption data, which could be used in unwanted targeted advertising.
- Trusting the Information Exchange Medium: Neglecting the importance of transparent information exchange media in an IE system may result in the residents' distrust in the IE system as a whole. For example, IE residents may prefer written communication regarding IE technologies to verbal communication over the phone, as having formal written documentations may give them assurance and also the capability to refer to them in the future.

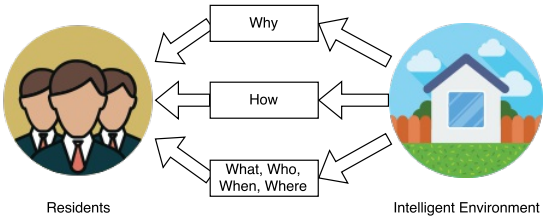

Figure 2: *Applying Transparency Depth Pyramid in the context of IEs*

3.2. Transparency Depth Pyramid

The utilisation of Transparency Depth Pyramid as a way to ensure transparency meaningfulness can potentially lead to an increase in the residents' trust in the IE system. This reference model draws our attention to three layers of contents produced by, and circulating in the IE system: data, process, and policy, which is represented in Fig. 2.

- Data transparency: to achieve data transparency in IEs, the answers to the following questions should be provided to the residents (the list is not exhaustive):
  1. What are the types of data collected by IEs?
  2. When (and if applicable, where) does the data collection happen?
  3. Who are the people who have access to the collected data, and are able to view, use, and probably disseminate the data?
  4. Are there other ways to collect the same data, and what are their advantages or disadvantages?
- Process transparency: to achieve Process transparency in IEs, the answers to the following questions should be provided to the residents (the list is not exhaustive):
  1. How is the residents' data collected?
  2. How is this data visualised and analysed?
  3. How is information rendered out of the data?
- Policy transparency: to achieve policy transparency in IEs, the answer to the following questions should be provided to the residents (the list is not exhaustive):

1. Why should the data be collected?
2. Why should certain stakeholders have access to such data?
3. Why is the data collected in this particular way, and not in other, possibly less intrusive or more convenient, ways?

Admittedly, it is not always plausible to provide answers to all questions. As we move towards the top of the pyramid, comprehending some of the answers by IE residents may require more expertise. Moreover, in some cases, considering other concerns regarding the IE system or the IE residents may mean that the answers should be concealed from them. For instance, a formal caregiver of an IE resident demands information for checking if the resident is developing diabetes. The caregiver requests a set of sensors to be installed in the kitchen to monitor changes in the eating habits. The caregiver does not want to cause unnecessary anxiety to the resident by informing them about their suspicion (a situation referred to as 'positive secrecy'). Therefore, no information on why the new sensors are installed will be provided to the resident.

3.3. Transparency Achievement Spectrum

Adopting this reference model is particularly effective in guaranteeing that transparency requirements of the residents are met accordingly. This reference model offers information providers a step-by-step approach, and facilitates easier problem detection and resolution in providing transparency, as follows:

- Information availability denotes that the collected data, processes and reasons for collecting data, stakeholders involved, etc., should be available to IE residents at all times.
- Information interpretation denotes that the data should be interpreted in a way that matches the understandings of the IE residents. For example, data in the format of large spreadsheet files or graphs and charts will need interpretation before they can be used by IE residents.
- Information accessibility denotes that the available information should be easily accessed by IE residents without much effort.
- Information perception denotes that IE residents' perception of information should be checked to ensure that it is not wrongly perceived. For example, a sensor constantly blinking may give an IE resident the wrong perception that it is constantly on and sending data. If they have been already told that the sensor is only active during certain times, but are not told that blinking does not mean that the sensor is working as it can be in the standby mode, this might lead to the resident's distrust in IEs.
- Information understandability denotes that information should be presented in a way that is comprehensible by IE residents. This can refer to, amongst other things, the volume of the information and its representation.
- Information acceptance denotes that information providers should check with IE residents to see if their information is accepted by them. Any failure in accepting the provided information, in part or as a whole, will result in failed transparency.
- Information actionability denotes that information providers should ensure that the provided information will lead to IE residents' perception change, informed decision-making, or informed consent, i.e., the provided information leads to useful transparency.

3.4. Information Quality in Transparency

The quality of information should be guaranteed by information providers, as without it, transparency usefulness or meaningfulness will lose its value. Information quality dimensions are categorised into four groups, as follows (Kahn et al. 2002):

- **Sound information** represents the quality of the information supplied by the information provider, and consists of the following information quality dimensions: *free-of-error*, *concise representation*, *completeness*, and *consistent representation*.
- **Dependable information** represents the quality of the service in providing information by the information provider, and consists of the following information quality dimensions: *timeliness* and *security*.
- **Useful information** represents the meeting/exceeding of the information receiver's expectations in the supplied information quality, and consists of the following information quality dimensions: *appropriate amount*, *relevancy*, *understandability*, *interpretability*, and *objectivity*.
- **Usable information** represents the meeting/exceeding of the information receiver's expectations in information provision service, and consists of the following information quality dimensions: *believability*, *accessibility*, *ease of manipulation*, *reputation*, and *value-added*.

4. A NOTE ON ADOPTING TRANSPARENCY IN IES

While understanding transparency requirements of IE residents is facilitated by these transparency reference models, several obstacles relating to the elicitation and implementation of transparency requirements still exist. Some of the obstacles are as follows:

1. In the IE literature, transparency, when discussed, has usually been mentioned as a second-hand concept, e.g., to privacy. The challenge, therefore, is to make IE designers and developers aware of the significance of transparency on residents' trust and consequently, IE acceptability.
2. The blurred line between transparency and other adjacent concepts, such as privacy, can lead to information disclosure problems. IE developers should find a way to balance IE residents' transparency requirements with their other requirements such as privacy and security, which are also important for IE residents. The obstacle is finding and managing such a tradeoff.
3. Implementing transparency in IEs could introduce some obstacle. Tailored transparency, i.e., transparency designated for each individual, is the ideal way of providing transparency. In practice, however, the costs and difficulties of providing tailored transparency may lead the designers to a less costly, less time-consuming type of transparency, which is targeted transparency, i.e., transparency designated for different groups of people (Kreuter and Wray 2003). Even then, identifying the metrics and criteria for grouping and classifying stakeholders may remain an obstacle.

4.1. The framework

In the IE literature, transparency, when discussed, has usually been mentioned as a second-hand concept, e.g., to privacy. The challenge, therefore, is to make IE designers and developers aware of the significance of transparency on residents' trust and consequently, IE acceptability. To address the challenge and to facilitate the means of adopting the transparency into the process of designing and developing IEs we suggest the following human-centred principle-based framework built on the previously mentioned (See Sec 2) reference models.

P1) Gather information regarding the adopted solutions for building and maintaining users' trust to the system components, information provider, and the exchange media.

P2) Gather information regarding the adopted solutions for three key transparency perspectives of data, process, and policy.

P3) Make the information produced in the past two principles available to the stakeholders in interpretable, accessible, perceptible, acceptable and actionable manners.

P4) Assure that the information is sound, dependable, useful and usable.

P5) Provide remedies for the failed transparency events. The remedies that introduce the responsible parties for providing the transparency information and their level of accountability.

P6) Ensure that only necessary information from users is collected, disclosed, and provided to necessary stakeholders, paving the way for ethical transparency.

5. CONCLUSION

The present paper discusses some of the key issues related to the acceptability of IE technologies from the lens of transparency. It reviews the existing transparency models that highlight the stakeholders involved in transparency, transparency meaningfulness and usefulness, and the quality of information in transparency. As the principal contribution, the paper presents a description of the models application in the context of IEs. Moreover, the paper attempts to start a novel discourse by advocating that transparency may lead to trust, which is an important contributing factor to the acceptability of IE technologies.

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