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Software Engineering for Smart Things in Public Spaces: Initial Insights and Challenges

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***Abstract*—Software engineering for mobile applications has its own challenges, different from when we engineer software just for desktop environments. With the emergence of smart things (including smart everyday objects embedded with connectivity, computational ability, sensors, and sometimes actuators, urban robots such as delivery and cleaning robots, smart street lighting, smart vehicles, and smart park benches, and so on) not just within the home but in public spaces, there is a need to consider software engineering challenges for software on such things. Human-centred software engineering and work on ethical behaviours in smart things will need to come together, even as we continue to understand what it takes to effectively develop software (and systems) for such emerging devices. In order to demonstrate how software (and systems) for intelligent devices in public places might be developed, findings from a quantitative survey we performed are discussed in this study. The survey was designed such that the questions focused on the socio-ethical behaviours of smart devices when interacting with people in public places. The survey was based on a supermarket scenario where the participants had to answer the different questions in the questionnaire. There were 250 participants who only completed part of the survey; of them, 60 participants finished it in full. The complete replies have been examined and analysed in this paper. To determine how people feel about employing smart technology in public places, a variety of smart devices, including robots, smart cameras, smart speakers, and smart trolleys, are utilised in the survey questions. According to the findings, more than 80 percent of respondents think it important for smart gadgets to be socially-aware and ethical in public places.**

General Abstract This paper examines the survey results conducted to explore if smart devices such as robots or smart cameras can be deployed in public areas. The respondents reply to survey questions asking them whether they believe it is crucial to keep smart robots, smart carts, or any other smart devices in the supermarket. The survey's questions are constructed in such a manner that participants are asked to imagine themselves as either a customer shopping for groceries at a store or a manager running the business and dealing with the friendly robot.This survey was created with the intention of thinking carefully about how intelligent software systems may be designed from the standpoint of software engineering for public settings. Later in this article, the survey findings and insights are discussed.

***Index Terms*—Smart devices, smart things, socio-ethical policy, supermarket, IoT, human-device interaction**

I. Introduction

A network of intelligent, Internet-connected items that can interact and share data is defined as the Internet of Things (IoT). There are different smart internet-connected devices (we include here networked robots, or smart things with "robot-like" functionality even if not in any human-like form) being used in different locations such as hospitals, aged-care centres, educational institutes, and many other such indoor locations, but also, such use of smart technology is emerging in public spaces such as supermarkets, restaurants, streets, and so on. Indoors or outdoors, there is a need to understand how people think about such smart things in public spaces, in order to inform their development, especially, their software behaviours.

This short paper presents highlights from a study done in the form of a questionnaire to identify people's thoughts on using smart devices that must behave socio-ethically in public areas. In the questionnaire, different questions are asked of the participants to make choices on how essential it is for the smart device to behave socially appropriately (and ethically) while interacting with them in public areas. For example, in a supermarket, if a robot is cleaning the floor and a customer is shopping in the same store, then how essential it is for the robot to inform the customer respectfully that the floor is wet or dirty. The survey is designed and analysed to determine whether (and how) such smart technology should be deployed in public areas, and the results are discussed later in this paper.

The smart devices carry out various jobs in various contexts, such as a robot (note that while we use the term "robot", it could be a concept of an embodied smart kiosk say with a displayed face and a conversational interface for answering questions and helping users) directing a person to various supermarket locations; a smart camera observing the shoppers at the store; and a smart trolley transporting the customers' food. Each smart device has a fundamental responsibility to fulfil, however it is crucial that the device behaves ethically while carrying out this responsibility. For instance, a robot may run into a crowd while directing a person to various spots in a store. In this scenario, the robot may gently ask the crowd to clear the way or it may change its path. The robots can act ethically in two distinct ways—by gently asking people in the crowd for directions or by changing their course—and the optimal course of action will depend on the circumstances. To identify the behaviours that smart devices can adopt in order to act in a socially-aware and ethical manner in public settings, this study looked at four types of smart device behaviours, including appropriate-behaviors, autonomous decision-making,

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transparency-in-actions, and handling-uncertainty. Each of these categories is explained in detail later in this paper.

In the rest of this paper, §2 presents the background and related work. §3 presents the categories of smart devices ethical behaviours. §4 presents the research methodology and participants recruitment. §5 highlights the survey results. §6 concludes with future work.

II. Background and Related Work

In many interior venues, including smart homes, healthcare facilities, educational institutions, and many more, smart gadgets are being employed to facilitate human-device interactions [1], [2], [3]. It is crucial to take into account how smart devices will be deployed in outside places as well, such as parks, open markets, open eateries, open/street parking, and so on.

Lewandowski et al. [4] demonstrated a system for a mobile robot that uses an out-of-stock detecting method for social navigation and human-robot interaction. The system classifies the scanning-related circumstances so that a mobile robot can politely interact with clients. Another study done by Batool et al. [5] has proposed a policy management framework that consists of three different types of socio-ethical policy rules, including authorisation, obligation, and prohibition rules The obligation policy has been designed to allow the devices to behave in a controlled manner, whereas the prohibition policy has been designed to prevent smart devices from performing specific tasks. The authorisation rules have been designed to allow the smart devices to perform the allowable tasks.

Batool et al. [6] has expanded the proposed policy management framework by including socio-ethical as well as administrative policy rules to be applicable to multiple smart devices. The administrative policy rules are scenario specific, whereas the socio-ethical policy rules are applicable in any setting or scenario. The study has also operationalised the policies through Xtensible markup language and prototyped the framework in an educational setting using smart robots, smart speakers, smart mobile devices, and smart cameras for illustration purposes. A substantial quantity of research has been done on how individuals interact with smart devices [7], [8], [9]. However, the research on having socio-ethical smart devices in public areas is yet to be considered. This study has highlighted the survey results done to get people's opinions on having socio-ethical smart devices in public areas. The results are discussed in detail later in this paper.

III. Smart Devices Ethical Behaviours Categories

To make smart devices behave in socially-aware and ethical manners in public spaces, this study presents four types of behaviours: appropriate-behaviors, autonomous decision-making, transparency-in-actions, and handling-uncertainty. Each of these behaviours is applicable to (and will have different manifestations in) different smart devices such as robots, smart cameras, smart speakers, smart trolleys, and others. Each behaviour is described in detail below.

(Socially) Appropriate-Behaviours: The smart devices must behave appropriately while carrying out certain duties. The appropriate behaviours include the devices behaving respectfully; communicating politely; respecting the users' privacy by not asking for their personal information; and securing data by not disclosing the personal details to someone else/third party. For example, a robot must take a person's photo for monitoring purposes after getting permission from the person in terms of privacy-respecting behavior. A robot as it moves around might also need to say "excuse-me" - this behaviour of robots in public spaces has been raised in the context of social design, see [10], [11].

Decision-Making: The decision-making behaviour means making a smart device autonomous in certain situations while performing its tasks. For example, if a robot has experienced a crowd while guiding a customer in a store, the robot can take an autonomous decision of altering the path instead of waiting for the crowd to give it space or letting the crowd free the space. Autonomous decision-making is an essential behaviour for smart devices to carry out as it assists them to complete the job on time. For example, in a hospital, if multiple robots are carrying out their duties and they come across each other, In this situation, a robot with the priority job must take an autonomous decision to alter the path, or other robots can also take an autonomous decision to give the path to the robot with the priority job. Note that the scope of such decision-making might be rather limited (e.g., only able to choose among two alternative routes), or much broader (e.g., able to reroute in any way within certain constraints), and may involve humans to different extents (e.g., human-in-the-loop for more interactive decision-making, human-over-the-loop where humans just supervise, or human-out-of-the-loop), with implications for practice.

Transparency-In-Actions: The "transparency in actions" behaviour is designed to allow the smart devices to keep the human/s informed of certain things while carrying out a specific task. For example, if a customer asks the robot to guide him or her to the biscuit location in the store, The robot should inform the customer that it is taking him or her to the particular biscuit brand so that if the customer does not want to go there, he or she can ask the robot not to go there. Similarly, a smart camera at a grocery store may be transparent in its actions by informing the customers that they are being monitored by it.

Handling-Uncertainty: The handling-uncertainty behaviour is designed to allow the smart internet-connected devices to handle the hurdles that come across their way while performing a specific or particular job. For example, if a robot is unable to assist the customer with their inquiries at a store, a robot might handle this problem by calling the staff member who can assist the customer. Similarly, if a smart trolley experience an obstacle on its way while carrying the customer's grocery, it must avoid that obstacle smartly. Handling difficult situations is an essential behaviour to be followed by the smart devices as it helps the devices to avoid the obstacles, handle the difficult situations and complete the job on time. This might be related to decision-making but more specific to error management or

when the device encounters a snag.

IV. Research Methodology

This study was conducted as an online survey that consisted of different supermarket scenario-based questions. The survey asked users' demographic questions and their understanding of the internet of things. The survey was designed in a way that participants imagine themselves as a person in a supermarket, buying the groceries as a customer or managing the store as a manager and interacting with smart technology (robots, smart trolleys, smart cameras, smart speakers). Based on the interaction, the participants had to respond to the survey questions to show if it is essential for the smart device to behave socio-ethically with them in different circumstances. For better understanding of the questions, images of smart devices such as robots interacting with humans in a store are also added along with the questions.

All respondents had to be at least 18 years old and proficient in reading and understanding English to participate, as determined by recruitment standards and pre-survey screening questions. The survey's completion time was estimated at 20 minutes for the participants. The survey requested individuals to voluntarily participate in the study and was promoted through advertising on social media platforms like LinkedIn. After removing the invalid replies, there were 60 valid responses out of the 250 people that attempted the survey. The outcomes of the valid replies have been examined in this paper, and the analysis is presented in the next section. This study was conducted with ethics approval (ID: 2021-77-MOD01) from Deakin university.

V. Survey Results

The survey was designed with the questions to ask the participants whether they think it is essential to have smart devices with socio-ethical behaviour in public spaces. The results from the survey are presented in relation to each of the behaviours mentioned in the section three. As it is mentioned earlier, the scenario used in the survey is the supermarket, so the questions in the survey are based on the supermarket scenario.

A. Smart Devices with Socially-Aware and Ethical Behaviours in public spaces

Figure 1a shows the results from the first category i.e., appropriate-behaviour of the smart device in a public area. The first pie chart in Figure 1a shows that many participants want the robot to interact with shoppers in a friendly manner. Participants were required to reply to the questions using the options on the likert scale, which ranged from highly important to not at all important. Almost over 80 percent of respondents, as indicated in the first pie chart, believe it is important that the robot use courteous language while moving about the store. Being polite reflects the appropriate behaviour of a robot towards the people in a supermarket or any public setting. Similarly, the second pie chart in Figure 1a analyses the participant's response to the question about whether they agree that a robot should warn people of a slippery floor it is cleaning at a supermarket in order to prevent accidents. According to the findings, more than 80 percent of the participants agreed that the robot should alert customers to the slippery floor. The findings indicate that individuals do desire the smart devices to be socially-aware while carrying out a certain task.

In Figure 1b, the results indicate if the robot/smart device must make autonomous decisions while carrying out any task. The first pie chart indicates that more than 80 percent of people think that it is important that a robot take an autonomous decision to discover a different route to guide the customers in a supermarket if a place becomes crowded. On the other hand, the other pie chart in Figure 1b show the analysis of how a robot must be autonomous in making decisions in certain situations, such as if a robot is guiding a person to a breakfast cereals location, then 90 percent of people think that it is useful if a robot guides the customer to the general area of a breakfast cereals location and then asks if the customer is after the specific brand, instead of just taking them to the most expensive brand, or the cheapest brand. The results suggests people do want, in some circumstances, to be involved in the machine's decision-making rather than just to be presumed to have certain preferences.

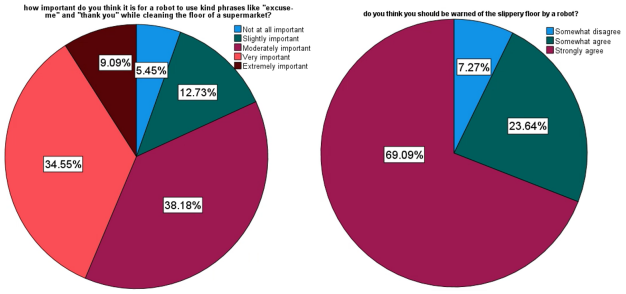
The analysis for whether users want the smart device to be transparent in its actions while carrying out a particular activity is presented in Figure 1c. According to the findings, more than 50 percent of the participants believe it is crucial for a smart camera to alert customers that they are being monitored in the store. A smart device's "transparent in action" behaviour includes notifying users that they are being watched in this scenario. The second pie chart in Figure 1c indicates that more than 50 percent of people want the smart camera to notify customers that their recorded footage will be deleted in the next 24 hours. In the same analysis, it was observed that around 20 percent of people disagree that smart cameras notify them about the deletion of their video. Smart device should be transparent in actions depending on certain situations.

In Figure 1d, the analysis is done to investigate what people think about the smart devices' handling of uncertainty in a public setting. The results in the first pie chart show that 50 percent of people think that it is extremely important for a smart trolley to be able to handle the obstacles that come in its way while carrying the customer's groceries in the store. On the other hand, the second pie chart indicates that more than 30 percent of people strongly agree that a trolley must be able to alert the customer about the obstacles that come in its way while carrying the customer's groceries. It is understood that a greater number of people want the smart device to have the capability of handling the uncertainties on their own.

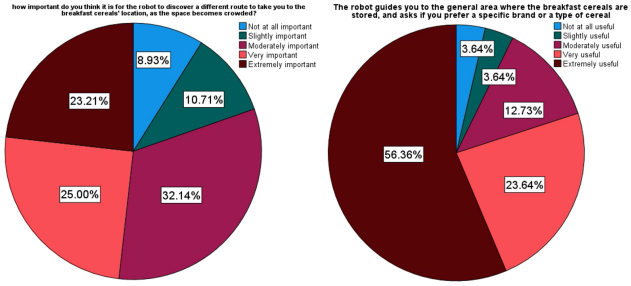
Overall, it indicates that people want the smart devices to behave socio-ethically while doing their tasks in public areas.

B. Insights into Developing Smart Devices for Public Spaces

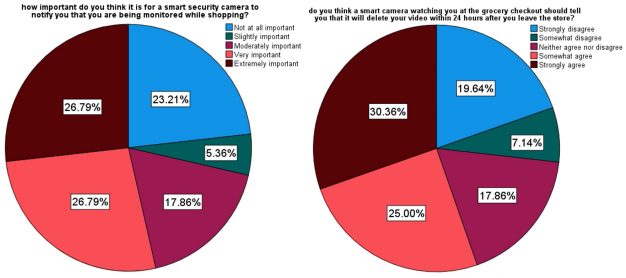
Our analysis has shown that people want smart technology to be deployed in public settings that behaves respectfully with



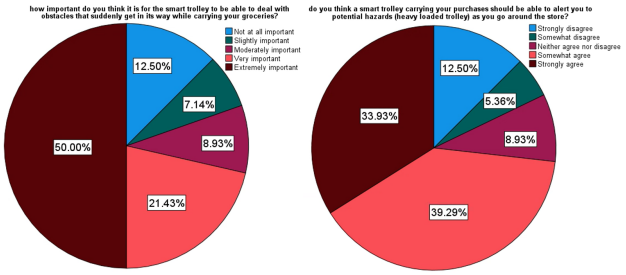
(a) Appropriate-Behaviours: Left: Robot's Polite Behaviour towards customers, Right: Robot warned customers about slippery floor



(b) Decision-Making: Left: Robot discovers a different route to avoid crowd, Right: Robot guide to a general area where breakfast cereals are located



(c) Transparency-in-Actions: Left: Smart camera notify customers that they are being monitored, Right: Smart camera notify customers that it will delete their video in 24 hours



(d) Handling-Uncertainty: Left: Smart trolley deal with the obstacles itself, Right: Smart trolley notify customers about the obstacles

Fig. 1: Survey Results

others, is able to make autonomous decisions in certain situations, must be transparent in its actions, and must also be able to handle the uncertainty that occurs while it is doing its job. The system needs to be developed where the smart internet-connected devices must be able to behave appropriately in public settings. From the survey results, it is clear that such systems can be developed as long as the public wants them in different areas. There are four types of behaviours captured in this study. More behaviours can also be thought of, such as making the device prohibited from doing certain jobs, as being ethical is one concern, but being non-ethical is also a concern in different situations. For example, if someone tries to escape with a product in a market, then a smart device that can be a robot, a smart camera, or a smart monitoring device must be able to alert the store staff to check that person, or a robot may approach that person in terms of warning behaviour. As the analysis has clearly shown that a greater number of people think that having smart devices with moral behaviour in public spaces is extremely important, then, using these findings, a system can be developed that enables the smart devices to be socially-aware and ethical in public settings. There are other questions from the survey which are not highlighted here. While indicative, our survey is by no means exhaustive, even for the supermarket scenario, since there are so many other possibilities with the set of devices we considered, and there are many other possible devices to consider. There are also many other scenarios in public settings such as a shopping mall, a hospital, a street, and so on.

VI. Conclusion

Smart technology to behave socio-ethically during human-device interactions is required as devices gain more agency, grow smarter, and may be used by multiple people. This paper highlighted results from a survey done to glean insights for developing smart devices that behave appropriately in a public area. There are four different behaviors, including appropriate-behaviours (being polite), decision-making, transparency-in-actions, and handling-uncertainty, that smart devices can attain while interacting with people in public spaces. We contend that software engineering for smart things in public spaces must consider socio-ethical behaviour in public spaces, including safety and inclusivity. It is also useful to consider how people of different age groups, and culturally diverse backgrounds and languages, (and those with disabilities) can easily interact with these smart devices. Seniors may not feel comfortable interacting with smart devices at times, but a device behaving courteous, polite and ethical towards the senior can be more acceptable. Future challenges include understanding principles underling a software engineering methodology tailored for software for smart things in public spaces. Also, there are policy issues for robots in public spaces [12] - how these considerations can translate into software engineering requirements and/or generalize to IoT devices in public are open questions.

REFERENCES

[1] N. Ramoly, A. Bouzeghoub, and B. Finance, "A framework for service robots in smart home: an efficient solution for domestic healthcare," *IRBM*, vol. 39, no. 6, pp. 413–420, 2018.

[2] R. Khosla, K. Nguyen, and M.-T. Chu, "Human robot engagement and acceptability in residential aged care," *International Journal of Human–Computer Interaction*, vol. 33, no. 6, pp. 510–522, 2017. [Online]. Available: https://doi.org/10.1080/10447318.2016.1275435

[3] L. Lammer, A. Huber, A. Weiss, and M. Vincze, "Mutual care : How older adults react when they should help their care robot," 2014.

[4] B. Lewandowski, T. Wengefeld, S. Müller, M. Jenny, S. Glende, C. Schröter, A. Bley, and H.-M. Gross, "Socially compliant human-robot interaction for autonomous scanning tasks in supermarket environments," in *2020 29th IEEE International Conference on Robot and Human Interactive Communication (RO-MAN)*. IEEE, 2020, pp. 363–370.

[5] A. Batool, S. W. Loke, N. Fernando, and J. Kua, "Towards a policy management framework for managing interaction behaviors in iot collectives," *IoT*, vol. 2, no. 4, pp. 633–655, 2021. [Online]. Available: https://www.mdpi.com/2624-831X/2/4/32

[6] A. Batool, S. W.Loke, N. Fernando, and J. Kua, "Operationalizing rule-based socio-ethical behaviour in iot collectives: A policy management approach," in *IEEE/WIC/ACM International Conference on Web Intelligence and Intelligent Agent Technology*, ser. WI-IAT '21. New York, NY, USA: Association for Computing Machinery, 2021, p. 506–511. [Online]. Available: https://doi.org/10.1145/3486622.3493987

[7] I. Aaltonen, A. Arvola, P. Heikkilä, and H. Lammi, "Hello pepper, may i tickle you? children's and adults' responses to an entertainment robot at a shopping mall," in *Proceedings of the Companion of the 2017 ACM/IEEE International Conference on Human-Robot Interaction*, 2017, pp. 53–54.

[8] R. Kachouie, S. Sedighadeli, R. Khosla, and M.-T. Chu, "Socially assistive robots in elderly care: A mixed-method systematic literature review," *International Journal of Human–Computer Interaction*, vol. 30, no. 5, pp. 369–393, 2014. [Online]. Available: https://doi.org/10.1080/10447318.2013.873278

[9] M. Tanaka, A. Ishii, E. Yamano, H. Ogikubo, M. Okazaki, K. Kamimura, Y. Konishi, S. Emoto, and Y. Watanabe, "Effect of a human-type communication robot on cognitive function in elderly women living alone," 2012.

[10] C. Diana, *My robot gets me: how social design can make new products more human*. Harvard Business Review Press, 2021.

[11] L. Major and J. Shah, *What to expect when you're expecting robots: the future of human-robot collaboration*. Basic Books, 2020.

[12] M. Mintrom, S. Sumartojo, D. Kulić, L. Tian, P. Carreno-Medrano, and A. Allen, "Robots in public spaces: implications for policy design," *Policy Design and Practice*, vol. 5, no. 2, pp. 123–139, 2022.