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Logical Expression Tutoring System for Controlling Smart Devices in Multi-User Environments

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Abstract: Incorporating robust authentication and authorization mechanisms is important to reduce the risk of credential information leakage in an application such as Internet shopping when a smart device is shared by multiple people. We developed a system that allows smart device administrators to customize the application by registering access control conditions expressed as logical expressions into our system. However, the administrator need logical thinking abilities when creating logical expressions, which is not easy to describe the logical expressions to ensure they work as intended for the specific processing flow because they are not programmers. This paper proposes a tutoring system that helps to express logically using a chatbot, which contributes to enhancement and flexibility for smart device security.

Keywords: Smart Devices, Authentication, Tutoring System, Chatbot

1. Introduction

Smart devices are used in private and public spaces by groups such as families and school classes. Smart speakers, one of the smart devices used in multi-person households, are the subject of privacy and consent studies (Nicole et al., 2021). In multi-user environments, there are challenges such as the risk of storing multiple users' biometric authentication information on the same device. Controlling the device based on its surrounding environment can be achieved by integrating factors such as the number of individuals nearby, the intentions they exhibit, and their interpersonal relationships as external information. We developed a system to control the application of smart devices collaborating with external information to adapt to the environment around the device to solve operational and security issues that arise when multiple people use a single device, as shown in Figure 1 (Takahashi et al., 2022). In this system, the Device Admin (administrator) describes combinations of external information as logical expressions to achieve more complex authentication and authorization than using voice-based verification codes built into smart speakers. Our paper shows a scene in which several students and a teacher with different privileges use a shopping app on a smart speaker in a laboratory. In order to allow students to freely use this app under their own authority, the teacher needs to set the logical expressions as a Device Admin. It is said that the degree of freedom in logical expression design varies greatly depending on the IT skills teachers possess, and the quality of educational content also changes (Karen E. I., 2006). Research is being conducted to assess the logical thinking abilities of Japanese high school students, and it has been found that some test takers do not fully understand the meanings of logical connectors such as "and" and "or" (Misono, et al.,2018). Therefore, a tutoring system is required to allow Device Admin with limited development skills to customize logical expression.

In this paper, we describe a system that performs control collaboration with external information based on a logical expression registered in advance by the Device Admin. Next,

we focus on the part where the Device Admin creates the logical expression and discusses a tutoring system to support it interactively using a chatbot. Even the Device Admin with limited logical thinking ability easily creates logical expressions by interacting with the chatbot.

2. Collaboration system with external information

We introduce the collaboration system with external information in Figure 1. This System consists of Process Flow Section, App/User Management Section, and App/User Management DB. App developers create apps and add API calls to the system at the point of customizing the flow. Device Admin registers a logical expression. A logical expression consists of a combination of logical operators and functions to retrieve external information, and the order of processing is determined by the state of the logical expression and external information. User Admin registers user information such as attributes and groups. When a user uses the app on a smart device, it calls the Process Logical Expressions section via API at the customization point. Next, it acquires the pre-registered logical expression from the App/User Management DB. The system processes the process according to the logical expression. If an instruction to the user is required when acquiring data, the contents of the instruction are returned to the application. App/User Management Section is an interface to register information in the App/User Management DB.

An example of control using this system implemented in a smart speaker is shown in Figure 2. We envisaged a situation where several students and a teacher use a shopping app on the smart speaker in the classroom. Existing shopping applications use voice-based confirmation codes for access control as shown in Figure 2(a). However, using voice-based confirmation codes is unsuitable in a space with many people, such as a classroom. By registering the logical expression shown in Figure 2(b) into the system, the teacher, as the Device Admin, can introduce processing in the application that utilizes external information such as authentication and relationship data. Even if people are around, secure authentication using ID and password can be performed. In addition, the purchasing authority can be changed according to the user's attributes, such as student or teacher.

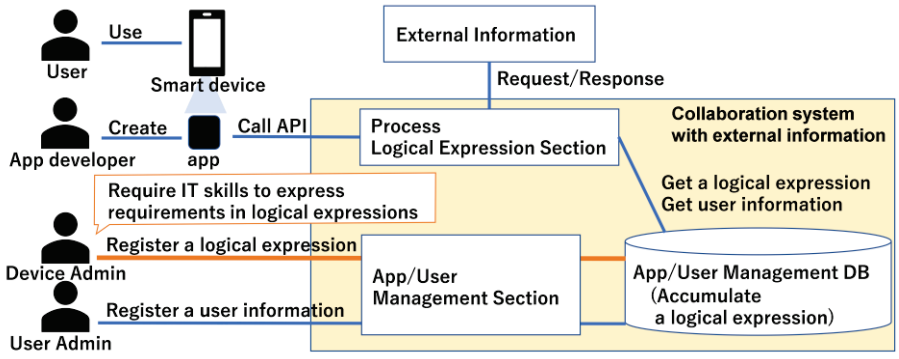

Figure 1. The overall structure of the collaboration system with external information

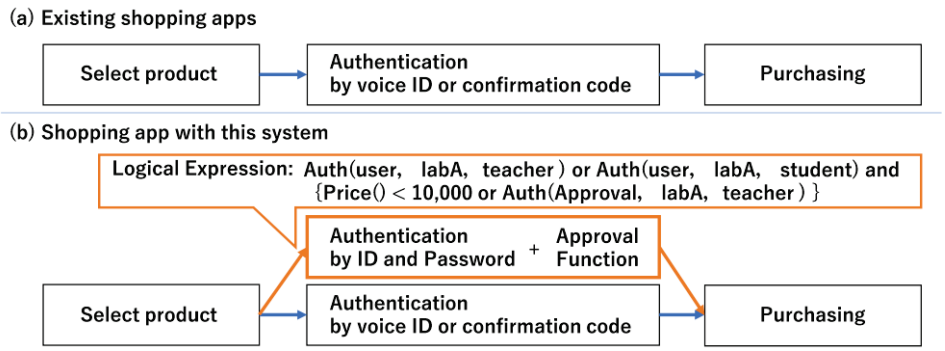

Figure 2. Changes in the shopping app before and after the introduction of this system

3. Proposal for an interactive tutoring system using a chatbot

In our system, the Device Admin is supposed to create a logical expression. Considering that devices are used in schools, the Device Admin would be a teacher, not a programmer. A more intuitive system is required for creating logical expressions.

Therefore, we propose a chatbot to assist in this task interactively, as shown in Figure 3. The chatbot assists in the creation of logical expressions through interactive dialogue, enabling Device Admin to intuitively configure logical conditions by asking questions and presenting choices. Additionally, by engaging in real-time feedback, the chatbot allows the Device Admin to make adjustments based on the situation, thereby preventing incorrect logical expressions. This chatbot helps with the following three points. First, express logical expressions in a natural language style to help Device Admin understand them. Second, by showing the priority of each function, it assists the understanding of the range of influence of "or" and "and". Finally, the logical expression eventually be correct even if the Device Admin adds the conditions in a different order. By supporting the above three points, even if the Device Admin does not understand the structure of logical expressions, the creation of logical expressions can be automated by taking information equivalent to logical expressions in a conversational format.

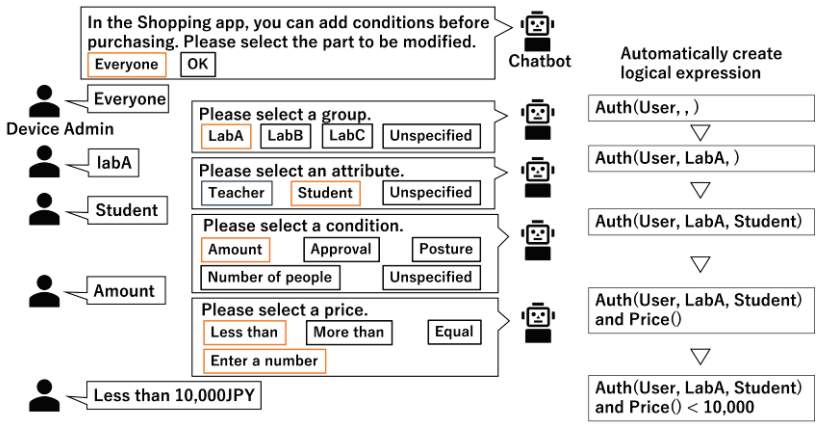

Figure 3. Overview of the tutoring system using a scenario-type chatbot

4. Conclusion

We develop a system that performs control collaboration to external information based on a logical expression registered in advance by the Device Admin to solve operational and security issues that arise when multiple people use a single device. Chatbots are used to easily create logical expressions even without the administrator being a programmer. In the future, it is possible to introduce a large-scale language model such as ChatGPT to the Chatbot part. Since it is good at explaining logical formulas in natural language, it is possible to help the Device Admin's understanding at the stage of creating logical expressions.

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