Developing an Integrated system of Robots and Toys with Internet of Things for Children's Language Development

Ya-Wen CHENG[a], Yuping WANG[b], Ming-Rong Liang[a], Nian-Shing CHEN[c] & Ya-Fei YANG[d*]
[a] *Department of Information Management, National Sun Yat-sen University, Taiwan*
[b] *School of Humanities, Languages and Social Science, Griffith University, Australia*
[c] *Department of Applied Foreign Languages, National Yunlin University of Science and Technology, Taiwan*
[d] *Department of Digital Design and Information Management, Chung Hwa University of Medical Technology, Taiwan*

*cillia55@gmail.com

Abstract: This study aims to create an interactive and immersive language learning environment for children with the support of robots and IoT sensors. In this paper, we first presented our key design principles for a system that integrates robots and IoT sensors into children's learning of a language while playing. The intergraded system was developed following the procedure of requirement analysis, prototyping and system testing and evaluation. Following the identification of learning needs and system requirements, a prototype of the system was built and evaluated using the cognitive walkthrough method. Although some usability issues were reported by the participants, the overall results confirm that learning tasks were successfully completed using this integrated system, and it is an easy-to-use system in that non-technical professionals were able to design scripts to control the robot and the IoT sensors.

Keywords: robot, IoT toys, robot for language learning, script editor

1. Introduction

Second language (L2) and/or foreign language learning has been driven by many theories and approaches such as the communicative, interactionist and intercultural approaches. With the adoption of technology in language learning, the validity of these theories and approaches have been further confirmed. At the same time, learning a second or foreign language through such a conscious learning process (Krashen, 1982; Schmidt, 1983) has also been criticized for their lack of effectiveness and native-like proficiency on the part of the learner in comparison with native language acquisition (Chang, Lee, Chao, Wang, & Chen, 2010; Pot, Monceaux, Gelin, & Maisonnier, 2009; Valk, 2010). Consequently, the advantages of acquiring multiple native languages at an early age in an immersive multilingual environment have received much academic attention. However, the reality is that most children lack access to such an environment during their critical period of language development. The current research aims to design such an immersive learning environment for children, taking advantage of the robotic technology and Internet of Things (IoT).

Robot-Assisted Language Learning (RALL) was introduced in early 2000 to facilitate learning foreign languages. Studies have shown that incorporating robots in young children's education may result in various benefits in terms of children' cognitive and behavioral development as well as language learning performance (Kanero et al., 2018; Kuhl, 2011; Mathur & Reichling, 2016; Morse & Cangelosi, 2017; Vogt, De Haas, De Jong, Baxter, & Krahmer, 2017). With the help of sensors, robots are able to perceive and react to the surrounding environments, providing proper responses through sounds or emotional expressions. In addition to affording anthropomorphic interactions, it is also an easy way to record and track the learning process. However, the incorporation of robots and sensors in language education can present various challenges to educators who do not have a technical background.

This study aims to design an easy-to-use system for language professionals who want to create an interactive and immersive language learning environment using robots and IoT sensors. To develop such a system is the end goal of the current study. Thus this study is guided by the following two research questions: 1) what are the design principles for developing an easy-to-use integrated system for non-technical background professionals to incorporate robots and IoT sensors in language education? and 2) what are the usability issues of such a system that system designers should be aware of?

2. Literature Review

2.1 Robot Assisted Language Learning (RALL)

Social robots, providing human like interaction through sounds and gestures have made great contributions to early language learning (Kennedy, Baxter, & Belpaeme, 2015; Vogt et al., 2017). Incorporating robots in language education is found to have positive effects on enhancing students' willingness to learn, students' learning motivation and learning performance (Kanero et al., 2018; Kuhl, 2011; Meltzoff et al., 2009; Morse & Cangelosi, 2017). Due to its humanoid features such as the appealing appearance, gestures and movements, a robot'' interaction with children can result in many positive effects on learning outcomes, such as increased vocabulary and willingness to speak in English (Alemi, Meghdari, & Ghazisaedy, 2015). However, most of the existing research into the use of robots in language learning only concern with the use of individual robots in a certain aspect of language learning in the context of traditional approaches (e.g., communicative approach) to L2 or foreign language learning. Different from the existing studies, our research approaches the use of robots from the perspective of language learning through immersion, with an emphasis on using the target language as the medium of communication and interaction between robots and children, much like the learning of one's mother tongue. Thus this research aims to create an immersive language learning environment for children, supported not only by robots but also by IoT sensors.

2.2 Script editor

Many studies have devoted to the simplification of programming for novice users. Visual programming language provides an interface that allows the user to create programs by manipulating program elements graphically rather than by specifying them textually. With the help the graphical display of programming elements, users are able to contemplate, reason and learn to program (Chao, 2016). In fact, many educational robots were designed to teach programming adopting the graphical approach, e.g., LEGO Mindstorms (Valk, 2010), Choregraphe for NAO (Pot et al., 2009), EV3 programmer app, Zenbo app builder, and scratch for programing Arduino robot. However, these apps were developed to support the teaching of programming, in which the users are expected to have basic prior knowledge of programming and to acquire more advanced programming skills after using the programming applications. Form-based user interface is widely adopted in the apps for mobile devices and information systems. Similar to graphical programming, form-based application provides a more intuitive user interface, through which users can accomplish tasks by simply using the controls in the form, e.g., dropdown buttons. These types of tasks do not require prior knowledge of programming. Informed by this technique, we adopted Windows Forms (WinForms) to develop a form-based script editor for non-technical professionals to incorporate robots in education.

3. Method

3.1 Research Design

The proposed system was developed through a non-linear and iterative process, which sought to identify users' needs and to develop the system through iterative cycles of testing and refinements. The process consists of three major phases: learning needs and system requirement analysis, prototyping, and testing and evaluation. Phase 1 was to understand users, to identify critical problems and to propose solutions to the users' needs. To this end, focus group discussions were held with the participation of two TELL (Technology Assisted Language Learning) professionals and the research team consisting of robot experts and curriculum designers. The two TELL professionals were invited because of their strong interest in incorporating robots and IoT sensors in language learning. Two themes characterized these discussions: 1) essential elements that are critical for children's language learning through playing with robots, and 2) the requirements of an integrated system that allows non-technical professionals to manage robots and IoT sensors to meet their teaching needs. The recordings of these discussions were coded and themes were identified to inform our needs and requirement analysis. This analysis led to the creation of the specifications of the proposed system. Phase 2 was to develop a prototype according to the specifications identified in Phase 1. To facilitate the iterative cycles of testing and refinements, we used 3D printing to build a prototype of a robot and used a plastic box to build a prototype of a toy. Phase 3 was to test the system and to identify usability issues in the early developmental stage. This study adopted the Cognitive Walkthrough method to evaluate how easy it is for new users to accomplish tasks using the system we developed. Cognitive Walkthrough is a usability evaluation method in evaluators work through a series of tasks to identify system usability issues. We invited four non-technical professionals and parents, who are interested in using robots for children's language education, to participate in the testing of the system. The participants were first given a 10 minutes introduction of the system and the tasks they were to perform. The participants were then asked to design a script to specify interactions between the robot and the IoT sensors using the system we developed. At the end, the participants were to report the usability problems they encountered and give a severity score to the problems.

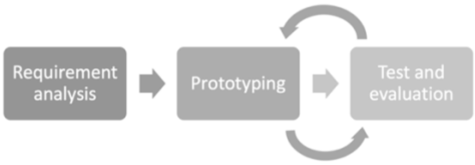

Figure 1. The developmental process of the proposed system.

3.2 The specifications of pedagogical needs and system requirements

Informed by the results from the focus group discussions, the following four specifications of pedagogical needs were identified. First, a toy should be used as the focus of the joint attention of the robot and children. That is, the robot was to play a toy with the children and provide linguistic input and output as parents would do. Second, the core functionality of the robot should be to provide linguistic cues, instead of performing the real tasks, whereas the tasks should be performed by the children. Third, toys should be included to better engage the children and help develop their cognitive skills while playing and receiving linguistic exposure. Fourth, the toy should be meaningful to the children while carrying multiple learning contents and functions to maintain children's engagement.

The focus group discussions also led to the inclusion of four key system requirements. The first requirement is the development of an easy-to-use script management system that allows users to program desired interactions between the robot, the IoT sensors and the children. As children's language cognition progresses rapidly with age, the learning contents should also be updated regularly and timely. It is thus crucial that the system allows language professionals to adjust the learning content in a timely manner in accordance with the developmental needs of the children. Second, a non-text programing environment, e.g., a graphical or iconic programming environment, is also deemed necessary to lower the technical barriers of incorporating robots in language education for language educators. Third, toys with IoT sensors should be able to be used together with the robot or independently from the robot. Fourth, scalability should also be an essential requirement for this system, allowing more sensors and modules to be included. This will ensure that the system is flexible enough to provide educators with rooms for catering to different children's individual needs, and for updating and creating learning contents for different playing scenarios and learning environments.

4. Results and Discussion

4.1.1 The Design of the Robot and Toys

This study used Raspberry Pi 3 as the hardware for the development of robots and toys. Owning high computing power and low power consumption wireless transmission devices, such as on-board WiFi and Bluetooth, Pi 3 is able to work well with IoT and is capable of adding on sensors. As the goal of the system was to facilitate children's language learning, providing contextual linguistic cues was considered as the first priority requirement of the system. Therefore, context awareness and providing corresponding linguistic information including speaking and facial cues were considered two key system requirements. Based on these considerations, a prototype of a robot was designed as shown in Figure 3. It was a light and portable robot that kids could move easily. The robot was equipped with a web camera to monitor children's motions, a microphone to receive voice commands and a screen to display learning materials and facial expressions. In order to increase the scalability, a breadboard was embedded inside of the robot, allowing more sensors to be added on to receive contextual information such as humidity, temperature, location etc.In order to maintain cost-effectiveness and quick turnaround of the iterations of usability tests and refinements, we used a 3D printer to build a prototype of the robot. The inner structure of the robot was designed to address the concerns of safety, a power supply and overheating. The robot was composed of the following components: a Raspberry Pi, a web camera with a microphone, a speaker, a 7 inches screen, a power bank, a breadboard and a humidity sensor. An expression management sub-system was developed to control the robot's facial expressions. In addition, the system also allowed the user to monitor the system's status, such as being disconnected with the cloud server and no script running at a specific moment, by observing whether the robot was displaying the animation of being confused or sleepy.

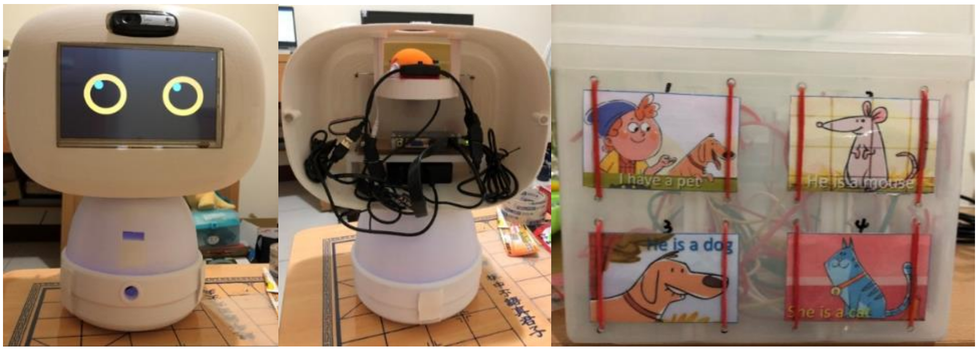

Figure 3. The design of the language learning robot and IoT toy.

The toy was designed as an interactive toy box, providing interactions through pressing the flashcards on the side of the toy box. Whenever the child pressed the flashcards on the side, either the toy or the robot would generate instant audio feedback to interact with the child, so as to engage he or she in playing. The toy was designed using a touch sensor board that connected to 12 objects, allowing children to learn through exploring nearby objects and to practice motor skills while listening and speaking the target language with the robot. Different from existing interactive sound books, of which the learning content is fixed and irreplaceable, this toy box was designed to provide flexibility to accommodate the needs of replacing learning contents whenever needed. Another reason for the inclusion of toys was to provide a focal object that drew the attention from both the robot and children, while the robot played toys with children in order to facilitate children's language development in an interactive and immersive environment. Scenarios were created using the toys as a stimulus for the robot to engage a conversation with children in the target language. With the help of the sensors on the toy, the robot was able to detect what children were doing and prompt instant feedback as parents would do when playing with their children.

4.1.2 The Design of Script Editing System

The script management sub-system provided the following four functionalities: allowing users to create and edit learning materials, to manage scripts, to view and search log files and to adjust system configurations. As shown in Figure 6, the script management sub-system was designed with a graphical programming interface, including filling-in-blank boxes and drop-down navigation bars. It also allowed users to perform different actions by selecting pages on the top. With these graphical programming features, this sub-system could ease users' cognitive loads. The first component of this sub-system was a content management sub-system, enabling users to create and edit learning materials by uploading pre-recorded mp3 files or simply applying the text to speech function to generate a spoken sentence. It also allowed users to delete or to modify the learning materials they created. The second component was a script management sub-system. It allowed the educators to edit or delete a script that they created. The third component was a log file management sub-system. It allowed users to view, search, sort and download the log files. The fourth component was system configurations, which allowed users to adjust system settings, e.g. the Internet access setting. This study also developed a graphical script editor. As shown in Figure 4, the script editor adopted Windows Forms, allowing users to program a robot and a set of touch sensors by clicking a few buttons. In order to generate multiple interactions using the 12 sensors, we designed two interaction modules to enrich the variety of interactions: a single sensor module and a multiple sensor module, allowing users to design the responses by specifying a set of sensors.

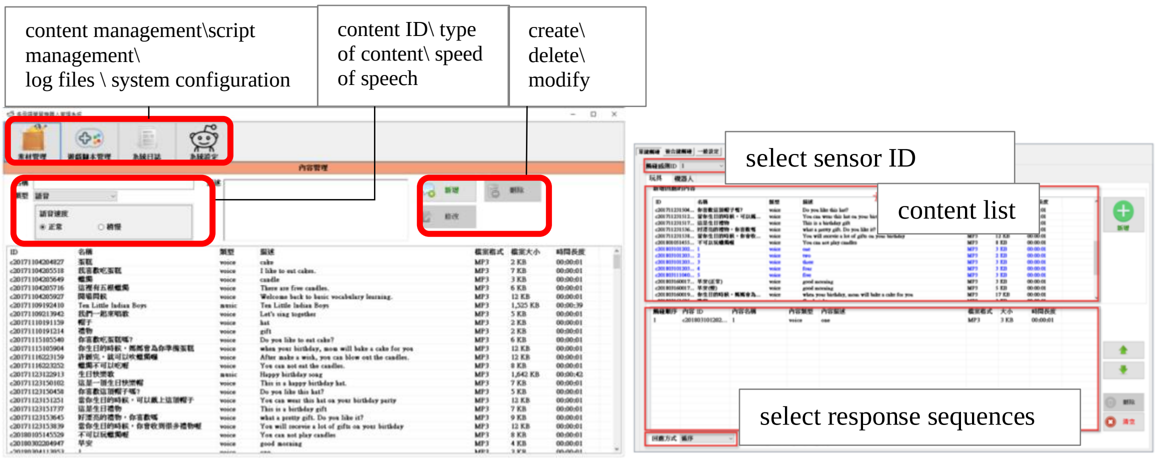

Figure 4. The interface of script management sub-system and script editor.

4.2 Preliminary Result of System Usability Evaluation

This study conducted a usability evaluation using the Cognitive Walkthrough method. The preliminary results from four participants are presented below. All of the participants, assuming the role of the end users, were able to complete the given task using the integrated system. 10 usability problems were reported, as shown in Table 1. The usability problems were categorized into six categories, including poor hardware design, system scalability, error prevention and recovery, system learnability, visibility of system status and efficiency of use. The participants also made two suggestions to improve the system, speech control and scheduling. With regard to affective speech, since the system was designed for children's language education, the TTS function provided by the system should be able to adjust the tones and speech speed of the speaker in order to effectively engage children's attention. As far as scheduling is concerned, the participants suggested that the system should include a scheduling function, e.g. executing good morning script before 9 am, and bedtime story script after 9 pm.

Table 1

The List of Usability Problems

Problem description	Numbers of participants	Average severity (1~5)	Problem Category
Bad connections	4	4	Poor hardware design
The way of creating and editing a script is not intuitive	3	3.7	System Learnability
Nonstop playing learning contents when the same button was mistakenly pressed.	2	3.5	Error prevention and recovery
Complex WiFi setting	4	3.25	System Learnability
Limited sensor slots	2	3	System scalability
Unable to add new functions to the script editing system	4	3	System scalability
Unable to adjust the sound volume of the toy and the robot from hardware	2	2.5	Poor hardware design
No information about the cause of system crash	3	2.3	Error prevention and recovery
Unable to observe battery status	2	2	Visibility of system status

Lack of accelerators to indicate which learning content has been selected or used	1	2	Efficiency of use

5. Conclusion

This study has discussed some critical issues relating to the design of creating an interactive and immersive language learning environment using robots and IoT sensors. The pedagogical concern of this study is to create a play scenario for children to learn a language through playing toys with a robot. To achieve this goal, we developed an intergraded system for non-technical professionals to control and specify interactions between robots and IoT sensors. In this preliminary study, we presented the design of the system architecture, system components and the employment of a graphic programming editor. As presented in this study, the system can be used in various learning scenarios, allowing educators and researchers to incorporate robots and IoT sensors in education effortlessly for language studies.

This study reports the preliminary results of an ongoing project with the aim to identify usability problems in the early developmental stage of the system, which will be addressed in our next round of design and improvement. We recognize that the complexity of designing an easy-to-use integrated system for children's cognitive and language development requires a systematic and iterative approach to the evaluation and improvements of the system design. We are planning to solve the identified usability issues and conduct more evaluations to improve the design of the system. Eventually the system will be evaluated in an authentic learning environment in which children will be invited to play and interact with the robot and the IoT toys, with the aim to develop a more comprehensive evaluation taxonomy for an intergraded systems of robots and IoT devices.

Acknowledgements

This research was supported by the National Science Council, Taiwan under project numbers 108-2511-H-224 -008 -MY3, MOST-107-2511-H-224-007-MY3 and MOST- 106-2511-S-224-005-MY3.

References

Alemi, M., Meghdari, A., & Ghazisaedy, M. (2015). The impact of social robotics on L2 learners' anxiety and attitude in English vocabulary acquisition. *International Journal of Social Robotics, 7*(4), 523-535.

Chang, C.-W., Lee, J.-H., Chao, P.-Y., Wang, C.-Y., & Chen, G.-D. (2010). Exploring the possibility of using humanoid robots as instructional tools for teaching a second language in primary school. *Journal of Educational Technology & Society, 13*(2), 13-24.

Chao, P.-Y. (2016). Exploring students' computational practice, design and performance of problem-solving through a visual programming environment. *Computers & Education, 95*, 202-215.

Kanero, J., Geçkin, V., Oranç, C., Mamus, E., Küntay, A. C., & Göksun, T. (2018). Social robots for early language learning: Current evidence and future directions. *Child Development Perspectives, 12*(3), 146-151.

Kennedy, J., Baxter, P., & Belpaeme, T. (2015). Comparing robot embodiments in a guided discovery learning interaction with children. *International Journal of Social Robotics, 7*(2), 293-308.

Krashen, S. D. (1982). *Principles and practice in second language acquisition*: Oxford: Pergamon.

Kuhl, P. K. (2011). Social mechanisms in early language acquisition: Understanding integrated brain systems supporting language. *The Oxford handbook of social neuroscience*, 649-667.

Mathur, M. B., & Reichling, D. B. (2016). Navigating a social world with robot partners: A quantitative cartography of the Uncanny Valley. *Cognition, 146*, 22-32.

Morse, A. F., & Cangelosi, A. (2017). Why are there developmental stages in language learning? A developmental robotics model of language development. *Cognitive Science, 41*, 32-51.

Pot, E., Monceaux, J., Gelin, R., & Maisonnier, B. (2009). *Choregraphe: a graphical tool for humanoid robot programming.* Paper presented at the RO-MAN 2009-The 18th IEEE International Symposium on Robot and Human Interactive Communication.

Schmidt, R. (1983). Interaction, acculturation, and the acquisition of communicative competence: A case study of an adult. *Sociolinguistics and language acquisition, 137*, 174.

Valk, L. (2010). A Beginner's Guide to Building and Programming Robots: starch press.

Vogt, P., De Haas, M., De Jong, C., Baxter, P., & Krahmer, E. (2017). Child-robot interactions for second language tutoring to preschool children. *Frontiers in human neuroscience, 11*, 73.