Using Storytelling Robot for Supporting Autistic Children in Theory of Mind

Sujirat Attawibulkul[1], Natthanicha Sornsuwonrangsee[2], Wisanu Jutharee[2], Boonserm Kaewkamnerdpong[1*]

[1] Biological Engineering Program, Faculty of Engineering, King Mongkut's University of Technology Thonburi, Bangkok, Thailand, 10140.
[2] Institute of Field Robotics, King Mongkut's University of Technology Thonburi, Bangkok, Thailand, 10140.

* Corresponding author. Tel.: +66-89-9228122; email: boonserm.kae@kmutt.ac.th
Manuscript submitted September 2, 2018; accepted November 23, 2018.
doi: 10.17706/ijbbb.2019.9.2.100-108

Abstract: Autistic children have deficit in the understanding of how other people think and feel which is an important factor for social interaction and social communication. The understanding of how other people think and feel is called theory of mind. The storytelling activity could help the autistic children to learn about the theory of mind from the communication between the characters in the story stand point. This study investigated the use of BLISS robot with mobile application in the storytelling activity for supporting the theory of mind in autistic children. Five children between 4 and 12 years old were recruited. All children listened to the story and answered questions about theory of mind from their parents in first week. For second week, all children listened to the story and answered question from BLISS robot that was controlled by their parents. Experimental result suggested that all children stay engaged throughout the storytelling activity. It was shown that BLISS robot can be used to reduce the burden of parent in storytelling activity. Moreover, some autistic children can answer all questions about theory of mind correctly.

Key words: Theory of mind, storytelling robot, storytelling activity, autism therapy, autistic children.

1. Introduction

Autism Spectrum Disorder (ASD) is a group of neurodevelopmental disorders. ASD was characterized by 3 areas: social interaction, social communication and repetitive behaviors. There are many possible causes of ASD such as imbalance in neural systems, genetics, environment and so on [1]. The prevalence of autistic children was found to increase when compared with that from previous years [2]. The treatment has not been found for autism because the absolute cause of this disease is still unknown; the possible cause may contribute in different combination for different children with ASD [1]. The current approach is to provide therapy in order to reduce inappropriate behavior and support development in each child. The cooperation of children with autism and therapist is important for all therapies; however, specialists have difficult times keeping the children engaging in session. Furthermore, the number of specialists in autism therapy is still insufficient to meet the ever-growing demand.

Robots have become interesting tools to assist specialists and parents in autism therapy and to support learning and development for children with autism [3]. Although many previous research studies have accepted the use of robot in autism therapy. KASPAR is the male robot [4] that can move arm, head, and hand to imitate gestures from therapist to improve interaction skills for children with autism. Keepon is

snowman-like in shape [5]. It has yellow color and made of silicon rubber. This robot has multi-axis movement, touch sensor, and camera inside its eyes for video recording. Children with autism can learn Keepon's emotions express through the pattern of Keepon's body movement. Previous studies designed the functionalities of the robot based on the purpose of each different therapy session. However, most previous studies did not focus on the theory of mind which are greatly needed for children with autism.

Theory of mind (ToM) is the understanding of how other people think and feel [6]. Autistic children lack theory of mind so that means they cannot understand what other people think and feel. Baron-Cohen et al. [7] used the Sally-Anne test for evaluating the theory of mind in children with autism. Their results shown that more than 80 percent of children with autism failed in the test. Generally, children with autism tend to developed theory of mind alongside their communication skill. Moreover, there is evidence that children listen and engage in conversations about mental state contribute to the development of theory of mind [8]. We anticipated that children with autism could gain theory of mind from the conversations between the characters in the story through storytelling activity.

Storytelling is one of activities that can develop the imagination and language skills of children [9]. This type of activity can increase the relationship between parents and children. Therefore, children can learn both the theory of mind and social skill from the story. Many research studies suggested that robots can help facilitator in storytelling activity. For example, ZECA robot [10] was used to help children acquire knowledge about different emotions and improve their skill in recognizing them by participating in storytelling activities. They used three autistic children for their research. Autistic children identified the emotion of the robot by showing the racket that had the picture of emotion face and QR code after ZECA finish telling the story. The ZECA robot detected the answer from the QR code on the racket using a build-in camera. Their results showed that the autistic children got the correct answers varied between 61% and 75% in 3 therapeutic sessions. Another related research used Probo robot [11] to study the role the social robot in providing assistance to a therapist in autism therapy. They used 2 boys and 2 girls in their study. This robot told the social story before the therapist tested the social response of children. Their result showed that the robot reduced the prompt of therapist in testing social responses when compared with the therapy session without the robot. Previous studies presented that the robot can be used in autism therapy to reduce the work load for facilitator and to improve emotion recognition skill. However, they did not focus on the detail of the story and the communication between characters which are the essential part for developing the theory of mind in children.

For our study, we focused on the theory of mind that children learned from the story. Moreover, we paid close attention on the role of the robot to help parents of autistic children. They are the most important people for their child's development because they have to constantly and continuously interact with the child, even more so than the therapist. The objective of this study is to investigate the use of robot and its mobile application in the storytelling activity for supporting the theory of mind in autistic children. Our research hypothesizes are the following: 1) the autistic children will have the attention at all time during storytelling activity; 2) compared with the session without the robot, the load of parent in storytelling activity should be lower; 3) the robot will support the theory of mind in autistic children through storytelling activity.

2. Materials and Methods

To investigate the use of storytelling robot, parent will use the tablet to control BLISS robot. BLISS robot will readout the story to the child. The child can interact with the robot through RFID card. The robot will be mediator between parent and child. Parent have the time that can stimulate the child to the storytelling activity. The system of application and BLISS robot was shown in Fig. 1. The results of the data collection

from the tablet, robot, camera in experiment room and experimenter will be analyzed and compared with when parents tell the story without the help from BLISS robot.

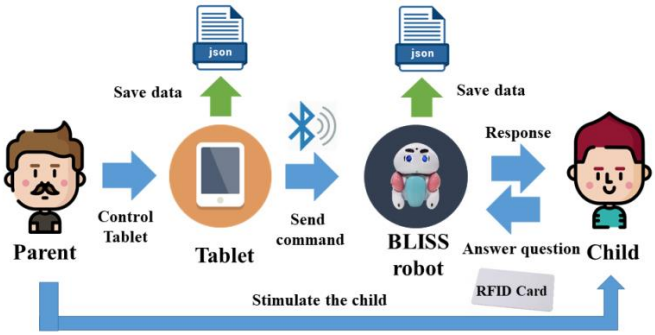


Fig. 1. The system of application and BLISS robot.

2.1. Participants

Five children between the ages of 4 and 12 participated in this study. All participants have the PDDSQ score ≥ 18. Pervasive development disorder screening questionnaire (PDDSQ) is the screening in the development of abnormalities that was developed by Yuwaprasart Waithayopathum Child and Adolescent Psychiatric Hospital from Department of Mental Health in Thailand [12]. In addition, all participants were screened by child psychologist before recruited in this study for confirming all participants had some receptive language. Moreover, participants had no significant vison, hearing, or motor impairments. Sally-Anne test was used for testing the theory of mind of participants.

2.2. BLISS Robot

In our previous study, BLISS (Using Robot in Learning Intervention to Promote Social Skills for Autism Therapy) robot [13] is an automatic mobile robot that looks like a toy as shown in Fig. 2 (a). This robot has two wheels for movement and can exhibit LED light and sound. The robot was designed to be durable and able to withstand harsh play. This robot has a RFID reader for playing the matching game and communicating with RFID card. BLISS robot can assist in the therapeutic activities as a medium between a therapist and a child; this is to reduce the burden from inexperienced facilitator and, in turn, to reduce negative influence toward autistic children.

In this study, BLISS version 2 was used. This BLISS robot is human-like appearance as shown in Fig. 2 (b). Almost all functions are the same as BLISS version 1. In addition, this robot has built-in computer so that they are more powerful and faster in computation. This robot can connect to the tablet by Bluetooth so that BLISS can play sound and express lights as requires.

(a) (b) (c)

Fig. 2. BLISS Robot System (a) BLISS robot - Toy-like, (b) BLISS robot - Human-like, and (c) The storytelling application.

2.3. Storytelling Application

We developed storytelling application as shown in Fig. 2 (c). Storytelling application connected to BLISS robot by Bluetooth. The system was shown in Fig. 1. When the parent opened the application and clicked the button to command the robot to readout the story, the application sent the signal to BLISS robot and collected the actions when the parent touched on the scene on tablet to the database. BLISS robot responded according to the application command and saved every action that the robot expressed in database. The children used the RFID card to communicate with the robot. The robot detected the RFID card, saved the action and sent the signal to the application so that the number of cards is recorded and continued to next response.

2.4. Story

The name of story is "Striped Watermelon with Grandmother Cow" that we got the permission from the Foundation for Children (FFC) in Thailand for usage in this study. This story got the 15th Rising Star Award from the Foundation for Children. The lesson of this story is for people to help each other and to not be discouraged when they encounter problems. The children can learn this lesson from the story to enhance their social skill. Moreover, in this story, 3 main characters including rabbit, pig and porcupine exchange their own idea for solving the problem. This is the reason for choosing this story because the exchange of ideas could support the autistic children in theory of mind.

2.5. Experimental Setting

Before the experiment, we evaluated the theory of mind in all participants by using Sally-Anne test. Parent and child participated in the experiment for 2 weeks (once a week). In first week, the parent told the story to the child by using the general storytelling book in experiment room. Child listened to the story from the parent and answered the question by pointing the answer on the storytelling book or speaking the answer. In the second week, the parent used storytelling application to control BLISS robot in the same room. BLISS robot told the story according to parent's command. The timeline of experiment was shown in Fig. 3 (a).

In experiment room as Fig. 3 (b), we had 3 cameras for recording the video during the experiment. Every window and glass wall were covered by the vacuum stickers for blocking the view from the outside which can distract the child from the storytelling activity. The experimenter was hidden from the participants by separating partition. The experimenter has control over the three cameras and one microphone for recording of the experiment. The level of prompt and the answer from the child was also manually collected.

The story will be read twice in one week. In the first time, the robot will read the story without any interruption in order to create the flow of the story; it is not yet necessary for the child to understand everything the first time. The second time, the robot will read some part of the story, then stop to ask some questions to evaluate how much the child could understand the words and meaning of the actions from the characters in the story. The questions about the theory of mind were created as to why the characters think or do the way that happen to evaluate the children with autism about theory of mind after listening the story. All questions and 2 choices were created by child psychologist. One choice is about the thinking of oneself and the other choice is about the thinking of others.

The detail of the story and the questions about theory of mind in session with BLISS were increased compared to the session without BLISS. There were only three questions in the first week. In the second week, there were six questions; three questions were the same as the first week. Another three questions were created according to the increasing detail of the story. For this design, we hope to see the progress of the development of children in theory of mind.

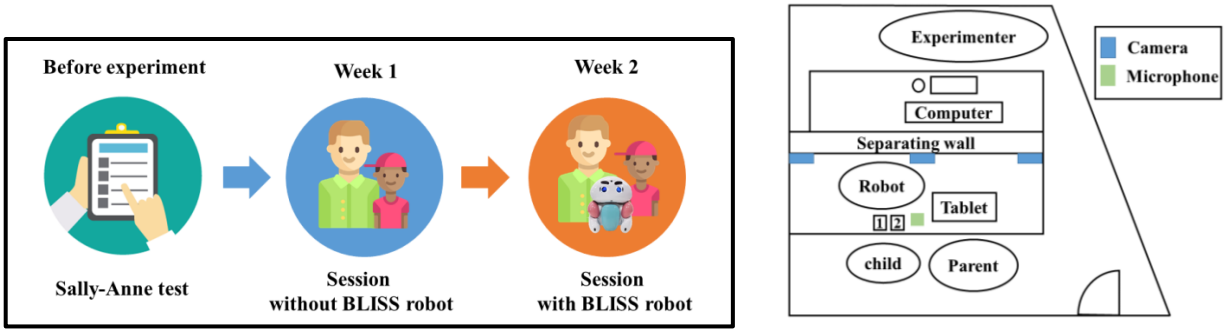
2.6. Data Collection

In term of attention time, the time when the child was engaged with storytelling activity, the video was used to find the time usage of child with autism in each session. We started to record the time when parent or robot started to readout the story and stopped when parent and child finished the activity and prepared to exit the experiment room. The participants are free to leave the experiment at any time.

Next, to measure the parent's burden, we used the level of parent prompt and the response time of children to answer each question. The level of prompt was recorded by the experimenter during the experiment. The level of prompt has 5 levels as shown in Table 1. From the recorded video and sound during experiment, we checked the response time in each question. We started recording of the response time after parent or the robot ask the question, and stopped when the child answered the question.

Finally, we collected the answers of children during the question and answer activity in experiment for figuring out whether the robot can support the theory of mind in children or not. The answers were recorded by the robot system and experimenter and were rechecked from video recordings.

To test for differences between the session with and without BLISS robot, the level of prompt, the number of correct answers, and the response time were compared using the Wilcoxon Signed Ranks Test (a non-parametric, within-subject test). All results about the Sally-Anne test, the attention time, the level of prompt, the number of correct answers, and the response time will be shown and discussed in next session.



(a) (b)

Fig. 3. Experimental settings (a) The timeline of experiment, and (b) The experiment room.

Table 1. The Level of Parent Prompt

Level	Description
1	The child can answer the question and do not need the help from parent.
2	The child can answer the question when parent repeats the question.
3	The child can answer the question when parent repeats the question and gives some keyword to help.
4	The child can answer the question when parent repeats the question and gives the answer to the child.
5	The child cannot answer the question. He/she did not do anything.

3. Results and Discussion

3.1. Attention Time

All autistic children had an interest in storytelling activity throughout the experiment. In the time usage as shown in Table 2, the median of usage in the session with BLISS robot is 18.32 minutes and the session without BLISS robot is 18.30 minutes. Most participants took the time on both sessions in range of their attention span (chronological age + 1) [14]. All participants used the time on both sessions longer than own attention span. It may suggest that children were well interested in this activity and the storytelling activity in the session with or without BLISS robot can engage the autistic children in the activity. Parent and child have a good time to do this activity together. However, it is difficult to interpret with confidence because it

could be due to other factors (e.g., the difference in speed of sound in robot and parent, and experimenter bias).

3.2. Supporting the Parent

In supporting the parent in storytelling activity, we used the level of prompt in question and answer to explain it. We focused only new questions (3 questions) in the session with and without BLISS robot that children with autism were asked at the first time because the same question in the session with BLISS robot may have bias from previous actions. Some autistic children may remember the question and can answer the question in the session with BLISS robot. In the result, we found that the level of parent prompt in the session with BLISS robot (median = 1) is lower than the session without BLISS robot (median = 2), p = 0.084 as shown in Fig. 4 (a). These results may suggest that BLISS robot can help the parent in the storytelling activity.

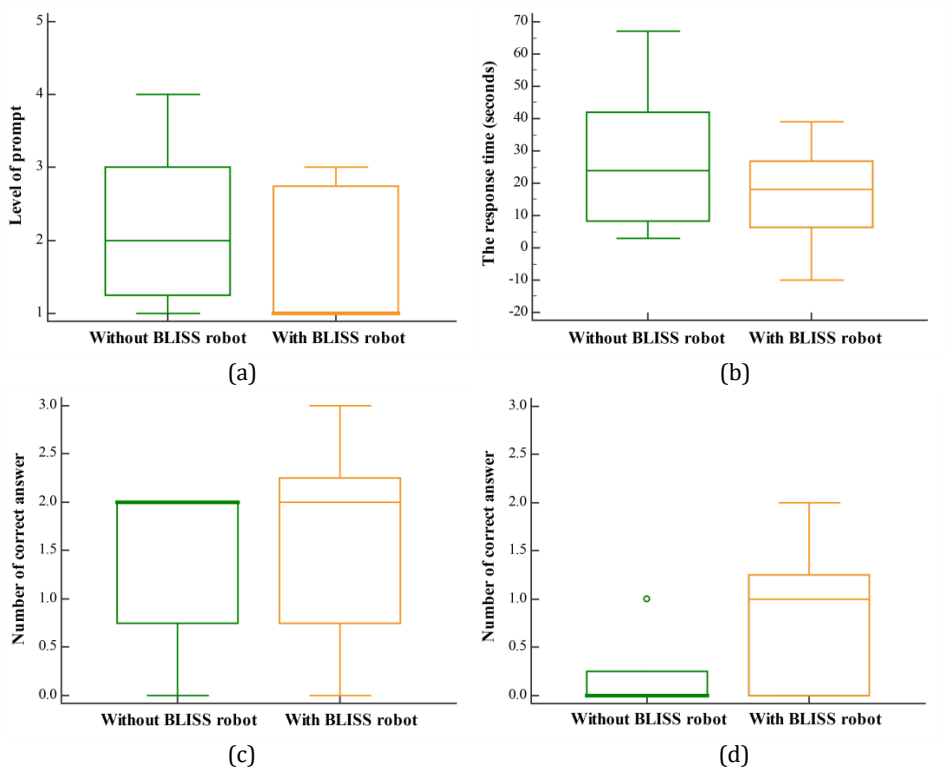


Fig. 4. The comparison on new questions between the session with BLISS robot and without BLISS robot: (a) level of parent prompt, (b) response time, (c) number of correct answer, and (d) number of correct answer without parent prompt.

Table 2. Demographic Data of the Result in Sally-Anne Test, the Time Usage in Session with and without BLISS Robot, and the Number of Correct Answers. (Week 1= Session without Robot, Week 2 = Session with Robot)

Participants	Age (years)	Attention span (minute) [14]	Sally-Anne test	The usage in session (minute)		Number of correct answer on new questions		Number of correct answer without prompt on new questions	
				Week1	Week2	Week1	Week2	Week1	Week2
1	5	6	Failed	22.49	26.23	2	2	1	1
2	9	10	Failed	17.10	17.39	2	3	0	1
3	4	5	Failed	8.30	16.55	0	2	0	2
4	9	10	Failed	20.20	26.12	1	0	0	0
5	7	7	Failed	18.50	18.32	2	1	0	0

Fig. 4 (b) shows the response time to new questions between the session with and without BLISS robot. The result stated that that the median of response time in the session with BLISS robot (median = 18 seconds) is lower than the session without BLISS robot (median = 24 seconds), $p = 0.0637$. These results may suggest that the robot can engage the children with autism to answer the question and that the robot can support the parent prompt. Moreover, some parents reduce their role and let their children freely play and learn by themselves in session with BLISS robot.

3.3. Supporting in Theory of Mind

Table 2 showed that there are no children with autism passed Sally-Anne test. It means that all 5 children did not know about what other think and feel before they joined the experiment. For the number of correct answer, we counted the number of correct answer to the never before seen questions that children with autism found for the first time in each session. In the result in the number of correct answer about the theory of mind question, the result showed that the number of correct answers of new questions in the session with BLISS robot (median = 2) is equal to the number of correct answers in the session without BLISS robot (median = 2). However, as shown in Fig. 4 (c), some children with autism can answer all questions correctly in the session with BLISS robot, but in the session without BLISS robot there is no children that was able to answer all question correctly.

In addition, if we focused only the number of correct answers without prompt from parent, we found that the number of correct answers without prompt in the session with BLISS robot (median = 1) is more than the number of correct answer without prompt without BLISS robot (median = 0) as shown in Fig. 4 (d). These results showed that some children with autism have more number of correct answers without the parent prompt in the session with BLISS robot. These results may have suggested that some children with autism in the session with BLISS robot have more attention and understanding of the story than the session without BLISS robot. For these cases, some children with autism did not need the parent prompt. They can answer the questions about the theory of mind correctly by themselves. However, in these results, this is no statistically significance between the session with and without BLISS robot.

4. Conclusion

In this study, we investigated the use of BLISS robot with mobile application in the storytelling activity for supporting the theory of mind in autistic children. The experimental results suggested that storytelling activity in session with and without BLISS robot can attract the attention of children along this activity. The parent reduced the level of prompt when using the BLISS robot in storytelling activity. In addition, the response time of the children with autism in the session with BLISS robot decreased from the session without BLISS robot. These results suggested that BLISS robot can reduce the burden of parent in storytelling activity.

Moreover, in supporting the theory of mind, some children with autism can answer all questions correctly in the session with BLISS robot. We found that some children with autism can answer correctly without the need of parent prompt in the session with BLISS robot. Nevertheless, we found no statically significant difference between the session with and without the robot. In the future, we would increase the number of participants in the study. Moreover, we will increase the number of stories in order to extend the use of storytelling robot and application for the social development of children with autism.

Acknowledgment

The study is financially supported by the Asahi Glass Foundation (Fiscal Year of 2017) and the National Research Council of Thailand (Fiscal Year of 2018). The authors are thankful for children with autism participated in this experiment. Moreover, we thank the Foundation for children (FFC) in Thailand for

supporting the story and pictures. Finally, the authors are immensely thankful for information and assistance in this study from Ms. Tichagorn Boonsri, Child psychologist, Play & Learn by Krunong.

References

[1] Volkmar, F. R., & Wiesner, L. A. (2009). Chapter 2 what cause autism? *A Practical Guide to Autism: What Every Parent, Family Member, and teacher Needs to Know* (pp. 25-44). New Jersey: Wiley.

[2] *Autism Spectrum Disorder: Data & Statistics*. (March 31, 2016). Retrieved from Centers for Disease Control and Prevention website: http://www.cdc.gov/ncbddd/autism/data.html.

[3] Cabibihan, J. J., Javed, H., & Jr, M. A. (2013). Why robots? A survey on the roles and benefits of social robots in the therapy of children with autism. *International Journal of Social Robotics,* 593-618.

[4] Huijnen, C. A. G. J., Lexis, M. A. S., & Witte, L. P. (2016). Matching robot KASPAR to autism spectrum disorder (ASD) therapy and educational goals. *International Journal of Social Robotics,* 445-455.

[5] Kozima, H., & Michalowski, M. P. (2009). A playful robot for research, therapy, and entertainment. *International Journal of Social Robotics,* 1-18.

[6] Korkiakangast, T., Dindar, K., Laitila, A., & Karna, E. (2016). The sally-anne test: An interactional analysis of a dyadic assessment. *International Journal of Language and Communication Disorders*, 1-18.

[7] Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a "theory of mind"? *International Journal of Cognitive Science,* 37-46.

[8] Miller, C. A. (2006). Developmental relationships between language and theory of mind. *American Journal of Speech-Language Pathology*, 142-154.

[9] Matos, D. C., Matos, P. G., & Figueiredo, R. M. É. (2015). Investigating the use of digital manipulatives for storytelling in pre-school. *International Journal of Child-Computer Interaction,* 1-10.

[10] Costa, S., Soares, F., Pereira, A. P., Santos, C., & Hiolle, A. (2014). A pilot study using imagination and storytelling scenarios as activities for labelling emotions by children with autism using a humanoid Robot. *Proceedings of the Joint IEEE International Conferences on Development and Learning and Epigenetic Robotics* (pp. 299 – 304). Genoa, Italy.

[11] Vanderborght, B., Simut, R., Saldien, J., Pop, C., Rusu, A. S., Pintea, S., Lefeber, D., & David, D. O. (2012). Using the social robot Probo as a social story telling agent for children with ASD. *Interaction Studies (INTERACT STUD),* 348-372.

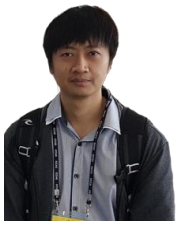
[12] *Pervasive Developmental Disorder Screening Questionnaire (PDDSQ)*. Retrieved March 2, 2018 from Department of Mentak Health website: https://www.dmh.go.th/tst/download/view.asp?id=20

[13] Santatiwongchai, S., Jutharee, W., Ounjai, K., & Kaewkamnerdpond, B. (2016). BLISS: Using robot in learning intervention to promote social skills for autism therapy. *Proceeding of the 10th International Convention on Rehabilitation Engineering & Assistive Technology (i-CREATe)*. Bangkok, Thailand.

[14] *Behavior Management Important Facts*. Retrieved May 25, 2018 from University of North Carolina at Chapel Hill website: http://www.unc.edu/depts/scale/Member/trainings/BehaviorManagement-ImportantFacts.pdf

Sujirat Attawibulkul received his bachelor of biomedical engineering from Srinakharinwirot University in 2016. Currently, he is a master student of King Mongkut's University of technology Thonburi (KMUTT), Thailand, and working on the game on robot for helping in development of children with autism.

Natthanicha Sornsuwonrangsee graduated from Mahaprutaram Girls' School under the Royal Patronage of her Majesty the Queen, Thailand. Currently, she is an undergraduate student of institute of field robotics, KMUTT, Thailand.



Wisanu Jutharee received his bachelor of engineering in mechanical engineering and master's degree of engineering robotics and automation from KMUTT, Thailand. He is currently a PhD student in Institute of Field Robotics from KMUTT. His expertise in robotics has been applied to research and development of humanoid robots.

Boonsern Kaewkamnerdpong received the master's degree from Asian Institute of Technology, Thailand, and the PhD from University College London, United Kingdom. She is currently an assistant professor at biological engineering from KMUTT. Her expertise in artificial intelligence has been applied to research in robotics, bioinformatics and neuroinformatics.