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Design of a Personalized R-Learning System for Children

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Abstract— **This paper introduces the r-learning (robot -learning) system that utilizes robotic interactions to personalize instructions for individual children. A child who is not familiar with using an educational tool to study could learn readily from educational contents through various interactions with a robot which is based on the behavior control. The contents which are chosen according to a child's learning data extracted by analysis from human-robot interaction data could lift the educational effectiveness. An r-learning scenario is designed by using Petri net to handle exception occurred in a learning process. The robot contents maker and the Open API for operating a robot are described as management utilities for a personalized r-learning system.**

I. Introduction

The learning system using and applying an educational tool is a very important factor to improve educational effects. Previous studies have proposed diverse educational tools and a learning system on the basis of these educational tools. Especially, after 1990' internet and personal computer became popular, e-learning system based on web has been developed. The initial e-learning system, however, has been limited as a learning system by an one-sided supplier. After that, multi-media and ubiquitous technology have rapidly developed, an e-learning system to be designed by a learner on the basis of web by both-sided e-learning system has been explored [1]. The e-learning system to fit for a learner status on the basis of web is characterized by the possibilities to evaluate the learning ability of the learner and offer appropriate education contents based of the information [2].

In the language education of a child, however, the effectiveness of this e-learning system based on web did not show difference or lower in specific language areas in comparison with that of the passive learning [3]. Thus, to achieve learning effectively, it is important to lead a child to concentrate on learning with intellectual curiosity continuously using the information on the basis of understanding the learner's emotional condition in the place for the education. However, the e-learning system based on the web is not enough to play this role.

To complement these problems, recently the studies have been attempted to use a robot to be capable of emotional communication with human in education places [4]. Interestingly, it has been supported that for leading a child to focus on learning, using a robot as an educational tool is more effective and efficient than using a passive educational tool or e-learning based on the web [5]. Especially intelligent robots bring effectively educational effect as the robots take place of teacher leading children who cannot use PC (personal computer) or PMP (Personal Media Player) to take part in learning and rising interests and curiosity of children. During learning with the intelligent robots, diverse Human-Robot Interactions induce children to learn more actively and excitingly than television or books do.

Moreover, for a child is hard to start to learn by himself/herself, the intelligent robot can lead the learning actively the child to participate in learning. Instead of a teacher, the intelligent robot can approach and persuade a child, evoke intellectual curiosity and interesting and increase the concentration of learning, and then efficiently bring the educational effect. Han et al. [6] compared the results of learning children in the three different methods. Each group of children was learned by book and audio tapes (non-computer based, NCB), (instruction, WBI), or a robot (Home Robot-Assisted Learning, HRL). Their results showed that the group learned by the robot had highest scores in the aspects of concentration, interest, achievement.

In these reasons, the dynamic and interactive education experienced by various functions of a robot can not only bring very efficient educational effects on a child, but, also improve of a child's concentration in learning.

However, previous studies for the child learning system using a robot have been focused on developing a robot to help the child to play a game or to watch the indicated contents. It has not studied for the learning system to maximize the educational effect by maintaining learner's concentration through communication with learning.

Therefore, in this paper, we suggest that personalized r-learning system for children learning. The personalized agent server has a function to select contents for offering appropriate learning contents to a child. Furthermore, the robot as a teacher has Human-Robot Interaction (HRI) functions to progress learning through various interactions with a child using speech recognition, voice composition, visual recognition, and other sensors.

Considering the characteristics of the dynamic environment that the r-learning system has, it is important that the design of the learning scenario includes the handling of exceptional situations. Therefore, the personalized r-learning scenario is designed using the Petri net [7][8], which is the method for modeling the discrete-event dynamic system, to investigate the order of incidents and cause-and-effect relationships of the events breaking out among a student, a tutor robot and an agent server. Moreover,

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the utilities for managing the personalized r-learning system are developed, the robot contents maker and Open API (Open Application Program Interface) for operating a tutor robot. The field experiment was carried out with children at a kindergarten.

This paper is organized as follows. At first, the personalized r-learning system is explained in the section II. The section III describes the r- learning scenario design using the Petri net, and then, the section IV shows the implementation and experiment for the r-learning system. Finally, the section V concludes the paper.

II. Personalized r-Learning System

A. Child-Centric System

Recently various studies have been proposed to select proper contents according to the characteristics of a learner and to offer the contents for a personalized e-learning.

The personalized e-learning system has been developed to estimate the level of the learner and select proper learning contents saved in a server according to the evaluation of learning through studies of the structure of e-learning system to choose contents and the concept map based on ontology to understand the characteristics of the learner.

However, a main problem of the personalized e-learning system is the limitation of evaluation methods to estimate the level of the learner.

The evaluation of learning is only based on the percentage correct score for the presented problems, and in the basis on that, the next contents of the learner is selected. This is the limitation of the personalized e-learning. It is required that the supplement evaluation method to find out the characteristics of the learner more precisely and details.

These requests, the diverse sensors of the robot in the r-learning system can be used as compensation tools to figure out the characteristics of the learner.

To interact between a robot and a human, the various equipments for speech recognition, visual recognition, and touch recognition are allowed to observe the condition of the learner during learning, to be the diversity of models for a learner, and to select effectively and efficiently the proper contents for the learner in the personalized learning system.

Fig. 1. shows the organization of the personalized r-learning system using a robot. Main Server holds various contents created by contents authors and transfers the contents by the request of Agent Sever on the web for learning. Agent Sever receives a robot profile including hardware information of the robot from the robot and sends the profile to Main Sever. According to the information, Agent Sever downloads proper robot contents and transfers the contents to the robot. The robot executes the received contents and processes learning with a learner by the various interactions. During learning, the robot arranges score for the items in Table I using the various inputs from a child such as visual data, vocal data, touch screen inputs and HRI tool inputs. After learning, the results of learning are saved in files and are transferred to Agent Server. Then, it analyzes the files, grasps the state of the learner, and selects contents for the next learning. Parents can receive information about the learner's status on the web.

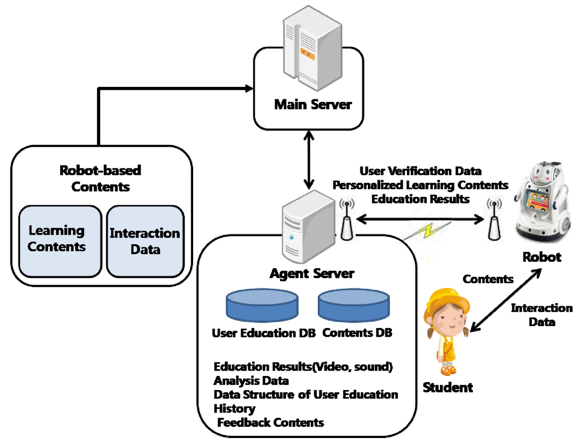


Fig. 1. The personalized r-learning system configuration

TABLE I
Assessment List of the Learning Result

Item	Description
Total_Class_Time	Duration time from the start and the end of a content
Completion_Status	Number of trial to complete a content
Activity_Score	Number of correct answers in a class
Story_Concentration_Rate	Duration time when a student watch the display of a content
Operating_HRI_Tool	Ability of operating a HRI toy
Keyword_Usage	Number of a student's usage of keywords

B. Intelligent Tutor Robot

Because an educational robot is distinguished from an industrial robot which operates behaviors in simple orders in static environment in the view of notable feature of human-robot interaction, it is important to execute behaviors properly with considering the dynamic situation related with a student to provide educational contents.

Fig. 2. shows the three-layer architecture for the behavior -based control. The top layer of the three layers in the architecture is the task manager which controls the learning content execution and lists up the sequences of behaviors to play the contents. At the middle layer, the behavior manager

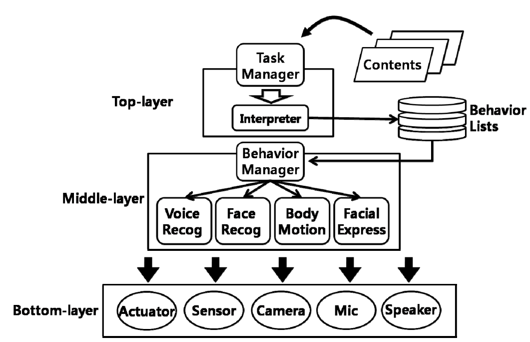


Fig. 2. The three-layer architecture of the behavior-based control system for operating an intelligent tutor robot

is responsible for carrying the behavior lists into practice. It checks the current learning situations based on the interactive sensor data and decides which behaviors would be executed. The hardware devices are controlled at the bottom layer to actuate motors and sense environment, for the robot executes behaviors. Each layer depends on those below it.

We classify the behaviors of an intelligent tutor robot as follows. The behaviors are split into three kinds of behavior with respect to complexity and composers such as the basis behavior, the composite behavior and the group behavior. The basis behavior consists of principle behaviors which a robot could operate and haves the criteria that it uses only one hardware resource of a robot to be executed. The composite behavior has combination of two or more basis behaviors. It is a compound behavior defined by a robot programmer to synchronize basis behaviors. Also it could be a set of the basis behaviors to be often used for education. The group behavior comprises of the basis behaviors and composite behaviors and is defined by a robot content developer.

III. R-LEARNING SCENARIO

The procedure of the r-learning is made up of the behaviors of components of the r-learning system, which are intimately connected to one another. The sequence of the behaviors has the pattern to invoke each behavior and constructs the learning scenario from the beginning to the end of a class. There are three stages for the r-learning: preparing, processing, finishing. In each stage, the group of the behaviors of the components of the r-learning system could be modularized according to their functionalities. The relationship of the modules is described in Fig. 3. The flow of modules has the rules which are explained in Table II.

Above all, at the learning preparing stage, the initialization module shows that an agent server connects communication with the robot and the introduction module describes the sequence of going around home to find a child student and asking him or her of studying to begin a class in Fig. 4. For the certification of the user, using the function of the face

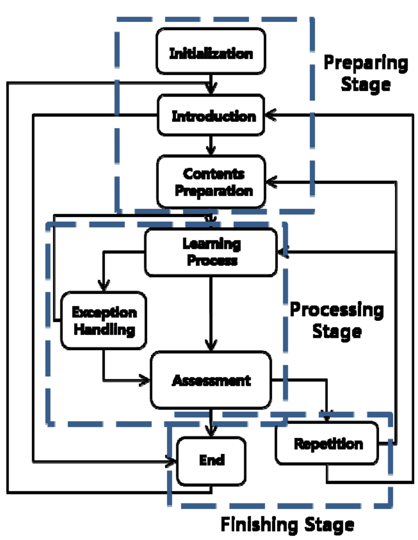


Fig. 3. The flow chart of the personalized r-learning procedure

TABLE II
THE RULES OF MODULARIZATION DESIGN METHODS

	RULE
1.	Every module has one more place and transition.
2.	All the input tokens of each module come into through places and all the output tokens go out through transitions.
3.	The number of input tokens is the same as the number of output tokens in every module.

recognition, the robot compares the face recognized by a camera with the face information of database for previously registered users. When the robot finds the learner, it greets and prepares a learning content. The contents preparation module is the process of choosing and downloading a learning content from an agent server according to the analysis result of the student's data such as education history, a current grade, preference and so on.

The agent server chooses the proper contents based on the learning result from the previous class to process a current class. When the tutor robot receives the contents from the agent sever, the preparing stage is finished. The descriptions of the places and the transitions of the modules at the preparing stage is showed in Table III.

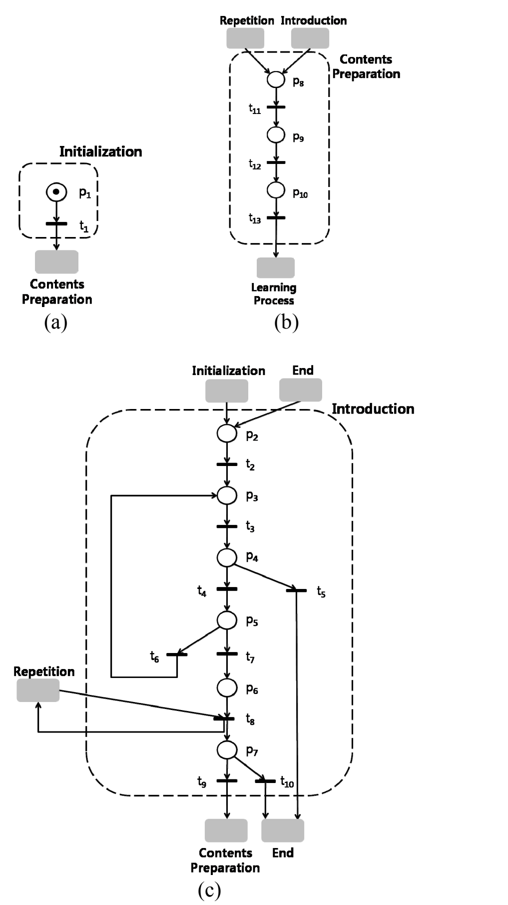


Fig. 4. The Petri nets of the modules at the preparing stage in r-learning (a) Initialization (b) Contents Preparation (c) Introduction

TABLE III
THE DESCRIPTIONS OF THE TRANSITIONS AND THE PLACES OF FIGURE 4

Place	Description	Transition	Description
p_1	System Initialization	t_1	Communication connection between a robot and an Agent Server
p_2	Standby mode	t_2	Command of beginning a class
p_3	Introduction mode	t_3	Finding a student
p_4	Checking the result	t_4	Meet a person
p_5	Verifying a student's identity	t_5	Failure of finding a student
p_6	Greeting a student	t_6	Failure of verifying a student's identity
p_7	Checking the response	t_7	Success of verifying a student's identity
p_8	Preparing a content	t_8	Asking a student to study
p_9	Choosing a content	t_9	Liking to study
p_{10}	Downloading a content	t_{10}	Hating to study
		t_{11}	Sending student's data
		t_{12}	Transferring a learning content
		t_{13}	Playing a content

At the beginning of the processing stage, the tutor robot progresses the class with playing the downloaded contents. The robot tries diverse interaction by voices, motions, and expressions to provide the required contents for the learner. During the class, the robot extracts scores of learning evaluation lists from information of the learner using various sensors. When the processing of the learning contents is finished, the robot transfers the results of the various learning evaluation list to the agent server and then, the robot asks if the learner would be continuous the study. According to the response of the learner, the learning is finished or the next contents will be provided. The agent server decides the next contents on the basis of the previous learning results information in the proper level of the learner.

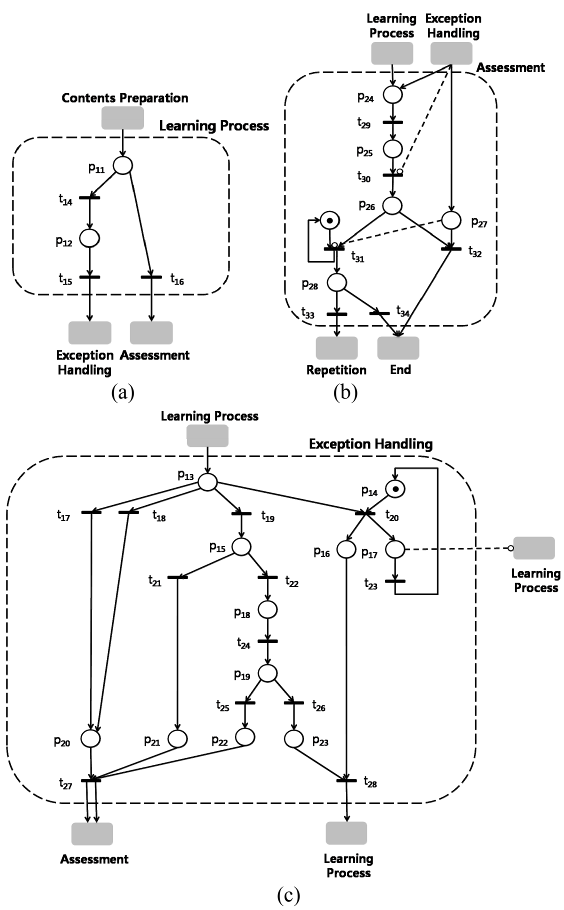


Fig. 5. The Petri nets of the modules at the processing stage in r-learning (a) Learning Process (b) Assessment (c) Exception Handling

TABLE IV
THE DESCRIPTIONS OF THE TRANSITIONS AND THE PLACES OF FIGURE 5

Place	Description	Transition	Description
p_{11}	Learning process mode	t_{14}	Occurrence of an exception
p_{12}	Pausing a content	t_{15}	Determination of the kind of the exception
p_{13}	Checking exceptions	t_{16}	Completion of playing a content
p_{14}	Stopping saving real-time data to send	t_{17}	Command to stop the class
p_{15}	Finding a student	t_{18}	Lack of a battery of a robot
p_{16}	Starting to save real-time data to send	t_{19}	Disappearance of a student
p_{17}	Disconnection of the communication	t_{20}	Failure of the wireless communication
p_{18}	Asking the cause of the student's behavior	t_{21}	Failure of finding a student
p_{19}	Asking a student to study	t_{22}	Success of finding a student
p_{20}	Informing the suspension of the class to a student	t_{23}	Reconnection of the communication
p_{21}	Save the cause of the suspension of the class	t_{24}	Recording the answer of the student
p_{22}	Informing the suspension of the class to a student	t_{25}	Decision of stopping to study
p_{23}	Informing resuming the class to a student	t_{26}	Decision of continuing to study
p_{24}	Ready for assessment of learning	t_{27}	Stopping the class
p_{25}	Completion of saving a learning result file	t_{28}	Resuming the class
p_{26}	Completion of sending data files	t_{29}	Assessing the student
p_{27}	Ready for finishing the class	t_{30}	Sending the learning result files
p_{28}	Checking the response	t_{31}	Asking repetition of studying
		t_{32}	Finishing the class
		t_{33}	Decision of continuing to study
		t_{34}	Decision of stopping to study

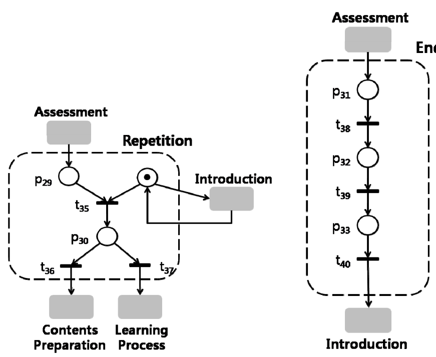
There is something important to be considered at the processing stage. The environment of learning with a robot is too complicated to predict circumstances and in 3 dimensions unlike learning with a personal computer. A learner in the r-learning system can show various reactions through the interactions with a robot. It is impossible to perfectly grasp correctly the information of the states of the learner and the environment through the sense equipments settled in the robot. Thus, in the learning with a robot, it is an importantly considered case for the robot to fail recognition of the circumstance so as to avoid deadlock by designing the learning model with considering the exceptional environments which can be occurred during learning. The examples of exceptional condition during learning are lack of a battery, disappearance of a student, reception of the command to stop a class and disconnection of the wireless communication between an agent server and a tutor robot.

Fig. 5. shows the Petri net models of Learning Process, Assessment and Exception Handling at the processing stage and Table IV describes the places and transitions of Fig. 5. With this, the process stage is finished and the final stage of the learning begins.

Lastly, the finishing stage has two modules, Repetition and End. Fig. 6. describes the Petri net models of Repetition and End and Table V. explains the places and transitions of them.

Once the learning status goes into the Repetition module, the tutor robot check which contents the student wants to learn again. If he or she hopes to study with the same content, the learning procedure migrates to the Learning Process module and the content is provided to him or her. Otherwise, the student wants to learn other contents, the learning procedure moves to the Contents Preparation module so that the agent server selects the proper contents for him or her.

Whenever the student does not like studying any more, the learning procedure goes into the End module. The end of the class is informed to the agent server and parents, and the class



(a) (b)

Fig. 6. The Petri nets of the modules at the finishing stage in r-learning (a) Repetition (b) End

TABLE V
THE DESCRIPTIONS OF THE TRANSITIONS AND THE PLACES OF FIGURE 6

Place	Description	Transition	Description
p_{29}	Repetition of studying	t_{35}	Asking preference on contents
p_{30}	Checking the response	t_{36}	Decision of a next content to study
p_{31}	End of the class	t_{37}	Decision of the same content to study
p_{32}	Informing the end of the class to parents	t_{38}	Informing the end of the class to the Agent Server
p_{33}	Parting with a student	t_{39}	Saying farewell to a student
		t_{40}	Homing

is over. A robot goes to the home position, and then waits for a start command for the next class.

IV. Implementation and Experiment

A. Implementation

For widely spreading the educational robot, one of requisites is to have diverse contents which learners want. To achieve this, an access to create contents for robots has to be easy. However, if a content creator does not have special knowledge of a robot, it is difficult for the creator to use programming language to input robot control commend to robot contents. Fig. 7. describes the tool to create contents based on graphics. Using this robot-contents-making tool,

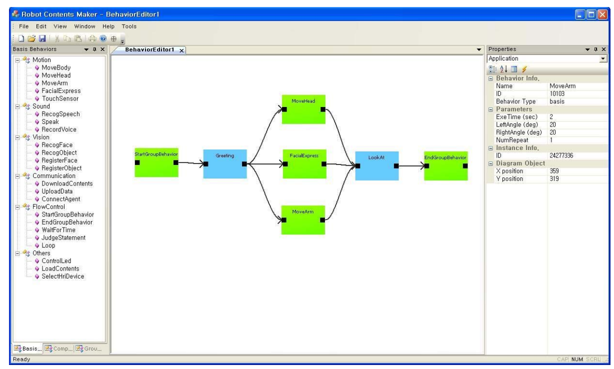


Fig.7. The robot contents maker

even a non-specialist in robotics can develop contents for robots as making the robots' behavior commend by means of the function of Drag & Drop.

The robot control program consists of the contents executive program taking charge of executing robot contents and communicating with an outer device and the hardware control program operating the hardware devices of a robot. The hardware control program dependent on the hardware configuration of a robot will be developed by a robot manufacturing company. It communicates with the contents executive program based on Open API to receive control commands to operate the hardware devices of a robot. Fig. 8. describes the application of Open API to a robot software platform.

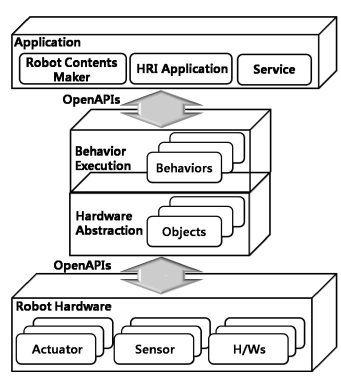


Fig. 8. The application of Open API to a robot software platform

B. Experiment

We made learning contents by using a robot content maker and taught children with the educational robot. The learning contents are flash movies containing commands to control a robot. They are designed to teach English to a child.

The sequence of the content is the followings. At first, a robot recognizes the face of a child which has been registered in advance and calls his or her name. Secondly, a robot narrates the story about a rainbow fish. Thirdly, after storytelling, a robot asks some question about the story to evaluate the comprehension and concentration of a young student by using communication, button input, touch screen input and facial recognition. Finally, the result of the assessment is transferred from a robot to an agent server through wireless local area network and analyzed to suggest a next step content to a child.

The experiment was performed to a child with a robot at a separated room in a kindergarten. Participants were nineteen children, nine boys and ten girls, who were 7 years old. The running time of learning contents was 8 minutes. Fig. 9. shows the child who was tapping the touch screen on the front side of the robot to choose an answer to the question presented by it.

After studying, the decision for the next contents is based on the child's abilities such as concentration, understanding, operating an additional tool and vocabulary. Physical inputs including touches and buttons rather than voice recognition was used in the evaluation of educational achievement of a child to insure the accuracy of the assessment because his or her ambiguous pronunciation has possibility to give rise to wrong recognition.

Through the results of the experiments, some interesting responses of children learning were observed. Boys more actively operated the buttons of the additional human-robot interaction tool than girls did. However, girls were more susceptible to the facial expressions of a robot than boys. Some children got frighten when a robot came up them closely. A robot's action of approaching at a child with wariness could be an inappropriate behavior. Also, it emerged that the preceding learning experience impacted on the learning attitude of a child so as that the children with pre-study activities had more interests in learning with a robot.

In the case of some children, the negative behaviors of a robot, such as shaking a head or body and a sad facial expression drew unwelcome attention to the children when they chose incorrect answers. Although their repulsion looks the emotion from the disappointment at the fact that they did not get the correct answer, the robot's negative expression needs to be ruled out as the robot behavior so as not to discourage children.

Fig. 9. A child is learning English through the interaction with a robot

V. Conclusion

This paper proposed a personalized r-learning system for children. The suggested educational system uses the visual and vocal data of a child student extracted by an intelligent tutor robot to assess him or her and provide the proper contents which is adapted to the student's personality traits. Petri net was used to design the r-learning scenario capable of treating exception during a class. The robot contents maker and the application of Open API to a robot software platform were treated as the management utilities for the personalized r-learning system.

Future research will include the emotional recognition and expression technology to sympathize a student's emotion during a class. The emotional interaction could help a child to be emotionally well-rounded and motivated and reinforce what he or she has learned.

Acknowledgment

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