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교육 보조 로봇의 자율성 지수☆

Degree of autonomy for education robot

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요 약

모바일 서비스와 교육 보조 로봇이 발달함에 따라, 로봇은 우리의 삶의 일부가 되었고 교육 보조 로봇은 선생님을 보조해 학생들의 교육과 학습에 참여하고 있다. 본 논문은 교육 보조 로봇의 자율성의 정도를 표시하는 자율성 지수를 측정하기 위한 방법을 규정한다. 자율성은 사람의 개입 없이 현재 상태 및 센서 값을 기반으로 주어진 작업을 수행하는 능력이다. 교육 보조 로봇의 자율성 지수는 작업 수준과 사람의 개입 수준으로 구성되며 1단계에서부터 10단계로 정의한다. 제안 방식은 지능형로봇표준포럼(KOROS) 표준으로 채택이 되었으며 해당 표준은 자율적으로 학생들을 지도하는데 활용이 가능하다. 향후 교육 보조 로봇을 활용한 교육 서비스에 큰 혜택을 가져올 것으로 예상하며 그 활용 분야 역시 교육 발전에 크게 이바지할거라 기대한다.

☞ 주제어 : 자율성 지수, 교육 로봇, 표준, 인간로봇상호작용, 서비스 로봇, 사람의 개입, 작업 수준

ABSTRACT

With the rapid development of mobile services and the prevalence of education robots, robots are being developed to become a part of our lives and they can be utilized to assist teachers in giving education or learning to students. This standard has been proposed to define the degree of autonomy for education robot. The autonomy is an ability to perform a given work based on current state and sensor value without human intervention. The degree of autonomy is a scale indicating the extent of autonomy and it is determined in between 1 and 10 by considering the level of work and human intervention. It has been adapted as per standard and education robots can be utilized in teaching the students autonomously. Education robots can be beneficial in education and it is expected to contribute in assisting the teacher's education.

☞ keyword : Degree of Autonomy, Education Robot, Standard, HRI(Human Robot Interaction), Service Root, Human Intervention, Working level

1. Introduction

In a ubiquitous environment, a personal service robot may play a key role as a mediator for user interaction and service provision. To enhance the usability of personal service robots, some levels of autonomous behaviors are required in the process of service provision so that the users do not need to intervene in every step of the service execution process[1].

This standard defines measurement method of autonomy degree, which indicates the autonomy extent of an educational robot among service robots. The autonomy is an ability to perform a given work based on current state and sensor value without human intervention. The autonomy degree is not a quality degree of a product but it is a degree of performing a given job without human intervention. The autonomy degree is determined in between 1 and 10 by considering the level of work and human intervention.

The rest of this paper is organized as follows: Related work is compared in the next section. In section 3, definitions of terms are described. The degree of autonomy for education robot is proposed in section 4 and 5. Conclusions are provided in the final section.

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2. Related Work

2.1 Service Robot

Robots have the potential ability to assist the teachers in education. The primary objective of tutoring, a practice designed to supplement classroom-based learning, is to assist and guide students to become independent learners. Although robots are not a replacement for human teachers, they can be beneficial in various areas of learning[2]. There is a broad range of robot platforms, application and subjects delivered in prior research studies. Karina et al. present a socially interactive robot teaching assistant and program the robot to ask a student multiplication questions based on the Common Core State Standards and used vision recognition to evaluate the student's response[3].

2.2 Standardization for service robots

If we are taking a look at the established standards regarding service robots, there are Degree of Autonomy for service robot[4], Test Method of Educational Robots[5] and Robotic Interaction Service(RoIS) Framework[6]. Standard[6] solicits proposals for robotic interaction service (RoIS) that specify data structures for each interface and common interfaces between robotic service applications and components that provide functions for performing human -robot interaction.

The standard [5] defines evaluation method of educational robot and educational robots come with curriculum that guides the students on how to program the robot, how to interface it to its environment, and how to maintain[7]. Educational robots also offer tremendous potential for providing exciting, dynamic learning experiences[8]. However, this standard does not apply to robots for the parish that users manufactured for the purpose of education

The degree of autonomy for a service robot, which is now established as the standard [4] is defined for measuring the degree of autonomy for the dry cleaning robots among the service robots which serves diverse services at home or public places. This standard is prepared to define the evaluation methods for the functional reliability of the household dry cleaning robot. It is applicable to dry cleaning robots for household use in or under conditions similar to those in households but it is limited to dry cleaning robots for the target to evaluate the degree of autonomy.

Thus, this paper proposes the degree of autonomy for education robot. Table 1 shows a degree of autonomy for dry cleaning robot[4,9].

(Table 1) Degree of Autonomy for "Dry Cleaning Robot"

Degree	Description
0	It cleans up needing frequent human interven- tion.
1	It needs human intervention once or twice while one time technical cleaning (If it is stuck in a narrow space and cannot get out), and it cleans up moving in a random pattern.
2	It has a "drop-proof" function, detects the positions of obstacles (e.g. furniture and walls etc.) with a bumper sensor/distance sensor and moves avoiding a collision.
3	When a clean-up operation is completed or the battery is low, it automatically moves to the charging station.
4	It occasionally needs human intervention during the cleaning process (Emptying the dust canister and removing an inlet clogging, etc.), or when a problem occurs (e.g. Exceeding the maximum capacity of the dust canister, inlet clogging and confinement to a narrow space), a user is informed via an indication when this happens.
5	If it is stuck in a confined space or on the wires, it escapes efficiently, cleans up dusty parts repeatedly and detects floor type (e.g. carpet and flooring etc.) to adjust the rate of movement and suction force.
6	It detects a space to clean, does appropriate path planning and figures out its relative position in the space to clean up according to the path planning.
7	A dust collecting system has been installed outside so that it needs human intervention occasionally, and to clean up several indepen- dent spaces (e.g. room, living room and kitchen etc.), it has path planning and moving feature for multiple spaces. Also, it has a self-position recovery function after problem-solving through human intervention (e.g. recleaning after cleaning the dust canister and removing entanglement of debris, etc.), so it can minimize repetitive cleaning and return to the recharging station.

8	If it detects an object that it should not suck, but put in order (things that may cause the inlet clogging if sucked, e.g. clothes and paper, etc.), it cleans up avoiding that.
9	Without a need of any human intervention, in other words, the dust canister is attached to the automatic air-conditioning system, so it operates while it automatically empties itself.
10	If it detects an object that it should not suck, but put in order (things that may cause the inlet clogging if sucked, e.g. clothes and paper, etc.), it puts it in a suitable place to clean up.

3. Definition of terms

For the purpose of this Standard, KS B 7301[4], ISO 8373[11], KS B 6937[14], KS B 6938[15], the following terms and definitions apply. Table 2 shows definition of terms for education robot.

(Table 2) Definition of terms for "Education Robot"

Terms	Definition
Robot	Actuated mechanism programmable in two or more axes with a degree of autonomy, moving within its environment, to perform intended tasks. A device, which operates in an environment to perform a given work and enables the programming of 2 axes or more with certain extent of autonomy.
Mobile robot	A mobile robot can be a mobile platform with or without manipulators and able to travel under its own control.
Service robot	Robot that performs useful tasks for humans or equipment excluding industrial automation applications.
Personal service robot	Service robot used for a non-commercial task, usually by lay persons.
Mobile household robot	A household robot able to travel under its own control.
Intelligent robot	Robot capable of performing tasks by sensing its environment and/or interacting with external sources and adapting its behavior.
Education robot	A robot, which can be utilized as an auxiliary means in education or learning.
Human - robot interaction	Information and action exchanges between human and robot to perform a task by means of a user interface.
Autonomy	Ability to perform intended tasks based on current state and sensing, without human intervention. An ability to perform a given work based on current state and sensor value without human intervention.
Degree of autonomy	Scale indicating the extent of autonomy considering the working level and human intervention .

4. Degree of autonomy

4.1 Definition

The autonomy is an ability to perform a given work based on current state and sensor value with minimal human intervention. The degree of autonomy consists of two factors such as working level required to perform a given task and human intervention.

4.2 The degree of autonomy

The degree of autonomy consists of two factors such as human intervention and working level. The degree of autonomy, DoA is defined as indicated in equation (1).

$$DoA = f(W, HI) \quad (1)$$

where ***DoA, W*** and ***HI*** are the Degree of Autonomy, Working level, and Human Intervention respectively. Working level is an ability to perform the given work. The present and future ability of robots must be taken into consideration. The degree of autonomy is considered high if the process involved less haman intervention.

The degree of autonomy for education robot is determined in between 1 and 10 (the highest) by considering the level of task and the level of human intervention. Here, the autonomy index is assumed as having a hierarchical structure, which includes all its sub-autonomies.

5. Measurement for the degree of autonomy for education robot

5.1 Working level

Working level is an ability to perform the given work. The detailed working level is following as below:

1) It is capable of voice recognition, which can also perform word-based simple communication.
2) It is capable of user motion recognition and can recognize a limited set of user motions.
3) It is capable of user (a student or teacher) face recognition. It can also recognize an object such as a desk or white-board.
4) It is capable of emotion recognition by perceiving the change of the user's facial expressions.
5) It is capable of simple movement and interaction with teacher.
6) It can avoid collision against an obstacle while it is moving along the path.
7) It is capable of localization recognition, path planning and path following.
8) It is capable of simple surrounding environment (situation) recognition using various sensors.
9) It can recognize most situations and make judgments based on results of the recognition.
10) It operates in an autonomous way by judging the situation itself.

5.2 Human Intervention

For most educational robots, when education has started, human intervention is required.

Human intervention is following as below:

1) Human intervention is required continuously.
2) Human intervention is required more than four times.
3) Human intervention is required three or four times.
4) Human intervention is required once or twice.
5) It does not require any human intervention.

5.3 The degree of autonomy for education robot

The degree of autonomy is determined from the rate of 1(the lowest) to 10 (the highest) by considering the working level and human intervention. It is assumed as having a hierarchical structure, which includes all its sub-autonomies.

Table 3 shows a degree of autonomy for education robot.

(Table 3) Degree of Autonomy for "Education Robot"

Degree	Description
1	It requires continuous human intervention and it is capable of voice recognition, which can also perform word-based simple communication. e.g. Education robot calls attendance of students on behalf of teacher.
2	It is capable of user motion recognition and can recognize a limited set of user motions. e.g. Education robot can recognize the behaviour of the teacher when the teacher has instructed to education robot for bringing the pointing book
3	It requires human intervention more than four times, and it is capable of user(a student or teacher) face recognition. It can also recognize an object such as a desk or white-board. e.g. Education robot can distinguish the individual student's face.
4	It is capable of emotion recognition by perceiving the change of the user's facial expressions. e.g. Education robot can recognize emotional feeling such as boredom and happiness with student's facial expressions.
5	It requires human intervention three or four times while it is capable of simple movement and interaction with teacher. e.g. Education robot moves when there are calls from the students or teacher.
6	It can avoid collision against an obstacle while it is moving along the path. e.g. Education robot can avoid obstacles such as desk and chairs.
7	It is capable of localization recognition, path planning and path following. e.g. Education robot leads the students to go to the gym.
8	It requires human intervention once or twice, and it is capable of simple surrounding environment (situation) recognition using various sensors.

	e.g. Education robot recognizes fire and other dangerous situations and makes warning sound to announce the dangerous situations to the students.
9	It can recognize most situations and make judgments based on results of the recognition. e.g. Education robot recognizes the situation of fire and other hazards and helps the students to escape.
10	It does not require teacher's intervention and it operates in an autonomous way by judging the situation itself. e.g. Education robot can manipulate the educational materials autonomously.

6. Conclusions

With the rapid development of robot technologies, service robots may play a key role as a mediator for user interaction and service provision robots. In a autonomous ubiquitous environment, students and robots are sharing the same physical space such as classroom and interact with each other in close proximity[1,11,12]. And robot's tasks may range from education or play, to assist the teachers without any intervention[13]. Therefore, there is a need to standard the degree of autonomy for service robots in order to verify their efficiency. To this end, Degree of Autonomy for service robot[4], Test Method of Educational Robots[5] and Robotic Interaction Service(RoIS) Framework[6] have been suggested by standardizing these procedures which is developed into various domestic and overseas standards as well.

Mobile service robots are intended to provide services in various domains of life [16,17] and there has been a significant increase in spending on robotics related educational technologies by schools, kindergartens and private institutions around the world. At the same time, there has been an active progress for the standardization of service robots. Thus, this paper has been proposed to define the degree of autonomy for education robot, which indicates its extent of autonomy. This standard can be applied to all educational industries to assist teacher's education such as school, kindergarten and special education institution for special children.

This standard is now enacted as the standard of KOROS(Korea Robot Standard) forum. It is expected that assistance in education using education robots will be conducted by this standard. By providing measurement method for degree of education using this standard, it is possible to use common index between manufactures of education robots and consumers. It is also expected that measuring the degree of autonomy by this standard will lead to competitiveness in the development of educational robotics technologies. But there still exists several points that must be discussed. Autonomy should be defined and limited to the specific domain and the degree of autonomy for education robot should not necessarily be 10. Rather, less number of stages will be easier to be used.

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