Humanoid Robots in Education

The use of Humanoid Robots as Teaching Assistants

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Introduction

The area of research concerning the use of social or humanoid robots in the field of education identifies three main areas where these robots can potentially be useful. The first of these areas relates to the learning and teaching of a second language. Belpaeme, et al. (2015) presented the L2TOR project which built on previous research and development the science and technology of language tutoring robots, developing a series of lessons that communicate with children following a specified scenario to obtain the learning targets (Belpaeme, et al., 2015).

The next area looks at how humanoid robots can be used to aid the learning of children with special needs such as autism. Amanatiadis, et al. (2017) proposed advances in robot-assisted special education using specially designed social interaction games. Their results concluded that the use of humanoid robots can improve behaviour and preliminary applications have been encouraging (Amanatiadis, et al., 2017).

The final area, and main focus of this literature review, studies the idea of using humanoid robots as teaching assistants, stressing on the importance of working alongside the teacher, rather than replacing the teacher, which is not going to be achieved any time soon (Hameed, et al., 2018). In this paper, Hameed, et al. develop a system where lecture slides are uploaded to the NAO robot, who delivers the material. Their results show that the use of humanoid robots can increase motivation and enjoyment in lessons, although state that their results only show proof of concept and should be tested over a longer period to consider the long-term relationships that students would have with the robot.

The use of Humanoid Robots in the Teaching of a Second Language

One area that has had extensive research, considers the use of humanoid robots in the teaching of a second language. This is particularly relevant as there are 120 different nationalities making up the student body at Keele alone, who receive between 800 and 1000 international students each year (Keele University, 2018). With this in mind, being able to entertain students of different nationalities, most of whom will have limited knowledge of the English language, is important.

The use of social robots in second language tutoring is studied by Belpaeme, et al. (2015). Their study introduced the development and evaluation of social robots in second language tutoring in early childhood. Their research is based on previous observation that social robots have had significant benefits in education in terms of learning outcomes and motivations. It is stated that the development of an effective tutoring robot should consider interactions in a similar way to a caregiver or teacher, allowing the construction and maintenance of a common ground, providing a suitable context to learn from. This paper is only a suggested implementation and so no conclusion could be formulated.

However, a study published a year later by Hong, et al. (2016), implemented similar ideas using the Robot-Assisted Language Learning (RALL) framework to design robot-assisted instructional materials for elementary students studying EFL in Taiwan. Similar to Belpaeme, et al., their experiments investigated learning performance and motivation of the materials produced. Their results revealed that when tested against a control group, without the presence of a robot, the experiment group outperformed in terms of improvement in listening and reading skills. In conjunction with a positive influence from a motivation survey, their research demonstrated that the materials developed provided a great opportunity, at least at an elementary level, to promote the use of social robots in EFL teaching. The limitation of their research however was brought to light by the Hawthorne Effect, which concluded that their experiment wasn't solid enough to conclude that the presence of a robot was the only parameter influencing the learning performance.

The use of Humanoid Robots in Special Education

Another tangent that has been researched in this area is the use of humanoid robots in special education, with particular focus on autism. This is an important area to consider as statistics from the National Autism Society show that around 700,000 people in the UK are on the autism spectrum (NAS, 2018), meaning that it is very likely that there will be at least one student in a class on the autism spectrum.

Research into this area has been encouraging in recent years with studies such as that conducted by Boccanfuso, et al. (2017), who look at implementing a low-cost, toy-like robot with autonomous games and a teleoperated mode. Their study consisted of 8 participants and 3 controls, diagnosed with Autism Spectrum Disorder (ASD). They implemented several pre- and post-intervention measures. The Vineland Adaptive Behavioural Scale II (VABS-II) is a measure of adaptive behaviour, used from birth to adulthood (Sparrow, et al., 2018). The Motor Imitation Scale (MIS) consists of 16 items involving single-step motor imitation tasks (Stone, et al., 1997). The Unstructured Imitation Assessment (UIA) was developed to measure a child's ability to imitate spontaneously during unstructured play (Ingersoll & Lalonde, 2010). Finally, the Expressive Vocabulary Test II (EVT-2) is a measure of expressive vocabulary and word retrieval for Standard American English (Pearson Clinical, 2018).

Results from these measures revealed that there were significant improvements in communication and socials skills. It is stated that this could be because an autistic child can associate more with a robot figure rather than a human. However certain limitations described in the study affect the interpretation of the results. Firstly, the limited sample size means that the results, although indicative of the benefits of using humanoid robots in this context, are not representative of the target audience and so further studies should take this into account. Secondly, although the Shapiro-Wilk test for normality (1965), was conducted, a skewness in some areas indicated that in further studies, the results should be considered with caution. Despite this, results indicate that there were relative increases in speech, communication and social interaction, which demonstrate that robot-enabled interventions can promote generalization of child-robot activities to child-other interactions.

The results of this study are backed up by a further study conducted by Amanatiadis, et al. (2017), who offered a similar experiment using the NAO robot. Their results also suggested improvements in social interaction and communication skills, as well as concluding that observations of joint attention, response inhibition and cognitive flexibility of ASD were encouraging. This allowed them to draw the conclusion that robot assisted treatment can improve child behaviour and that social robots can teach ASD children more effectively, as well as being available all the time. However, technical drawbacks with the NAO robot, particularly with voice recognition which could not always recognise words spoken load and with wavy intonation, mean that improvements should be made to further cement the conclusions presented.

The use of Humanoid Robots as 'teaching assistants'

Implementing social or humanoid robot into the classroom, assuming the role of a teaching assistant is a relatively new area of research with studies only being conducted in the last few years.

Fernandes-Llamas, et al. (2017) published a study focusing on the attitude student have towards social robots. Using the Baxter robot to teach basic computational principles to 210 students, allowed for comparison between a teacher and robot lesson. The ultimate sample size, as shown in the results was reduced to 190 due to the use of 'between subject experimental design (Charness, et al., 2012), which requires a similar number of students in all sample groups.

Attitude was measured using the NARS (Negative Attitude towards Robots Scale) (Syrdal, et al., 2009) and RAS (Robot Anxiety Scale) (Nomura, et al., 2006). NARS creates a Likert Scale (Likert, 1932) based on open responses by participants (Syrdal, et al., 2009), measuring psychological states expressed in these responses. The scale consists of 14 statements, split into 3 subscales. The first subscale, 'negative attitude towards interaction with robots' revealed that most students felt comfortable interaction with the robot. The second subscale, 'negative attitude towards he social influence of robots', showed that students were not worried about the future role of robots, although younger students appeared more fascinated by technology and cannot imagine potential problems. The third subscale, 'negative attitude towards emotional interactions with robots', caused irregularity in the results as the younger students understood the questions in a literal way, so their answers were not always what the researchers were looking for.

RAS, also split into 2 subscales, measures "the anxiety that prevents individuals from interaction with robots having function of communication in daily life" (Nomura, et al., 2006). The first subscale, 'negative attitude towards communication with robots', revealed that students were not worried about behaviour or whether the robot understands them. The second subscale, 'negative attitude towards robot behaviour', showed that young students were not concerned with movement, strength or interaction with the robot. The third subscale, 'negative attitude towards robot discourse', discovered that younger students were more worried about talking properly, suggesting they were more interested in establishing relationships with the robot. However, as stated by Kahn, et al. (cited in (Kim & Smith, 2017)), children develop social and emotional attachments to robots and voluntarily give sustained attention to learning tasks, delivered by robots.

Overall analysis of the results revealed that the main factor affecting attention levels is age, however other differences were identified. Only one group taught by the robot got a lower score than the human class. This was theorised by the paper as possibly being because the students are not interested as much in the human-like element of the robot, as they would not pay as much attention in the human taught class. There is also a theory that as the class was not formally evaluated, motivation levels were reduced, having a negative impact on test scores.

Fernandes-Llamas, et al. draws multiple conclusions, some of which have already been highlighted. Another emphasises the possible reduced levels of motivation in older students. This is due to the robot delivering a one-way lecture and is not programmed to answer questions, meaning there is no opportunity for interaction with the students. This is backed up by a similar study by Hameed, et al. (2018) who arrived at a similar conclusion, although implemented methods to overcome this by mixing serious teaching, with entertainment.

Hameed, et al. (2018) proposed the use of a robot platform (NAO) to teach the same content as a teacher, without having a degrading effect on academic achievement. It was hoped that by doing this, the quality of teaching could be improved. One issue is that repeating elements of a lesson can induce anger and fatigue which can have a negative effect on understanding, as stated by Graham (1990), “the inferred attribution of the teacher [can] influence self-perceptions of ability or effort”. It is also hoped that this will benefit special needs students by giving them the right information at the right time. It is important to identify students who are having particular issues getting to grips with concepts, as highlighted by Westwood (2007), it is crucial to provide support and skilled teaching to improve achievement levels and restore these students’ self-efficacy.

Looking at attention levels, the robot incorporates ‘entertainment mode’ to regain student attention and improve the educational atmosphere, making lessons more attractive to students. This is done by first observing the number of faces that are heading towards it. Facial detection can be achieved using the Viola/ Jones algorithm for object detection which, despite advances in deep learning, is still in use today. Viola & Jones (2001), talks about the construction of a frontal face detection system which, as stated, “is most clearly distinguished from previous approaches in its ability to detect faces extremely rapidly”. This system is proven to be highly successful in multiple areas and can transfer well to a classroom setting.

In terms of social interaction, the robot uses a natural language toolkit (NLTK) to build user profiles which work with human language data. The NLTK is a suite covering symbolic and statistical natural language processing, written in Python (Bird & Loper, 2004). The aim of using the NLTK is to enhance long-term interactions and develop long-term relationships between students and robots using vocal interaction and speech recognition with either the built-in or Google cloud speech recognition library. This is something that can be measured using either the Inclusion of Other in Self (IOS) scale or a Social-Relational Interview (Westlund, et al., 2018).

Results showed that robots could attract more students and provide them with deeper understanding of technical terms. In terms of material delivery, the robot was able to deliver 65 slides in 12 minutes, whereas the teacher could only deliver 12 slides in 20-25 minutes. Although this shows the robot can deliver more material in a shorter time, the robot was not programmed to ask or answer questions, therefore the lesson was a one-way lecture. Despite this, the students enjoyed having the robot in the classroom.

The paper makes three main conclusions. With regards to focus, the students were paying attention in both classes, however this could be down to the nature of the topic being different to what the students are used to, as focusing on potential interest rather than knowledge can create more engaging environments for students (Monteiro, 2016). In terms of noise levels, the class with the teacher gave a higher reading, however this was due to the students asking questions. Finally, excitement levels were higher in the robot class, mainly due to the use of 'entertainment mode'. The paper can be criticized for its use of a small sample size and testing it in only one lecture. However, the experiment was only to show proof of concept and further work could build on it with the possible incorporation of in-lecture interaction with students.

Interaction with students, although in a one-to-one setting, is something that was explored by Budiharto, et al. (2017). This paper researches intelligent humanoid robots for education, looking at natural interaction for teaching basic mathematics and entertainment. They propose a speech recognition system based on the Google translator and basic Natural Language Processing (NLP) techniques. This begins by translating speech to text to find important keywords. The system then uses NLP techniques such as stemming (Lovins, 1968) and tokenization (Manning & Schutze, 1999). A stemming algorithm is a computational procedure which reduces all words with the same rot to a coming form by stripping each word of its derivational and inflectional suffixes (Lovins, 1968). Tokenization is where the input text is divided into units called 'tokens' with each one being either a word, number or punctuation mark (Manning & Schutze, 1999). Compared to the speech recognition used in the NAO robot for example, it is stated that the proposed system will be able to detect multi-word commands. This would be better than the NAO robot as although NAO software (Coreographe) can be used to make a system to detect speech input, it can only accept single word commands.

Their experiment was conducted where the distance between the student and the robot was 45cm. The program began by detecting the students' face using the Haar cascade classifier (Wilson & Fernandez, 2006). The basis for the Haar classifier object detection is the Haar-like features which were also adapted in the Viola & Jones algorithm (Viola & Jones, 2001). "These features use the change in contrast values between adjacent rectangular groups of pixels" (Wilson & Fernandez, 2006). Results show that this method was able to detect the students' face with an accuracy of 73.3%. The system would then ask the student whether they are ready to learn. If the student responds, implying they are ready, the system presents the student with a list of options for them to choose including giving tutorials in mathematics or entertainment, or answering questions. The systems' speech recognition and NLP were able to recognise correct answers with an accuracy of 63.3%. The program would loop until the student didn't want to continue, when the system would end, once notified.

The paper concludes that they successfully proposed speech recognition using stemming and tokenization techniques. They also imply that they would make the learning fun, similar to ideas presented by Hameed, et al. (2018). It is stated that the reason for this is because students learn better when they are relaxed and focused. This is backed up by Caine, et al. (2015), who state that “relaxed alertness is the optimal state of mind for meaningful learning”. Future work would present the robot with more complex spoken interaction, incorporating more variations of actions, an ability to recognize emotions and longer speech.

Summary

In summary, there has been significant research to suggest that the use of humanoid robots in education has definite promise and can have drastic improvements in student motivation, focus and knowledge retention. In particular, the use of robots as ‘teaching assistants’ is an ever-growing area of research which will be expanded on in the coming years. Currently, there is great focus on this implementation in early-years education, sometimes in a one-to-one setting, (Budiharto, et al., 2017). Some studies have included implementing ideas in group-based settings, (Hameed, et al., 2018). However, in terms of implementation in larger setting, for example, University lectures, there has been no studies to suggest the benefit of robot presence in this type of scenario.

It is reasonable to assume that as far as age is concerned, the inclusion of humanoid robots in lectures would be beneficial as Fernandes-Llamas, et al. (2017) showed that robot tutoring can increase motivation across all ages. In terms of increased numbers, it has not been tested whether robot tutoring would work in a setting with a large number of students, which if implemented in lectures, would have to be considered.

Finally, studies which deliver material to classes, although may be able to deliver more material in shorter lengths of time (Hameed, et al., 2018), lack the inclusion of student interaction, something which can enhance the learning experience and understanding of key concepts. Therefore, further research should consider the possibility of incorporating interaction, tested in a one-to-one setting, in larger scale lectures and classes.

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