様　式　Ｃ－１９、Ｆ－１９－１、Ｚ－１９　（共通）

科学研究費助成事業　　研究成果報告書

令和　４ 年　 ６ 月 １４ 日現在

機関番号：１２６０５
研究種目：基盤研究(C)（一般）
研究期間：2019～2021
課題番号：１９Ｋ１２１６７

研究課題名（和文）Development of artificial agents for the classroom and study of their efficiency

研究課題名（英文）Development of artificial agents for the classroom and study of their efficiency

研究代表者
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交付決定額（研究期間全体）：（直接経費）　　3,300,000円

研究成果の概要（和文）：高等教育の知的・行動的インパクトを研究・支援するために、ソーシャルロボットの利用を検討しました。大学の教室で教授スタイルと学生の行動の定量的・比較的分析を行い、リアルタイムに反応する人工エージェントの行動を開発した。
マーカーレスカメラベース技術を用いて、教室内の学生の行動データを収集した。そして、そのデータを自動的かつ定量的に行動分析するためのソフトウェアツールを開発し、ビッグデータを用いて学習スタイルと学生の行動との関係のモデルを作成しました。最後に、このモデルをソーシャルロボティクス・バーチャルエージェントに展開し、オンラインコースの教材開発や教師のトレーニングを支援することができた。

研究成果の学術的意義や社会的意義
この研究は2019年に始まり、2020年にはオンライン授業が一気に一般化するパンデミックに世界が見舞われるという、非常にタイムリーなものでした。本研究の結果となされた展開は、学生の幸福を分析し支援するために最も重要なものである。プロジェクトの成果は、さらに継続されることが有益であっただろう。

研究成果の概要（英文）：The project explored the use of social robots to study and support the intellectual and behavioural impact of higher education. A quantitative and comparative analysis of teaching styles and students' behaviour was conducted in university classrooms and the behaviours of an artificial agent have been developed to react in real-time.
We collected behavioural data of students in classrooms using marker-less camera base technology. Then we developed a software tool for automated and quantified behavioural analysis of the data and created models of the learning styles and their relationship with students' behaviours using big data. Finally, we deployed the models in social robotics virtual agents that could support online courses' material development and teachers' training.

研究分野：ロボティクス

キーワード：ロボティクス　教育支援

１．研究開始当初の背景

Developed countries are facing a well-documented engineering skills crisis, as the supply of individuals into engineering occupations is not keeping pace with demand. At the same time the number of MOOCs, on-line trainings and certifications hasn't ceased increasing. This is an opportunity for people that have not chosen at first a training in STEM (Science, Technology, Engineering, and Mathematics) and wish to change career, for the underrepresented population of women and minorities. However, as Hone et al. reported in their study in Computer and Education 2016, MOOCs often fail in being engaging and drop-out rate is high because of the lack of interactive content as shown in Fig. 5 top left corner. To improve the quality of the teaching in such courses it is important to understand students' behaviour when taking the course and to develop more engaging teaching material. Recent development in AR (Augmented Reality) and in personal robotics have democratized such technologies and they are now relatively accessible as can be seen in Fig. 1 and Fig. 2 and in my past work. The inclusion of robotics avatar or the use of real robots to support teaching material of online course present multiple advantages as they can be programmed to react to the student behaviour in real time and improve engagement to sustain learning. With the new development of motion capture technology, it is now possible to use single camera data and obtain the subject motion data with algorithms and libraries such as "open pose". New devices allow also to track head and eye movement with a good accuracy without being too invasive and impeding the student.

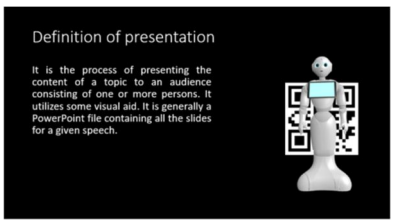

Fig. 1 Teaching avatar in VR environment

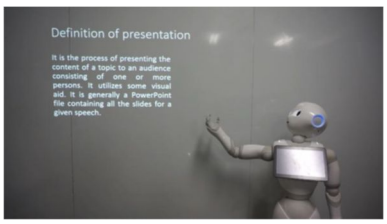

Fig. 2 Teaching robot in real environment

２．研究の目的

The purpose of this research is two-fold. It consists in:

1. Collecting lecturers and students' behaviour data and learning ability data during classroom lectures and during online courses using motion capture technology and eye tracking technology and camera to develop and evaluate a portable and affordable measuring tool; and analysing this data using state of the art machine learning algorithms such as deep neural networks to discover the features and correlation between engagement, learning ability and behaviour.
2. Developing the appropriate behaviour of a small humanoid robot that will improve the quality of learning during online teaching, as seen in Fig. 2, by reacting to the behaviours detected in 1. Adequately and using the best teaching styles to increase engagement.

This research is based on our previous findings where teaching styles and students gaze data were recorded using an eye tracking system and analysed and annotated manually as shown in Fig. 3 and Fig. 4.

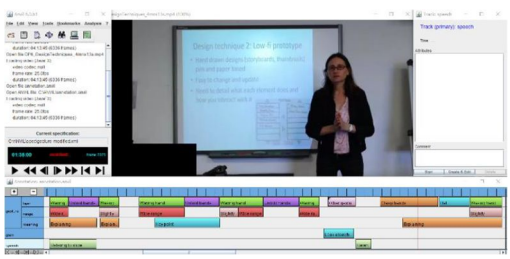

Fig. 3 Manual annotating and analysis of video of lectures

Fig. 4 Gaze tracking results: region of interest are marked in orange

３．研究の方法

Data collection: using motion capture technology (camera and Open-pose or Mediapipe) and eye tracking technology we collected the behaviour data of students. This data contains different behaviours during a lecture and the effect of material and lecturer's actions on concentration and learning ability.

To be able to analyse the data objectively questionnaires about personality, learning styles etc…were used. Quizzes to check the retention of the class content have also been.

Big data/Machine learning: all the collected data in A were then processed for analysis with machine learning algorithms. This data allowed us to create an offline behaviour analysis software of both lecturer and students' behaviours, enabling us to choose the relevant features for step C. Relevant features will be compared with the know-how in education and see if they are in adequation or if other features need to be considered.

Realtime behaviour recognition system: The relevant features found in B. were then used to develop a real-time algorithm to identify the changes in students' behaviour as shown in Fig. 5. Again, this is based on an implementation of machine learning algorithm in real-time for classification.

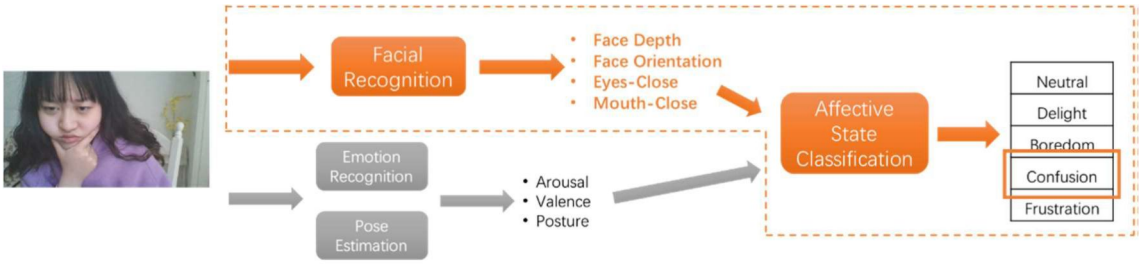

Fig. 5 Student's state estimation from facial recognition, facial expression and pose.

Development of an avatar teaching assistant: using participatory design two teaching assistant digital avatars (Fig. 6) were created and tested.

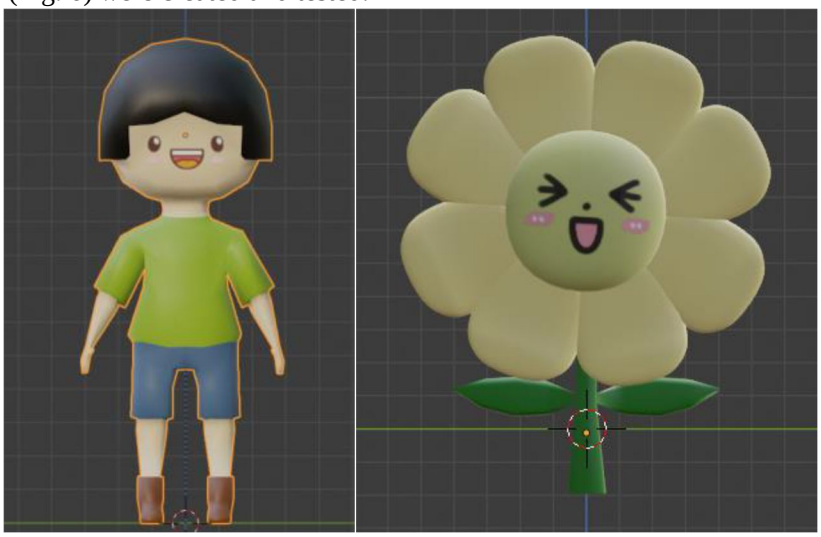

Fig. 6 Teaching assistants avatars developed from the participatory design workshops

4．研究成果

Our research was timely as with the pandemic a sudden shift in education operated, and for more than a year all classes went online. Rather than focusing on the lecturer's behavior we focused on the student's behavior solely as students wellbeing was challenged. The research topic that was quite abstract for many in 2019 became suddenly very practical. Our research results have proven that even with minimum equipment it is possible to use video data to evaluate student's engagement and behavior during online lectures. That machine learning techniques allow to extract in realtime this information and it can be used to animate a character (in our case a digital avatar). One important outcome despite the technical feasibility we have showed, is the necessity for adaptive behaviors of the avatar and the necessity for personalization. Students' personality, learning style and environment affect the requirements for the avatar. However the development of 3D technology is very promising and could be used together with physical avatars.

International Journal peer reviewed publications

[1] E. Coronado, G. Venture, Towards IoT-aided Human-Robot Interaction using NEP and ROS, a Platform-Independent, Accessible and Distributed Approach, Sensors, Vol. 20, No. 5, 1500, 2020. 1500; doi:10.3390/s20051500

[2] E. Coronado, F. Mastrogiovanni, B. Indurkhya, G. Venture, A Survey on Visual Programming Environments for End-User Development of Intelligent and Social Robots, Journal of Computer Languages, Vol. 58, 2020. https://doi.org/10.1016/j.cola.2020.100970

[3] D. Deuff, I. Ocnarescu, E. Coronado, L. Rincon, I. Milleville, G. Venture, Designerly way of thinking in robotics research project, Journal of the Robotics Society of Japan, Vol. 38, No 8, p. 692-702 2020. DOI: https://doi.org/10.7210/jrsj.38.692

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[6] M.-L. Bourguet, Y. Jin, Y. Shi, Y. Chen, L. Rincon-Ardila, G. Venture, Social Robots that can Sense and Improve Student Engagement, IEEE Int. Conf. on Engineering, Technology and Education, 8-11 December, 2020.

[7] H. Khalil, E. Coronado, G. Venture, Human Motion Retargeting to Pepper Humanoid Robot from Uncalibrated Videos Using Human Pose Estimation, RoMAN 2021

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５．主な発表論文等

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１．著者名 Coronado Enrique、Mastrogiovanni Fulvio、Indurkhya Bipin、Venture Gentiane	４．巻 58
２．論文標題 Visual Programming Environments for End-User Development of intelligent and social robots, a systematic review	５．発行年 2020年
３．雑誌名 Journal of Computer Languages	６．最初と最後の頁 100970～100970
掲載論文のDOI（デジタルオブジェクト識別子） 10.1016/j.cola.2020.100970	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

１．著者名 Coronado Enrique、Venture Gentiane	４．巻 20
２．論文標題 Towards IoT-Aided Human?Robot Interaction Using NEP and ROS: A Platform-Independent, Accessible and Distributed Approach	５．発行年 2020年
３．雑誌名 Sensors	６．最初と最後の頁 1500～1500
掲載論文のDOI（デジタルオブジェクト識別子） 10.3390/s20051500	査読の有無 有
オープンアクセス オープンアクセスとしている（また、その予定である）	国際共著 該当する

１．著者名 Ardila Liz Rincon、Coronado Enrique、Hendra Hansen、Phan Julyando、Zainalkefli Zur、Venture Gentiane	４．巻 none
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３．雑誌名 International Journal of Mechanical Engineering and Robotics Research	６．最初と最後の頁 207～219
掲載論文のDOI（デジタルオブジェクト識別子） 10.18178/ijmerr.8.2.207-219	査読の有無 有
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３．雑誌名 Proc. of the Int. Conf. on Human-Agent Interaction	６．最初と最後の頁 200-201
掲載論文のDOI（デジタルオブジェクト識別子） なし	査読の有無 有
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2．論文標題 On the Role of Trust in Child-Robot Interaction*	5．発行年 2019年
3．雑誌名 Proc. of the 28th IEEE Int. Conf. on Robot & Human Interactive Communication, New Delhi, India, October 14-18, 2019	6．最初と最後の頁 none
掲載論文のDOI（デジタルオブジェクト識別子） 10.1109/RO-MAN46459.2019.8956400	査読の有無 有
オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

1．著者名 M.-L. Bourguet, G. Venture	4．巻 none
2．論文標題 The Challenges of Working on Educational Social Robots	5．発行年 2019年
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1．著者名 Coronado Enrique、Venture Gentiane	4．巻 20
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2．論文標題 Egg shaped, white and emotional robots: Design space survey on social robotics in the market	5．発行年 2022年
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オープンアクセス オープンアクセスではない、又はオープンアクセスが困難	国際共著 該当する

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Impression evaluation of robot’s behavior when assisting human in a cooking task

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2021年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

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６．研究組織

	氏名 （ローマ字氏名） （研究者番号）	所属研究機関・部局・職 （機関番号）	備考

７．科研費を使用して開催した国際研究集会

〔国際研究集会〕　計0件

８．本研究に関連して実施した国際共同研究の実施状況

共同研究相手国	相手方研究機関			
英国	Queen Mary University London			
ポーランド	AGH			
中国	中国　BUPT（QMUL中国キャンパス）			