様　式　C－19、F－19－1、Z－19　（共通）

科研費 KAKENHI

科学研究費助成事業　　研究成果報告書

令和　３ 年　 ５ 月 １７ 日現在

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研究課題名（和文）Engineering virtual reality for real learning

研究課題名（英文）Engineering virtual reality for real learning

研究代表者
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研究成果の概要（和文）：太陽光発電会社の専門知識をもとに、Unityを使ってVR太陽光発電所を設計。実際の太陽光発電所のデータを取り込み、SolarVR内でリアルタイムに3Dビジュアライゼーションとして表示しました。Oculus Rift HMDは、開発された仮想太陽光発電所を見るために使用されました。学習者は、経験を積むにつれて、受容的、分析的、生産的、発展的、心理社会的の5つのモードを経ていきます。

研究成果の学術的意義や社会的意義
Varying 3D displays of voltage, current, inductance and power promoted inter and intra-cognitive communication of 3D data. It was determined that learners progress through five modes as they gain experience: receptive, analytic, productive, development, and psychosocial.

研究成果の概要（英文）：A VR solar power plant was designed using Unity, informed by the expertise of a solar power company. Data from a real-world solar plant was then captured and viewed in real-time as a 3D visualization within SolarVR. The Oculus Rift HMD was used for viewing the developed virtual solar plant. A local solar panel was physically set up to capture data of temperature (C), humidity (%), power (W), voltage (V), and current (A), recorded from the MPPT Controller to a web-based Dashboard programmed using NODE-Red. The data was sent to an Azure server database and then streamed direct to the SolarVR Unity Project to be viewed in a custom-designed 3D Visualization. Learners progress through five modes as they gain experience: receptive, analytic, productive, development, and psychosocial.

研究分野：virtual reality

キーワード：virtual reality　education　engineering

1．研究開始当初の背景

In 2014 Joichi Ito, then Director of the MIT Media Lab, suggested that the silo-effect of traditional disciplines need to be discouraged [1]. His solution was a re-focus upon an education where collaboration and processes are valued above independent exam scores and end products. He termed it antidisciplinary. In 2017 Vallance [2] applied Ito's antidisciplinary approach, bringing together students and educators of multiple disciplines to exploit their skills, but also valuing the heuristic knowledge acquired during the collaborative and cooperative development of an immersive learning experience. The research project was initially an environment to learn basic nuclear power plant concepts, contextualized by the Fukushima nuclear power accident of March 2011. As the project matured, the student developers honed specific disciplinary skills such as C# programming and 3D modelling and design. However, it also became very apparent that the students appeared to span disciplines as each began to share designs, models, and programming. They considered user assessment and usage criteria, acquired new knowledge of the Fukushima nuclear accident and the related theory of nuclear power and radiation exposure, subsequently developing a more critical analysis of mainstream media and expert reports. With the Oculus Rift HMD, they tested each iteration with passers-by in the lab and always received exhilarating responses; a sense of fascination of a challenging but quite depressing context. Within the project the students learned, they taught, they played with ideas, they exhibited passion, and they shared new knowledge with their peers and the researcher. The result was a novel virtual environment called Fukushima_RMI2 [3]. The project became an exemplar of working in an antidisciplinary space.

The aim of our research over the past 10 years has been in line with the desires of practitioners in which, like the Fukushima project exemplified above, students are empowered in the development of their immersive learning experiences, and collaborating with researchers, practitioners and advisors. For instance, Information Systems students, Computer Science students and Design students have cooperated and collaborated. Computing, Engineering, Humanities, and Psychology academics, along with external content advisors and professional programmers, have also contributed to the research. In effect, they have all been engaged within and beyond their respective disciplines; an example of an antidisciplinary way of working. This Virtual Reality research had an external advisor for solar power expertise, and the development was fully undertaken by undergraduate Systems Information and Design students. The Principal Investigator has a Doctorate in Education and over 20 years of experience. Occasionally, academics from disciplines as diverse as Engineering to Linguistics, and Computer Science to Art were invited to advise and collaborate with the students.

2．研究の目的

The original hypothesis informed the research: *Learning in a virtual world is significantly increased when virtual activities are synchronized with real-world outcomes.* To design rich learning and training scenarios in VR, it is not only necessary to focus on different interactivities but also to design experiences with diverse characteristics and problems. A virtual solar power site named SolarVR was developed in Unity, and linked to remotely located real-world sensors. Varying 3D displays of voltage, current, inductance and power were trialed to develop a narrative template for effectively communicating 3D data. Educational activities were designed to determine the efficacy of real-to-virtual VR for learning. A virtual robot and drone which could be maneuvered remotely in the SolarVR Unity project – viewable using the Oculus Rift HMD – were used to seek out maintenance issues and provide opportunities to develop learning experiences.

3．研究の方法

The research hypothesis was answered from two perspectives, resulting in qualitative and quantitative data sets from which to draw conclusions. Firstly, an analysis of the experience of the student developers was undertaken using Gibbons and Hopkins' Scale of Experientiality [4] (see Fig. 1). It is considered that learners progress through five modes as they gain experience: receptive, analytic, productive, development, and psychosocial. Each of these modes are represented by the descriptors as learners climb the experientiality scale. To obtain data of the progressive experiences of the student developers of SolarVR, observations were undertaken periodically. The collection of this qualitative data is a technique which utilizes observation of participants' actions and reactions to environmental stimuli. It is acknowledged that such observations and subsequent interpretations may not capture the participants' emotional state such as anxiety or stress (this is solved below). These results were considered as qualitative data.

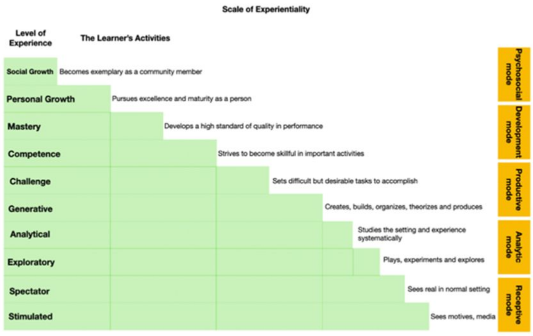

Fig. 1. Scale of Experientiality

Fig. 2. Physiological data.

As mentioned, SolarVR was designed for technicians to access data remotely, and then interpret and act upon that data as necessary. The second challenge was to determine the effectiveness of the VR solution given that the technicians will already be familiar with the data being displayed; e.g., current, voltage, irradiation, humidity, power. Based upon the outcomes of another research project by the PI's graduate student, it was decided to measure the participants' physiological data using the Empatica wearable device. The data was recorded using a customized iOS application called Cybatica (developed by the PI's graduate student Takurou Magaki), in which heart rate, skin conductance, temperature and movement can be accurately measured in pre-set time epochs [5] (see Fig. 2). Capturing such biodata can determine the anxiety that the participant may be experiencing while engaged in a particular task. Control and Experiment groups were to be set up where participants needed to solve a solar panel problem scenario provided by our external advisor. The participants wear the Empatica for the duration and physiological data recorded. The Control group use the traditional web-browser interface of acquired data while the Experiment group utilize the immersive SolarVR space and three-dimensional representations of the live data. Of course, time for task completion and its level of achievement was also to be recorded. It was anticipated that by comparing the data of the participants, we would be able to determine the efficacy of VR as a viable solution for educational implementation. These results were considered as quantitative data.

In summary, to determine the efficacy of VR as a viable solution for educational implementation, first the data of the student developers' scale of experientiality is analyzed. It is anticipated that the developers will grow in experience as their engagement in activities progress from a receptive mode to analytic mode, productive mode, development mode and onto to psychosocial mode. However, at present, we cannot predict with any certainty this may be the case. Second, data of task completion and time of completion by Control and Experiment group participants is compared, alongside physiological data which, we anticipate, indicate levels of anxiety at certain time epochs during the task process. Although task success may be considered a metric of learning, the Empatica's biodata may indicate a physiological toll which, in turn, presents a limitation of the efficacy of VR.

To conclude, initially we were going to collect qualitative data of learners using pre and post-task surveys; using Bloom's Taxonomy. We recognized that such self-reporting, although commonplace, can be unreliable. In 2018 we discovered a more effective and, we posit, informative quantitative data acquisition using a physiological device named Empatica, and data recorded using a customized iOS application called Cybatica.

4. 研究成果

A VR solar power plant was designed using Unity, informed by the expertise of a solar power company. Data from a real-world solar plant was then captured and viewed in real-time as a 3D visualization within SolarVR. The Oculus Rift HMD was used for viewing the developed virtual solar plant. A local solar panel was physically set up to capture data of temperature (C), humidity (%), power (W), voltage (V), and current (A), uploaded to a dedicated Microsoft Azure database. Data was collected by Arduino sensors connected to a Raspberry Pi which acted as the combiner box. In addition, solar power, voltage and current, along with load power and current were recorded from the MPPT Controller to a web-based Dashboard programmed using NODE-Red,

a browser-based flow editor built on Node.js. The data from the Raspberry Pi and the PC Dashboard were sent to the Azure server database and then streamed direct to the SolarVR Unity Project to be viewed in a custom-designed 3D Visualization.
The communication scenario in the VR project is as follows [6] (see Fig 3):
Inter-cognitive communication:
• A user maneuvers a drone over the solar panels with the help of the Oculus Touch controller. A problem solar panel will display emanating particles. The drone is then flown into the particles which, in turn, teleports the user to the data Scene.
• An interactive graph in the new Scene illustrates live data. The user can 'touch' options for selecting different metrics, and maneuvers herself around the graph using the Oculus Touch controller, view the data, and select current, voltage, power, humidity, and temperature data metrics;
• The user identifies a problem given the visualized data and determine a possible solution.
Intra-cognitive communication:
• A virtual user at Location A communicates to another virtual user at Location B (see Fig. 3);
• An attempt is made identify and repair the problem remotely (e.g., sensor malfunction);
• If unsuccessful, the dispatch of a local technician to conduct physical repairs is authorized.

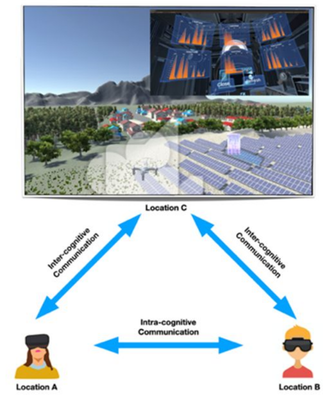

Fig. 3. Inter and intra-cognitive communication

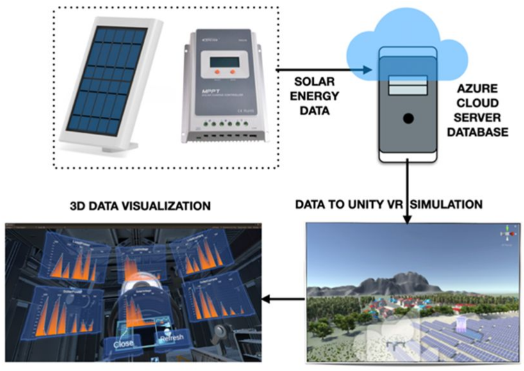

Fig. 4. SolarVR data acquisition and visualization process

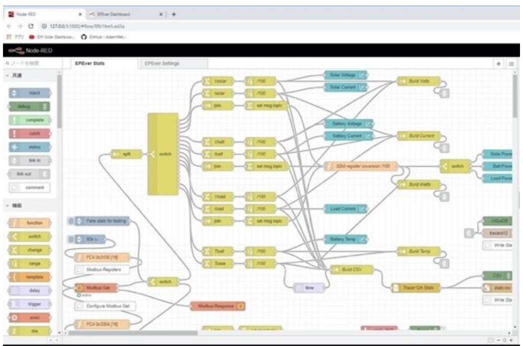
Fig. 5. Node-RED

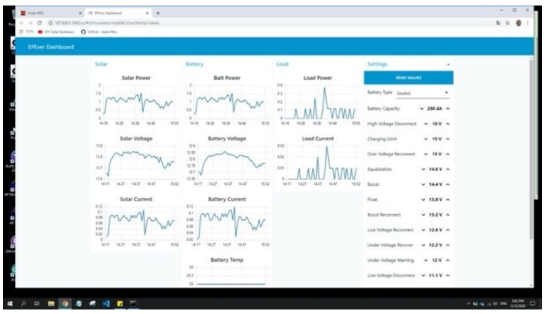
Fig. 6. Solar panel data dashboard

The operational scenario in the VR project is as follows [7,8] (see Figs. 4-6):
• Grasping a controller, the user maneuvers a drone over the solar panels.
• One panel row will display particles emanating above it thereby indicating a problem.
• The drone is flown into the particles which, in turn, will teleport the user to a data scene.
• The user then manipulates the Oculus Hand Controller to maneuver herself in a virtual lab, seeking out the real or simulated data.
• A 3D visualization graph of different data metrics (current, voltage, power, humidity, temperature) are shown; either simulated data or, if selected, live data.
• The user attempts to identify a problem given the visualized data and determine a possible solution to a pre-defined problem.
• The user will be able to attempt to repair the identified problem remotely (e.g., sensor malfunction). If unsuccessful, however, the user can then authorize the dispatch of a local

technician to conduct physical repairs.

It is acknowledged that current non-VR solutions offer a comprehensive analysis of solar plant data. A regular PC with a monitor initially appears to currently have advantages over 3D VR; e.g., sensors can be monitored using dedicated software or via a web service. However, researching the efficacy of VR enables educators and even investors to seriously consider immersive learning as a viable alternative.

In summary, the restrictions due to the COVID-19 pandemic curtailed participation data in 2020.without access to participants in 2020. Due to the coronavirus and prohibitions of face-to-face and regular interactions with students, learning data through tasks of increasing complexity could not be acquired. Therefore, further theorization of learning and educational development in VR was undertaken. This included utilizing the Scale of Experientiality and physiological metrics. It is reasoned that future quantitative biometric data of the research participants and insights from the experiential qualitative data from the student developers can be used to determine the efficacy of VR for education.

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５．主な発表論文等

〔雑誌論文〕　計12件（うち査読付論文　12件／うち国際共著　12件／うちオープンアクセス　1件）

１．著者名 Thomas, M., Can, T. & Vallance, M. (Eds.)	４．巻 12.2
２．論文標題 Impact Educational Cases	５．発行年 2019年
３．雑誌名 The Journal of Virtual Worlds Research	６．最初と最後の頁 -
掲載論文のDOI（デジタルオブジェクト識別子） 10.4101/jvwr.v12i2.7392	査読の有無 有
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１．著者名 Vallance, M.	４．巻 1
２．論文標題 Create-and-Learn: Education 'in' a Synthetic Learning Environment.	５．発行年 2019年
３．雑誌名 Integrating Multi-User Virtual Environments in Modern Classrooms. Y. Qian (Ed.),	６．最初と最後の頁 280-298
掲載論文のDOI（デジタルオブジェクト識別子） 10.4018/978-1-5225-3719-9.ch013	査読の有無 有
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２．論文標題 Real-time Monitoring Method for Cybersickness using Physiological Signals.	５．発行年 2019年
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２．論文標題 Antidisciplinary learning and the TKF creativity spiral.	５．発行年 2018年
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１．著者名 Rivers Damian J.、Vallance Michael、Nakamura Michiko	４．巻 -
２．論文標題 Metacognitive Knowledge and the Self as Socially Distanced Online Learner: A Virtual Reality Assisted Analysis of Academic Self-Concept	５．発行年 2021年
３．雑誌名 Journal of Educational Technology Systems	６．最初と最後の頁 1~30
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１．著者名 Vallance Michael、Towndrow Phillip A.	４．巻 15
２．論文標題 Computational thinking and interdisciplinary learning: time to focus on pedagogy	５．発行年 2020年
３．雑誌名 International Journal of Learning Technology	６．最初と最後の頁 180～200
掲載論文のDOI（デジタルオブジェクト識別子） 10.1504/IJLT.2020.109573	査読の有無 有
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１．著者名 Magaki Takurou、Vallance Michael	４．巻 4
２．論文標題 Seeking Accessible Physiological Metrics to Detect Cybersickness in VR	５．発行年 2020年
３．雑誌名 International Journal of Virtual and Augmented Reality	６．最初と最後の頁 1～18
掲載論文のDOI（デジタルオブジェクト識別子） 10.4018/IJVAR.2020010101	査読の有無 有
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２．論文標題 Determining the Efficacy of Virtual Reality through Experientiality and Biometrics	５．発行年 2020年
３．雑誌名 In Proceedings of International Learning Research Network (iLRN)	６．最初と最後の頁 344 ~ 347
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１．著者名 Vallance, M., Magaki, T. & Kurashige, Y.	４．巻 -
２．論文標題 Development of a Virtual Environment for Extrasomatic Communication	５．発行年 2020年
３．雑誌名 In Proceedings of IEEE TALE2020	６．最初と最後の頁 15 ~ 18
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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〔学会発表〕　計5件（うち招待講演　0件／うち国際学会　3件）

１．発表者名 Vallance, M., Kurashige, Y. & Magaki, T.
２．発表標題 Creative learning in VR: an antidisciplinary approach.
３．学会等名 IEEE VR 2019（国際学会）
４．発表年 2019年

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２．発表標題 Cybersicknessのリアルタイム予測 (Real-time Forecasting of Cybersickness).
３．学会等名 The 24th Annual Conference of the Virtual Reality Society of Japan.
４．発表年 2019年

１．発表者名 Kurashige, Y. & Vallance, M
２．発表標題 Proposing a Hand-Tracking Device using a Tangential Force Mechanical Sensor.
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４．発表年 2019年

１．発表者名 Vallance, M., Kurashige, Y. & Magaki, T.
２．発表標題 Creative learning in VR: an antidisciplinary approach.
３．学会等名 IEEE VR 2019（国際学会）
４．発表年 2019年

1．発表者名 Vallance, M.
2．発表標題 Inter-cognitive and intra-cognitive communication in Virtual Reality
3．学会等名 Educators in VR International Summit（国際学会）
4．発表年 2020年

〔図書〕　計0件

〔産業財産権〕

〔その他〕

International Virtual Environments Research Group http://www.mvallance.net All publications of all lab research http://www.mvallance.net/publications.html Video demonstrations of research projects http://www.mvallance.net/videos.html About Michael Vallance web page http://www.mvallance.net/about.html

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