Impact Objective

- Develop an environment design support mixed reality system capable of environment estimation using deep learning

Challenging occlusion in landscaping simulations

***Dr Tomohiro Fukuda** explains research work developing a mixed reality system for landscaping simulations that seeks to overcome the challenge of occlusion*

Can you explain in lay-person terms what your work involves?

Occlusion is still one of the major hurdles in realising realistic future landscape simulation in augmented and mixed reality (AR/MR – referred to as 'MR') systems. Many objects such as pedestrians, cars, buildings, bridges, trees, and electric poles that exist in the real world can be moved and changed. When the models for occlusion are pre-defined before the MR landscape simulation starts, the changeable objects will change in the run-time process and correct occlusion cannot be expressed. Therefore, a system that detects objects in real-time is necessary to deal with occlusion objects. We have focused on the real-time semantic segmentation technique by deep learning to realise occlusions in real-time. We have developed a MR system on a game engine and have connected the semantic segmentation module to the game engine. After semantic segmentation from live videos, some (currently pre-defined) segmented classes such as trees and fences near the MR camera (or user) to be set in front of a 3D virtual model are rendered by live video images in front of a 3D virtual model. Using a semantic segmentation technique can also estimate the visual environment before and after a construction project, such as the green view index (GVI), automatically.

What are some of the current gaps in our knowledge in mixed and diminished reality (MR/DR) that you are keen to fill with your research?

When designing a new environment, such as a building, landscape simulation, at the planning and design stage is necessary to simulate future images and build consensus among stakeholders. MR can help visualise full-scale design projects on a planned construction site since MR overlays 3D virtual objects such as buildings onto real things using real-world images with computer-generated data by using video or photographic displays.

Diminished reality (DR) is a similar technology to MR in that it removes the image of existing objects from a real scene virtually, replacing it with the background image of the object's area. In the environmental renewal design, existing buildings will sometimes be demolished as part of the project when creating a new landscape. DR is useful in simulating the demolition of existing buildings virtually (a new 3D virtual building model can be inserted as MR after using DR to remove the old building). To remove the moving objects, semantic segmentation by deep learning can be also applied.

What type of research is currently underway at the Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University?

The Division covers a wide variety of research areas, which includes the Course of Environmental Engineering. Some of my colleagues tackle issues such as green urban energy environments, environmental conservation and purification and environmental management. There is a lot of very exciting and topical research going on within the Course.

Can you talk a little about your own research background in environmental engineering?

My research background is within the environmental design and information technology area, focusing on creating and/or preserve the environment. I explore and develop new environmental design methodologies that can organise the relationships of humans, artificial objects such as buildings and nature systematically, deploying advanced information and communication technologies (ICT) and also explores a new environment in which ICT is embedded such as media architecture. When creating new environments, a wide variety of stakeholders are involved to build consensus. New environmental design and communication methods and tools are necessary to overcome the conventional design and communication tools among stakeholders. ▶

Overcoming challenges in mixed reality

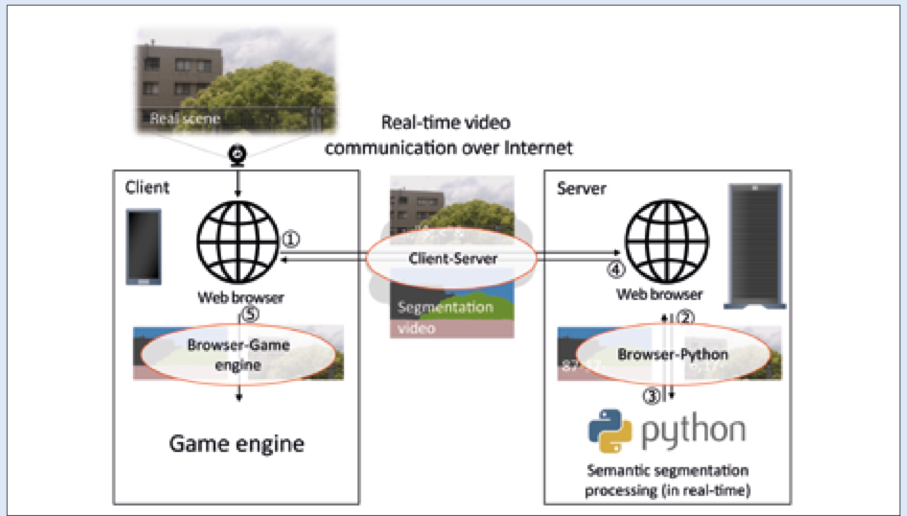
***Dr Tomohiro Fukuda** from **Osaka University** uses deep learning together with the power of the internet to push the boundaries of MR technology*

Mixed reality (MR) is rapidly becoming a vital tool, not just in gaming, but also in education, medicine, construction and environmental management. The term refers to systems in which computer-generated content is superimposed over objects in a real-world environment across one or more sensory modalities.

Dr Tomohiro Fukuda, who is based at the Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering at Osaka University in Japan, is an expert in this field. He explains that the information overlaid can add to the environment (constructive) or mask existing objects (destructive). 'MR systems must combine both real and virtual features, allow real-time interaction and offer accurate 3D representation of real and virtual objects,' he says. The goal of MR is to alter the user's perception of reality by replacing their real-world environment with a simulated environment created by seamlessly weaving the physical world with computer-generated elements.

Although most of us have heard of the use of MR in computer games, it also has applications in military and aviation training, as well as tourism, healthcare and more. In addition, it has the potential for use in architecture and design, where buildings can be superimposed in existing locations to render 3D generations of plans. However, one major challenge that remains in MR development is the issue of real-time occlusion. This refers to hiding 3D virtual objects behind real articles. 'Currently, no MR system is able to achieve this satisfactorily as none yet exist that are capable of sensing its environment with sufficient speed or detail for adequate occlusion,' highlights Fukuda.

Researchers, led by Dr Tomohiro Fukuda, are tackling the issue of occlusion in MR. They are currently developing a MR system that realises real-time occlusion by harnessing deep learning to achieve an outdoor landscape design simulation using a semantic segmentation technique. This methodology can be used to automatically estimate the visual environment prior to and after construction projects.



System overview

HARNESSING INTERNET POWER

Fukuda's research has direct real-world applications as the use of MR spreads into more areas such as engineering and design. 'In recent years, the AEC field (architectural, engineering and construction) is shifting to digital usage. Designers and engineers are more interested in digital technology and its applications than ever before,' he observes. 'New tools are attracting attention for more effective and higher value use in the design and construction stages.' The team hopes to use their design and engineering industry contacts to help them evaluate the prototypes they have built.

Fukuda developed the methodology used to design his MR system in conjunction with his laboratory student Daiki Kido, and the system was designed with use on mobile devices client-server communications for real-time semantic segmentation processing. They used a standard monocular camera to carry out the imaging functions of the system.

Semantic segmentation is a useful technique to carry out dynamic occlusion handling as it allows the system to extract the region of each object on a frame-by-frame basis. However, performing semantic segmentation in real time currently requires a high-end desktop computer capable of the heavy processing required. Fukuda's system is designed for use in outdoor landscape simulations which would make this unfeasible, therefore he has developed his system to be used on a mobile device, such as a laptop or tablet. 'I have overcome this dilemma by connecting client devices with a server that performs the semantic segmentation processing tasks on the image frames that have been transferred by the mobile device,' he outlines. The processed frames are then returned to the user. This client-side communication was accomplished using Flask, a Python web application framework using hypertext transfer protocol (HTTP). 'Technically, a live video is captured on the web camera on laptop PC onsite, then the video data will transmit to desktop PC for semantic segmentation,' confirms Fukuda. 'Following that the semantic-segmented video data will transmit to laptop PC again to render MR.' The team have also designed the system to take advantage of advances in VR module technology by allowing the segmentation module to be replaced and/or updated as newer, better versions are released.

REAL-TIME ACHIEVEMENT

Fukuda has been pleased with his results so far. 'We have achieved real-time dynamic MR occlusion and have used the internet to facilitate the MR and semantic segmentation processing,' he says. They have created a 3D virtual building to test the system before positioning and orientating the model in the 3D virtual space of the MR game engine. When the MR system on the laptop and the deep learning system on the desktop PC are activated, MR users are able to see the virtual design targets in the MR environment on their laptops. 'By panning, tilting up/down, etc., users can control the view of their environment and we were able to confirm that semantic segmentation is running successfully on the MR by witnessing successful occlusion of objects within the environment,' he continues.

This project has very much been a learning experience for Fukuda and his team. 'I have learned a wide variety of technologies such as computer graphics, virtual/augmented /mixed reality, computer vision, internetworking and deep learning, to realise this MR system with real-time occlusion using semantic segmentation by deep learning,' states Fukuda. 'As a result of my ambition to realise the MR landscape simulator to overcome conventional photo montage limitations, we have learned the need for landscape simulation from architects and designers.' In expanding his knowledge in these related fields, Fukuda has paved the way to further develop this technology. Following discussion with designers and architects, he has also considered how the work he and his team have undertaken can be used in landscaping, design and construction applications.

MR IN PROPERTY DEVELOPMENT

The impact of Fukuda's work will be felt amongst the various users of MR technology, but especially those using it in landscaping and design applications. Having overcome the challenge of enabling mobile devices to render occlusion in real-time by harnessing file transfer protocol to shift the processing load, Fukuda has realised more accurate, realistic and flexible landscape simulation using MR and deep learning. Key amongst the principal beneficiaries of this advancement in MR technology will be stakeholders in building projects, including governments, property investors, architects, engineers and even neighbourhood residents who could potentially be affected by the projects.

Looking forward, Fukuda has uncovered new avenues he can explore to further the work completed during this project. 'One of the new challenges we found through developing this system is that semantic segmentation cannot segment the different objects of the same class,' he outlines. In essence, correct occlusion is difficult to achieve if there are many objects such as buildings or trees in the planned build site. 'Thus, where there are many objects of the same class, like a forest, a 3D computer-generated object would be rendered either to the front or back of the mass of objects, which would be treated as one entity.' It would therefore be difficult to place the virtual object within the forest. Fukuda hopes to tackle this challenge as the next logical step on his research pathway. ●

Project Insights

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BIO
Dr Tomohiro Fukuda is an associate professor in the Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University, Japan. He worked for the Matsushita Electric Works Co., Ltd. (now known as Panasonic Corporation) from 1996 to 2004, and then has been an associate professor at Osaka University since 2004. Fukuda's research interests are mainly environmental design and engineering, design support, computer-aided architectural design, virtual, augmented and mixed reality (VR/AR/MR), and media architecture.