Computer Vision and Hybrid Reality for Construction Safety Risks: A Pilot Study

Rita Yi Man Li and Tat Ho Leung

Abstract Construction sites are among the most hazardous venues. While most of the previous research has shed light on the human aspect, we propose to utilise the fast R-CNN object detection method to detect the construction hazard on sites and employ mixed reality to enable the artificial intelligence to detect the hazard. Fast region-based convolutional neural network object detection acquires expert knowledge to identify objects in the image. Unlike image classification, the complexity of object detection always implies an increase in complexity which demands solutions with regard to speed, accuracy and simplicity.

Keywords Construction hazard · Computer vision

1 Construction Hazard

Construction sites have been considered as some of the most hazardous venues. Many previous researches have studied the causes of construction accidents and various safety measures. One company in Hong Kong aspires to improve safety via the utilisation of virtual reality [10, 11]. While most of these studies have highlighted the human aspect, we propose to utilise the fast R-CNN object detection method to detect the construction hazard on sites and employ mixed reality to enable the artificial intelligence to detect the hazard.

R. Y. M. Li (✉)
Hong Kong Shue Yan University, Hong Kong, China
e-mail: ymli@hksyu.edu

T. H. Leung
University of Manchester, Manchester, UK

X.-S. Yang et al. (eds.), *Fourth International Congress on Information and Communication Technology*, Advances in Intelligent Systems and Computing 1027, https://doi.org/10.1007/978-981-32-9343-4_2

2 Object Detection—Related Works

Object detection has been prominently adopted within image recognition processes and computer vision tasks such as pose estimation [6, 8], vehicle detection [14, 25], surveillance [7, 13], face detection, face recognition [12] and pedestrian detection [23, 26]. In object detection, an algorithm is required to solve two basic problems which are image classification and localisation.

This paper attempts to construct an object detection model to identify hazardous objects which may exist in construction sites. The photograph database we have built recognises and locates similar objects such as holes and wires which can then be displayed in an MR environment projected on HoloLens. Once the database sets up, it can establish the prediction API for training iteration (Figs. 1, 2, 3, 4 and 5).

Fig. 1 Sample object input of the 'hole' figures

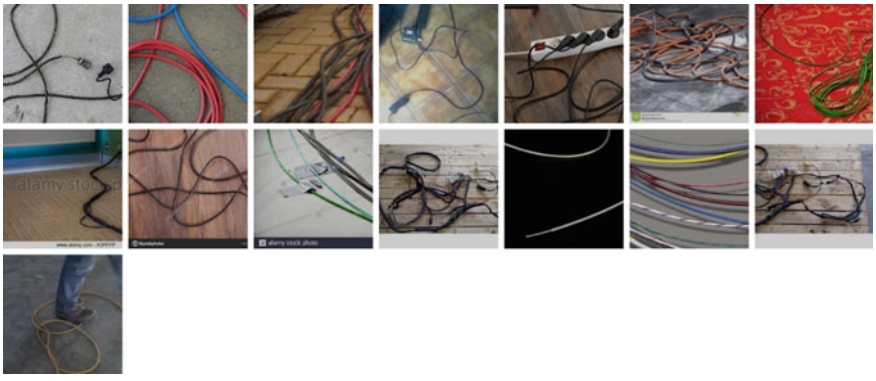

Fig. 2 Sample object input of electrical wire figures

Fig. 3 Test for hole 1

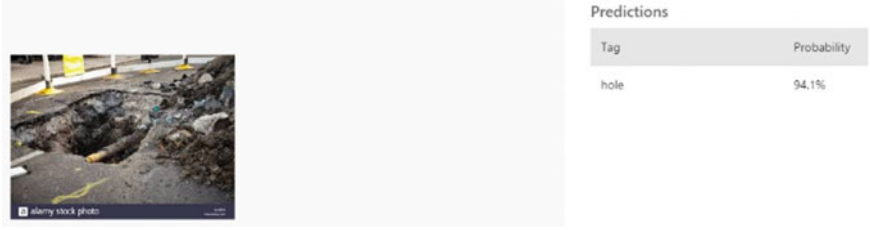

Fig. 4 Test for hole 2

Fig. 5 Test for wire

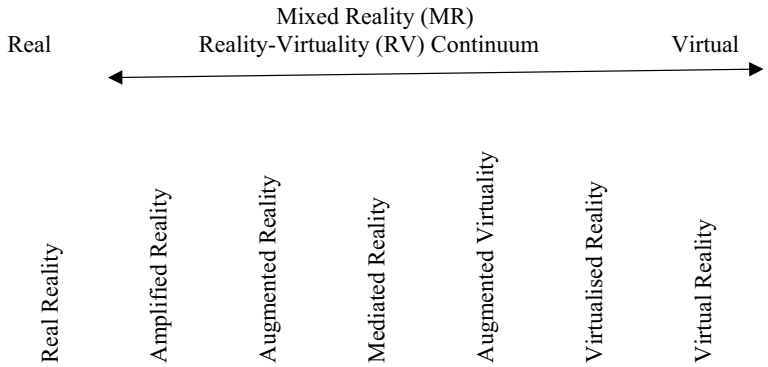

Fig. 6 Order of reality concepts ranging from reality to virtuality [15, 20]

Mixed Reality

In recent years, technological breakthroughs in mixed reality (MR) have allowed us to apply such holograms in various ways. Using the novel techniques in MR, real-life situations and computer-generated visual information are combined to create a hybrid expression which enhances the technological developments and practices in the architecture, engineering and construction (AEC) industries [1, 19].

Basically, MR consists of a variety of realms from real reality to virtual reality as precisely shown in Fig. 6. According to Milgram and Colquhoun [15], the 'real' and 'virtual' environments do not imply merely conceptual alternatives; rather, they are poles lying at opposite ends of a reality–virtuality (RV) continuum. Essentially, within the RV continuum, this is where the MR technologies take place [20]. We can use the mixed reality to see the real hazard but with a virtual label, say, for example, 'hole'.

Although researches in MR have been carried out continually for several decades, the application of MR technologies is becoming mature in practical use [19]. This includes various degrees of applications such as the collaborative web space [2], scientific visualisation [18], the augmented reality (AR) system [2, 3, 5, 21, 22], displays on unmanned air vehicles [16] and 3D video-conferencing systems [17]. More recently, incredibly specific topics in MR-based technological developments have been initiated by global IT leaders such as Microsoft.

In the construction sector, the AR system has widely been adopted in practices [4, 9, 24]. AR-based devices such as head-mounted displays (HMDs) and portable tracking systems are used in different situations. Meanwhile, this paper aligns its concern specifically on the object detection embedded in MR environments, which can provide extraordinary enhancements to construct safety training and management. After successfully detecting a hazardous object, we propose to utilise the mixed reality hologram for construction workers to detect the existence of hazard or safety training, which can then allow them to have an objective criteria on whether or not that is a risk, and enhance safety on sites.

3 Conclusion

It can be advantageous to apply MR technologies into construction practices as such technologies entail a wide range of benefits ranging from efficiency enhancement to safety improvement. This paper highlights the critical architecture in object detection in the fast R-CNN method; hence, with the assistance of Azure, it can adapt the pre-structured scripts to save time in code development. At the same time, it performs effectively with a sufficient database installed and accurate training tests. The custom vision tests 1–3 demonstrate that it is capable of training and recognising the hazardous objects and their locations which may exist in construction sites. If we go one step forward, we can deploy it to HoloLens and consequently identify the hazard on sites.

Acknowledgements Ocular behaviour, construction hazard awareness and an AI chatbot UGC/FDS15/E01/18.
Willingness to share construction safety knowledge via Web 2.0, mobile apps and IoT, RGC grant, UGC/FDS15/E01/17.

References

1. Anders, P.: Cynergies: technologies that hybridize physical and cyberspaces. Paper presented at the 2003 ACADIA. Indianapolis, Indiana (2003)
2. Billinghurst, M., Kato, H.: Collaborative mixed reality. Paper presented at the 1st ISMAR. Yokohama, Japan (1999)
3. Broll, W., Lindt, I., Ohlenburg, J., Wittkamper, M., Yuan, C., Novotny, T., Mottram, C., Gen Schieck, A.F., Strothman, A.: ARTHUR: a collaborative augmented environment for architectural design and urban planning. J. Virtual Reality Broadcast. **1**(1), 1–10 (2004)
4. Dunston, P.S., Shin, D.H.: Key areas and issues for augmented reality application on construction sites. In: Wang, X., Schnabel, M.A. (eds.) Mixed Reality in Architecture, Design and Construction. Springer, Dordercht, The Netherlands (2009)
5. Dunston, P.S., Wang, X.: Mixed reality-based visualization interfaces for architecture, engineering, and construction industry. Ind. J. Constr. Eng. Manag. **131**(12), 1301–1309 (2005)
6. Fang, Q., Li, H., Luo, X., Ding, L., Luo, H., Li, C.: Computer vision aided inspection on falling prevention measures for steeplejacks in an aerial environment. Autom. Constr. **93**, 148–164 (2018)
7. Fang, Q., Li, H., Luo, X., Ding, L., Luo, H., Rose, T.M., An, W.: Detecting non-hardhat-use by a deep learning method from far-field surveillance videos. Autom. Constr. **85**, 1–9 (2018)
8. Fang, W., Ding, L., Luo, H., Love, P.E.D.: Falls from heights: a computer vision-based approach for safety harness detection. Autom. Constr. **91**, 53–61 (2018)
9. Hammad, A.: Distributed augmented reality for visualising collaborative construction tasks. In: Wang, X., Schnabel, M.A. (eds.) Mixed Reality in Architecture, Design and Construction. Springer, Dordrecht, The Netherlands (2009)
10. Li, R.Y.M.: An Economic Analysis on Automated Construction Safety: Internet of Things, Artificial Intelligence and 3D Printing. Springer, Singapore (2018)
11. Li, R.Y.M., Poon, S.W.: Construction Safety. Springer, Berlin (2013)
12. Li, J., Zhang, D., Zhang, J., Zhang, J., Li, T., Xia, Y., Yan, Q., Xun, L.: Facial expression recognition with Faster R-CNN. Proc. Comput. Sci. **107**, 135–140 (2017)

13. Li, X., Ye, M., Liu, Y., Zhang, F., Liu, D., Tang, S.: Accurate object detection using memory-based models in surveillance scenes. Pattern Recognit. **67**, 73–84 (2017)
14. Li, S., Lin, J., Li, G., Bai, T., Wang, H., Pang, Y.: Vehicle type detection based on deep learning in traffic scene. Proc. Comput. Sci. **131**, 564–572 (2018)
15. Milgram, P., Colquhoun, H.: A taxonomy of real and virtual world display integration. In: Ohta, Y., Tamura, H. (eds.) Mixed Reality: Merging Real and Virtual Worlds. Springer, Berlin, Heidelberg, Germany (2001)
16. Rackliffe, N.: An augmented virtuality display for improving UAV usability. MITRE technical papers. MITRE (2005)
17. Regenbrecht, H., Lum, T., Kohler, P., Ott, C., Wagner, M., Wilke, W., Mueller, E.: Using augmented virtuality for remote collaboration. Presence teleop. Virt. Environ. **13**(3), 338–354 (2004)
18. Schmalstieg, D., Fuhrmann, A., Hesina, G., Szalavari, Z., Encarnacao, M.L., Gervautz, M., Purgathofer, W.: The studierstube augmented reality project. Presence Teleop. Virt. Environ. **11**(1), 33–54 (2002)
19. Schnabel, M.A.: Framing mixed realities. In: Wang, X., Schnabel, M.A. (eds.) Mixed Reality in Architecture, Design and Construction. Springer, Dordrecht, The Netherlands (2009)
20. Schnabel, M. A., Wang, X., Seichter, H., Kvan, T.: From virtuality to reality and back. Paper presented at the 12th IASDR. Hong Kong (2007)
21. Seichter, H., Schnabel, M.A.: Digital and tangible sensation: an augmented reality urban design studio. Paper presented at the 10th CAADRIA. New Delhi, India (2005)
22. Seichter, H.: Sketchand+: a collaborative augmented reality sketching application. Paper presented at the 8th CAADRIA, Bangkok, Thailand (2003)
23. Silver, D., Hubert, T., Schrittwieser, J., Antonoglou, I., Lai, M., Guez, A., Lanctot, M., Sifre, L., Kumaran, D., Graepel, T., Lillicrap, T., Simonyan, K., Hassabis, D.: A general reinforcement learning algorithm that masters chess, shogi, and go through self-play. Science **362**(6419), 1140–1144 (2018)
24. Tonnis, M., Klinker, G.: Augmented 3D arrows reach their limits in automotive environments. In: Wang, X., Schnabel, M.A. (eds.) Mixed Reality in Architecture, Design and Construction. Springer, Dordrecht, The Netherlands (2009)
25. Xu, Y., Yu, G., Wang, Y., Wu, X., Ma, Y.: Car detection from low-altitude UAV imagery with the Faster R-CNN. J. Adv. Transp. (2017)
26. Zhao, Z.-Q., Bian, H., Hu, D., Cheng, W., Glotin, H.: Pedestrian detection based on fast R-CNN and batch normalization. Paper presented at the ICIC 2017. Liverpool, UK (2017)