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Digitalisation of collaborative human-robot workspaces

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The project has investigated a way of enabling humans and robots to work together safely and closely in a shared industrial workspace. The project explored using a network of cameras to produce digital images of the workspace and machine learning to predict events and prevent dangerous situations. Further work is required to realise this vision.

Human-robot collaboration

Human-robot collaboration (HRC), in which humans and robots work together on tasks, is a key feature in realising the frequently alluded to 'Factories of the Future' scenario. Robots and humans bring complementary abilities. The robot can undertake physically strenuous work while the human worker monitors production. The ultimate goal is for humans to work with robots in open spaces to allow maximum co-operation; robots are not kept in protective cages and can assist humans going about their tasks with agility and speed. Suitable robots arrived on the market in 2014. In the automotive and electronic industries their use is already a reality; it is, however, extremely limited.

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Complex manufacturing environments in which digitalisation, monitoring and machine awareness could help improve efficiency and productivity

The safety of human workers is a critical consideration. The majority of strategies to ensure safety, which have been taken so far, have implications for the robot's size, capabilities and output.

Strategies either focus on damage limitation 'post-collision' or on averting collisions 'pre-collision' through the robot sensing its surroundings, predicting an impending collision, and altering its speed and movement. Either way, productivity is limited and the opportunities for human-robot collaboration to cooperate on manufacturing tasks are reduced.

It will be beneficial to capture an industrial workspace in high detail to underpin a safety system based on the prediction of events to avoid dangerous situations arising. This requires a robust perception system. Current approaches to real-time representation of workspaces are reliant on point-based tracking of pre-marked objects or on sensing people using 3D cameras. This project's approach is more flexible; the system could be applied in a new environment and learn its critical features, without the need for marking-up objects.

The project is the first to create a real-time digital representation of an industrial workspace using the latest techniques in machine learning.

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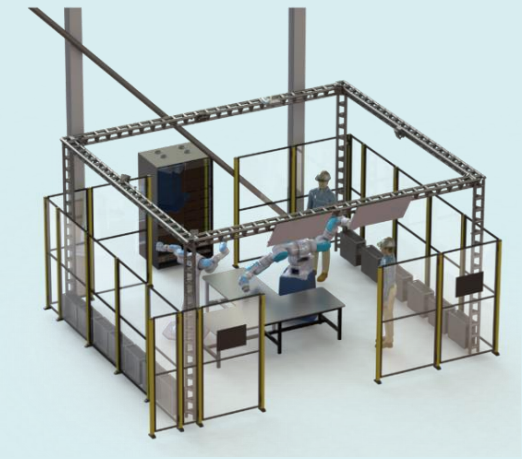
Towards real-time digitalisation of shared human-robot workspaces



The project created an HRC test cell equipped with both a network of 2D high resolution cameras and the latest tracking technologies.

The test cell at the Intelligent Automation Centre, Loughborough University, is openly accessible, offering a testing environment for human-robot collaboration in the UK.

Eight high resolution, wide field of view cameras were mounted in the corners and half way along each wall.

By combining the images using off-the-shelf processing algorithms, reconstructions were possible based on both volumetric occupancy (software programmes: Mask R-CNN, Dense Pose, Deeplab) and by skeletal reconstruction (Open Pose).

Results

Skeletal reconstruction was achieved via the algorithm in the Open Pose software. At times, non-human objects are mistakenly identified as humans (2nd top panel below).

Reconstructions achieved by the other algorithms tested are shown overleaf. There were some instances of misclassification in all cases, such as robots mistakenly classified as humans.

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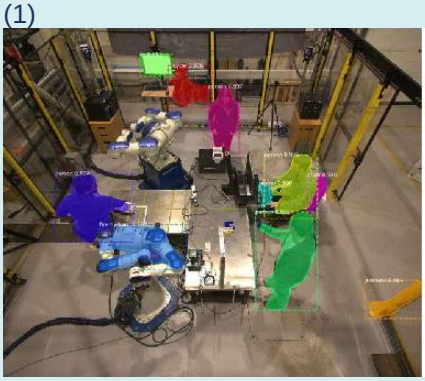
Segmentations of objects, humans and robots in the test cell via off-the-shelf algorithms:
(1) Mask R-CNN, (2) Dense Pose and (3) Deeplab

(1)



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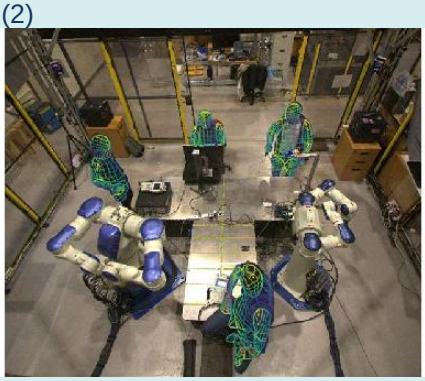

(3)

Key finding 1

3D reconstructions can be generated in under 0.1 seconds, demonstrating that near real-time localisation of objects in a 3D space is feasible.

Key finding 2

Currently, off-the-shelf deep learning algorithms do not recognise uncommon objects that might be important features in a specialised manufacturing environment.

Wider applications

Creating real-time digital twins of human machine environments is expected to have many benefits not only for safety but also for analysis and continuous improvement of workplace ergonomics, quality and performance.

What next?

Further research into human-robot workspace digitalisation, extending to detailed investigations of:

- Safety systems
- Observation-based modelling and anticipation of human behaviours
- Workspace design and validation
- Autonomous robots for complex hand-eye coordination tasks