UNIVERSITY OF TECHNOLOGY SYDNEY

MASTER'S THESIS

Sensing and Human Pose Estimation in Extreme Industrial Environments for Physical Human Robot Interaction

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Certificate of Original Authorship

I, Christian REEKS, declare that this thesis titled *Sensing and Human Pose Estimation in Extreme Industrial Environments for Physical Human Robot Interaction* and the work presented in it are my own. I confirm that:

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- I have acknowledged all main sources of help.
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ANBOT	**A**ssistance as **N**eeded Ro**BOT**
AR	**A**ugmented **R**eality
RGB	**R**ed **G**reen **B**lue
Cobot	**Co**llaborative Ro**bot**
DF	**D**ynamic**F**usion
ED	**E**mbedded **D**eformation
F4D	**F**usion**4D**
KF	**K**inect**F**usion
PCL	**P**oint **C**loud **L**ibrary
PCA	**P**rinciple **C**omponent **A**nalysis
pHRI	**p**hysical **H**uman **R**obot **I**nteration
PPE	**P**ersonal **P**rotective **E**quipment
ROS	**R**obot **O**perating **S**ystem
STL	**ST**ereo**L**ithograph
ToF	**T**ime-**o**f-**F**light
VD	**V**olume**D**eform

Abstract

Sensing and Human Pose Estimation in Extreme Industrial Environments for Physical Human Robot Interaction

Collaborative robotic systems which physically interact with a user are gaining popularity in industry. Collaborative robots can combine the power, precision and repeatability of robots with the skill and cognitive ability of a human to complete a task with greater efficiency and reduced risk of injury. One such industrial application that would benefit from collaborative robots is abrasive blasting. Abrasive blasting produces a large reaction force on to the worker and creates enormous amounts of dust filling the workspace. While the robot can handle the reaction forces of blasting, the user's safety must be ensured. A non-invasive vision-based human detection system would be ideal to handle this. However, there are many challenges that need to be overcome when attempting human detection in such hazardous environments.

This thesis proposes a vision system for human pose estimation in hazardous environments. Four sensing technologies are evaluated during abrasive blasting and a suitable sensor is chosen. To determine the ideal placement and number of sensors, an optimisation model is developed. Sensor enclosures are fabricated and experiments conducted to validate the quality of the point cloud data. The point cloud specific to the human is identified and extracted from multiple point clouds. Marker-less and marker-based pose detection are implemented using the human point cloud. Occluded body parts are estimated by tailoring the embedded deformation algorithm to physical human robot interaction. This work is implemented on a custom assistive robotic platform. Additional methods to improve sensing and detection are discussed along with possible directions for future work.