Worker-in-the-Loop Cyber-Physical System for Safe Human-Robot Collaboration in Construction

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ABSTRACT

Efficient implementation of robots in dynamic, human-populated construction sites will require the assistance and supervision of workers. Several hazards exist when workers are within the robot's working envelope, including high mental stress induced by the robot as well as the risk of physical collision. To mitigate these risks, this study proposes a cyber-physical system (CPS) for safe, worker-centered, human-robot collaboration (HRC). The physical components of the CPS include a wearable biosensor for assessing workers' mental conditions and a video camera for evaluating the risk of collision accidents. The cyber component incorporates a machine learning layer that employs a kernelized logistic regression to translate worker bio-signals into distinct physiological states. Simultaneously, the system monitors the relative distance between workers and robots by applying computer vision techniques (i.e., video frame differencing, dilation, and contour detection). To test the feasibility of the proposed CPS, six subjects were asked to perform a series of bricklaying tasks jointly with a vehicle robot with different risks of collision (various distances from the robot) and at different levels of cognitive load (various tasks complexity). The findings revealed that the proposed CPS allows the co-bot to adjust its speed relative to the subject's physiological states with 93.70% accuracy. In addition, the proposed system shows promising performance in collision avoidance with the accurate monitoring of position between robots and humans. The results unfold the feasibility of the proposed CPS in enhancing safe and intelligent HRC in construction under the trend of Industry 4.0.