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Integrating Real-Time Fatigue Monitoring into Adaptive Human–Robot Collaboration Systems

The increasing use of collaborative robots in warehouse logistics is changing intralogistics systems, improving productivity, but is also creating significant challenges for operator safety, ergonomics, and operational reliability. The introduction of new technologies implies continuous cognitive and physical pressures on operators in modern warehouses, increasing the impact of human fatigue on system performance and the risk of accidents. In this context, traditional models of human-robot collaboration are mostly static and unresponsive to changes in workers' psychophysiological states. To overcome this gap, an integrated approach will be proposed by combining real-time biometric fatigue monitoring with adaptive robotic behavior and dynamic risk assessment.

The development and validation of a socio-technical framework will allow estimating operator fatigue using specific indicators derived from non-invasive eye-tracking data; hence, a quantitative cognitive fatigue index will be defined and integrated into a decision-making model that dynamically adjusts task assignment and robot behaviour in collaborative warehouse operations. Unlike traditional Human Robot Collaboration (HRC) systems that rely on fixed safety thresholds, a model enabling the robot to proactively adapt its contribution to the task in response to changing human conditions and the relative Risk Assessment will be proposed.

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