Semantic Data Integration for Monitoring Operators' Ergonomics in an Automotive Manufacturing Setting

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Abstract. This paper presents a novel semantic data integration framework for monitoring and safeguarding the ergonomics of human operators during a collaborative assembly task in an automotive manufacturing environment.

Keywords: Semantic Data Integration, Ontologies, Knowledge Graphs, Automotive Manufacturing.

1 Motivation and Setup

This paper presents our work within the H2020 ICT-01-2019 CPSoSaware project [1] in the context of a use case based on a collaborative application in an automotive assembly line. In the scenario, a human operator performs manual assembly operations on a windshield handled and moved by a robot before assembly on the chassis. Our overarching aim is to protect the operators from injuries and muscle strain and to reduce their body's strain by performing biophysics assessment for ergonomic optimization. Towards this end, we deploy a semantic data integration framework for monitoring the human operators' safety and well-being as they are performing the requested operations.

The proposed implementation focuses on adjusting the position of the windshield according to the operator's ergonomics and providing personalized suggestions and warnings to the operator based on their postures and the way that they use their body to perform an operation, in order to avoid long-term musculoskeletal problems and other health and/or safety risks. The foreseen benefits of our solution are: (a) improvement of the workers' wellbeing at work; (b) mitigation of risks and accidents; (c) flexibility of workplace management.

2 Deployment

A set of IoT sensors submit their measurements to respective analysis components: (a) footage from static cameras analysed by computer vision components for estimating the operator's anthropometrics parameters (i.e., posture); (b) wearables (inertial measurement units – IMUs, i.e., accelerometers and gyroscopes) for motion analysis and body tracking. The analysis outputs (and not the raw sensor measurements) are then fed to an ontology-based semantic Knowledge Graph (KG) through CASPAR [2], a flexible semantic data integration framework, already being deployed in various domains [3, 4]. Our overall aim is to perform a proactive ergonomics optimization of the equipment. Fig. 1 gives a diagrammatic overview of the workflow; message exchange and data streams are based on the popular RabbitMQ message broker [5]. Note that only the higher-level analysis outputs are stored and not the raw data itself, preventing issues of performance and storage costs.

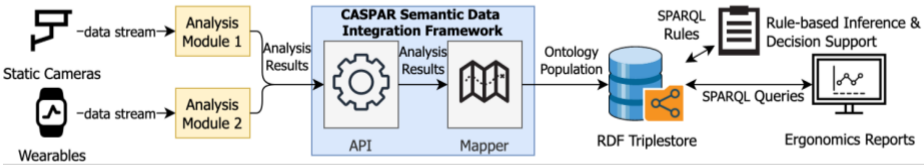

Fig. 1. Workflow overview.

The proposed deployment is currently being tested in a virtual environment (i.e., simulator designed in Unity [6]) and in a real industrial environment. The simulation involves three static RGB cameras located in three different areas of the working environment monitoring the "human's" (i.e., a digital human model) actions, while he collaborates with a robot to perform together a specific task. Fig. 2 illustrates a set of snapshots from the three different views in the simulated environment. A pose estimation algorithm extracts in real time the posture landmarks and a confidence rate for each estimation. The outputs are fed into the ontology via semantic data integration, while a set of rules determine the camera with the best view. For instance, Fig. 3 displays the average confidence rate per camera during a testing session, which can help determine the most reliable camera depending on the conditions each time.

Fig. 2. Simulated environment snapshot.

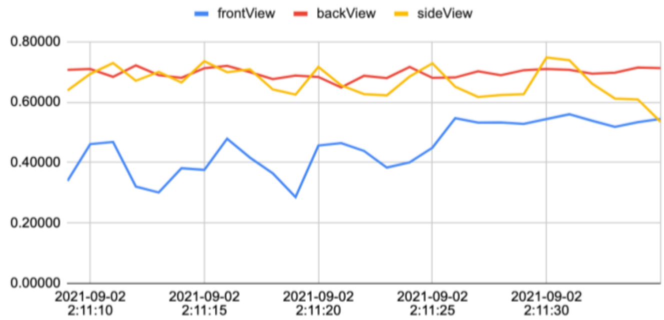

Fig. 3. Evolution of pose estimation confidence rate during a demonstration scenario.

The same pipeline process is adopted in the real-life industrial environment, with camera-based estimations from computer vision algorithms now coupled with body joints' estimation based on the IMU sensors in online monitoring.

3 Benefits of Applying Semantic Technologies

The application of semantic technologies in this scenario results in: (a) richer representation of the domain knowledge and of the respective provenance of the incoming information; (b) better explainability of the derived outputs; (c) deeper insights, e.g., discovery of underlying patterns "hidden" in the data. Moreover, being naturally inclined to addressing semantic data integration and interoperability issues, semantic technologies offer a significant degree of extensibility, allowing the addition of more input sources as deemed necessary by potential future scenarios.

4 Discussion and Next Steps

In industrial environments, the use of ergonomics aims to optimize the body physical parameters during repetitive tasks, searching for wrong postures and positions in order to help the operator avoid long term health problems. Towards this aim, our solution aspires to deliver a novel tool for optimizing the design of the workplace.

Note that in the current scenario we are not considering the sensors and actuators of the robot as an additional data source. The reason behind this decision is due to the fact that we wanted to avoid continuous adjustments of the robot, because the type of control that should be performed would most probably not be robust, reliable, and fast enough to allow a safe control in the presence of the human operator. At this stage we will use the system information and the anthropometric/ergonomics assessment to evaluate the most suitable height of the gripper, towards making the position as comfortable as possible reducing the ergonomics workload of the operator, and to adjust the gripper height from the ground. The system should adjust the height only when the operator is "far enough", otherwise the actuation could result in a danger.

Our upcoming efforts will be aimed at standardising and improving the cross-domain interoperability of our developed knowledge-based tools for scene analysis, posture recognition, and ergonomic assessment in a manufacturing environment.

Acknowledgment

This work has received funding from the European Union’s Horizon 2020 research and innovation programme under Grant Agreement No 871738 - CPSoSaware: Crosslayer cognitive optimization tools & methods for the lifecycle support of dependable CPSoS.

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