Cyber-Physical Sensing, Modeling, and Control with Augmented Reality for Smart Manufacturing Workforce Training and Operations Management

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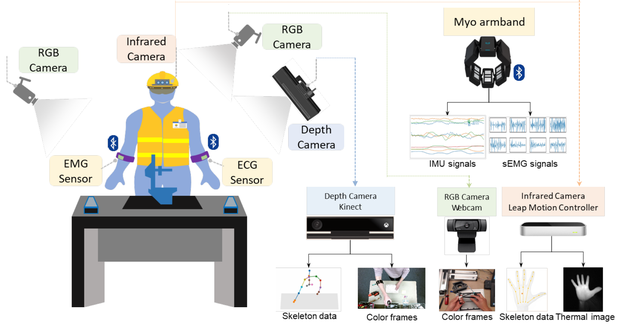
Key Focus

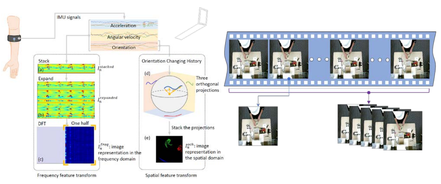
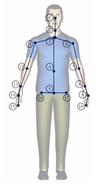
This project aims to develop a **worker-centered intelligent manufacturing system** to **sense**, **understand**, and **optimize the learning and operations of manufacturing workers**, so as to achieve significantly improved efficiency of worker training, effectiveness of behavioral operations management, and safety of front-line workers for smart manufacturing. While doing so, following fundamental challenges need to be addressed:

- **Integration and fusion** of multimodal sensor data
- Understand **complex and intricate worker action**
- Provide **inclusive assistance** in a real time manner and **evaluate worker performance**

1. Sensing and Data Acquisition

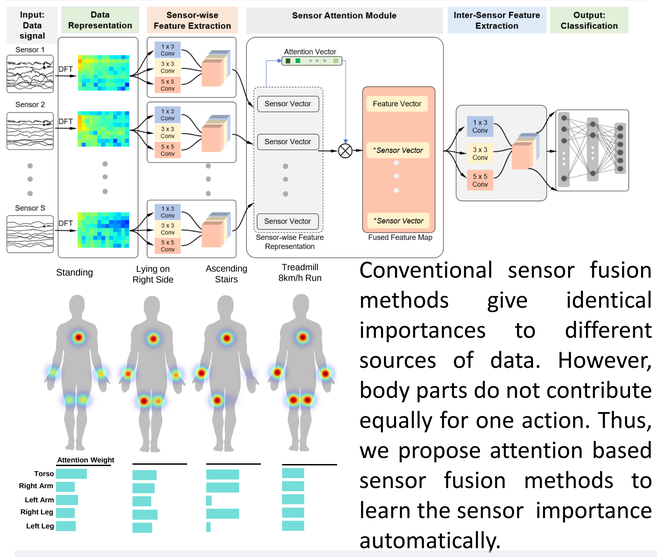


Webcam, Microsoft Kinect, and Leap Motion Controller have been used as ambient sensors to capture video data. These sensors have some issues with occlusion and cluttered background. To overcome this problem, Myo Armband, a wearable sensing device has also been used.

Signal data pro.	Video data pro.	Skeletal data pro.
		
Orientation Changing History (OCH), a novel method has been proposed to capture the spatial feature.	Image data have been processed both at frame and video level $I_n^{frame} = T_{frame}(v_n)$, $V_n^{clip} = T_{clip}(v_n)$.	Line between any two joints (JJL) and angle of two adjacent links (LLA) is used as skeletal features.

2. Cognition

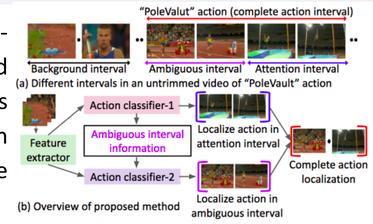
Attention-Based Sensor Fusion for Action Recognition



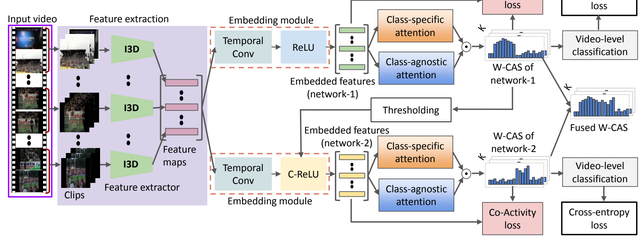
Conventional sensor fusion methods give identical importances to different sources of data. However, body parts do not contribute equally for one action. Thus, we propose attention based sensor fusion methods to learn the sensor importance automatically.

Action Completeness Modeling for Weakly Supervised Temporal Action Localization

Propose a novel end-to-end weakly supervised framework that contains two parallel action classifiers to localize the complete action.

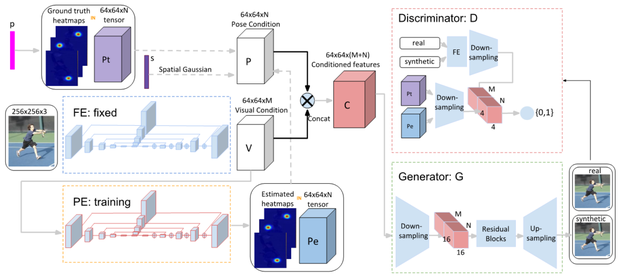


Action classifier-1 discovers the action instances in attention intervals, while the action instances in ambiguous intervals from action classifier-1 are discovered by the action classifier-2, based on the shared features.

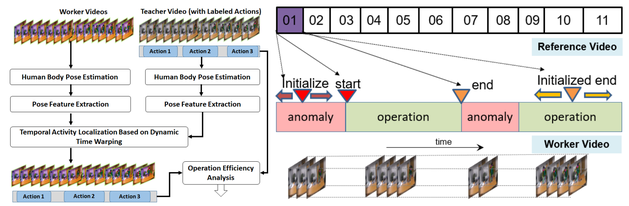


Worker Pose Tracking for Performance Evaluation

We aim to develop an automatic system to monitor and evaluate worker's efficiency for smart manufacturing based on human body pose tracking and temporal activity localization and segmentation.



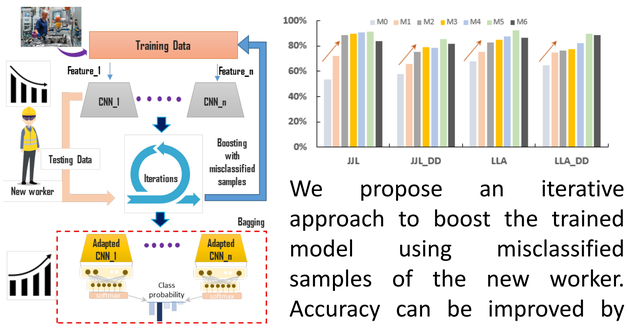
The overall framework of our proposed poseGAN for the human pose. It includes the following components: Generator(G), Discriminator (D), Feature Extractor (FE), and Pose Estimator (PE). M and N are the number of channels of a tensor.



Efficiency evaluation **Temporal localization of actions**

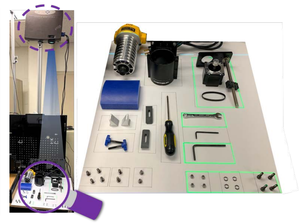
Iteratively Improving Oncoming Worker Performance

A trained AR model might perform poorly on new coming operators due to heterogeneous workforce behavior and anthropometric variation.



We propose an iterative approach to boost the trained model using misclassified samples of the new worker. Accuracy can be improved by 25% -38% using this method.

3. Assistance



The assembly task can be assisted more synergistically by incorporating virtual CAD model in an in-situ manner.

A smart projector is synchronized with the object detection module to localize the parts/tools.

4. Evaluation

Our proposed model can automatically do action segmentation from input video stream and compute cycle time (sec.) for each of the actions which laid the foundation of worker performance evaluation.

Scientific Contribution

#1 To understand the hand activity, we propose a method for complex hand gesture recognition using CNN with multi-view augmentation and inference fusion. (1 journal paper and 1 [Best Paper Award] conference paper)

#2 To sense and understand the worker in a more comprehensive way, we propose a multi-modal approach for worker activity recognition using IMU signals and videos, where four different modalities are applied. (1 journal paper and 1 conference paper)

#3 To learn the importance of different sensors, we propose a novel attention-based approach to human activity recognition using multiple IMU sensors worn at different body locations. (1 journal paper)

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