NRI: INT: COLLAB: Manufacturing USA: Intelligent Human-Robot Collaboration for Smart Factory

- Robert X. Gao, Department of Mechanical & Aerospace Engineering, Case Western Reserve University
- Ming Leu, Department of Mechanical & Aerospace Engineering, Missouri University of Science and Technology
- Gloria Wiens, Department of Mechanical & Aerospace Engineering, University of Florida
- Zhaozheng Yin, AI Institute, Department of Biomedical Informatics and Department of Computer Science, Stony Brook University

Partners:

COMAU

STIIMA

National Research Council of Italy

Manufacturing USA

NSF/NRI 2.0: ENG/CMMI and CISE/IIS
Award ID#: 1954548/1830479/1830383/1830295
Poster # TBD

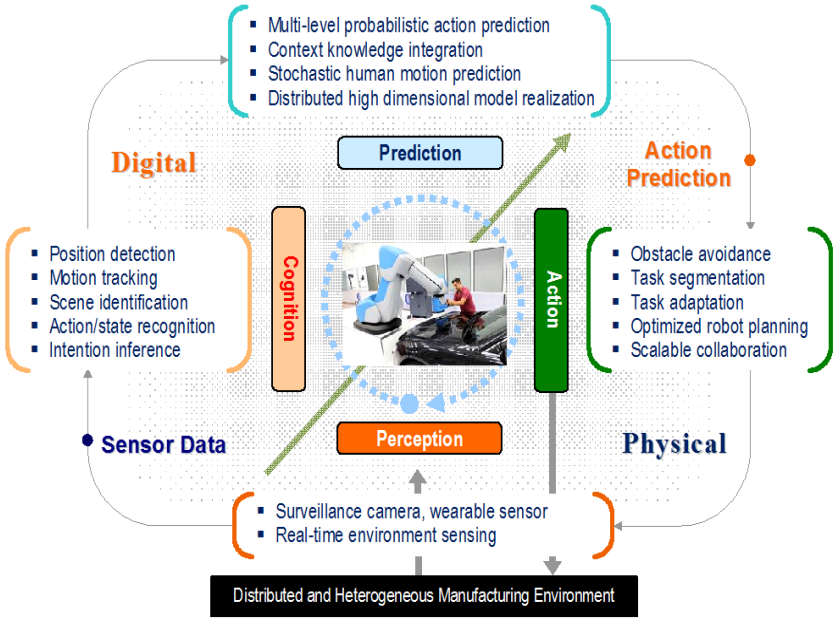
NRI: INT: COLLAB: Manufacturing USA: Intelligent Human-Robot Collaboration for Smart Factory

Challenge

- Separating and highlighting relevant content from irrelevant/ambiguous information in **sensing** data for human action and command **recognition**
- Accounting for uncertainty in human action and trajectory **prediction**
- Estimating collision risk between robot and human trajectory in collaborative **action**

Solution

- Background aware **network**, **attention mechanism**, and **sensor fusion**
- **Probabilistic sequential modeling** for uncertainty quantification
- **Temporal point clouds** for trajectory evaluation and collision prediction



Scientific Impact

- Improved understanding of: 1) discriminative **features** in sensing data relevant to action recognition, and 2) sequential **pattern** underlying human motion trajectory
- Ensured **safety** with mitigated risk of robot mis-trigger and collision

Broader Impact

- Demonstrated **viability** of human-robot collaborative solution that is **generalizable** to various sectors, from education to healthcare
- Improved human **trust** in collaborative robots

NSF/NRI 2.0: ENG/CMMI and CISE/IIS
Award ID#: 1954548/1830479/1830383/1830295
Poster # TBD

Sensing and Recognition: Real-Time Multi-modal Human-Robot Collaboration Using Gestures and Speech

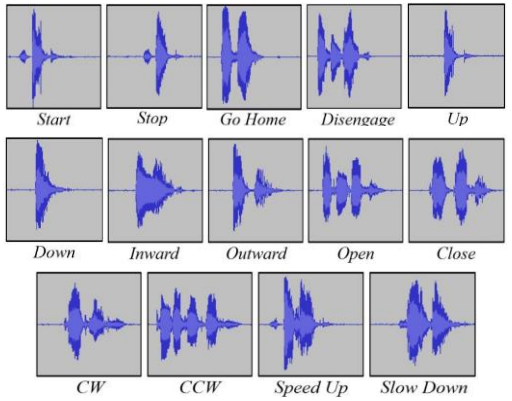
Challenge:

- **Real-time** sensing, recognition and integration of **dynamic gestures** with temporal sequence features and **speech commands** with background noises simultaneously in human-robot collaboration.

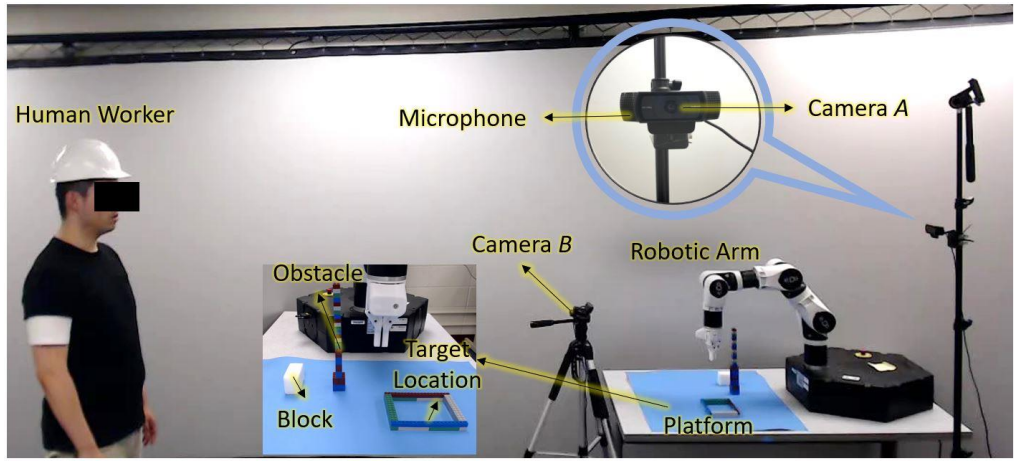
Solution:

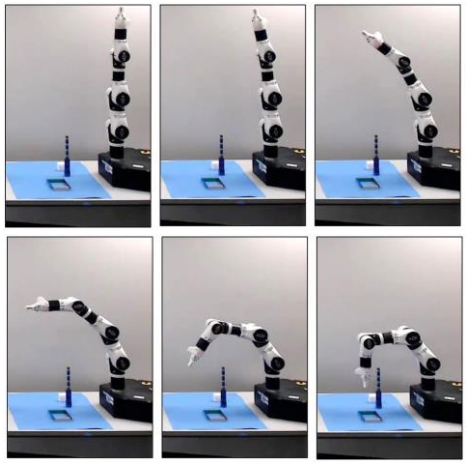
- **Real-time Motion History Image (MHI)** method has been proposed for feature extraction of dynamic gestures in different backgrounds.
- A **multi-threading** architecture has been constructed to operate **parallel tasks simultaneously** in real time.
- A data set of **dynamic gestures** has been designed and a gesture recognizer is built using a multi-view data set and **a convolutional neural network (CNN)**. Robust **speech recognition** is achieved through improvements to an online open-source speech recognizer.

MHIs samples of dynamic gestures in different backgrounds



Waveform samples of speech commands





Overview of the multi-modal human-robot collaboration system using dynamic gestures and speech commands

NSF/NRI 2.0: ENG/CMMI and CISE/IIS
Award ID#: 1954548/1830479/1830383/1830295
Poster # TBD

Sensing and Recognition: Reconstructing and Predicting 3D Human Poses from Wearable Sensors

Challenge:

- For the **human pose reconstruction** and **prediction**, we need a feasible and an effective approach to accurately sense human poses with a small set of wearable sensors.

Solution:

- We propose the wearable motion capture problem of **reconstructing and predicting 3D human poses** from a small number of wearable IMUs and wearable cameras.
- We introduce a novel **Attention-Oriented Recurrent Neural Network (AttRNet)** to reconstruct the current pose and predict the future poses.

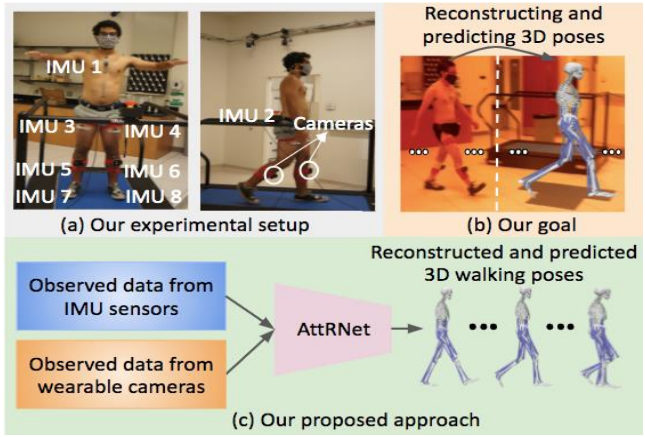
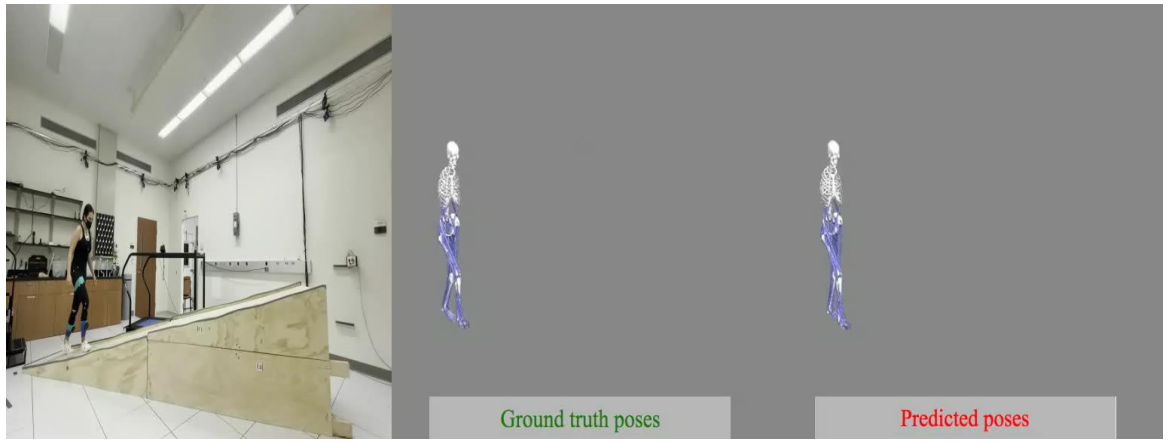
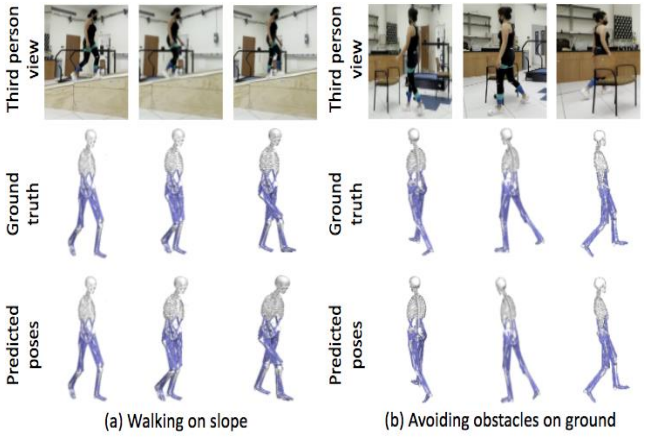


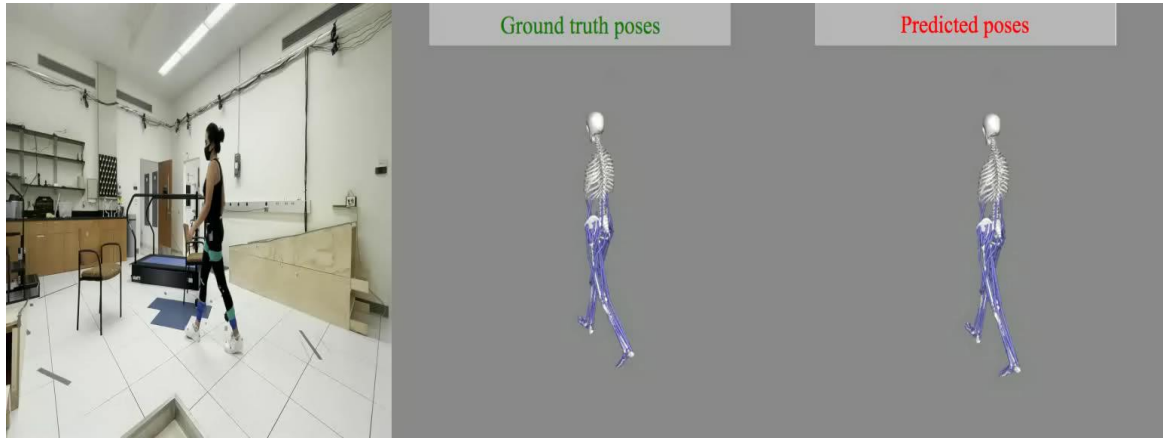
Illustration of our proposed approach



The subject walks on slope



Visualization of predicted poses over time



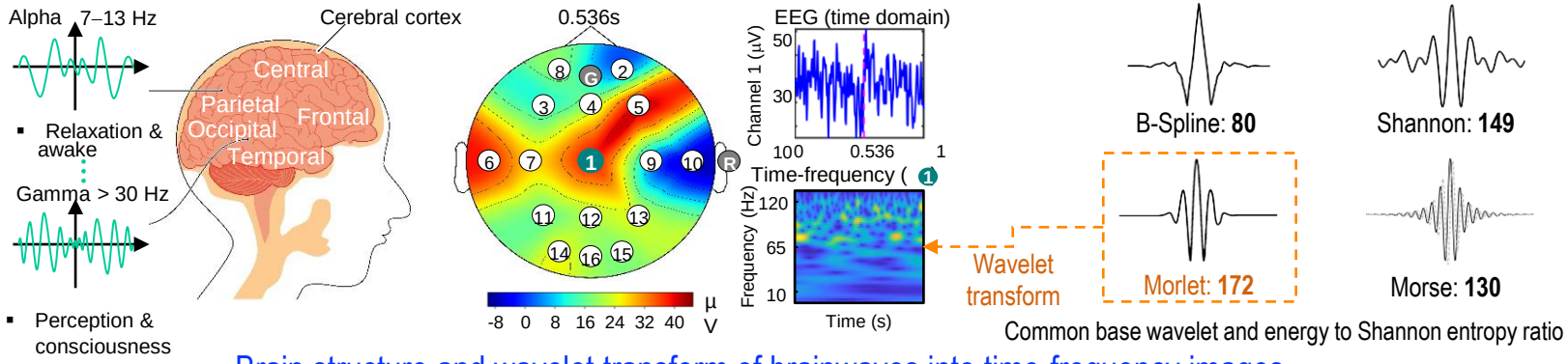
The subject walks on ground and avoid the obstacles

NSF/NRI 2.0: ENG/CMMI and CISE/IIS
Award ID#: 1954548/1830479/1830383/1830295
Poster # TBD

Prediction: Collaborative Action Prediction Based on Brainwaves

Challenge:

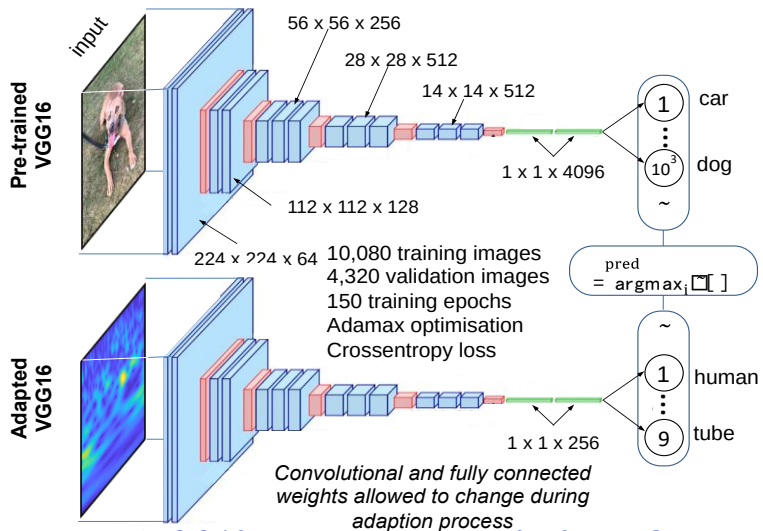
- To investigate how **human brainwaves** can be leveraged to **predict and control robot's action** in collaborative assembly, without the limitations of sensing modalities such as vision and voice under environmental disturbance on the shop floor.



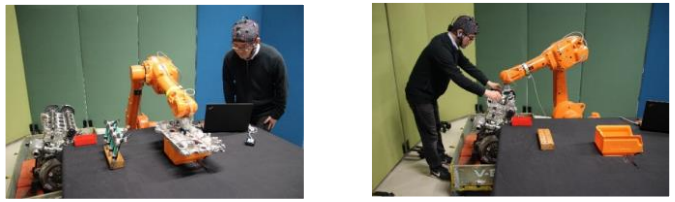
Brain structure and wavelet transform of brainwaves into time-frequency images

Solution:

- A robot action prediction and control method based on **wavelet transform of brainwave EEG signals** has been developed and evaluated.
- Optimal base **wavelet selection** is based on maximizing the energy to Shannon entropy ratio.
- **Transfer learning** is investigated to adapt a pre-trained VGG16 CNN structure for efficient robot activation and control using wavelet transformed EEG images as input to CNN.

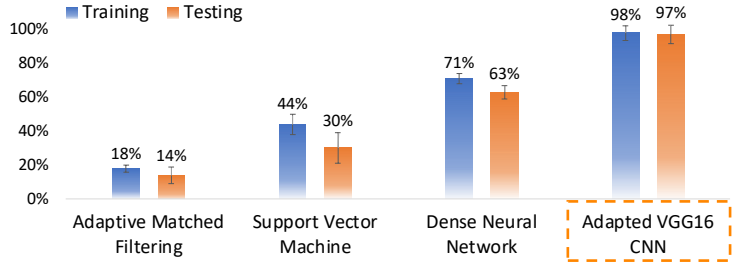


Pretrained VGG16 structure and transfer for EEG-based action prediction



"Robot place cylinder" "Robot insert tube"

Predicted action: examples



Prediction accuracy comparison with other techniques

NSF/NRI 2.0: ENG/CMMI and CISE/IIS
Award ID#: 1954548/1830479/1830383/1830295
Poster # TBD

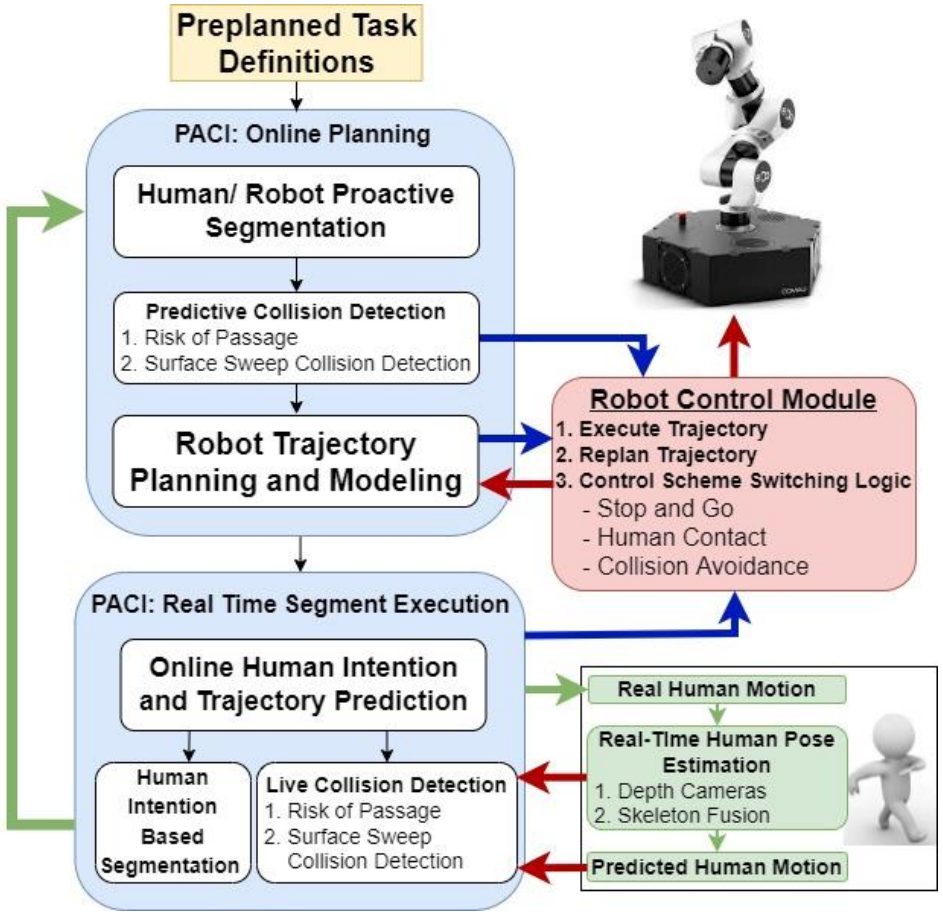
Robot Action: Proactive-n-Reactive Behavior Intelligence

Challenge:

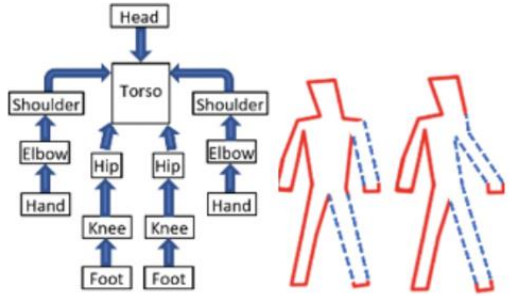
- Seamless **integration** of sensing, cognition, and prediction into robot controller yielding efficient Proactive Adaptive Collaboration Intelligence (PACI) to ensure **safe interactions** with humans and **mitigate production disruptions.**

Solution:

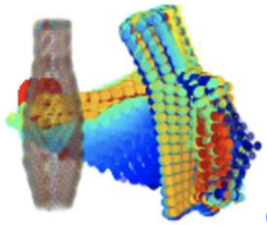
- **Segmentation** framework of predicted, real time, and behavioral classifications to allow for modularity and flexibility within PACI for task and motion adaptation.
- **Parent-child human kinematics** algorithm to correct joint locations from vision trackers→ **mis-trigger reduction.**
- Combining and filtering human poses from multiple cameras with skeleton tracking via stitching **'best' quaternion** representations into a fused skeleton for more accurate tracking of human motion.



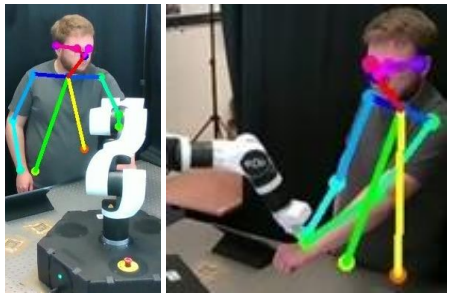
PACI control architecture



Parent/child kinematic model



Improved temporal point cloud generation for predicted human-robot collision detection



Tracked human skeleton with robot as occlusion

NSF/NRI 2.0: ENG/CMMI and CISE/IIS
Award ID#: 1954548/1830479/1830383/1830295
Poster # TBD