Robot Action Anticipation for Collaborative Assembly Tasks

LITERATURE REVIEW

Definition of **Anticipation**

Anticipation: “predict what is the future action by observing only a few portion of an action in progress.”

(Action Anticipation By Predicting Future Dynamic Images, 2019)

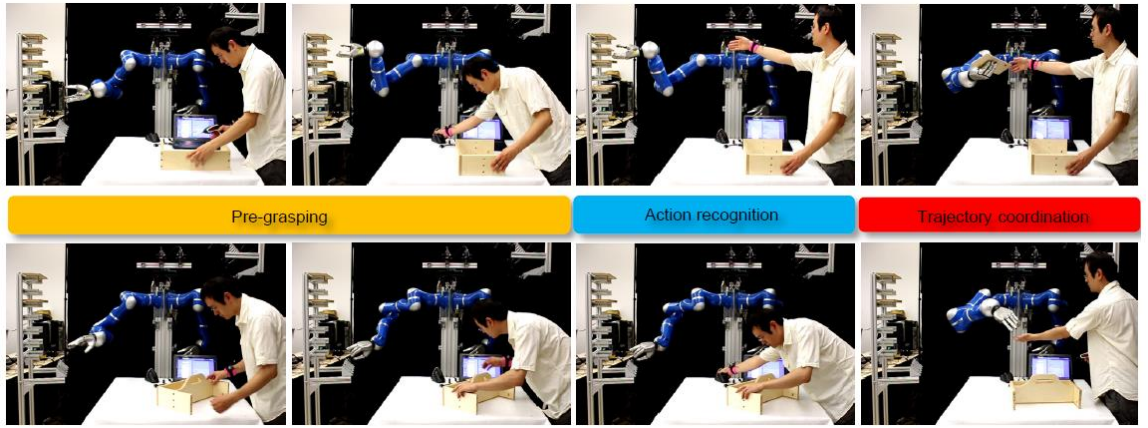
Anticipative interaction primitives for human-robot collaboration

Authors: Guilherme Maeda, Aayush Maloo, Marco Ewerton, Rudolf Lioutikov, Jan Peters

Publisher: AAAI Fall Symposium - Technical Report

Year: 2016

- **Objective:** The robot should decide whether to hand over a screw or a plate and which plate; as the experience with a given user grows, it learns the pattern in which the parts are being assembled;
- **Sensors:** A camera is used and the user has a optical marker on the hand;
- **Methods:** Use a lookup table containing variations of assembly sequences, previously demonstrated by different users; use nearest neighbour sequence in the table that matches the actual sequence of human actions;
- **Contribution:** Simple initial example.



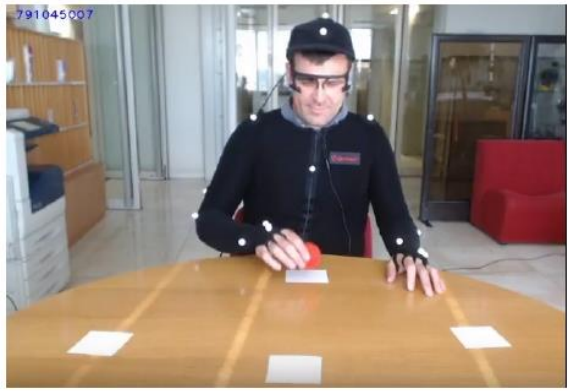
Anticipation in Human-Robot Cooperation: A recurrent neural network approach for multiple action sequences prediction

Authors: Paul Schydlo, Mirko Rakovic, Lorenzo Jamone, José Santos-Victor

Publisher: Proceedings - IEEE International Conference on Robotics and Automation

Year: 2018

- **Objective:** The robot must predict human actions and intent, and understand human non-verbal cues: gaze and body posture;
- **Sensors:** one dataset containing images with optical markers and data from wearable sensors to detect gaze and another dataset containing RGB-D images;
- **Methods:** Predicts multiple action sequences using a Encoder-decoder recurrent neural network topology;
- **Contribution:** Example of using deep neural networks and suggests the idea of predicting multiple actions while the model is unsure of the next action.



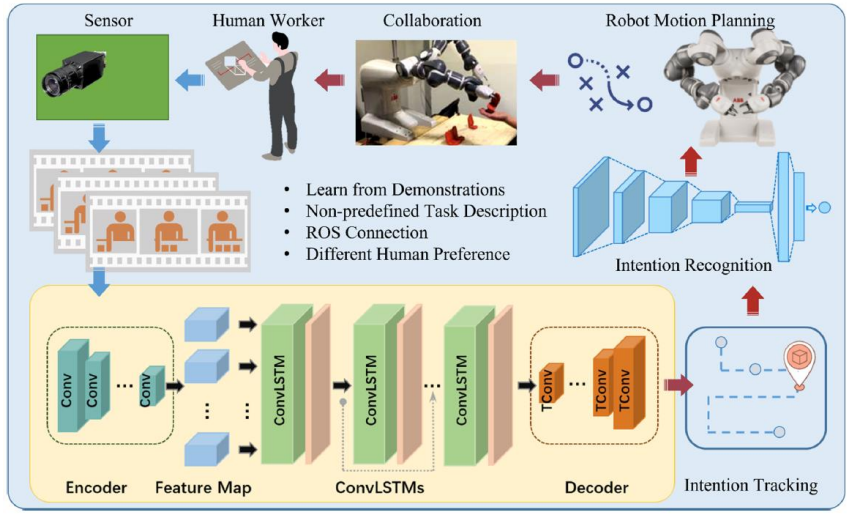
Prediction-Based Human-Robot Collaboration in Assembly Tasks Using a Learning from Demonstration Model

Authors: Zhujun Zhang, Gaoliang Peng, Weitian Wang, Yi Chen, Yunyi Jia, Shaohui Liu

Publisher: Sensors

Year: 2022

- **Objective:** Human intention prediction providing the required pieces to the human worker; learn from user demonstration;
- **Sensors:** Camera;
- **Methods:** ConvLSTM to predict human intention, CNN to recognize the part needed, tracking module based on an extended Kalman filter, ROS Open Motion Planning Library (OMPL) to handle the trajectory planning jobs, speed limits on the robot when close to the human;
- **Contribution:** Contains details about the entire system including collaboration security.



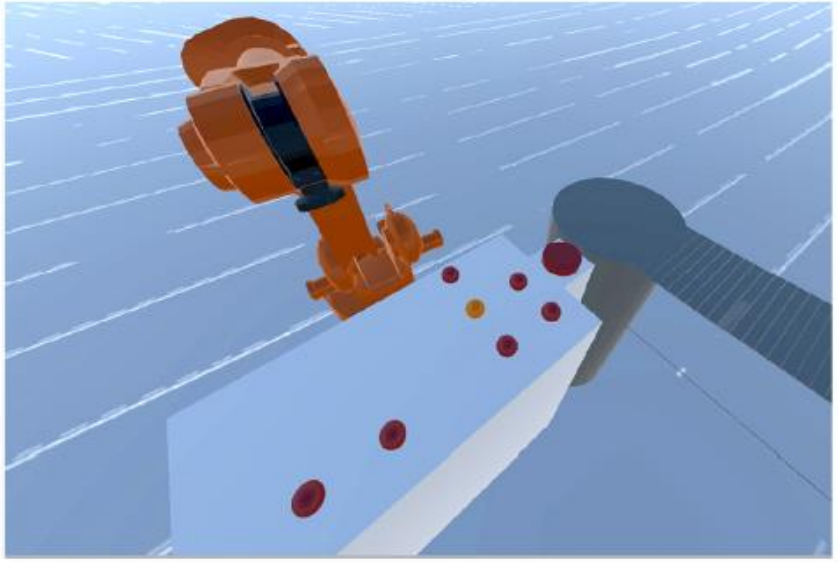
Fostering short-term human anticipatory behavior in human-robot collaboration

Authors: Loizos Psarakis, Dimitris Nathanael, Nicolas Marmaras

Publisher: International Journal of Industrial Ergonomics

Year: 2022

- **Objective:** fostering human anticipatory behavior towards the robot, through visual cues of the robot's next move; robot adaptiveness to the human actions;
- **Sensors/Methods:** Virtual Reality simulation environment along with a human arm motion tracking system;
- **Contribution:** Suggests the idea of making the user know the robot's intent, helping the user have more trust in the robot and therefore decrease task completion time.



Social Cobots: Anticipatory Decision-Making for Collaborative Robots Incorporating Unexpected Human Behaviors

Authors: Görür O., Rosman B., Sivrikaya F., Albayrak S.

Publisher: ACM/IEEE International Conference on Human-Robot Interaction

Year: 2018

- **Objective:** handle unexpected conditions:
  - when the human's intention is estimated to be irrelevant to the assigned task and may be unknown to the robot, e.g., motivation is lost, another assignment is received, onset of tiredness;
  - when the human's intention is relevant but the human doesn't want the robot's assistance in the given context, e.g., because of the human's changing emotional states or the human's task-relevant distrust for the robot;
- **Sensors:** Camera;
- **Methods:** Partially observable Markov decision process (POMDP);
- **Contribution:** Alerts to unexpected situations that must be dealt with.

Summary

DATA SOURCES	SUPERVISED LEARNING	UNSUPERVISED LEARNING	REINFORCEMENT LEARNING	OTHERS
• RGB/RGBD images: pose, gaze, hand gestures, emotions, object information • Voice commands • Accelerometry • Muscular Activity • Sensor Fusion	• Recurrent Neural Networks such as LSTM • Convolution Neural Networks (CNN) • Nearest Neighbor • SVM • Decision Trees • Naive Bayes	• Gaussian Mixture model (GMM) • Hidden Markov model (HMM) • Variational Autoencoder (VAE)	• Q-learning • SARSA • Markov decision processes (MDP)	• Look-up table of assembly sequences • Open Pose