Robot Action Anticipation for Collaborative Assembly Tasks

LITERATURE REVIEW

Definition of **Anticipation**

Anticipatory System: "a system containing a predictive model of itself and/or of its environment, which allows it to change state at an instant in accord with the model's predictions pertaining to a later instant"

"robots can use anticipation to learn how to control their own bodies"

"robots can use anticipation to predict the behaviour of themselves interacting with others, and hence demonstrate improved safety, or simple ethical behaviours"

"Anticipation in Robotics", 2018

Action **Recognition** vs Action **Anticipation**

Action Recognition: “uses an entire sequence of information, which represents one performed action, to associate the observed action to one possible action class”

Action Anticipation: “classifying an action even before it occurs, by using the partial information provided up to a certain moment in time”

“Action anticipation for collaborative environments: The impact of contextual information and uncertainty-based prediction”, 2021

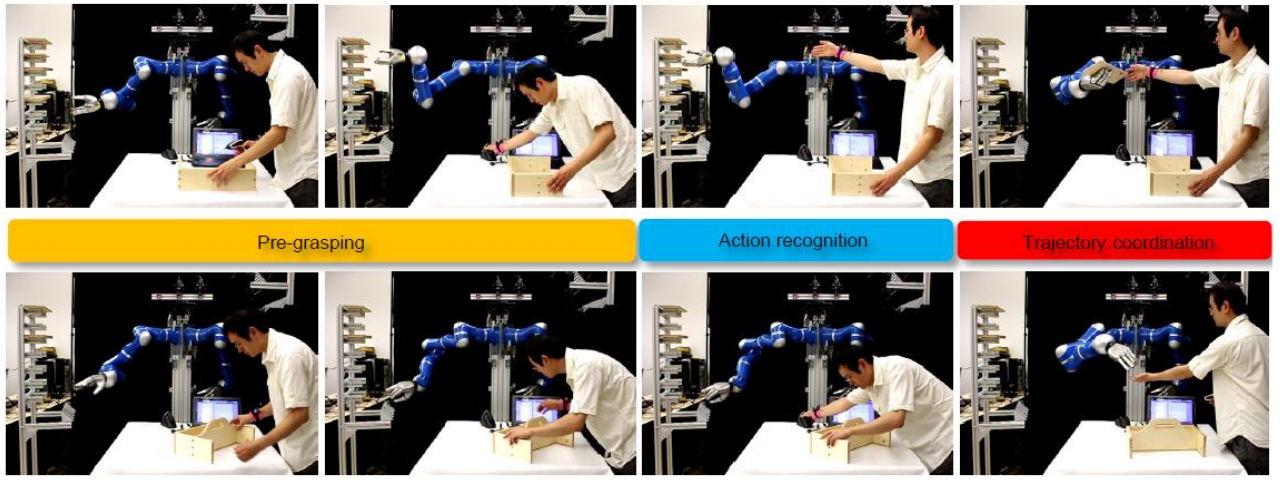
Anticipative interaction primitives for human-robot collaboration

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

Publisher: AAAI Fall Symposium - Technical Report

Year: 2016

- The robot should decide whether to hand over a screw or a plate and which plate;
- A camera is used and the user has a optical marker on the hand;
- As the experience with a given user grows, it learns the pattern in which the parts are being assembled;
- 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.



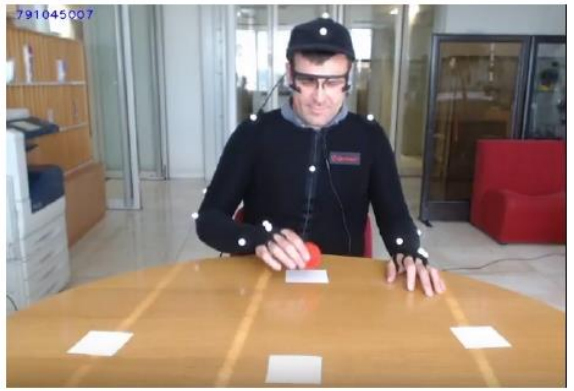
Anticipation in Human-Robot Cooperation: A recurrent neural network approach for multiple action sequences prediction

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

Publisher: Proceedings - IEEE International Conference on Robotics and Automation

Year: 2018

- The robot must predict human actions and intent, and understand human non-verbal cues: gaze and body posture;
- Encoder-decoder recurrent neural network topology;
- Predicts multiple action sequences;
- 2 datasets were used: the first one contained images with optical markers and data from wearable sensors to detect gaze and the second one contained RGB-D images.



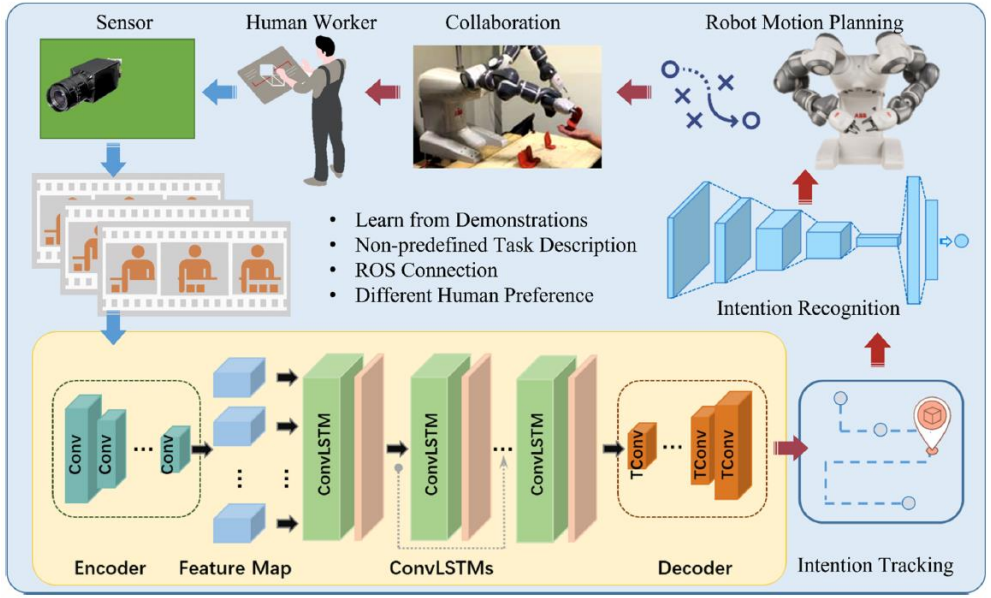
Prediction-Based Human-Robot Collaboration in Assembly Tasks Using a Learning from Demonstration Model

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

Publisher: Sensors

Year: 2022

- Human intention prediction providing the required pieces to the human worker;
- ConvLSTM to predict intention and CNN to recognize the part needed;
- There are speed limits on the robot, it normally stays out of the human safety zone and when moving close to the human, the robot moves at a speed that is slow enough to raise no risk;
- The users shows first the assembly order.



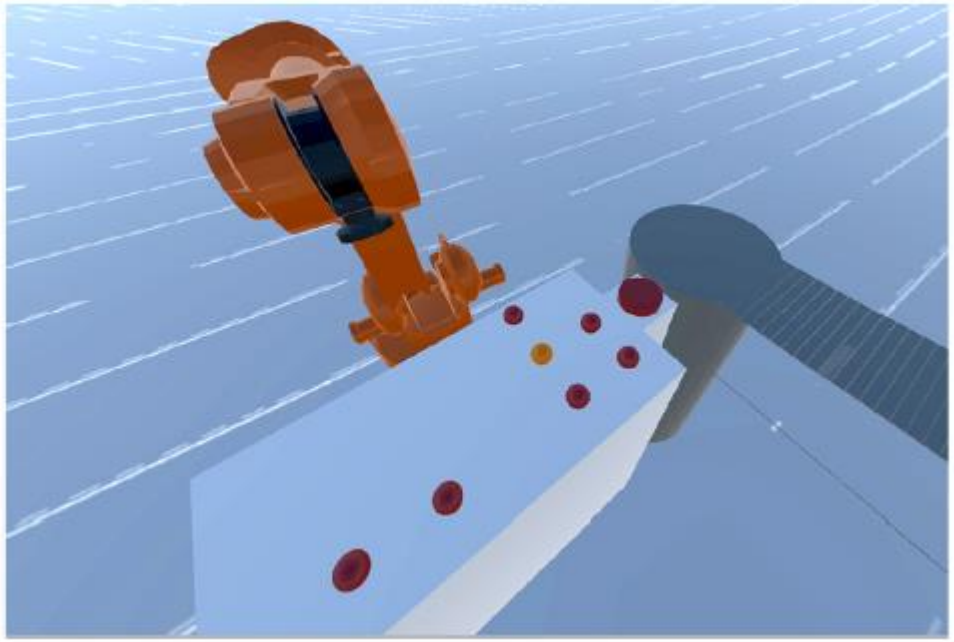
Fostering short-term human anticipatory behavior in human-robot collaboration

Authors: Loizos Psarakis, Dimitris Nathanael, Nicolas Marmaras

Publisher: International Journal of Industrial Ergonomics

Year: 2022

- Tried to foster human anticipatory behaviour towards the robot, through visual cues of the robot's next move;
- The user has more trust in the robot and therefore the task completion time is decreased;
- The testing remained limited to VR;
- The user movement was detected using wearables.



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

- The objective is to 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;
- Partially observable Markov decision process (POMDP);
- Tested in Simulation.

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