THEMA

Enhanced Dynamic Movement Primitive for „Learning from Demonstration“ in Robotic Applications

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Motivation

- The main principle of robot LfD is that end-users can teach robots new tasks without programming.

Method	Descriptions
Traditional Programming	1. Difficult to model a movement 2. If the context changed, need to rebuild the model again
Learning by Demonstration	1. “Programming” by Demonstration 2. If the context changed, simply demonstrate to the robot again

- Learning and utilizing the professional skills from experts

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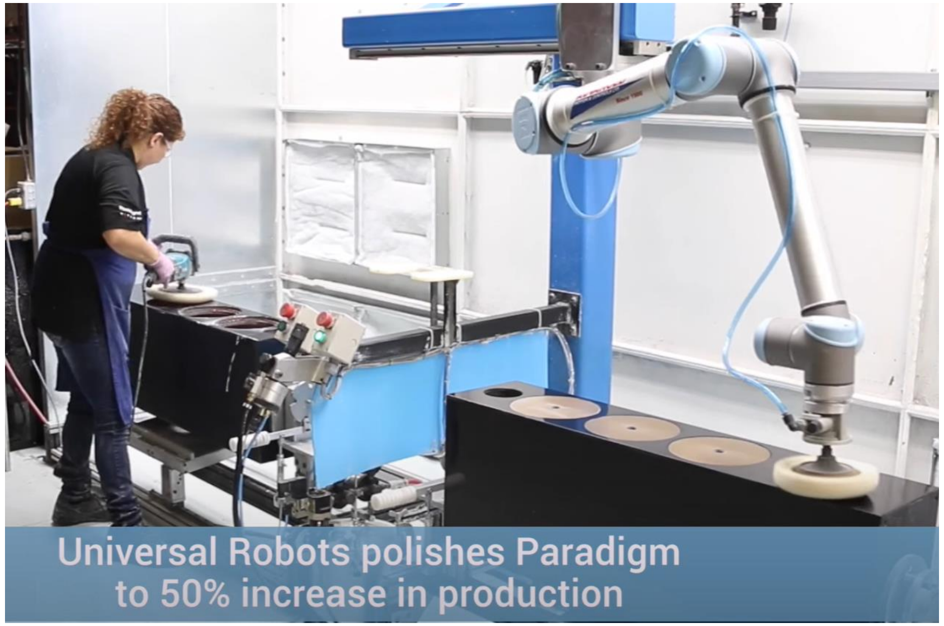
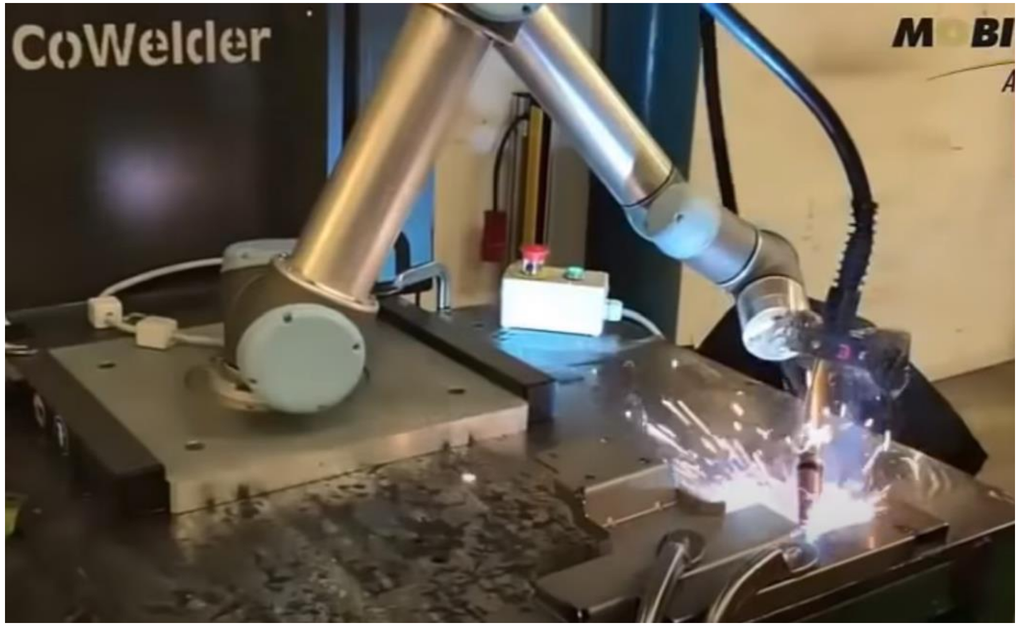
Motivation

- **Learn professional skills from experts**
  - The trajectory of the movement
  - The orientation between the tool and object





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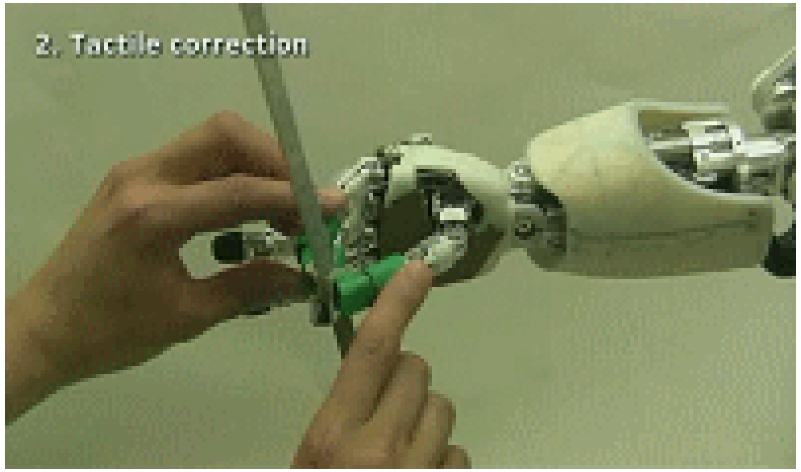
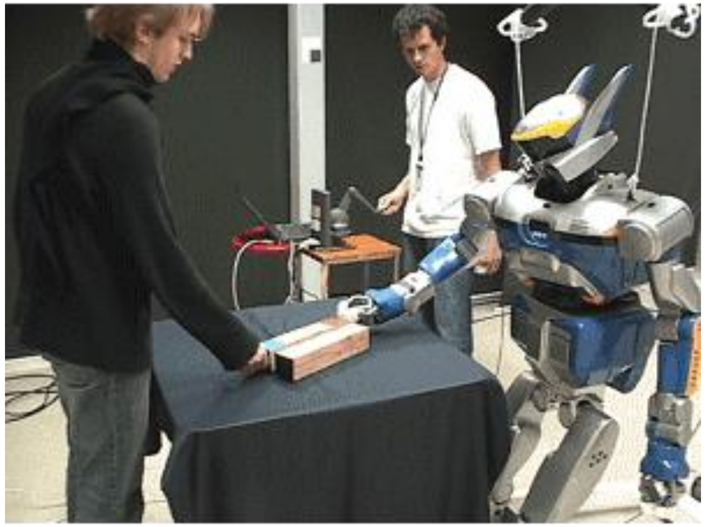
State of the Art

- Teaching Methods
  - Observational Teaching
  - Kinesthetic Teaching
  - Teleoperatioanal Teaching





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State of the Art

Comparison of Teaching Methods

Methods	Description
Observational Teaching (video)	• Teaching is simple, flexible and safe • Can better demonstrate experience
Kinesthetic Teaching	• Have to touch and share the same workspace with the robot
Teleoperatioanal Teaching	• Workers need be trained to use the controller before teaching • The experience cannot be taught directly

State of the Art

- **Model Training (Movement Primitive Representations):**
  - **Dynamic Movement Primitives**
  - **Probabilistic modeling methods**: Hidden Markov Models, Gaussian Mixture Regression, some combination

Comparison of Movement Primitive Representations	
DMP	1. Stability is high 2. Only need one Demonstration 3. Low computational cost 4. Combine with other technical (e.g. Reinforcement Learning)
Probabilistic modeling methods	1. Encoding of multiple demonstrations 2. Expensive computational cost

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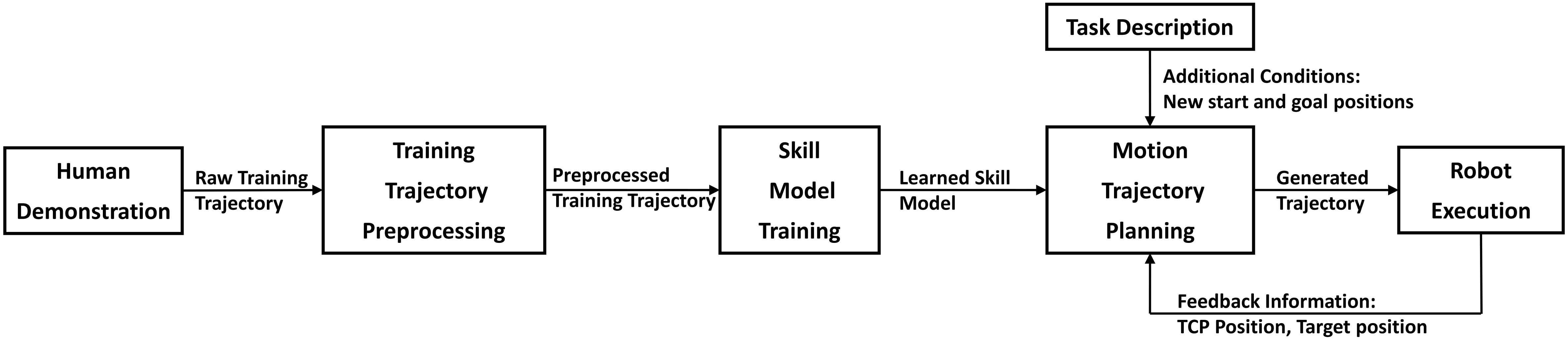
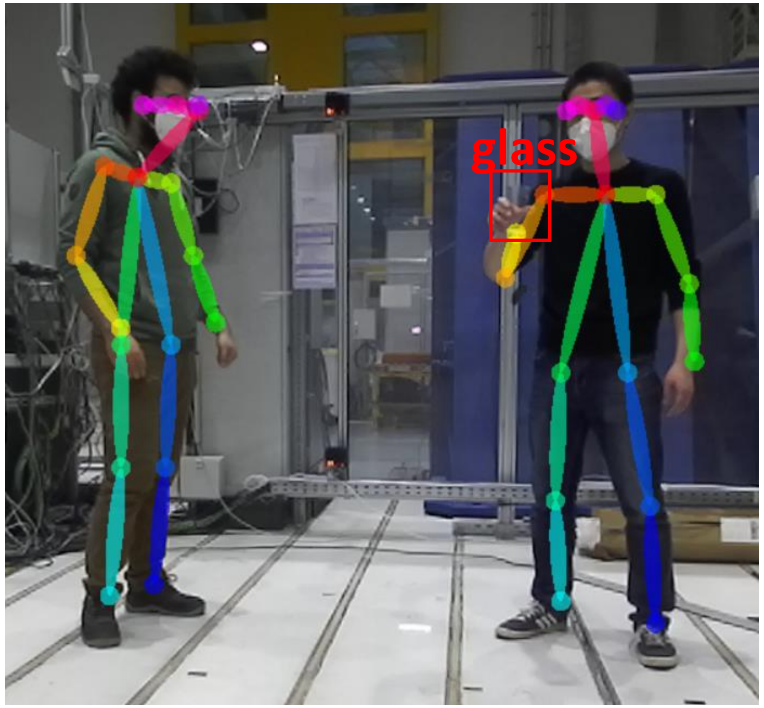
System Overview of Learning from Demonstration

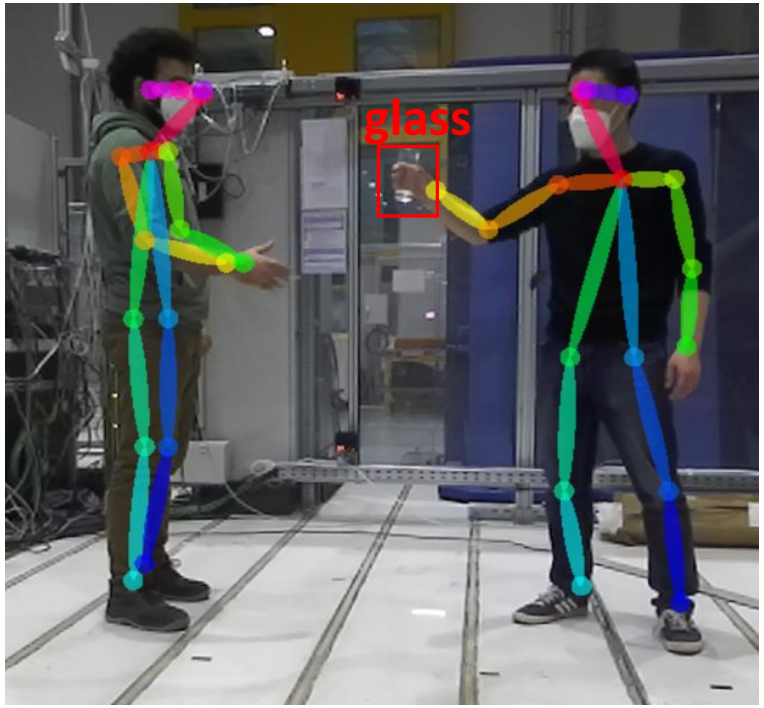


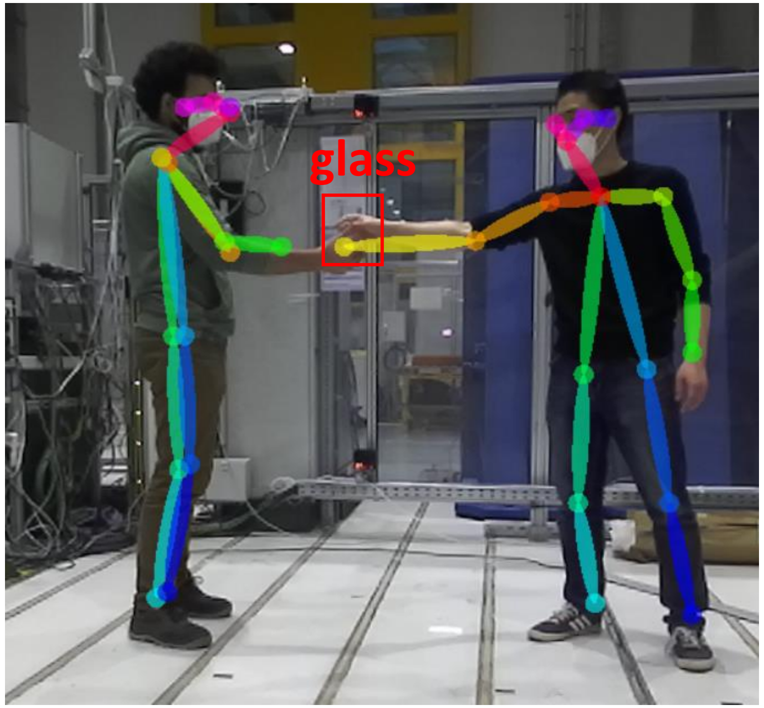
1. Collect training data from human‘s demonstration (OpenPose)
2. Preprocess the raw training trajectories
3. Use training data to get the model of the movement (DMP)
4. Set the new start and goal positions and use learned model to generate the new trajectory
5. Robot executes the generated motion trajectory

Human Demonstration

- Handover a glass to another people
- Use human body-detect algorithm (OpenPose) and ZED camera to detect and record the handover trajectory







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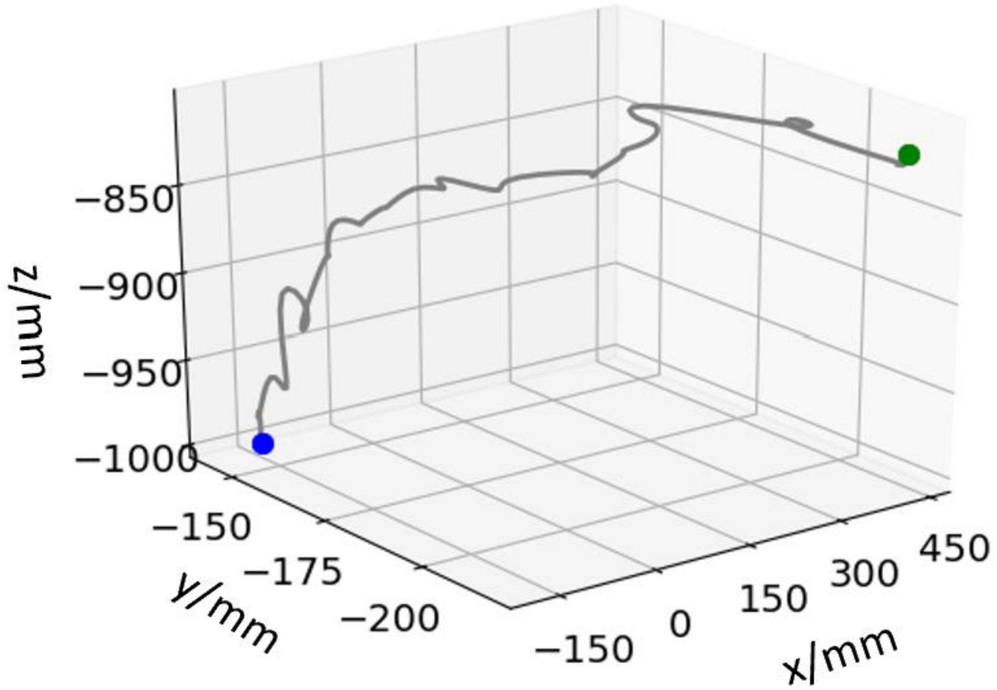
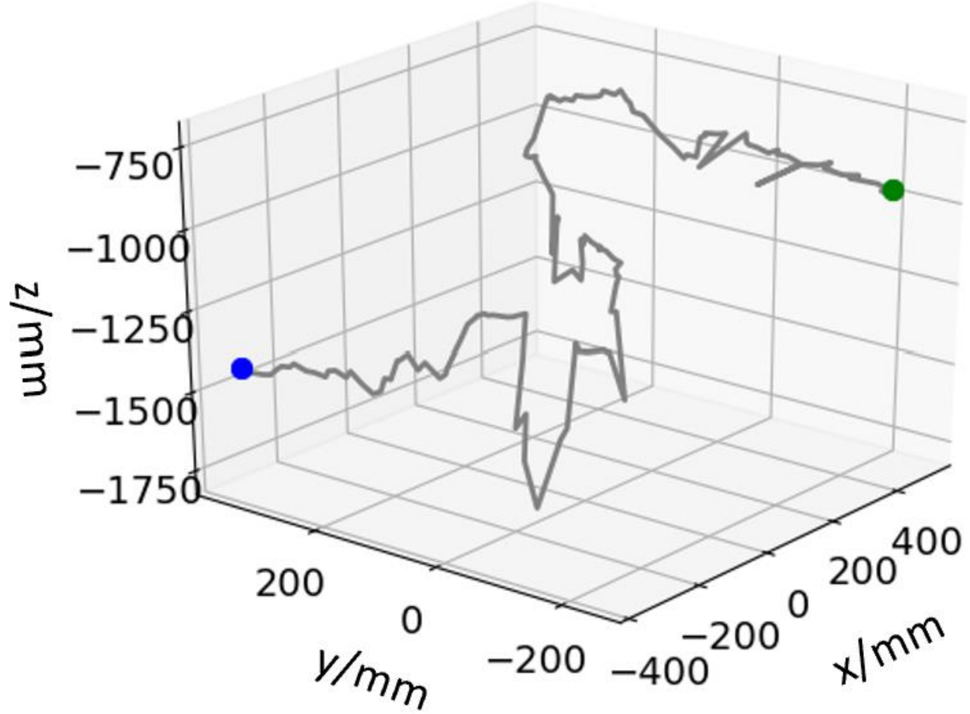
Human Demonstration

- **Recorded raw motion trajectories**





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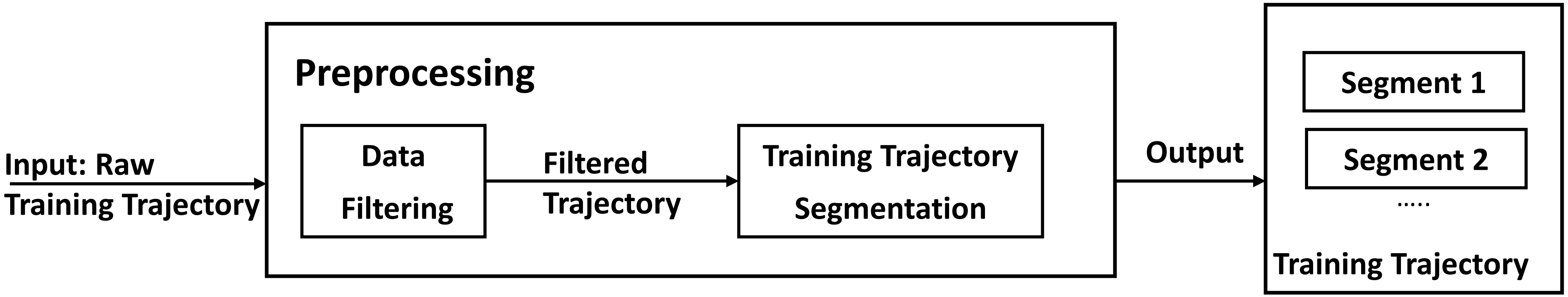
Training Trajectory Preprocessing

- Data Filtering
- Training Trajectory Segmentation



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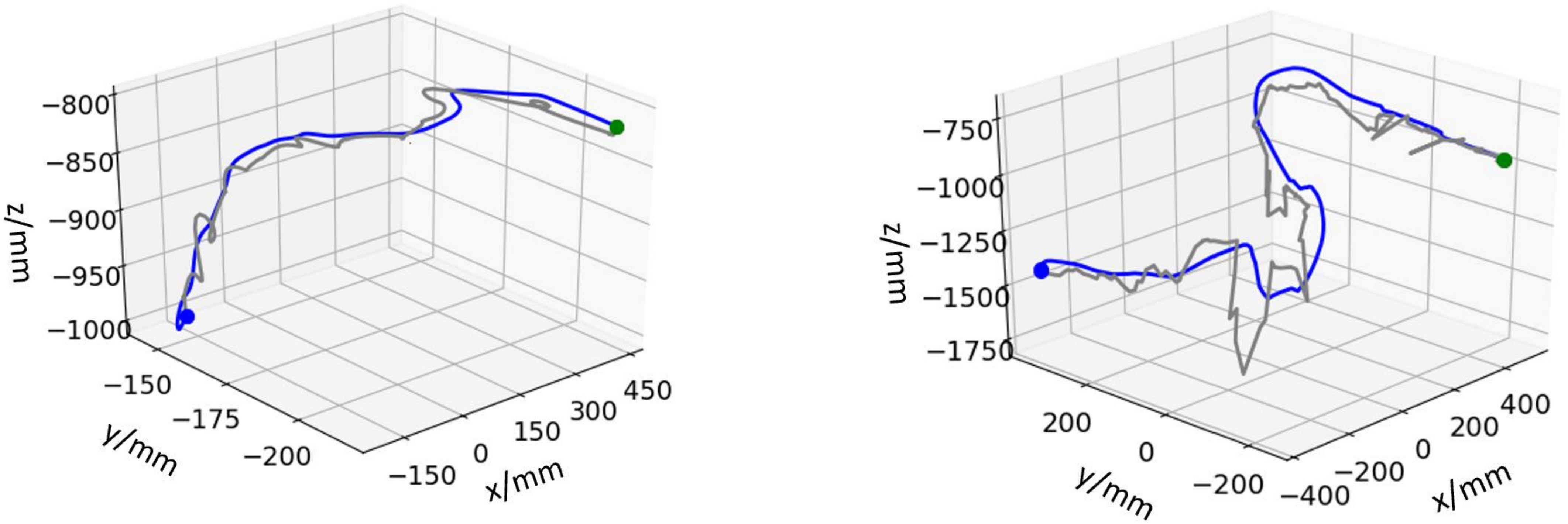
Training Trajectory Preprocessing

- **Preprocessed motion trajectories by using Kalman filter**



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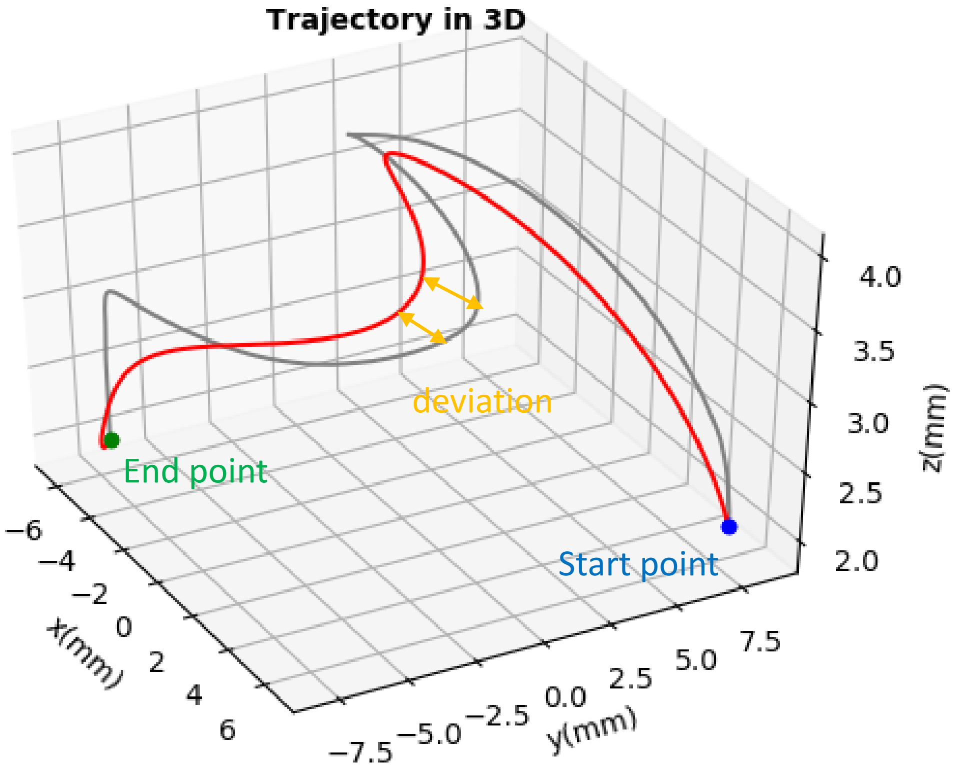
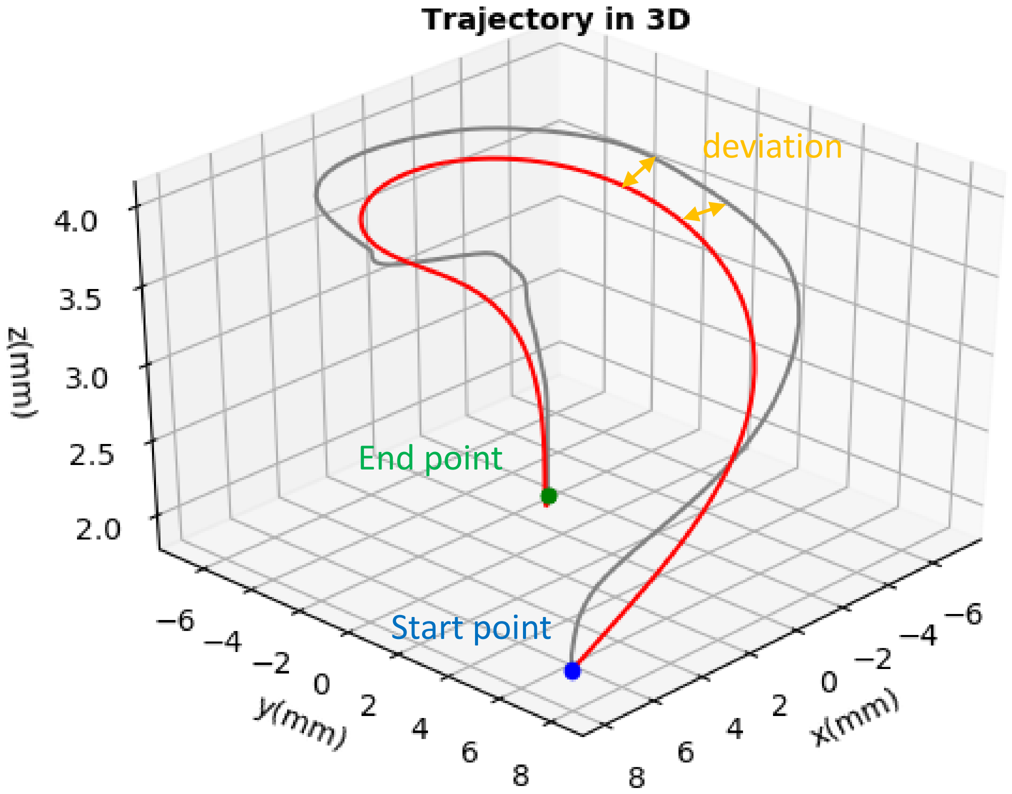
The Accuracy of the Learned Model by using Standard DMP

Deviation between generated trajectories and training trajectories





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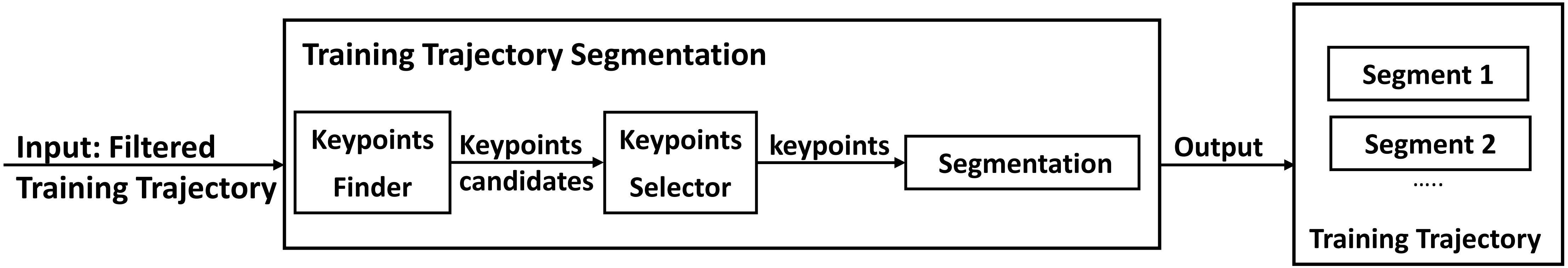
Training Trajectory Segmentation

- **Idea: Segment the training trajectory into several parts to increase the accuracy of the learned model**
- **Preprocessing Module:**
  1. **Keypoints Finder**: Find keypoints candidates based on the velocity of the training trajectory
  2. **Keypoints Selector**: Remove keypoints which do not need
  3. **Training Trajectory Segmentation**



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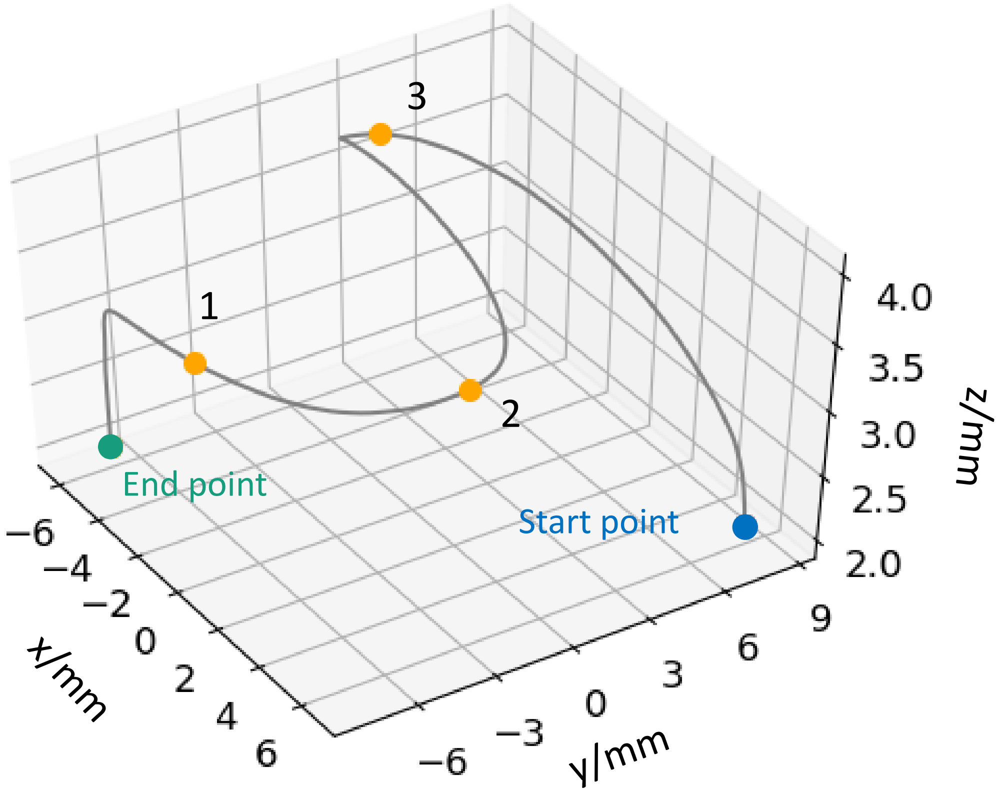
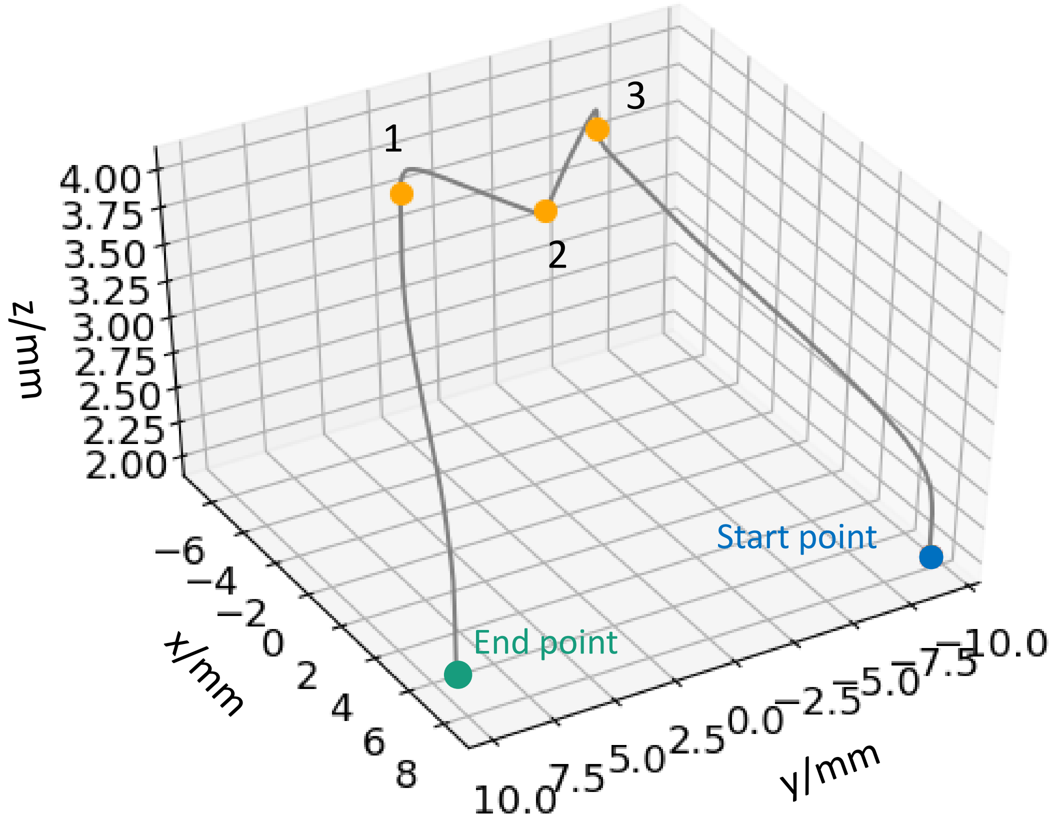
Found keypoints of training trajectories





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Model Training

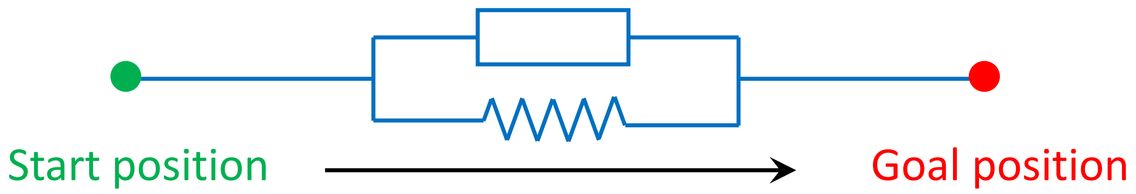
- **Dynamic Movement Primitive**

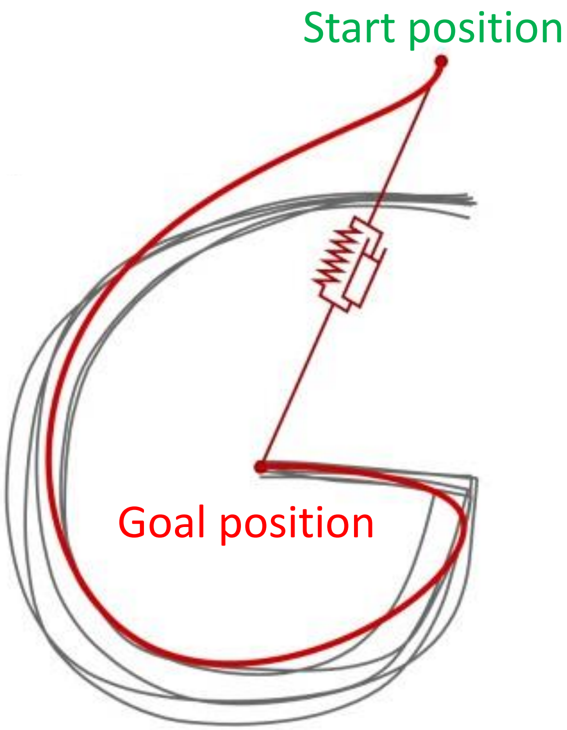
$$\ddot{\boldsymbol{x}} = \boxed{k^{\mathcal{P}}(\boldsymbol{\mu}_T - \boldsymbol{x}) - k^{\mathcal{V}}\dot{\boldsymbol{x}}} + \boxed{\boldsymbol{f}(s)}$$

PD-Controller

External Force Term

μT: Goal position
X: Position of the system
Kp: Spring constant
Kv: Damped term
f(s): External force term
S: Phase variable





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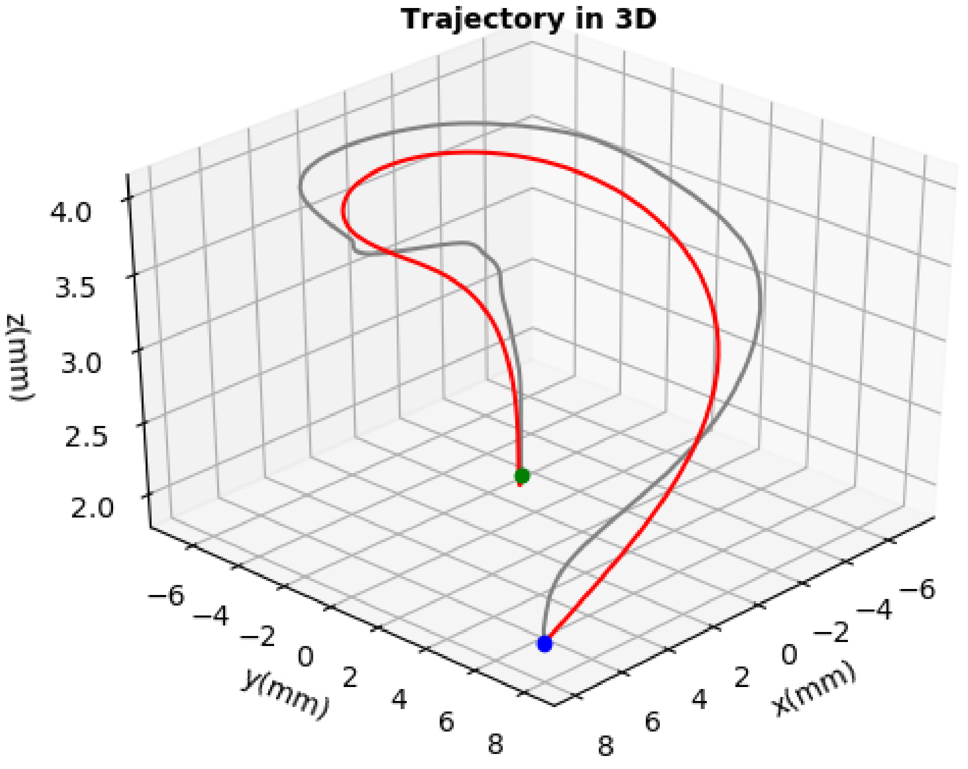
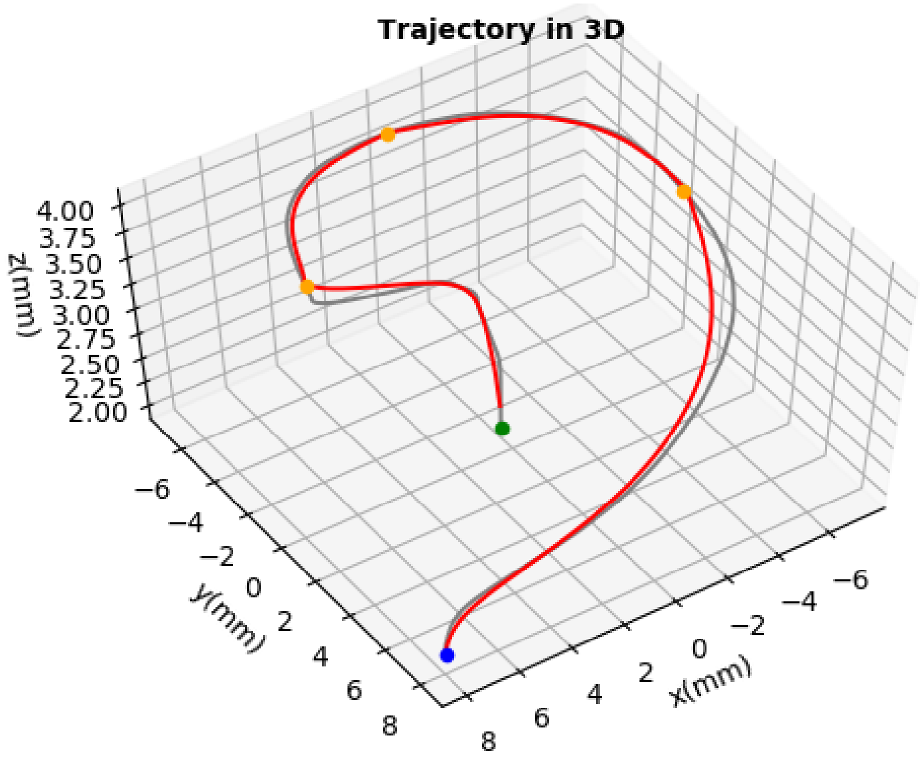
Generated motion trajectory by DMP when using with and without keypoints





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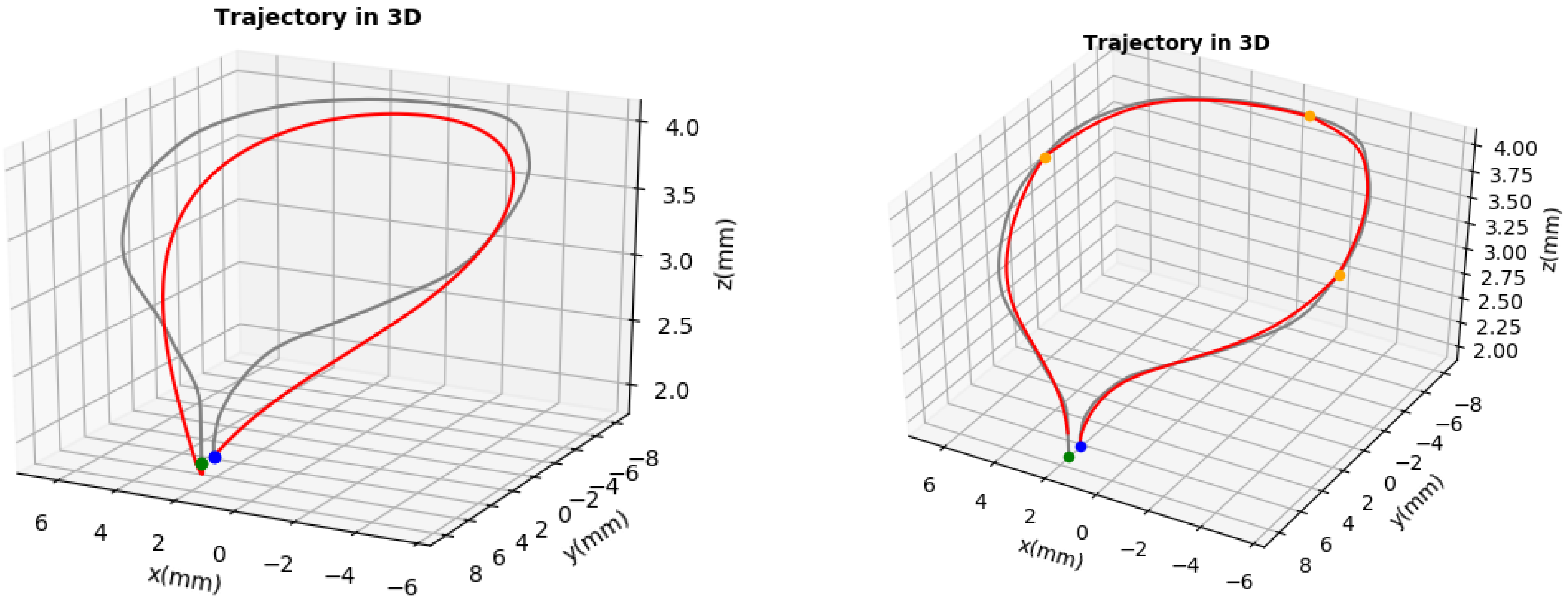
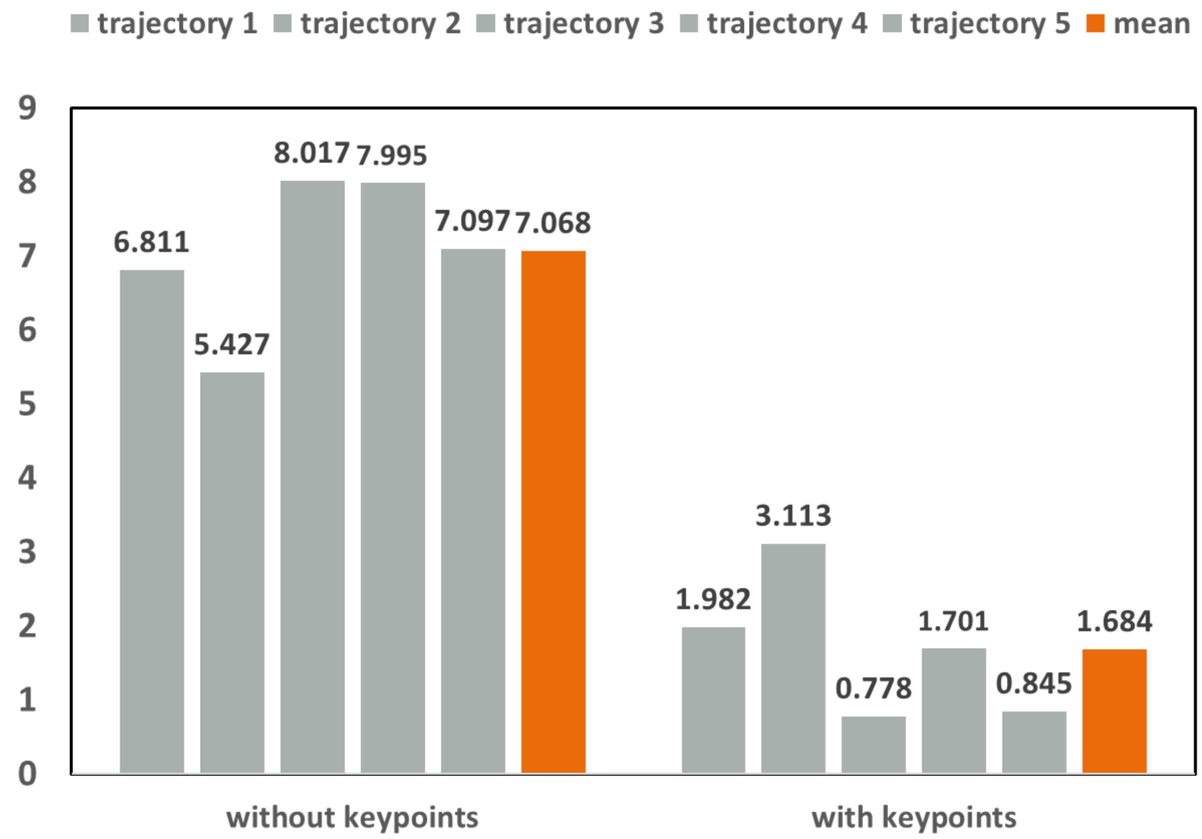


Accuracy of learned Model by using DMP with and without keypoints

$$deviation = \frac{\sum_{i=1}^{N} \sqrt{(x_i^{train} - x_i^{gen})^2 + (y_i^{train} - y_i^{gen})^2 + (z_i^{train} - z_i^{gen})^2}}{N}$$



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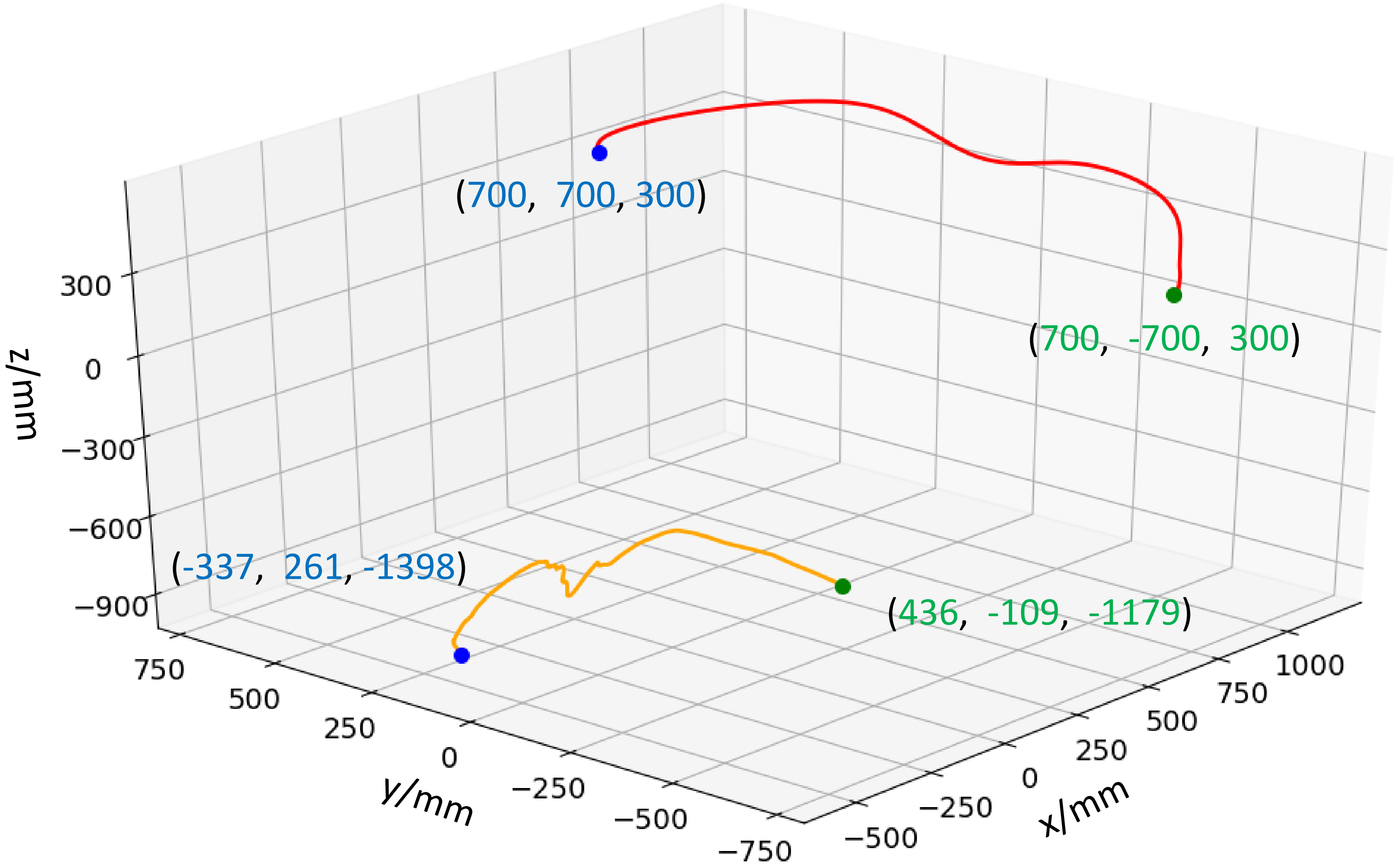
Generated Motion trajectory (change the start and goal positions)



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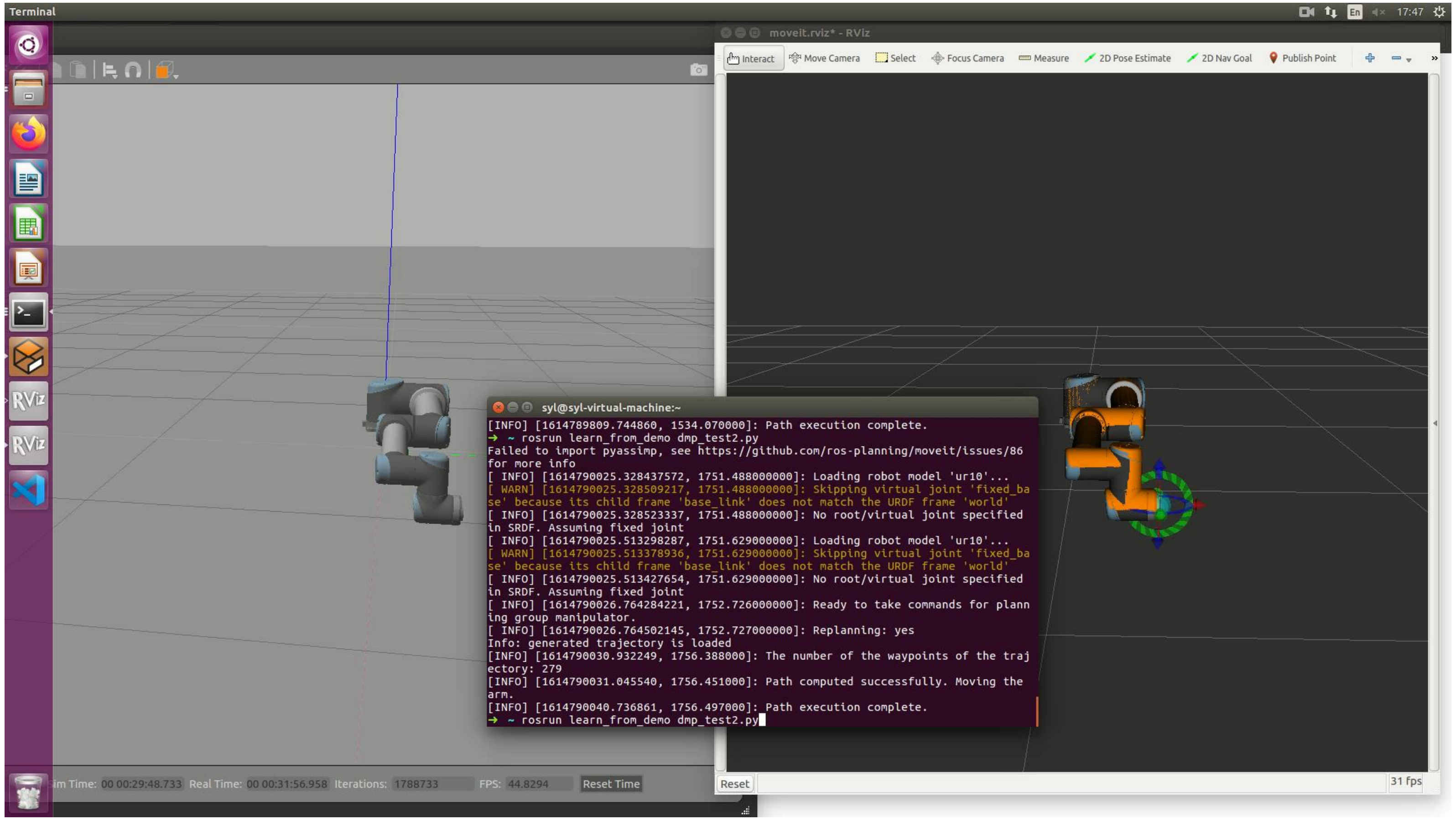
Robot Execution in ROS Gazebo



THEMA PRESENTATION

Thank you for your attention !