QDP: Learning to Sequentially Optimise Quasi-Static and Dynamic Manipulation Primitives for Robotic Cloth Manipulation

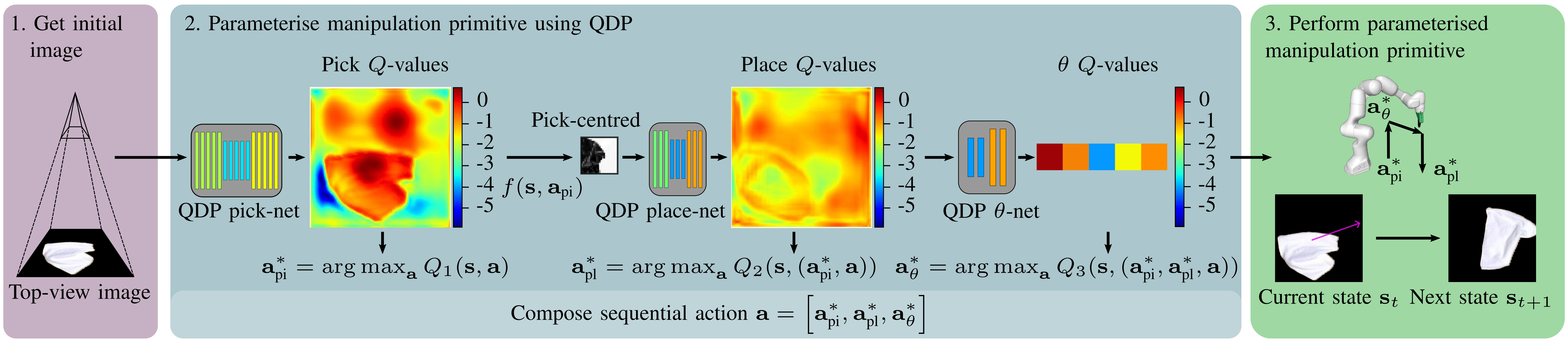
David Blanco-Mulero[1], Gokhan Alcan[1], Fares J. Abu-Dakka[2], Ville Kyrki[1]

[1] Aalto University, [2] Munich Institute of Robotics and Machine Intelligence

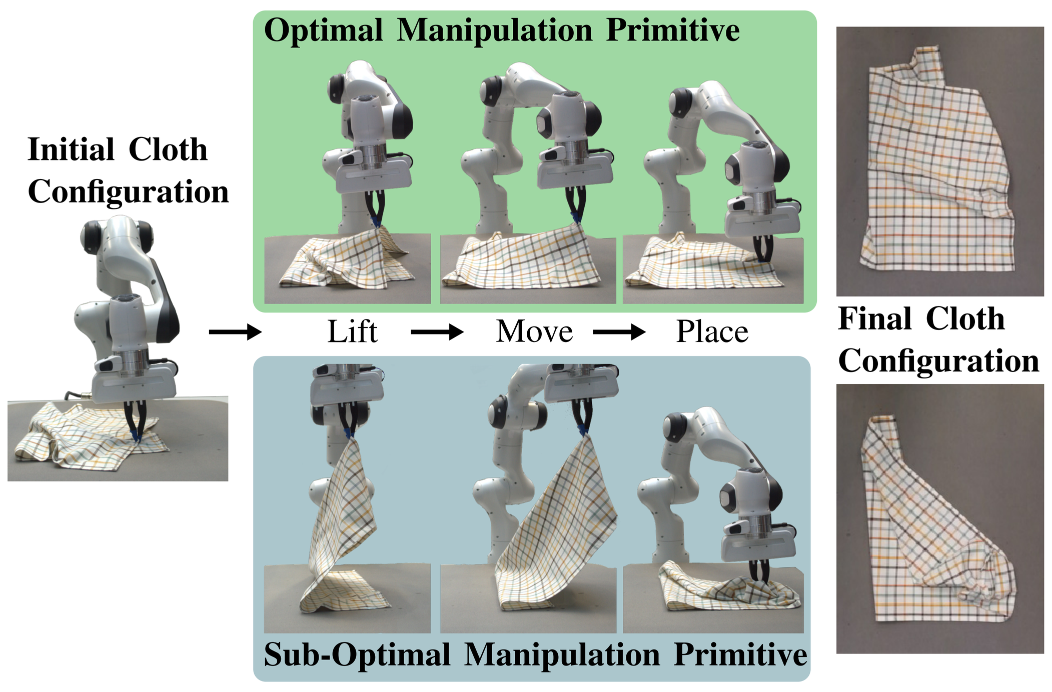
Contacts: *david.blancomulero@aalto.fi*

Project website:

Cloth manipulation performance is significantly affected by variables such as stiffness or density, and the **velocity** or **trajectory** of **quasi-static** and **dynamic manipulation primitives**, an aspect often **neglected**. To address this, we have developed the **Quasi-Dynamic Parameterisable (QDP)** method, which optimizes parameters like motion velocity alongside pick and place locations. Our method uses Sequential Reinforcement Learning to optimise the primitive parameters sequentially. Our results show that optimizing these parameters improves cloth unfolding performance by 20% in simulations, and real-world experiments prove the **benefits** of **adjusting velocity and height** for **cloths** of **different properties**.



QDP sequentially optimises the manipulation primitive parameter values to achieve better cloth configurations (*green*) compared to sub-optimal parameter values (*blue*) for a manipulation primitive such as pick-and-place.



Manipulation Primitives

- **Dynamic Quintic Polynomial:**

Dynamic manipulation primitive which is defined by its velocity. This primitive follows a semi-circle shaped trajectory from $\mathbf{a}_{pi}$ to $\mathbf{a}_{pl}$ using a fifth order polynomial.

- **Pick-and-Place (P-n-P):**

Quasi-static manipulation primitive with parameters $\{h_\theta, t_\theta\}$, where the height has the range of values $h_\theta \in [0.1, 0.2, 0.3, 0.4, 0.5]$ m. to lift the cloth; and the time to move from $\mathbf{a}_{pi}$ to $\mathbf{a}_{pl}$ is within the range of $t_\theta \in [10, 11, 12, 13, 14, 15]$ seconds.

- **Drag:**

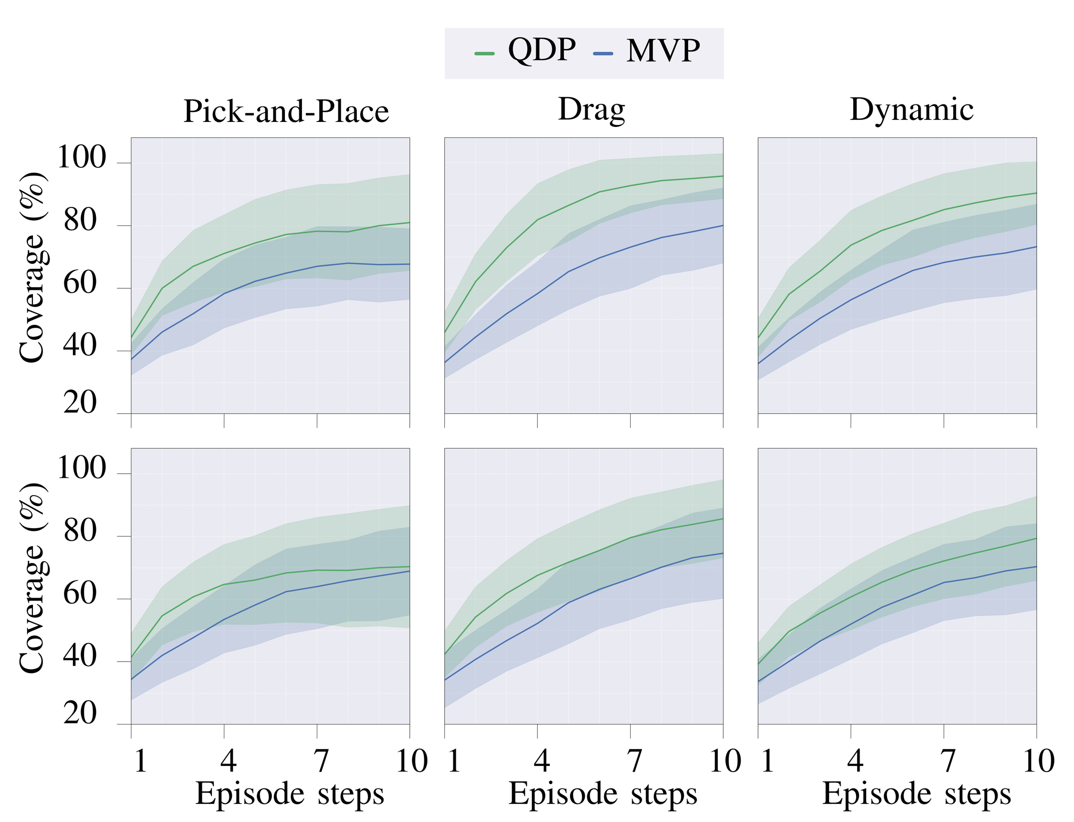
Quasi-static primitive which can be seen as a P-n-P primitive where h_θ is equal to zero, and the time has the range of values as the P-n-P primitive.

Experimental Results

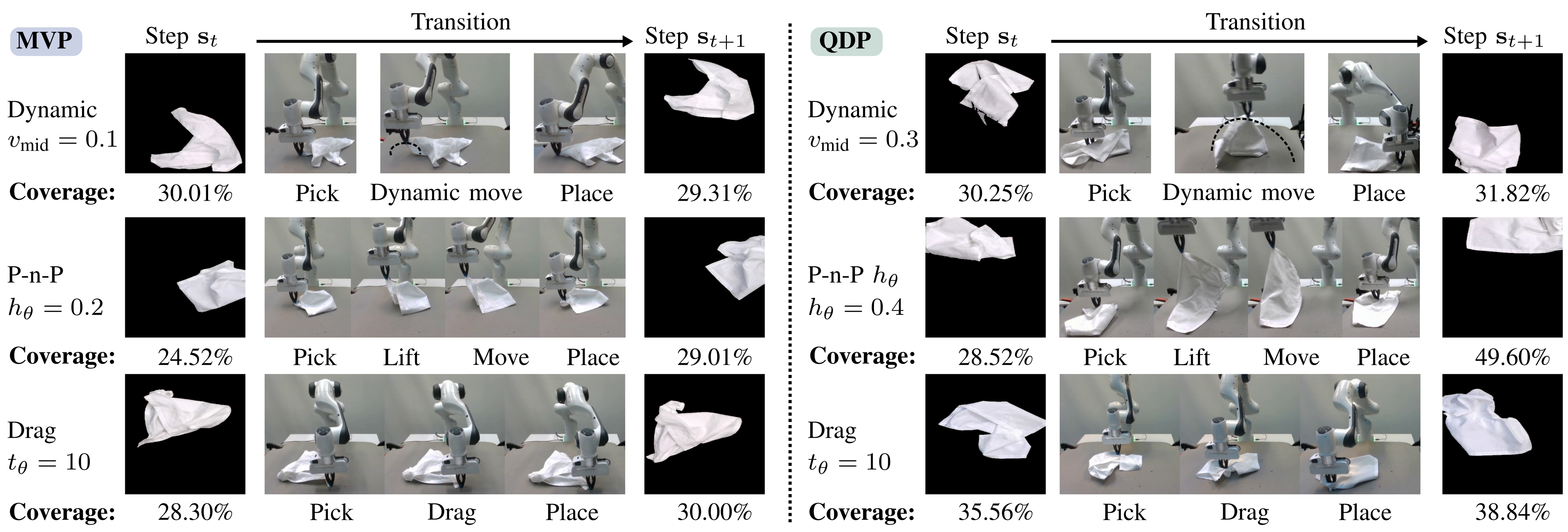
What do we analyse?

- The **impact** of learning to **sequentially optimise** parameters such as the **height** or **velocity** of **pre-defined manipulation primitives**
- The **performance** of **QDP** when transferred to the real-world in a **zero-shot manner**

Simulation Results



Real-world Results



The proposed sequential decision process allows a **greater variety** and **complexity of primitives** to be used. **QDP** paves the way to:

- **a broader range** of complex manipulation primitives,
- **eliminating the human effort** of fine-tuning or designing primitives,
- **reducing computational requirements** due to the sequential decision process.

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