Position and Orientation Control of Shadow Arm with Dual Quaternions

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Motivation

- One important task for dexterous manipulation is the control of the arm where the multi-fingered hand is installed since the controlled arm approaches the hand towards the object to be manipulated.
- **Classical Position Control** of robotic arms has several disadvantages:
  - Two control loops: one for translation and one for rotation.
  - It is difficult to calculate the orientation error.
  - There are some singularities due to orientation representation (such as gimbal lock in Euler angles).
- A new arm control scheme based on dual quaternions is proposed in order to overcome these limitations.

Dual Quaternion Representation

- Rigid motions can be represented by dual quaternions:
  - Singularity-free representation
  - Only 8 parameters
  - Rotation and translation are represented in a single vector.
  - A sequence of ridig motions is equivalent to dual quaternion product.
- Standard **Denavit-Hartenberg convention** is adapted to the dual-quaternion space so that forward kinematics can be calculated with dual quaternions:

$$\boldsymbol{q}_{effector}=\boldsymbol{q}_{DH(1)}\cdot\boldsymbol{q}_{DH(2)}\cdots\boldsymbol{q}_{DH(n)}$$

$$Where\ \boldsymbol{q}_{DH}=\boldsymbol{q}_{rot}(z,\theta)\cdot\boldsymbol{q}_{trans}(z,d)\cdot\boldsymbol{q}_{trans}(x,a)\cdot\boldsymbol{q}_{rot}(x,\alpha)$$

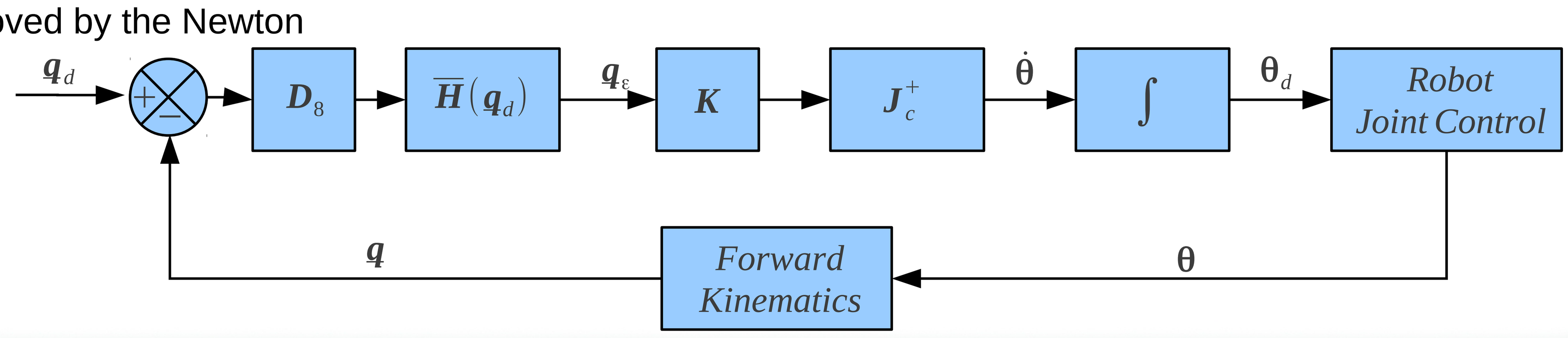
Dual Position/Orientation Control

- The dual quaternion error is expressed with a simple difference.
- $\overline{\boldsymbol{H}}$ is the Hamiltonian operator.
- $\boldsymbol{D}_8=Diag(1,-1,-1,-1,1,-1,-1,-1)$
- $\boldsymbol{J}_c$ is the **constrained Jacobian** : $\boldsymbol{J}_c=\overline{\boldsymbol{H}}(\boldsymbol{q}_d)\boldsymbol{D}_8\boldsymbol{J}$

  Where $\boldsymbol{J}$ is the analytical arm Jacobian obtained from the FK.
- Stability of the controlled system is proved by the Newton

  Method: $\dot{\boldsymbol{q}}_\varepsilon+\boldsymbol{K}\,\boldsymbol{q}_\varepsilon=\boldsymbol{0}$

  Where: $\boldsymbol{q}_\varepsilon=\overline{\boldsymbol{H}}(\boldsymbol{q}_d)\boldsymbol{D}_8(\boldsymbol{q}_d-\boldsymbol{q})$

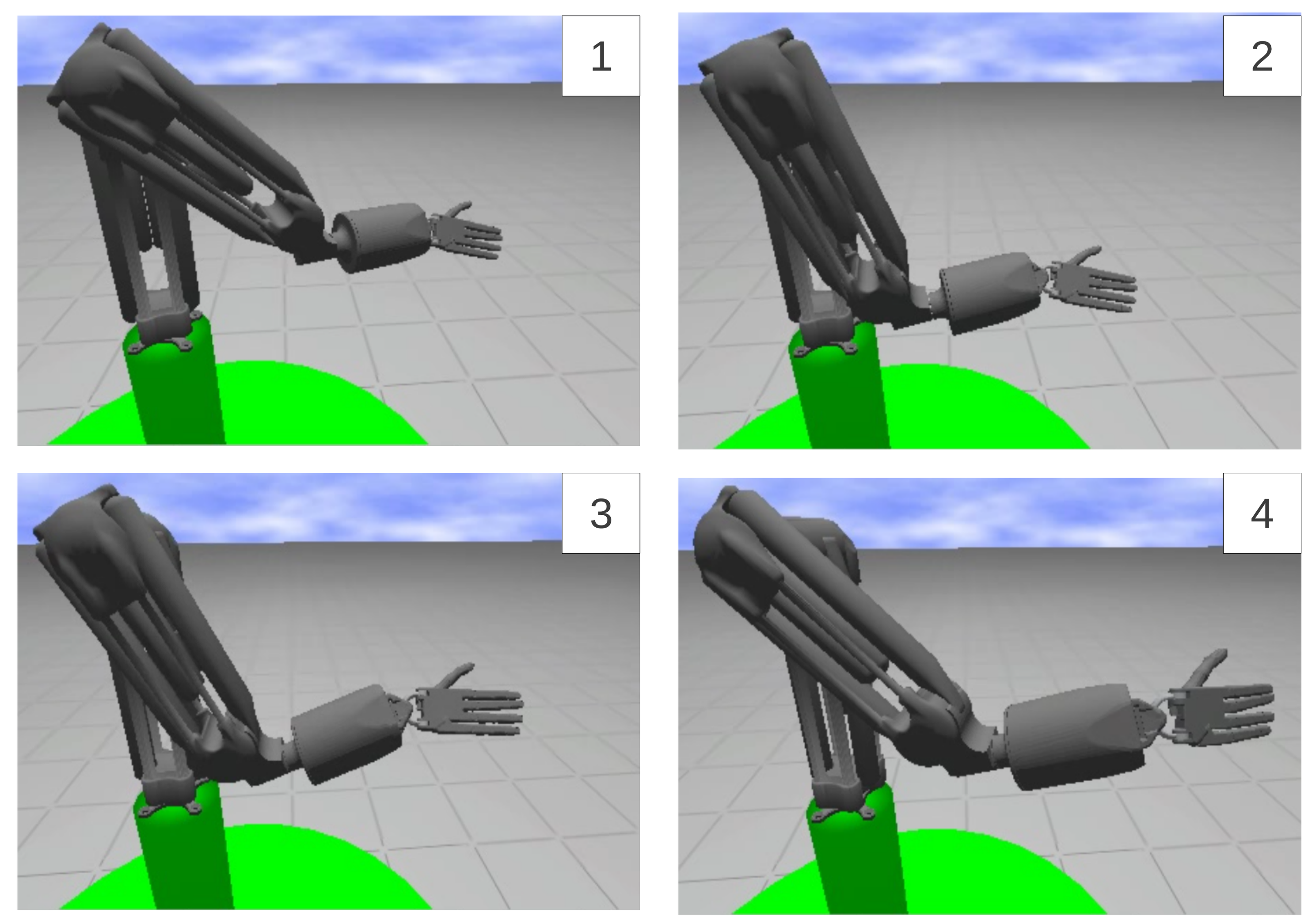


ROS Implementation

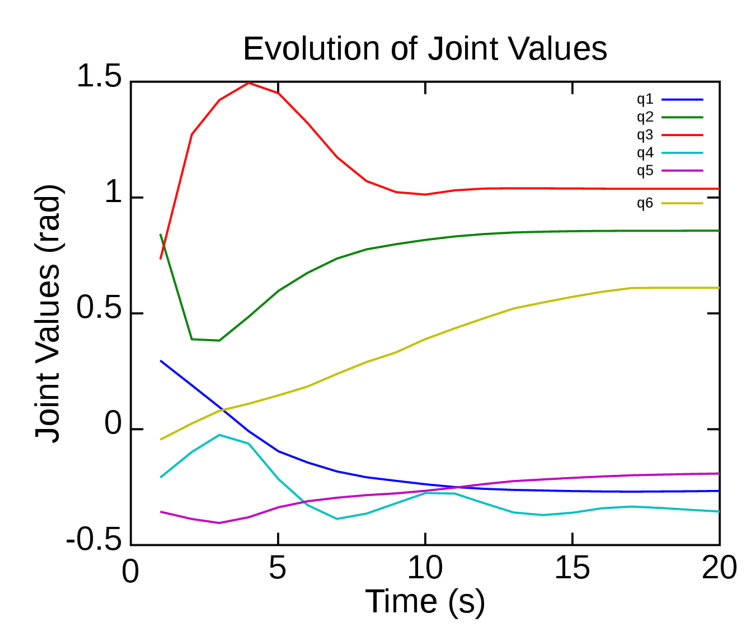
- C++ program which communicates with the Gazebo simulator of the **ROS plaftorm**.
- **Experimental example** of Shadow robot arm control:

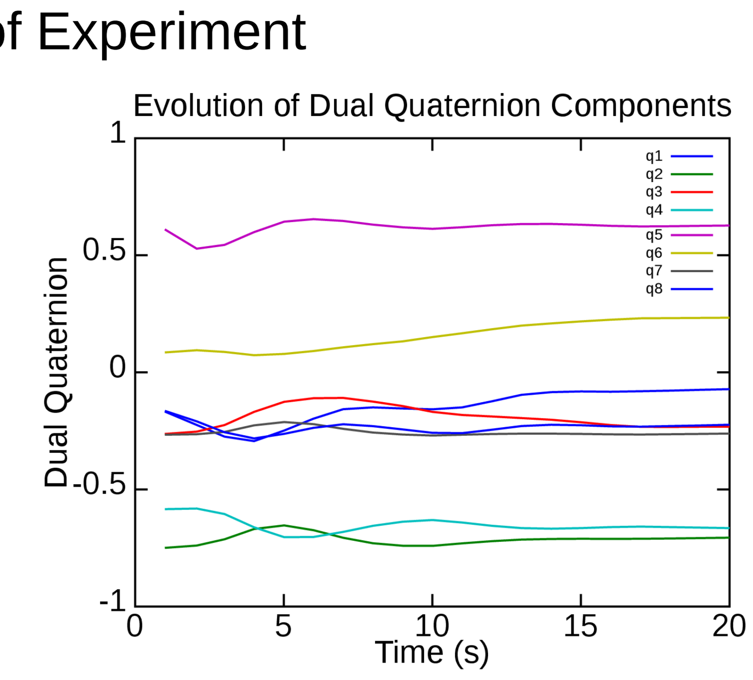
$$\boldsymbol{q}_{begin}=(-0.167393,-0.749489,-0.262869,-0.584060,0.610439,0.085160,-0.266136,-0.164453)$$
$$\boldsymbol{q}_{end}=(-0.071439,-0.705970,-0.232051,-0.665309,0.627193,0.233346,-0.261348,-0.223800)$$
$$\boldsymbol{q}_{desired}=(-0.078996,-0.692088,-0.239818,-0.676197,0.635605,0.238755,-0.251310,-0.229491)$$

Frames of Experiment



Results of Experiment





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Conclusions

- A new dual quaternion position/orientation controller is designed and implemented in ROS (Gazebo) in order to move the Shadow arm to a desired manipulation pose.
- **Future work:** When the distance between the initial and the final poses of the arm is too high, the controller produces too high initial joint velocities in order to converge to the desired pose. In order to solve this problem, a list of intermediate poses should be computed by dual quaternion interpolation.