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自主可控强实体　新质生产创未来

Identifying the tracking motion pattern in rehabilitation using inverse optimal control

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Introduction & Formulation

Hemiplegia patients always have their affected and non-affected side. The patient's non-affected aside is a **more natural motion reference** for minimal assist-as-need strategy instead of the intuitively simple ones, which lead to motion identification problem. The following assumptions are made:

- The human motion control signal is corrupted with **signal-dependent noise**, which is proportional with the scale of control input force. [1]
- The human motion is modeled as an **optimal control problem**, whose trade-off matrix "Q" denotes different motion habits. [11]

Challenge

- Can the optimal framework to reproduce human tracking motion?
- Is there a unique optimal solution "Q" for the identification algorithm?
- How to deal with the corrupted data with muscle actuation noise, random starting time and position?

Methods

- **IOC Algorithm**

To eliminate local minima solutions, we constructed IOC algorithm as a **convex** optimization problem based on the observed trajectories and control signals, using optimality condition.

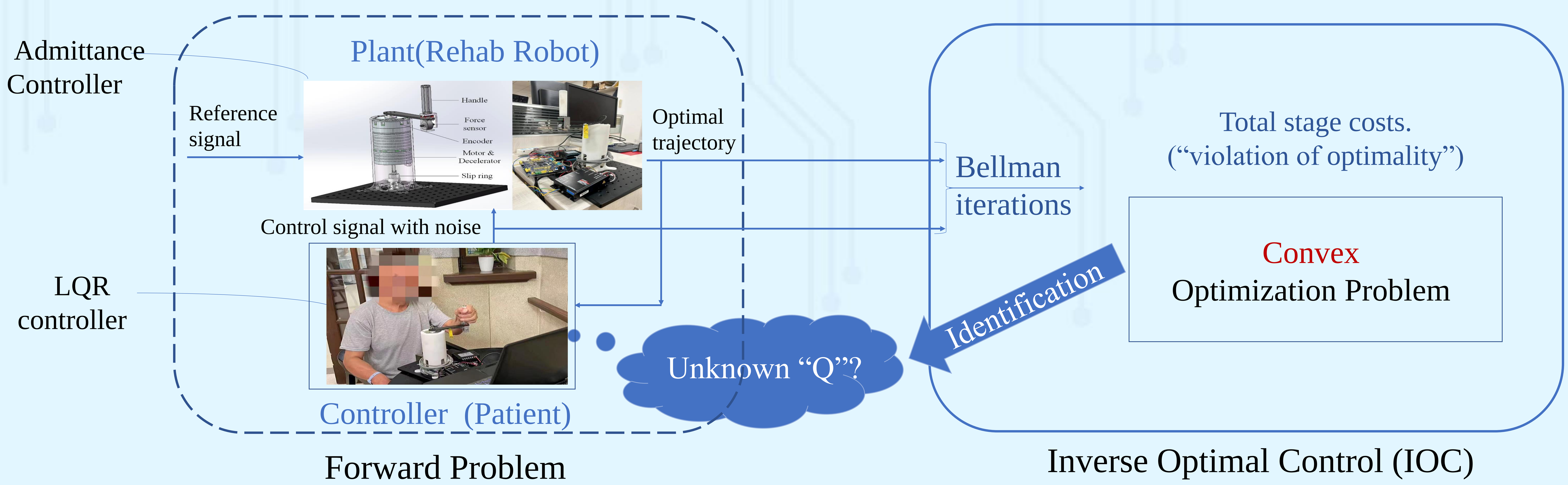
- **Proof -strictly globally identifiable**

There doesn't exist that $Q^{'} \neq Q$ lead to the same model structure $\{\tilde{K}_k(Q)\}_{k=1}^{\nu-1}$

- **Proof -Statistical consistency**

We proved the **uniqueness** of the optimal solution. The numerical solution is proved to **converge** to it under basic assumptions and theorem[23].

Total Structure



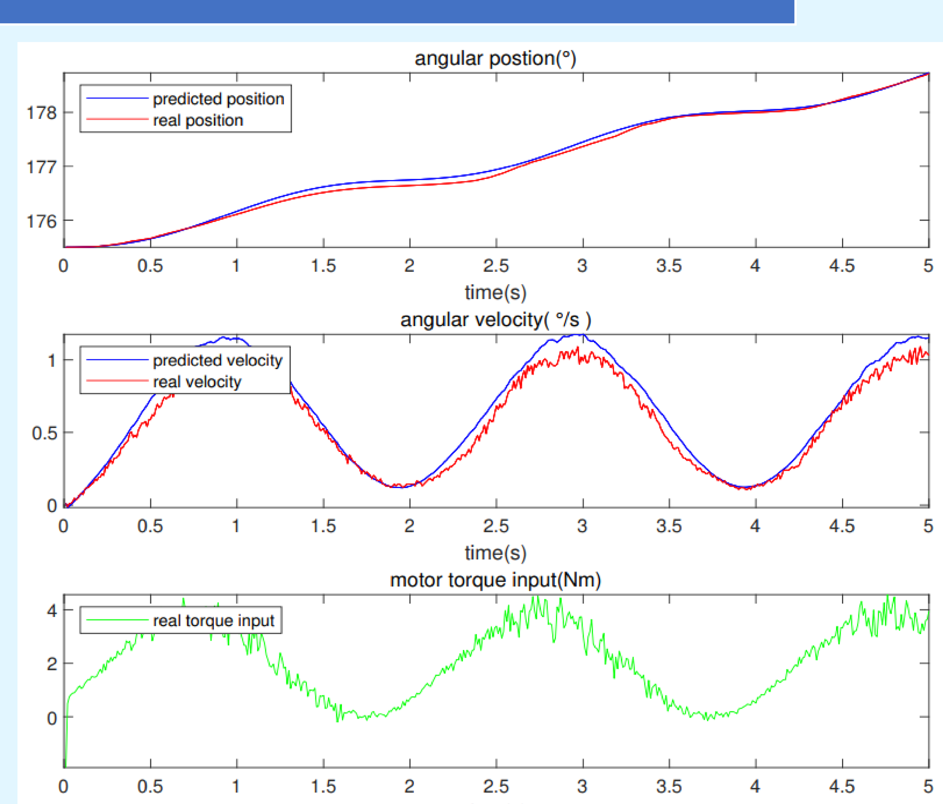
System Dynamics & Noise Estimation

- **System Identification for the robot:**

We use the PEM method in MATLAB toolbox to identify the origin physical dynamics.

- **Dynamics Design:**

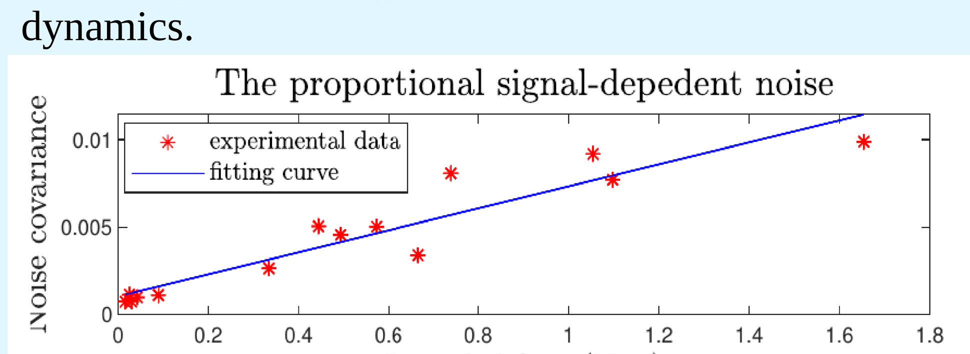
We apply the admittance controller to design a proper physical dynamics.



The comparative responses of the real and identified dynamics.

- **Covariance Estimation of Signal-dependent Noise :**

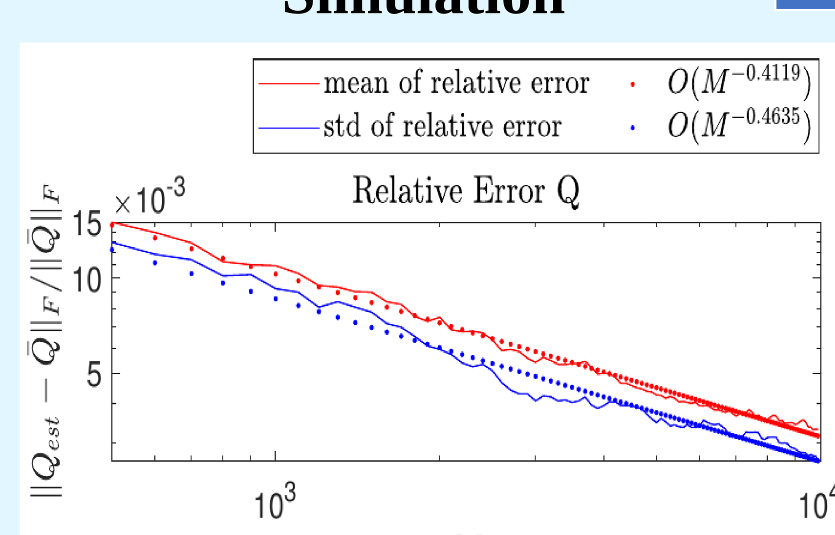
The slope of **linear regression** represents the estimated covariance.



The covariance of signal-dependent noise is growing with the intended force proportionally

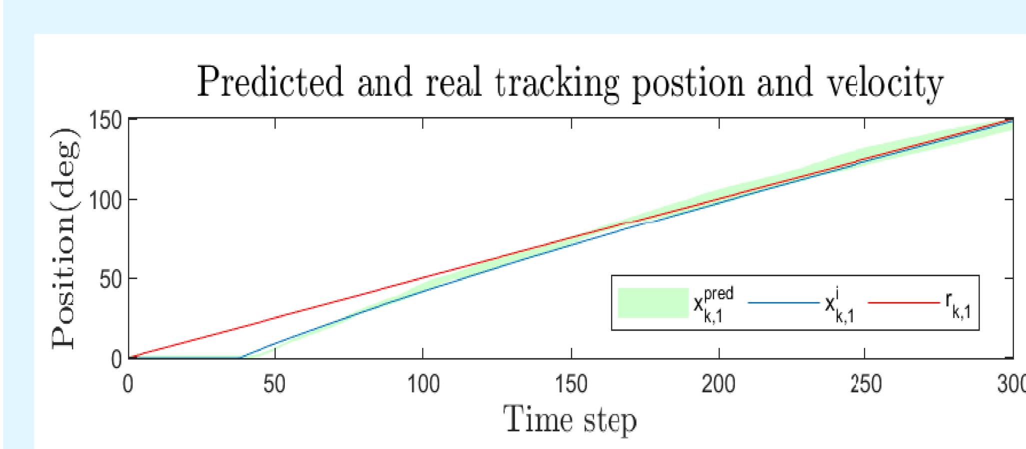
Results

- **Simulation**



Log-log plot of the **mean** and standard **deviation** of the relative estimation error **decreases** with the number of trajectories.

- **Experiment**



predicted trajectories v.s. actual ones.

Conclusion & Takeaways

- We prove that the model structure is **strictly globally identifiable** and the **statistically consistent** IOC algorithm for human tracking motion.
- The crank system **dynamics** and the covariance of **multiplicative noise** are estimated.
- Based on the identified parameters, the performance of the IOC algorithm is tested and verified by simulations and experiments.

Note: The reference note is the same as the origin paper.