On the Motor Learning of "Fully Dynamic Systems"

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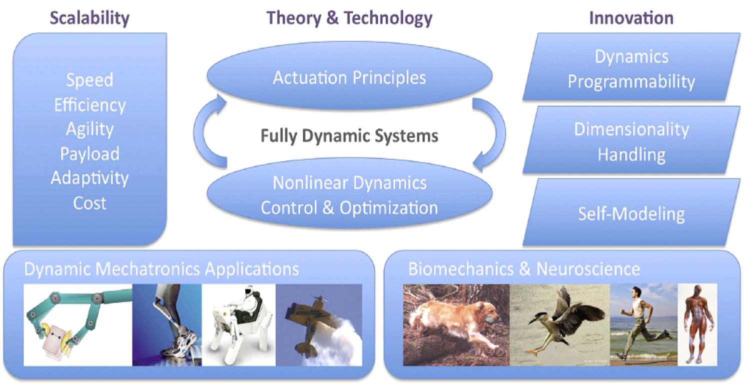
Introduction

The goal of this project is to substantially increase motor capabilities of dynamic robotic systems by exploring novel actuation principles and control optimization architectures. Inspired from motor control in biological systems [1, 2], we have been investigating actuation techniques to achieve "full range dynamics", i.e. control architectures that utilize passive and viscous-elastic dynamics [3, 4] as well as high-torque actuation. With a synergy of full range dynamics and computational control optimization techniques, we expect to provide a broad range of impact not only in dynamic mechatronic machines, but also in our comprehensive understanding of biological systems.

This poster presents an overview of our recent results that demonstrate the basic concept of this project. Our current activities include prototyping of new actuator modules and their motor learning in the context of swing-up reaching control of a 2-DOF arm system.

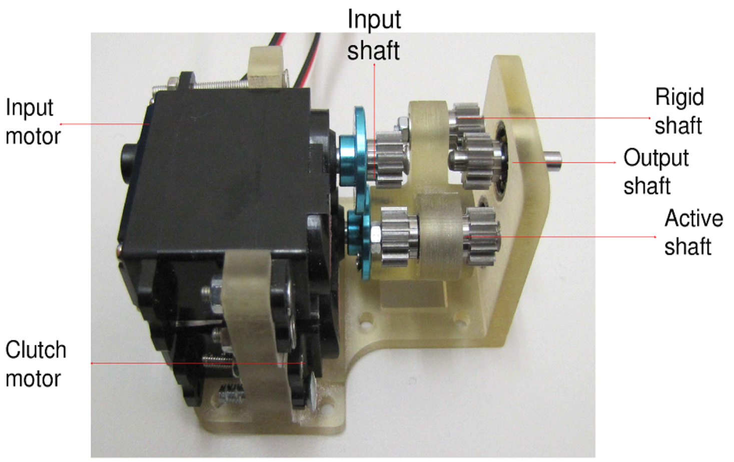


I. Three Mode Actuator (TMA)

The full range dynamics can be practically achieved by implementing an adaptive clutch mechanism. Our first prototype consists of two servomotors, in which an additional motor is used for the adaptive clutch, and this actuator as a whole provides the capability of switching among three modes as follows.

- Active(A) – Output shaft is connected to input shaft via active shaft
- Passive(P) – Output shaft and input shaft are independent
- Rigid (R) – Output shaft is connected to a rigid shaft

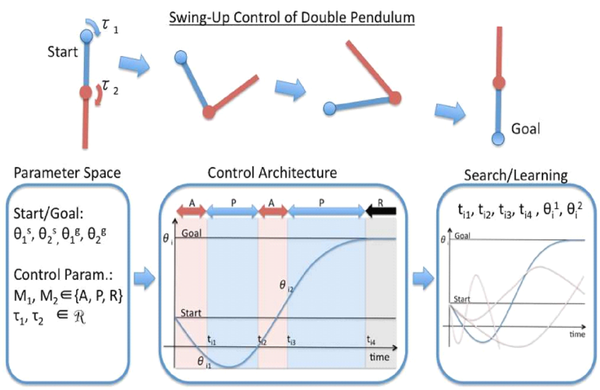
This actuator can be used, for example, to maintain a constant joint angle with very little energy consumption by a rigid mode. Also passive dynamics can be exploited when the actuator is set to a passive mode.



II. Motor Control&Learning of Full Range Dynamics

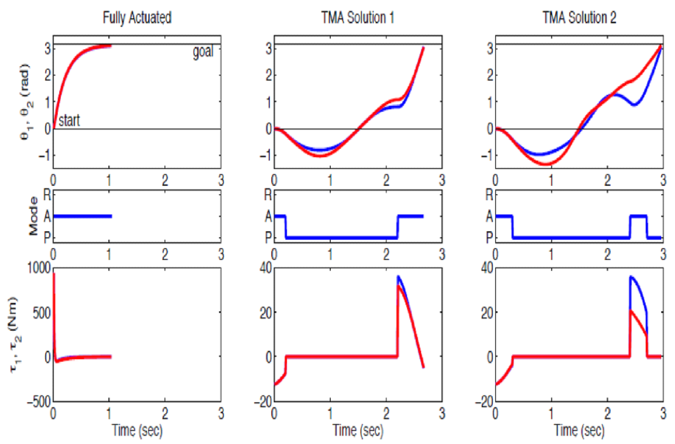
A special treatment has to be made in the control architecture and motor learning of fully dynamic systems. With the TMAs, in particular, the system needs to cope with a few additional parameters of mode switching. It is, however, possible to significantly improve energy expenditure and maneuverability, if these computational challenges can be handled in a reasonable amount of efforts.

In this simulation experiment of swing-up control of a 2-DOF arm system, we developed a control architecture and motor learning process that can achieve the task with improved energy efficiency and maximum joint torque.



III. Simulation Experiment of Reaching with TMAs

By running a simulation of an underactuated 2-DOF arm, the motor learning process identifies the timing of mode switching in order to successfully achieve a swing-up. From the simulation results, we found that the swing-up task can be achieved with significantly smaller energy by using the TMAs, if compared to those of fully actuated motor control. In particular, the maximum torque and energy consumption is significantly lower when the controller exploits passive dynamics of a back-swing before reaching straight to the goal.



Our research demonstrates for the first time an actuator with full range dynamics to achieve agile motor tasks, where the synergy of actuation and "cognitive" dynamics plays an important role. In the future, we will further investigate more complex motor tasks by extending the proposed motor learning architecture.

Acknowledgements and references

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