RSEA: Torque Actuation Approach for Robotic Joints

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August 2017

Introduction

Torque control is used widely in robotics as it allows for the exploitation of the robot's own natural dynamics. One possible approach to torque control is a "Serial Elastic Actuator" (SEA). The SEA sits between the DC motor's shaft and the robotic limb.

This project is based on a previous one [1] as shown in Fig. 2. Our main goal is to improve the setup so it could be applied to one of the lab's robots. Using a more effective SEA could allow for robots to be more precise and more efficient.

Series Elastic Actuation (SEA)

A SEA is essentially an elastic element in series with a motor and a output load as can be seen in Fig. 1 (the output load can be a robotic limb).

Figure 1: Basic scheme of an SEA.

The elastic element provide robot with higher robustness and energy efficiency. Due to its lower mechanical output impedance and passive energy storage [2].
Finally, SEA facilitates accurate torque control by measuring the deflection of the elastic elements.

Our stages in building the SEA are:
1. Implement a position control loop on a DC motor (Servo) using a PID controller.
2. Optimize the PID parameters.
3. Design and build our SEA implementation (Fig. 3).
4. Implement a torque controller.

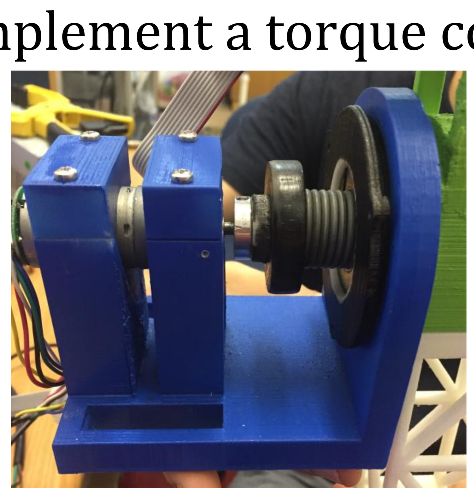


Figure 3: Our SEA using a metal spring.

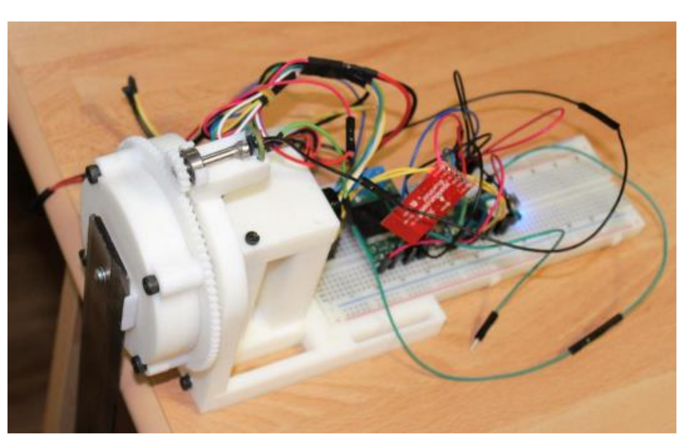


Figure 2: SciTech 2015's SEA using a plastic spring.

Position Control Loop

A proportional—integral–derivative (PID) controller is a control loop feedback mechanism (see Fig. 4), which can be used to control the position of the motor. The loop requires at least one sensor that sends feedback about the current position. With that information and the motor's desired position, the PID controller calculates the output voltage delivered to the motor. PID controllers minimize the error between the desired position and the current position using the error's size, integral and derivative with the following formula:

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(t)}{dt}$$

$u(t)$ - The PID controller output

$e(t)$ - The difference between the desired (θ_{des}) and the current position (θ_{real})

K_p, K_i, K_d - The PID control coefficients

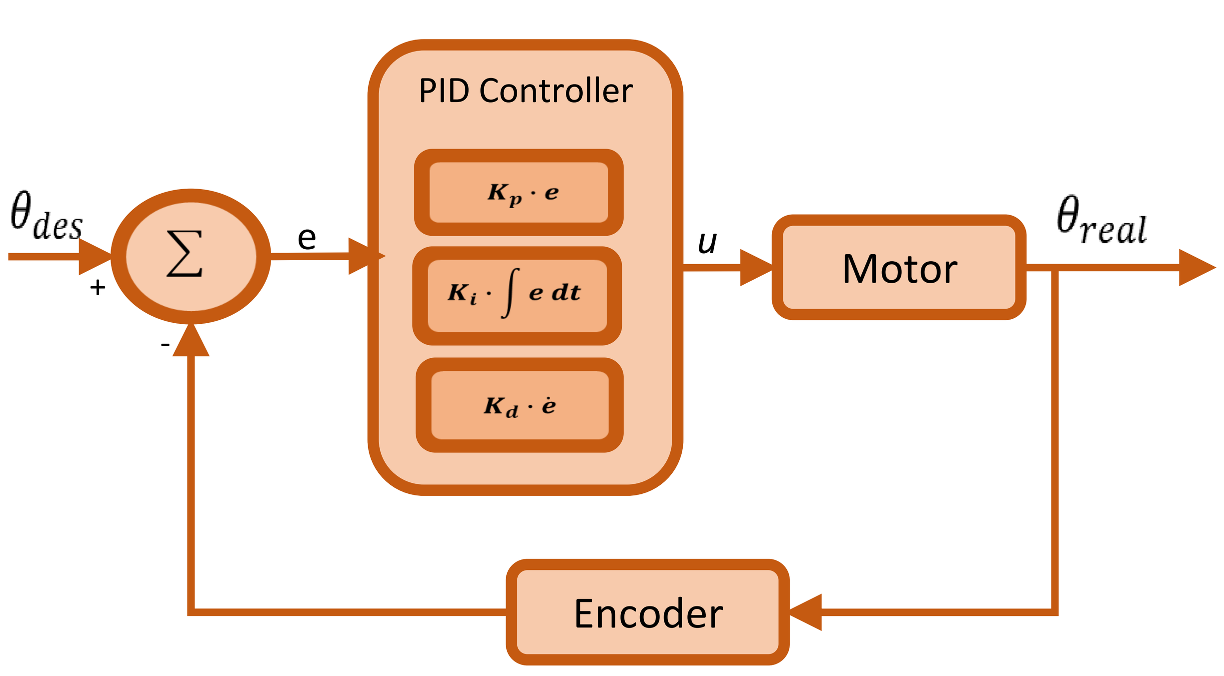


Figure 4: PID Control block diagram

Our Mechanical Design

Due to a more compact design, the chosen SEA type was a metal spring based Rotational SEA (RSEA). The rotational spring was attached to the motor shaft and to the leg (Fig. 5a and the close-up in Fig. 5b). Encoders were placed on either side of the SEA; the magnetic encoder read the position of the motor and the optical one read the position of the leg relative to the motor.

Figure 5a: On the left, the new RSEA setup with the leg attached to it. Next to it, the lab's current biped with the old RSEA design.

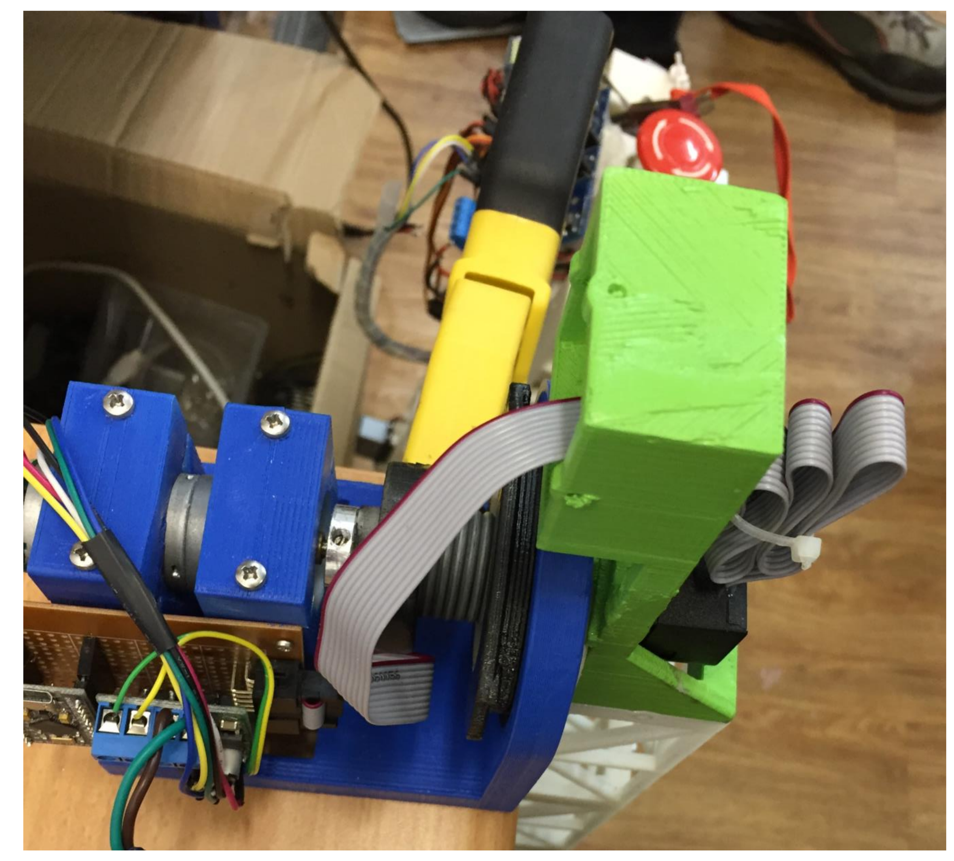
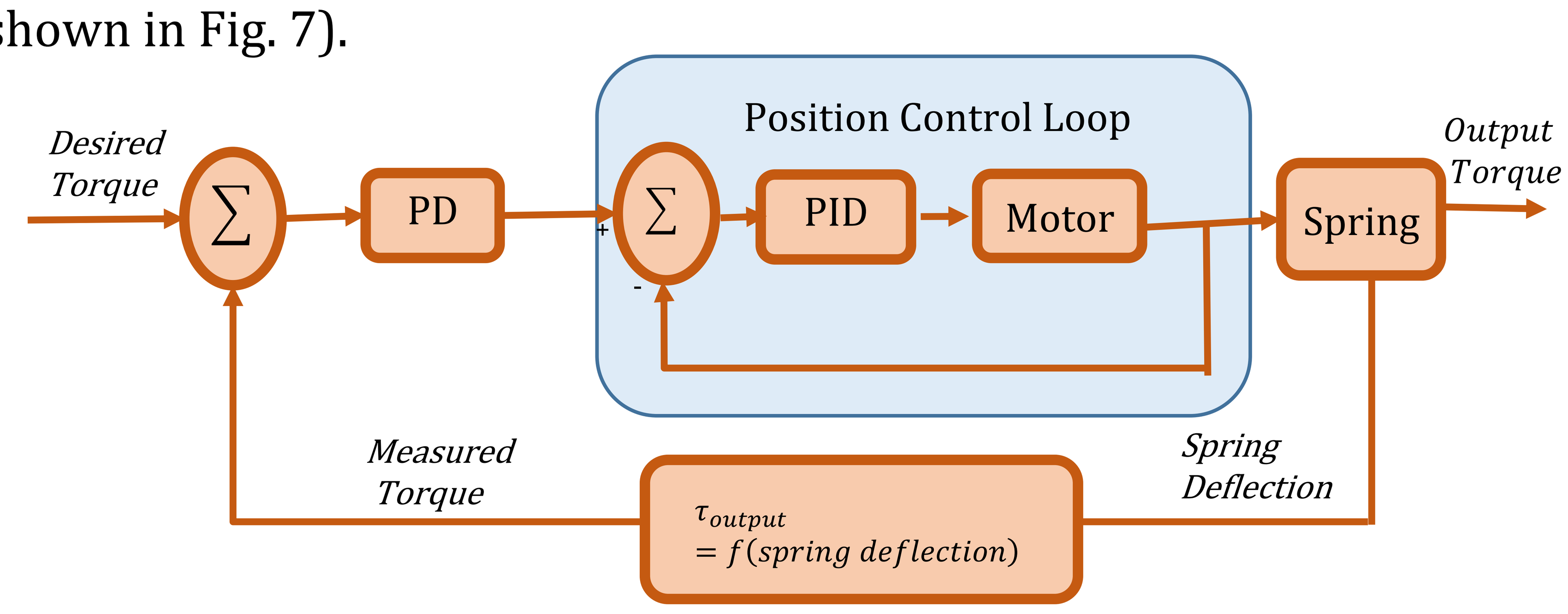


Figure 5b:
A close-up look on the RSEA.

Our Controller Design

The selected method is a two-stage control (see Fig. 6). One inner loop controlling the motor shaft position and another external loop outputting the desired shaft angle to reach the desired torque (as shown in Fig. 7).



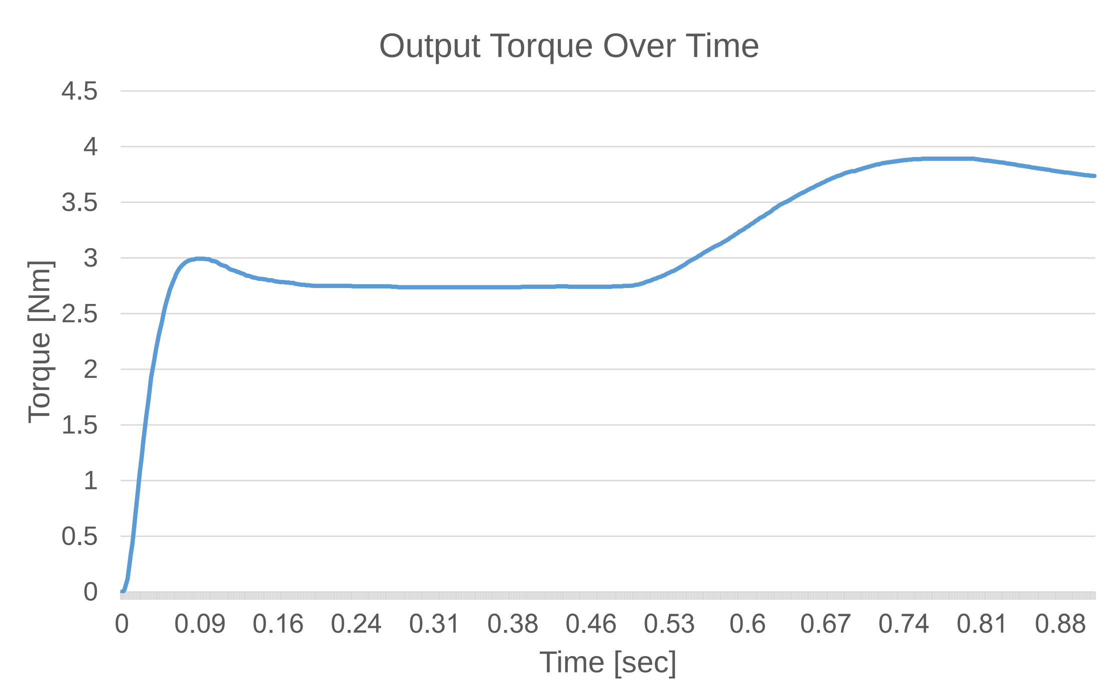


Figure 6 (above): Torque control block diagram.
Figure 7 (left): Torque step response over time. The backlash between the motor's shaft to the hub caused some unwanted movement.

Conclusions and Future Work

- The position control system worked very well.
- The torque control still needs more fine tuning.
- Our current spring is too rigid. However, a more compliant spring is necessary.
- The 3D printed interface of the metal spring perfectly fit the spring.

References

[1]http://www.noar.technion.ac.il/images/stories/scitech/past/3D_PRINTED_BIO.pdf
[2] N. Paine, S. Oh, and L. Sentis, "Design and Control Considerations for High Performance Series Elastic Actuators," *IEEE/ASME Trans. Mechatronics*, vol. PP, no. 99, pp. 1–12, 2013.

Acknowledgements

We would like to thank Rea Yakar and Prof. Miriam Zacksenhouse for hosting and guiding us through our research in their laboratory. We would like to thank the foundation and donors for their generous support of SciTech Program.
This work was supported by Gordon Center for System Engineering [grant number 2023426].