

## Precision Motion Control – Final Exam

As a closing remark, you will DAVI learning-based controllers for the galvanometer in this exam. Our target reference trajectory  $r(k)$  is a 400 Hz triangular wave with an amplitude of 1 degree and duration of 2 seconds, same as the one you work with in Lab Assignment #2.

### Please complete the following assignments:

1. Derive an FIR inverse filter  $F(z)$  for the open-loop stable plant  $P$  using the method proposed in [1]. You may apply the ILC algorithm you implemented in Lab Assignment #2. Alternatively, you may apply time-reversal-based ILC [2] to obtain a purely 'data-based' inverse filter.
2. [Data-Based Feedforward] Track  $r(k)$  by feedforward filtering, i.e.,  $u(k)=F(z)r(k)$ .
3. [Model-Free ILC] Track  $r(k)$  by ILC with  $F(z)$  as the learning filter. Refer to [2] for more details.
4. [Model-Free RC] Track  $r(k)$  by RC with  $F(z)$  as the stabilizing controller. Refer to [3] for more details.
5. Analyze and compare the above results in your report. It is suggested to use the same  $Q(z)$  in Steps 3 and 4 for a fair comparison.

### Please submit the following items to NTU COOL:

A written report that includes the discussion made on your results. Place and sign the following statement in your submitted work: *We did this exam by ourselves without working with or getting help from any other group.*

### Hints:

1. The first iteration of ILC is actually done by feedforward filtering, i.e.,  $u_0(k)=F(z)r(k)$ .
2. Zero padding is required when implementing ILC.
3. A zero-phase low-pass filter can be constructed by  $H(z)H(z^{-1})$ , where  $H(z)$  is a simple low-pass filter you can design via MATLAB toolbox.

### Reference

- [1] C. W. Chen, S. Rai, and T. C. Tsao, "Iterative Learning of Dynamic Inverse Filters for Feedforward Tracking Control," *IEEE/ASME Transactions on Mechatronics*, 25(1),

pp. 349-359, 2020.

- [2] C. W. Chen and T. C. Tsao, "Accelerated Convergence Interleaving Iterative Learning Control and Inverse Dynamics Identification," *IEEE Transactions on Control Systems Technology*, 30(1), pp. 45-56, 2022.
- [3] L. W. Shih and C. W. Chen, "Model-Free Repetitive Control Design and Implementation for Dynamical Galvanometer-Based Raster Scanning," *Control Engineering Practice*, 122, p. 105124, 2022.