# Progress Report

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# 1 Specific Research Goals

- DLO Manipulation Dataset (ICRA - Sept. 19th) - on-going.
- VPQEKF (—): On pause. Asif may look into it.

# 2 To Do

- QEKF Paper (On pause):
  - Noise issue: noise cannot be modeled - DMD is a robust noise on high dimensional orthonormal time series and should be able to denoise QuEst solutions.
  - SfM: RQuEst cannot find solution - A potential solution is described briefly above.
- DLO Manipulation: (ICRA - section out of date)
  - Work on the paper everyday – up-coming
  - ICRA 2022 RL workshops: gym, stable-baseline3, and RL zoo – on-going
  - Setup digital twin reinforcement learing setup:
    * Unity Robotics extension setup – on-going.
    * Design dynamic DLO data collection system.
    * Build work cell. – on-going
    * Collect data and create a dataset.
    * Define evaluation metrics.
    * Create a high frequency RGBD dataset with UV-frames and open-loop input control actions as the ground truth.
  - Real-Time Preception – on hold
  - Learning DLO Dynamics and System Identification
    * List feasible approached for learing DLO dynamics – done
    * Model dynamics and deformity in a latent space

# 3 Progress

The following items are listed in the order of priority:

- DLO State Estimation (IROS): On piDMD $\boldsymbol{BCCB}$, it stands for *block-continuous-continuous-block* and is a cubic configuration for performing 3D *fast Fourier transform.* The presented implementtation does not run and its root cause was not investigated. The implementtation is equivalent to multiplying data matrix $\mathbb{X}$ with the Kronecker product of two *discrete Fourier transform matrices* (DFTMat) with dimension factors of M and N as input. M and N are the least factors for square matrices to become the size. This condition is necessary for DFTMat to be applied to a Tensor. I wonder if using a tensor might be necessary to correctly meet 3D adjacency constraints of the physical world. *(*UpperTriangular and diagonal) constraints enforce 2D adjacency but we are only able to run the diagonal. Triangular methods use RQ decomposition (yields a singular and full-rank matrix for model) and are thought to be computationally more efficient as authors claimed [1].
  I was able to run the algorithm with various *circulant* constraints which, resulted in poor performance but its surface plot clearly shows a frequency reconstruction in polar coordinated frame. The implementtation calls $fft2()$ routine which, performs *discrete Fourier transform* on a matrix (2D). Understanding these details is essential for constructing a viable solution for real-time manipulation and control on DLOs.
  Furthermore, I continued testing and investigating piDMD and all it can possibly offer. I plotted reconstructions and model *performance surfaces* and made a startling realization that piDMD is only performing system identification task and as implemented, resultant reconstructions cannot possibly be very accurate. This is related to highly chaotic nature of DLOs; no matter how accurate and precise the model is, it will go out of *synch.* Chaotic systems are still nonlinear systems and they need to be treated *locally in time.* What we are aiming to achieve is to *model (or linearize)* a DLO *globally in space.* Thus, there needs to be online observations.
  I went back to Murphy's paper to implement a Koopman-based controller where, they use data collected from a vertical take-off and landing (VTOL) pendulum system [2]. In the paper, they mentioned data collected is a combination of multiple test runs with different initial conditions. The purpose of this is to obtain a set of Koopman operators or model that is robust to a range of initial conditions. Moreover, they use Koopman operator only for system identification and utilize optimal control with a L2 regularizer. Currently, I am working on Koopman operator approximator routine that takes in number of

lifting dimensions and choice of basis functions. On a side note, we never lifted the space in the current implementation of DLO code with piDMD but we can as the feature exists.

- Maicol (REU): I want him to continue developing high quality model of workcell (not the lab) and implement basic manipulation tasks. I need this for DLO project and I can not do everything on my own. I can learn anything so I aim high enough that I can barely make it. You do not support that eventhough you have been patient with me. In my strategy, I work on cutting edge problems that others can not and I start with what is of most strategic importance to me, i.e. learning controls and classical computer vision while I am still a PhD student. I am sacrificing more than anybody else to achieve my goals and increasingly I feel isolated because of your comments. Comments that show no interest or respect for my work and seem be betting against me everytime. I came here to do good research and no one has any interest in that.

- DoD SMART (Dec 1st.): I started the application.

- XEst (RAL —): No update.

## References


[1] P. J. Baddoo, B. Herrmann, B. J. McKeon, J. N. Kutz, and S. L. Brunton, “Physics-informed dynamic mode decomposition (pidmd),” *arXiv preprint arXiv:2112.04307*, 2021.

[2] I. Abraham, G. De La Torre, and T. D. Murphey, “Model-based control using koopman operators,” *arXiv preprint arXiv:1709.01568*, 2017.