Progress Report

Bardia Mojra

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Robotic Vision Lab

The University of Texas at Arlington

1 Research Plan - Out of date

This section outlines my current research plan where the main ideas, target conference/journal, and expected date of completion for each paper are provided. Target conferences: ICRA, IROS (March), CASE (Late Feb.), NIPS. Target Journals: RAL, CVPR, CORAL.

- Koopman-01 (IROS - Dec. 1st - active): Koopman-based MPC control of VTOL-DIP and VTOL-TIP in simulation, DLO pose estimation in simulation, experiments on choice of basis function and lifting dimensions, and performance comparison with optimal, robust, and/or adaptive control schemes.

- Koopman-02 (ACC - Sep 30th - active): A review on Koopman-based control schemes. Not enough, make it part of another paper. Read papers and write literature reviews.

- Koopman-03 (RAL - Mar. 1st - status): Extension to Koopman-01, Koopman-based dynamic estimation of DLO, collect dynamic DLO dataset, prediction of DLO configuration.

- Quest-01 (IROS - Mar. 1st - next): Optimal transform solution for QuEst based on dominant mode decomposition (DMD).

- Quest-02 (IROS/RAL - date - status): QuEst-based EKF, structure from motion, and VSLAM, compare performance with existing methods.

- Koopman-04 (IROS/RAL - date - status): Physics Informed (PI) Koopman-based control of a DLO, show obtained is persistant, compare to other non-PI methods, offline-online learning.

- Koopman-05 (IROS/RAL - date - status): PI Koopman operator (PIKO) based persistant model for DLOs, low dimensional, compare performance, offline-online learing/adapting, fast transfer learning.

- Koopman-06 (IROS/RAL - date - status): PIKO-based unit segment model for DLOs, more generalized, should yield better performance if number segments are selected online in order to obtain optimal representation in real-time given available hardware, compare results.

- Koopman-07 (IROS/RAL - date - status): DLO dataset, PIKO-based reinforcement learning of real DLO dynamics in a digital twin (DT)

setting, experiments of model persistance, compare learning rate with neural network based methods, compare performance with available methods, and experiments on learing limitations.

- Koopman-08 (IROS/RAL - date - status): Koopman-based real-time control of DLO on GPU.

- Koopman-09 (IROS/RAL - date - status): PIKO-based real-time control of DLO on GPU.

- Koopman-10 (IROS/RAL - date - status): PIKO-based real-time control of deformable planar objects (DPO).

- Koopman-11 (IROS/RAL - date - status): PIKO-based real-time control of deformable volume objects (DVO).

- Koopman-12 (IROS/RAL - date - status): PIKO-based unit segment for DPOs, on GPU.

- Koopman-13 (IROS/RAL - date - status): PIKO-based unit segment for DVOs, on GPU.

2 To Do - Out of date

- 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)

  - Setup digital twin reinforcement learing setup:
    * Unity Robotics extension setup – done.
    * Design dynamic DLO data collection system.
    * Build work cell. – done
    * 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 - PIKO - Ongoing

3 Progress

The following items are listed in the order of priority:

- DoD SMART (Dec 1st.): I will be working on this for the next couple weeks.

- DLO Dataset (Dec 1st.): I am currently designing the test. Later this week, I need to figure out how I want to collect visual and pose data for the DLO. I think the best method would be a combination of multiple cameras and depth sensors. I will discuss this with Dr. Gans and Chris to get their input. For the test, so far I have the following:

  - Clamped end low, DLO on table and flat, change gripper pose, no twist on DLO: omega shape, s shape, u shape, circle shape, ellipse shape, spiral.
  - Clamped end low, DLO on table and 3D, with twist: same shapes.
  - Clamped end low, DLO angles at 30 degrees and 3D, without twist: same shapes.
  - Clamped end low, DLO angles at 45 degrees and 3D, without twist: same shapes.
  - Clamped end low, DLO angles at 60 degrees and 3D, without twist: same shapes.
  - Clamped end low, DLO angles at 30 degrees and 3D, with twist: same shapes.
  - Clamped end low, DLO angles at 45 degrees and 3D, with twist: same shapes.
  - Clamped end low, DLO angles at 60 degrees and 3D, with twist: same shapes.

- DLO Manipulation (IROS): Dr. Gans and I reviewed the Koopman cart-pendulum controller and there seem to be a bug in the code, [1]. The solution does not converge to zero as it should. I suspect the issue is related to Matlab and Python handle vectors differently. I will inject known vector into both implementation and trace where computational divergence begins. I am putting this on pause until after the dataset is collected or some progress has been made on that effort.

- Maicol (REU): I gave him my paper on optimal control of double inverted pendulum to read, it is gentle introduction to advanced robotics. There, I show modeling and derivation of optimal controller for a nonlinear and chaotic system.

- XEst (RAL —): No update.

References

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