Progress Report

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1 Specific Research Goals

- VPQEKF (April 13th): Work on the paper.
- DLO Manipulation Dataset (ICRA - Sept. 1st)

2 To Do

- QEKF Paper - 30% extension (April 13th):
  - Edit VEst section and add updates.
- QEKF/QuEst+VEst Implementation (April 13th):
  - OOP Integration: QuEst is tested and other algorithms have been integrated and tested as well. Integrate VEst — On-going.
  - Feature point extraction: implement semantic segmentation
  - Address scale factor (depth-scale) issues: DL solutions?
  - Address "hand off" issue when objects enter or leave field of view
  - Real-time streaming images for real-time operation (optional)
  - Experiments
  - Noise issue: noise cannot be modeled - revisit
- DLO Manipulation: Sept. 1st
  - Find other ICRA dataset papers and summarize the structure. — This week.
  - Dataset (ICRA - Sept. 1st):
    * Finalize MoCap design, design digital twin work cell. — This week.
    * Build work cell.
    * Collect data and create a dataset.
    * Create object dynamics ground-truth method, format, and evaluation metrics.
  - Control and Tracking
    * Create UR5+DLO simulation in Matlab and begin work on H-Infinity control before Reza leaves for Indiana State.
    * Model dynamics and deformity

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> main
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	EightPt	Nister	Kukelova	QuEst
Rot err mean	0.06361	0.0059552	0.013913	0.003214
Rot err std	0.091232	0.0069446	0.018129	0.0031175
Rot err median	0.0029372	0.0020042	0.0020599	0.0013304
Rot err Q_1	0.0022136	0.00088513	0.00083714	0.0007197
Rot err Q_3	0.11534	0.010447	0.025988	0.0059129
Tran err mean	0.049233	0.13449	0.14946	0.061282
Tran err std	0.048413	0.11632	0.13914	0.065601
Tran err median	0.014529	0.049237	0.053502	0.011805
Tran err Q_1	0.01076	0.040477	0.032613	0.0073206
Tran err Q_3	0.094997	0.26048	0.30012	0.13456

Figure 1: Classical Pose Estimation Methods

- Real-Time Preception
  - Implement PVnet, perform transfer learning and retrain using in house dataset.
  - Time model inference, using auto-encoders generate the lowest dimensional representation for each object.
  - Use another GAN model for object deformity for each object.
  - Evaluate encoded representation for accuracy.
  - Used another GAN to explore other abstraced representations from individual encoded representation. In theory, we can create a low dimensionsal representation for multiple similar objects, given all individual low-dimensional representations. This is inspired by "fundamental principles first" approach which has universal applicability.
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3 Progress

The following items are listed in the order of priority:

- VPQEKF (RAL - April 1st, 2022): This week, I finished testing and validating QuEst source code into the integrated system environment. Moreover, I integrated other classical pose estimation algorithms.

Figure 2: DLO Sample Image

- DLO Dataset: I will look into the bill of material and the final design this week. I should perhaps have a discussion with Sami about this. I am sure he knows a lot more than me. He can probably provide very good insight on topology representation and preception. Moreover, I took the following photos as initial samples. In my work, I need to take more photos of the marker from different angles and train a minimal model that robustly detects this marker from any angle (with glare). I have not gone through the papers we found last week. In fact, it seems that I have lost them since I had to reinstall my OS on Friday. I will make an outline for the dataset paper and will do some tutorials on Dataset generation from ICRA.

- DLO Control: I had a meeting with Dr. Gans and Reza where we discussed H-Infinity and Mu-Synthesis control design and it seems to be a great fit for controlling a DLO in stable congfiguration. In theory, a H-infinity controller takes advantage of one additional constraint to bound the output. The constaint is conservation of energy from thermodynamics. In context of H-infinity control, it assumes that no matter how unstable the output, its magnitude will never be larger

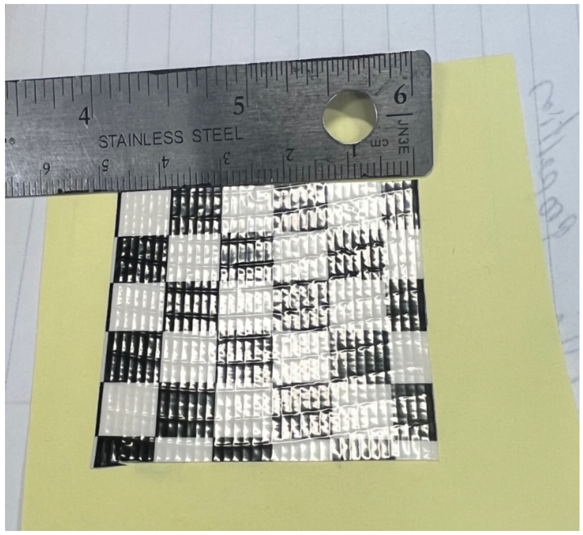

Figure 3: Shiny Marker

than the energy of the input and the system itself (maximum gain in any dimension and at any frequency). The controller pays attention to the ratio of the input and resulting output change. Thus, one can define a optimization criterion, e.g. local estimation accuracy, model input noise to the system and H-infinity controller will guarantee the system will preform within a certain bound. This bound is defined by ratio of magnitude of the input and the system where sensitivity is minimized recursively. This creates robustness in control while maintaining optimality to defined criterion. H-infinity is used for linear or linearized systems and Mu-synthesis is for nonlinear systems where there is uncertainty. Moreover, Reza mentioned *Linear Parameter Varying control* (LPV) where a nonlinear system is model as parameterized linear system with *Gain Scheduling*. LPV can be particularly helpful in controlling DLOs, and perhaps it could be extended to multiple DLO classes. We can begin this project in simulation and quickly publish a paper with Reza on just the controller design for DLOs.

- DLO Perception: Building scanner would be too time consuming. Ensenso makes high quality 3D scanners and UTARI has one. We could borrow it or we can set the scanner there [1].
- Semantic segmentation (DLO-02): Per my discussion with Dr. Gans,

I will explore DL methods for the depth or scale problem.

- Grasping Project (DLO-03): I am making this a part of the DLO project.
- PyTorch Tutorials: Transfer learning.

4 Intermediate Goals - Fall 2021:

- QEKF: Finish paper.
- UR5e: Do the tutorials.

References

[1] "3d cameras overview - ids imaging development systems inc." https://www.ids-imaging.us/ensenso-stereo-3d-camera.html. (Accessed on 05/16/2022).