Progress Report

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1 Specific Research Goals

- VPQEKF (May 30th): Work on the paper.
- DLO Manipulation Dataset (ICRA - Sept. 1st)

2 To Do

- QEKF Paper - 30% extension (May 30th):
  - Edit VEst section and add updates.
- QEKF/QuEst+VEst Implementation (May 30th):
  - OOP Integration: QEKF - 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 - on-going.
  - 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

  - 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 had to spend couple days on the system architecture but it is complete now. Now, I have a complete OOP implementation in Matlab that share the same architecture with my Python implementation. This will allow me to easily reuse, integrate and run source code between the two programming languages. This code is also ready for field deployment since it only saves the estimates at run-time and performs error computation at post processing. The following are the results for QuEst and VEst methods compared against top pose and velocity estimation methods. We compared QuEst against Eight-Point, Nister, and Kukelova pose estimation algorithms and results are shown in figure [1]. Figure [2] shows output results for VEst module with pose estimates from mentioned methods. So far, we have tested our algorithm on KITII, ICL, and TUM benchmarks. I will add Kneip and Stewenius pose estimation methods and NAIST benchmark at a later time.

- DLO Dataset: Last night, I recreated Jerry's design for the work cell cage, he no longer has the CAD file. I sent out a link to the file and asked if they want to make any changes or add anything. We will

KITTI

	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

ICL

	EightPt	Nister	Kukelova	QuEst
Rot err mean	0.0010922	0.23039	0.22911	0.00058779
Rot err std	0.0006694	0.23005	0.22886	0.00033422
Rot err median	0.0011073	0.2292	0.22805	0.00059275
Rot err Q_1	0.00043139	0.0003558	0.00025794	0.00025402
Rot err Q_3	0.001753	0.46043	0.45796	0.00092156
Tran err mean	0.35684	0.36008	0.40947	0.37134
Tran err std	0.051426	0.068961	0.067391	0.05834
Tran err median	0.34197	0.35476	0.42785	0.36769
Tran err Q_1	0.31048	0.29358	0.34804	0.31348
Tran err Q_3	0.4032	0.42658	0.47089	0.42921

TUM

	EightPt	Nister	Kukelova	QuEst
Rot err mean	0.065759	0.033586	0.031964	0.016095
Rot err std	0.082624	0.026133	0.024479	0.014543
Rot err median	0.027054	0.034868	0.034785	0.012323
Rot err Q_1	0.0077886	0.0079305	0.0078698	0.004591
Rot err Q_3	0.12373	0.059242	0.056059	0.027599
Tran err mean	0.22021	0.30581	0.15831	0.15692
Tran err std	0.075288	0.11595	0.059177	0.076958
Tran err median	0.20802	0.33699	0.14571	0.15662
Tran err Q_1	0.14782	0.21827	0.1171	0.087069
Tran err Q_3	0.29261	0.39336	0.19953	0.22677

Figure 1: Classical Pose Estimation Methods vs. Benchmarks

KITTI

	EightPt	Nister	Kukelova	QuEst
ang vel err mean	0.064102	0.0091675	0.017262	0.01136
ang vel err std	0.089114	0.010387	0.018881	0.016136
ang vel err median	0.0080543	0.0068706	0.0067954	0.0061639
ang vel err Q_1	0.0020751	0.00096347	0.001013	0.00050656
ang vel err Q_3	0.1155	0.013731	0.034319	0.01565

ICL

	EightPt	Nister	Kukelova	QuEst
ang vel err mean	0.0005236	0.23075	0.22952	0.00041843
ang vel err std	0.00029957	0.23043	0.22917	0.00018787
ang vel err median	0.00056929	0.22948	0.22843	0.00049146
ang vel err Q_1	0.00024303	0.0003327	0.00035234	0.00027872
ang vel err Q_3	0.00080418	0.46118	0.45869	0.00055815

TUM

	EightPt	Nister	Kukelova	QuEst
ang vel err mean	0.057976	0.022464	0.021728	0.015371
ang vel err std	0.091796	0.024741	0.023527	0.013708
ang vel err median	0.0061791	0.011483	0.011468	0.011341
ang vel err Q_1	0.003982	0.0054316	0.005417	0.0054477
ang vel err Q_3	0.11197	0.039496	0.038039	0.025294

Figure 2: Velocity Estimation Methods vs. Benchmarks

finalize the design this week. I reached to Sami, he seems interested and we agreed to meet today. I need to read more on digital twin as well as the dataset papers Dr. Gans and I found last week.

- DLO Control: No update.
- DLO Perception: No update.
- 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.