Compliant and Intelligent Grasping with Parallel Kinematic Mechanism and its Agricultural Application

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CHICO STATE ENGINEERING

PROJECT OVERVIEW

This project aims to address the labor-intensive and repetitive tasks of agricultural food processing by introducing a parallel kinematic robot (Omron Hornet 565) with a compliant end-effector fabricated from a soft material and image recognition algorithms to pick and place the product for packaging accurately.

The requirements of the project included:

- Pick and place produce based on an image recognition framework.
- Use a compliant end-effector
- Meet the dimensional limitations of the Omron Lab
- End effector must be compatible with Hornet

The objectives of the project included:

- Be reliable to function with little to no human interaction
- Have >90% accuracy in 2D image processing
- Work more efficiently than a human
- Utilize OpenCV libraries for accurate object recognition

SOLUTION APPROACH

Much of the physically demanding agricultural work has the potential to be improved upon and automated. The project's work primarily addresses the use of a compliant end effector and the integration of a 3rd party single-board computer to the Omron proprietary operating environment to implement computer vision algorithms. These algorithms, which are developed using pre-existing foundations from OpenCV, recognize the product as they appear in the camera's field of vision for higher sorting accuracy. The System then uses a compliant end-effector 3D printed from NinjaFlex filament and a pneumatic system to pick and place agricultural produce as they appear in the camera's field of vision on a conveyor belt.

GRIPPER DESIGN

The finalized gripper design consists of a four-finger end-effector that was fabricated using a 3D printer and the Ninjaflex filament. As shown in the research paper titled The GRASP Taxonomy of Human Grasp Types [1], a four-finger gripper offers a high level of precision when grasping objects and will be the most effective design choice when considering the Project's objective of a compliant end-effector.

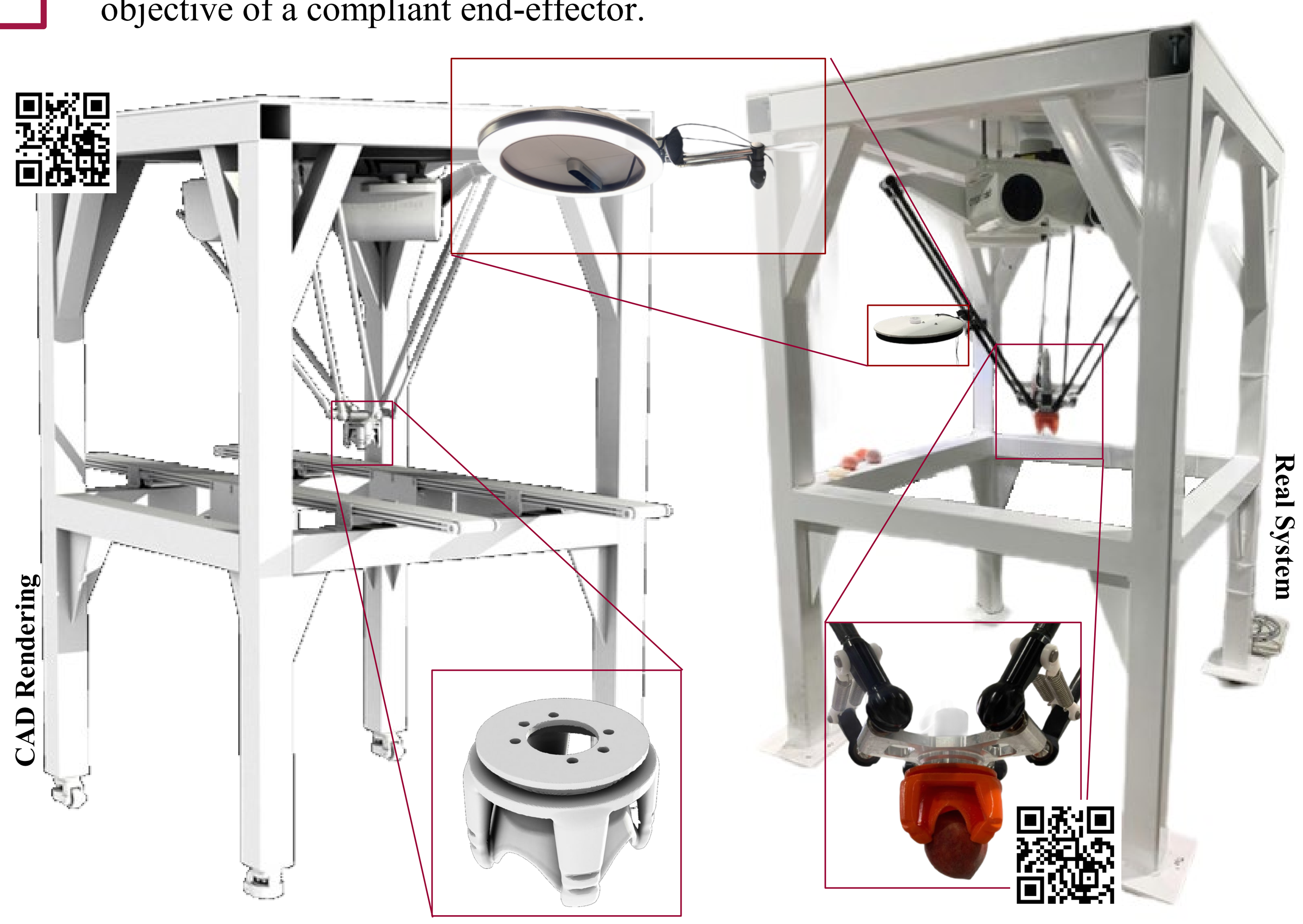
CHASSIS DESIGN

As described in the Omron Adept Hornet 565 User Guide, the Hornet is designed to be mounted on top of a work area and suspended on a user-supplied frame that must rigidly hold the robot as it moves in its workspace. Following the User Guide specifications for the mounting of the Hornet, the System's final design consists of a chassis, mostly constructed from A500 steel. The chassis will also be mounted on four-level caster wheels to allow for mobility in its operating environment.

ubuntu NVIDIA OpenCV python

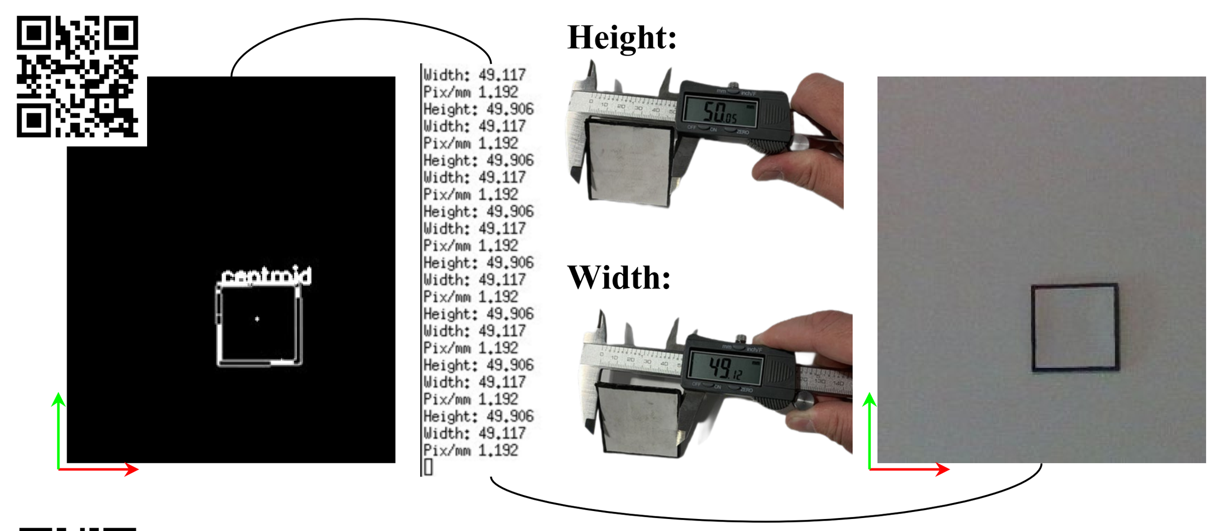
OPC UA MATLAB

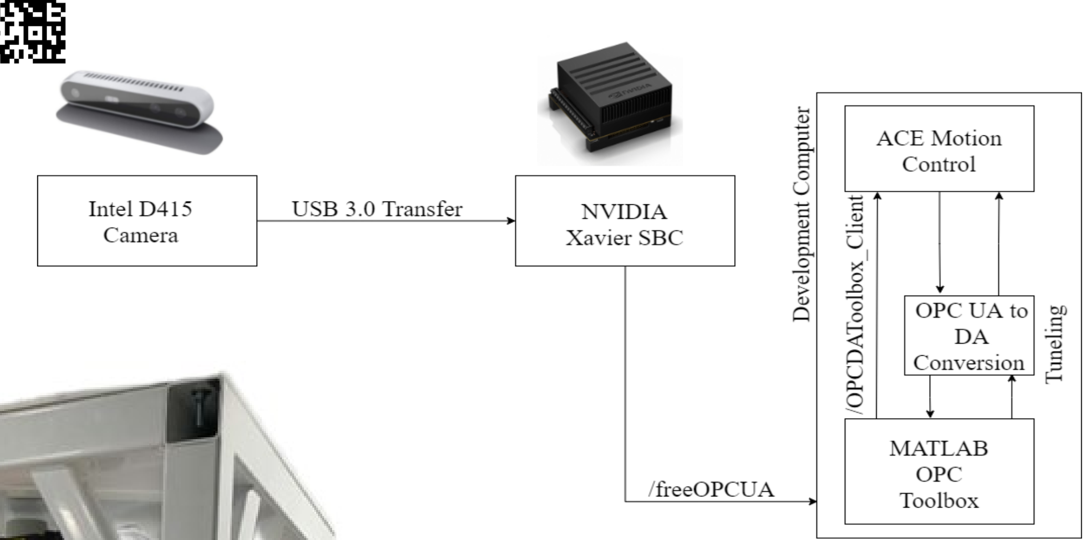
SIEMENS NX OMRON adept intel REALSENSE

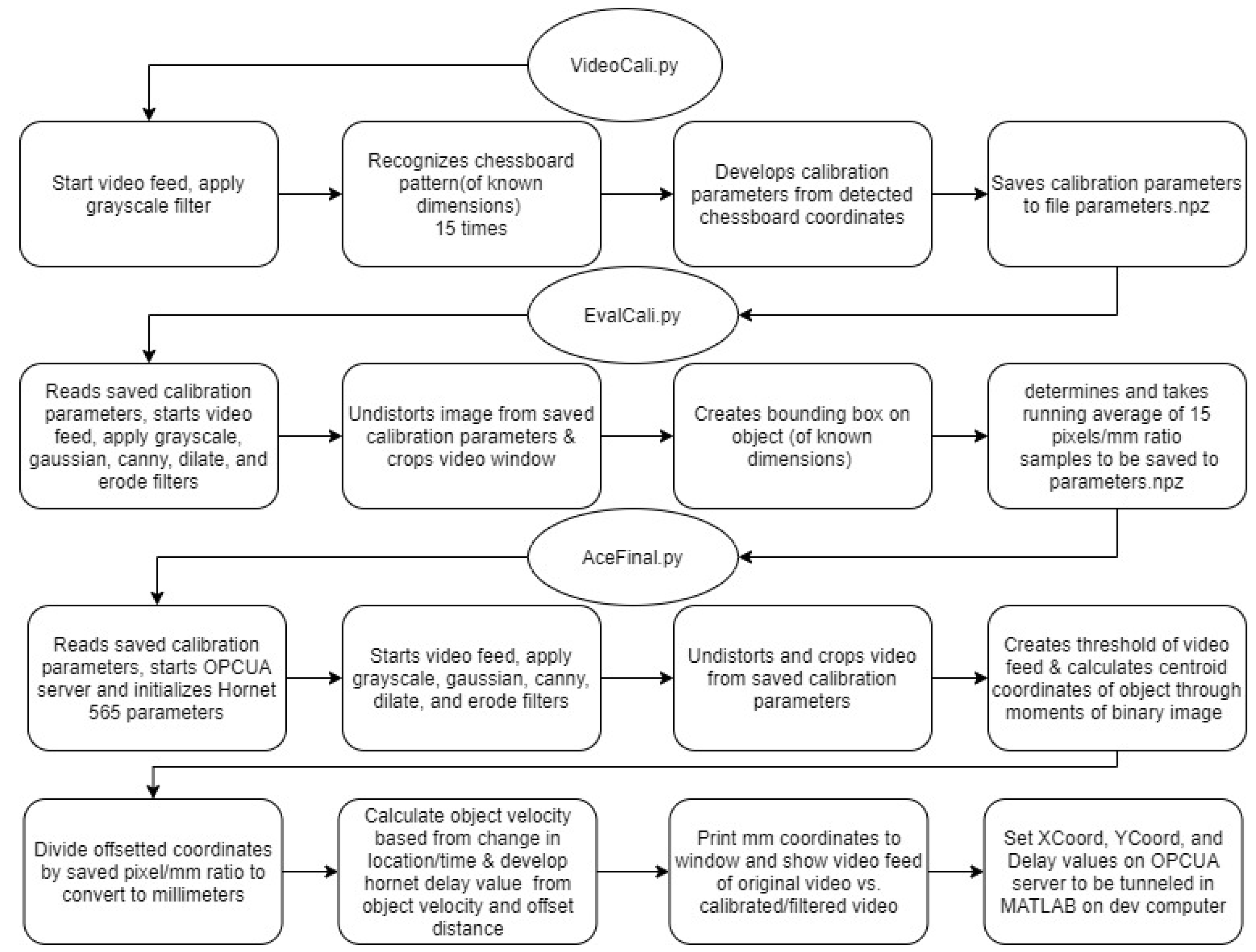


SOFTWARE DESIGN – VISION AND COMMUNICATION SYSTEMS

The System's final software design consists of four essential components, Omron's proprietary Automation Control Environment (ACE), the Open Platform Communication (OPC) infrastructure, the computer vision development done on Visual Studio Code (VS Code) using OpenCV, and the use of an Ubuntu 18.04 operating system (OS) on an Nvidia AGX Xavier Single Board Computer (SBC) for the integration of the Intel D415 camera and computer vision algorithms. OpenCV libraries were used for generating edge and centroid detection algorithms for object tracking. The OPC infrastructure was used to facilitate data transmission in the System through components including the SBC, ACE, and MATLAB via different devices on a singular network.

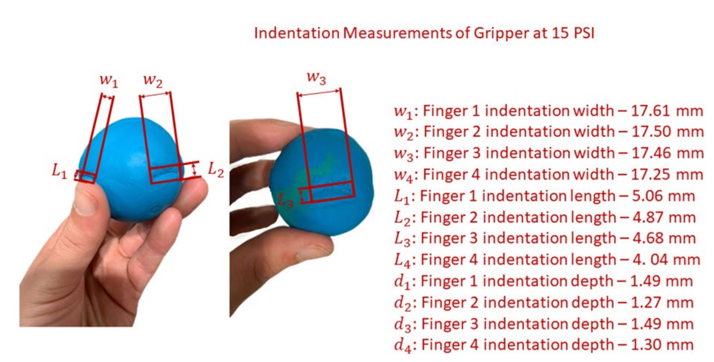






RESULTS

The results of the System testing with the compliant gripper showed that using the NinjaFlex filament and a PSI of 15 would result in completely compliant picking and placing of symmetrical agricultural produce. The computer vision algorithms that were used to facilitate the pick and place procedure showed an over 90% accuracy following correct calibration procedures.



CONCLUSION - FUTURE WORK

As a first step of an Industry 4.0 system in the Omron Colab, this project will have the flexibility of continuous improvement and integrated into the lab's future autonomous factory setup. The Industry 4.0 setup will utilize the lab's array of robotic systems to effectuate a miniature implementation of a smart assembly line and would include industry commonalities such as Cyber-Physical Systems (CPS). Specialized networks such as CPS utilize five functions: computing, communications, precision control, coordination, and autonomy [2]. Future work also includes implementing object depth detection for 3D recognition and other gripper modalities to such as a vacuum pad for more versatile pick and place applications[3].

References

[1] Cini , Francesca, Marco Controzzi , Valerio Ortenzi , and P Corke . "On the Choice of Grasp Type and Location Hen Handling over an Object ."

[2] K. Zhou, Taigang Liu and Lifeng Zhou, "Industry 4.0: Towards future industrial opportunities and challenges."

[3] Mahler, Jeffrey, et al. "Dex-net 3.0: Computing robust vacuum suction grasp targets in point clouds using a new analytic model and deep learning."

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