PartID-2

Part Identification and Post-Processing using a collaborative robot

ELECOMP Capstone Design Project 2020-2021

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https://web.uri.edu/elecomp-capstone/project-details-by-team/2016-2017/hexagon/

https://web.uri.edu/elecomp-capstone/project-details-by-team/2017-2018/hexagon-cmm/

https://web.uri.edu/elecomp-capstone/project-details-by-team-2018-2019/hexagon/

https://web.uri.edu/elecomp-capstone/files/ELECOMP-Hexagon-Proposal-2019-2020.pdf

Sponsoring Company:

Hexagon Manufacturing Intelligence
250 Circuit Drive,
North Kingstown, RI 02852
Phone: 401-886-2704
http://www.hexagonmi.com/en-US

Background:

Hexagon Manufacturing Intelligence, formerly known as Hexagon Metrology, is the world leader in quality control solutions for manufacturing. Solutions include hardware, software and services in a broad portfolio of products which include stationary coordinate measuring machines (CMMs) for the automated inspection of manufactured components. Coordinate measuring machines are essentially large precision positioning systems that carry accurate sensors in the x, y, z directions for the dimensional inspection of manufactured components. These machines have specialized controllers and firmware and are programmable through dedicated software. They are produced here in Rhode Island at Hexagon's Quonset facility for North America and are a corner stone in many automated quality system solutions in today's manufacturing. CMMs provide measurement data not only for the validation of final product quality but for the continuing improvement of the manufacturing process. Unfortunately, the measurement process is often the bottleneck in manufacturing. Manufacturing companies often have trouble collecting enough measurement data or are unable to fully analyze it without holding up production. This is due to the fact that the measurement process and analysis of the measured data is inherently slow and can be prone to operator errors. For example, care must be taken to maintain the calibration of the system, select the correct measurement routines in the software, properly load parts on the CMM and interpret the results for corrective action. Mistakes at any step in the inspection process can have very expensive consequences for the whole manufacturing operation. This is where intelligent automation systems can provide tremendous value for inspection.

Technical Director:

Jonathan O'Hare
Business Development Manager
jonathan.ohare@hexagon.com
https://www.linkedin.com/in/jonathanjohare/

Project Motivation:

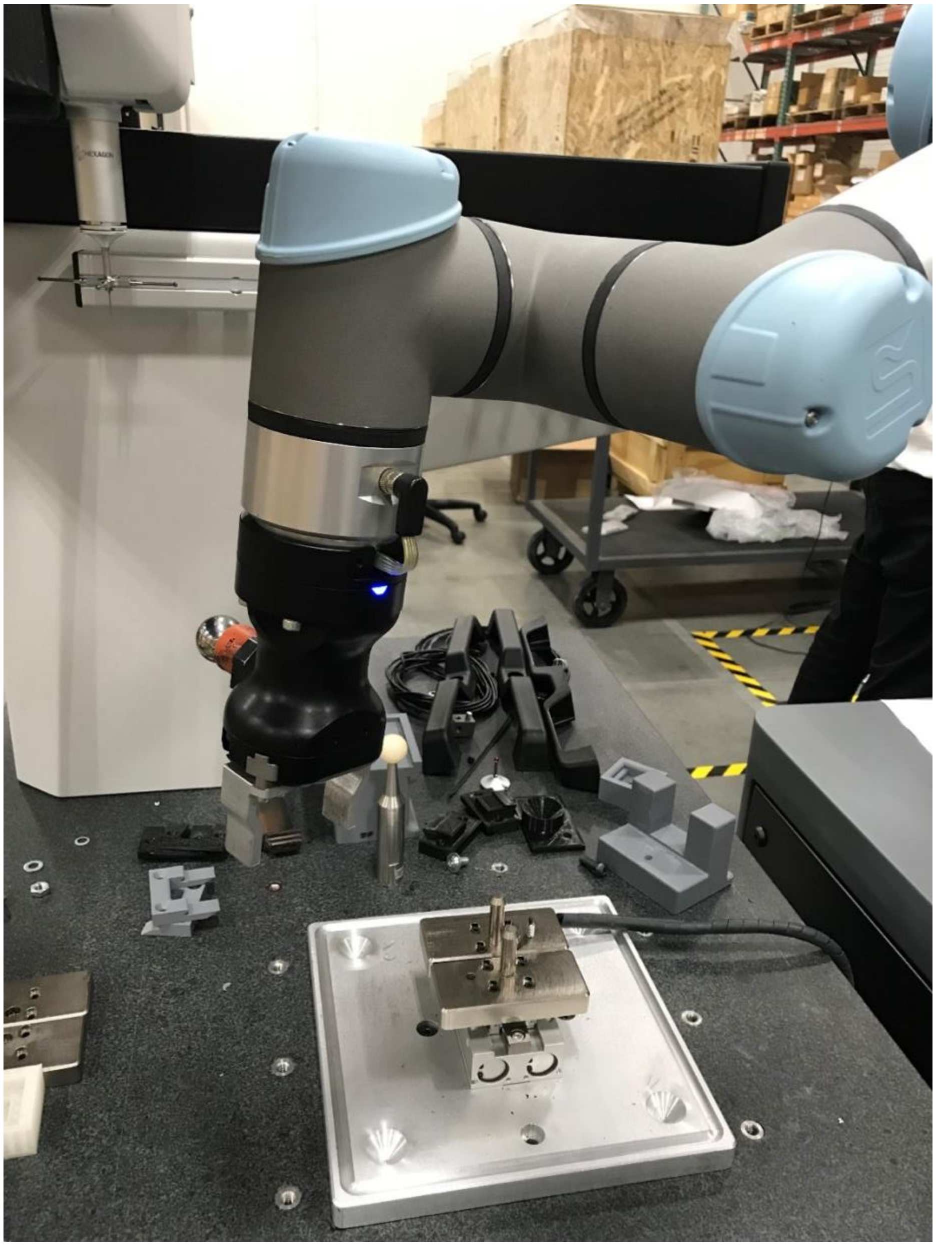
One of the most rapidly growing areas in manufacturing is automation. Companies today need to be globally competitive and thus must be able to justify highly skilled labor through the efficiency of their operation. To this end, collaborative robots (COBOTs) as well as other automated machinery, must be effectively integrated into each production process and work as independently of human intervention as possible.

One such production process in virtually every manufacturing operation is the inspection or measurement process. Coordinate measuring machines (CMMs) have long been used to assist in providing critical measurement data to provide the necessary feedback to control all of the other processes responsible for producing the product. Although CMMs are already computer automated and somewhat intelligent in their own operation, they currently do not collaborate with other equipment or share the information they acquire to enable process level decisions to be made on their own. CMMs still often rely on human operators to make decisions to prepare parts for inspection as well as analyze the results for corrective action.

The ***goal of this project*** is to develop a ***simple and reliable method*** to identify machined parts so that a COBOT is able to select and transfer that part to a CMM and activate its respective inspection routine. Not only is it currently time consuming for a human operator to load parts, but sometimes also prone to operator error when many families of parts look similar to one another. For example, in some instances a single mishandled part in a batch order for an aerospace or medical device company can jeopardize a company's supplier status. It is also time consuming for operators to enter serial numbers or other unique identifiers for individual parts when traceability is required. It is also of interest to be able to read barcodes or other labels on the parts to reduce data entry. Component traceability is important for the aerospace and medical device industries but is not required for all manufacturing processes, therefore this can be a stretch goal and not a requirement for this project.

Another objective of this project is to be able to create an intelligent response to the possible error conditions as a result of the automatic identification of parts prepared for inspection. For example, a robust algorithm may be developed to recognize a part but what if the part is loaded the wrong way or there is an unknown part without information in the database to compare it to? In a real-world environment, the system must be able to address these error conditions and have a way of handling them without operator intervention. Therefore, the developed algorithm must be able to give the part orientation and position in 3D space as part of its output. This result can also be used to help direct the robot to position the part to a camera more specifically to be able to read its serial number.

Automated Inspection System Overview



Automated Inspection System:

Close up of COBOT with gripper and part fixture on CMM table

Project Details

Part identification for the inspection process can be defined in several ways. Most fundamentally it can be defined as the ability to recognize the type of part based on its shape in order to match it with its correct part drawing number. This enables the system to launch the part specific inspection routine based on the part's drawing number. Another important definition is the ability to recognize the position and orientation of a part in 3D space thereby enabling the part to be handled for automatic processing. In other words, it is not always merely enough to know which part, but where it is so that a COBOT can decide how to grip it and place it onto a fixture for the next step in the process. Lastly, another form of part identification is unique part identification. This requires the ability to read a UID code or label on the part itself. For example, a QC code reader or OCR of a part serial number may be used to process a small subsection of the image. If this method is done then both part type and specific part identification can be done at the same time since a visible label on the part would also be able to defined both information, however this method is less flexible since it requires a consistent labeling format among customers. The expectation for this project is to leverage what has been done in last year's Capstone project and build on those achievements in order to obtain a more thorough solution including some basic UI for independent testing as well as the previous project's specified stretch goals.

In summary:

Identification Type	Method
Shape recognition	Image processing / edge detection
Shape recognition + position/orientation	Image processing / edge detection + force sensing
Unique part identification	Barcode reader or OCR

The focus of this second stage Capstone project is to focus on the two identification types/modes highlighted in the above table. This existing sensing technology developed by the previous Capstone Team uses CCD cameras and a proven algorithm to identify the part based on learned values derived from a nominal part surface model. This CCD camera has been mounted externally at some distance from the part ranging from 200 to 500mm.

For this project, the COBOT being used for the part positioning is a Universal Robot model UR5e with a Robotiq model Hand-E gripper as an end effector. Some other considerations in developing a proof of concept for robot positioning may be the substitution of an actual robot with a movable test fixture with a similar gripping scenario to hold the part.

The test application is an assortment of manufactured components representative of the automotive, aerospace and medical device sectors. These components will have typical cast or machined surfaces and made of a range of materials including aluminum, steel and titanium. The size range of these components will be less than a 150mm cubic volume. Other factors influencing the recognition of the components such as focal distance, angle and lighting conditions may all be changed or adjusted as necessary. If cameras are fixed in a stationary position then the cobot can position the part at any different orientation for possible improved imaging. Additional lighting may also be mounted around the system or robot as long as it does not interfere with the motion path of the robot or system's moving components.

Robotiq Wrist Camera:

Unmounted view   Mounted onto Hand-E gripper

https://www.universal-robots.com/plus/vision/robotiq-wrist-camera/

Sample Parts Requiring Recognition:

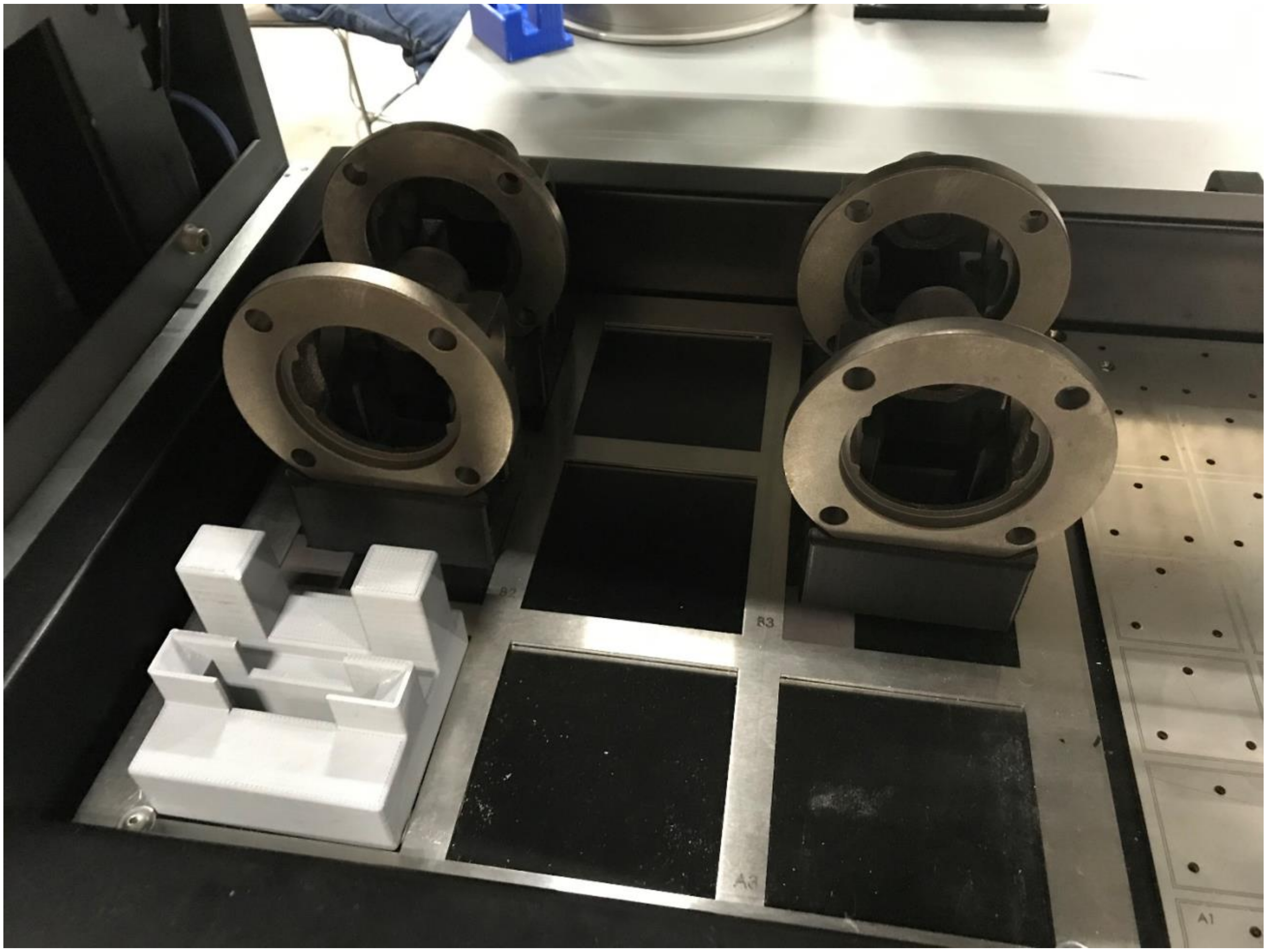
CV flange (automotive)

Jet turbine blade (aerospace)

Hip prothesis (medical device)

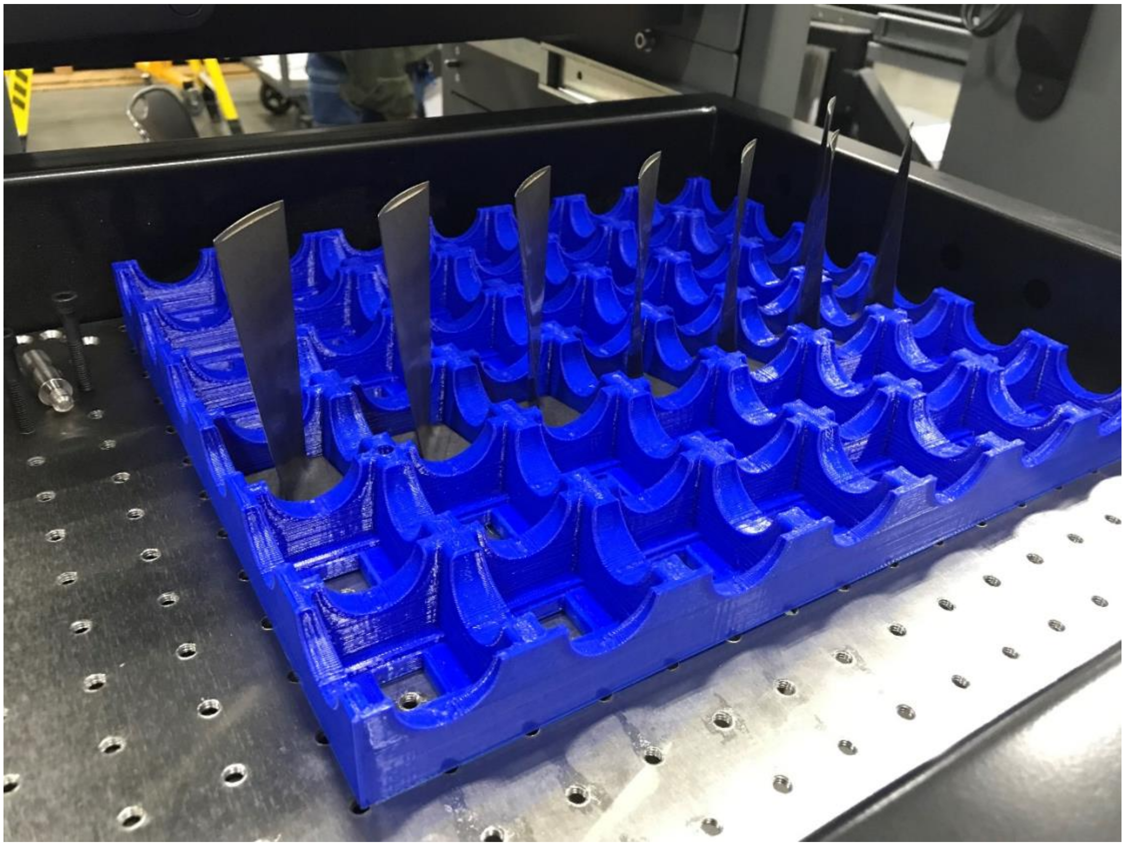
Air bearing (internal CMM part)

The images below show the various parts loaded into their respective pallets in their storage position. These positions are arranged for COBOT part handling or accessibility and may not be in the ideal position or orientation for recognition purposes. Therefore it is assumed that some repositioning by the COBOT may be necessary. Further study may also reveal that a camera mounted on the cobot wrist is not ideal for the most effective imaging.



View of the CV flange pallet arrangement plus CMM support fixture (white)

View of the air bearing pallet arrangement



View of the blade pallet containing a single row of parts

Example of a difficult serial number to capture without human assistance.
(Serial number is on the base of a jet engine vane)

Team Composition

1 electrical engineer (ELE) and 1-2 computer engineers (CPEs)

(The full team will also have 1-2 industrial engineering students; these will be selected by Professor Sodhi, and the full team will also work under his supervision, as well as the Technical Director)

Student Skills Required & Division of Work

It is envisioned that **at least one Computer Engineering student** will be required to focus development effort on (1) UI/frontend coding for making the existing algorithm user friendly for testing purposes, (2) produce a resulting json file with required outputs for robot positioning and (3) tie in the OCR algorithm as a next step operation in the workflow of the core software. Two students may be able to divide the workload between the above tasks, since the UI will need to accommodate functionality for both the shape recognition and OCR methods.

It is envisioned that **another student from the Industrial Engineering Dept** will assist with the verification of the existing recognition algorithm with additional parts, test bench for the OCR method, training the OCR algorithm as required by the process

It is expected that ***ALL*** students involved will have good background in computer programming, where implementing robot scripts for the UR5e COBOT will be needed for testing purposes. This robot scripting language is similar to Python, so that this would be most similar. It is expected that more of the robot testing can be done at a later stage once the hardware and algorithm selections are made and system mappings completed. Most of algorithm testing can be done without a robot by manually positioning test parts on a precision stage or sine block. Once the project reaches the testing stage with the robot, both disciplines may participate in implementing test procedures using the COBOT. Not only will this give all team members experience using the COBOT but also more practical since availability of the COBOT and team member's schedules may not always align.

Anticipated Best Outcome and Deliverables

The Anticipated Best Outcome will be: a part recognition method that is reliable and fast enough for the inspection process, easy to teach for new parts and able to be easily integrated with existing hardware. The integration of the part recognition method must also be demonstrated to handle the various error conditions previously described which are typical for the inspection process. Some stretch goals, or better than expected outcome, would include using camera systems already designed for the UR robot and having that system also capable of barcode reading and or OCR reading of labeled or marked parts.

Deliverables Summarized

- A part recognition system with a training procedure that takes no more than 10 mins to acquire the necessary images and process user inputs. (completed June 2020)
- Parameters needed for input during the teaching process, should be documented.
- An algorithm with 99% success rate for trained parts (completed June 2020 - needs further verification using more test parts)
- Processing time for positive recognition in under 5 seconds (average). (completed June 2020 – exceeded expectations)
- Conditions defined for 99% successful part recognition, if any.
- Output file from part recognition with setup conditions and reference system to determine orientation and position
- Application of secondary recognition algorithm to analyze close zoom location on part containing a UID (unique part identifier) such as a serial number using an OCR algorithm.

Anticipated Best Outcome's Impact on Company's Business:

A system that is 99% successful at identifying trained parts will contribute significantly to labor cost reduction for the inspection process since no data entry will be required by an operator at the time an inspection job is initiated. Although the present solution automates the physical loading of parts onto a CMM for inspection, it still requires data entry by an operator. This data entry is both prone to error as well as time consuming since someone must still be physically present at the system's PC to enter the information. This functionality will solve this very apparent problem for our customers and they will recognize the value added in terms of both efficiency and traceability. It will also be a useful sales tool because it will be easy to demonstrate.

Broader Implications of the Best Outcome on the Company's Industry:

A truly automated process implies that human interaction is not needed for any step in that process. Visual confirmation and data entry may not be labor intensive, however they are still steps in a process that includes human interaction. Smart vision systems remove this step and move us one step closure to realizing a truly "lights out" manufacturing environment; the promise of Industry 4.0.