2018 Capstone project brief:-
Automated Check-in Station (ACIS)

Oct 2017

CQR
Customer Quality & Reliability

Introduction

The brief is to build a robotic ‘check-in station’ that automatically captures component ID information from silicon chips that need to undergo failure analysis in a lab environment.

The project involves a mix of hardware and software

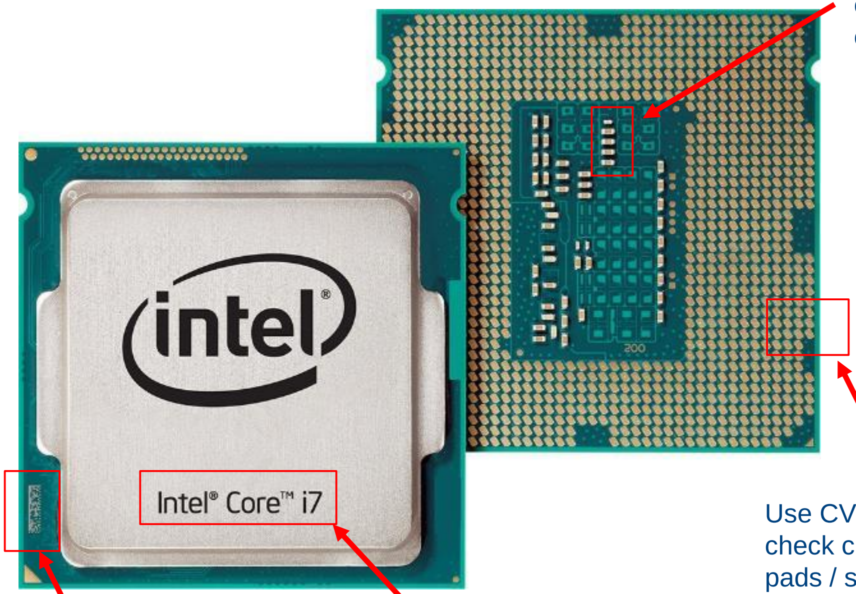
The primary goals are

- To have a fully automated ‘check-in’ that reliably identifies the component
- The system should use off-the-shelf hardware and software where possible.

The secondary goal is:

- To performs a useful level of visual inspection via CV software.

Example ‘chips’ showing typical information needed

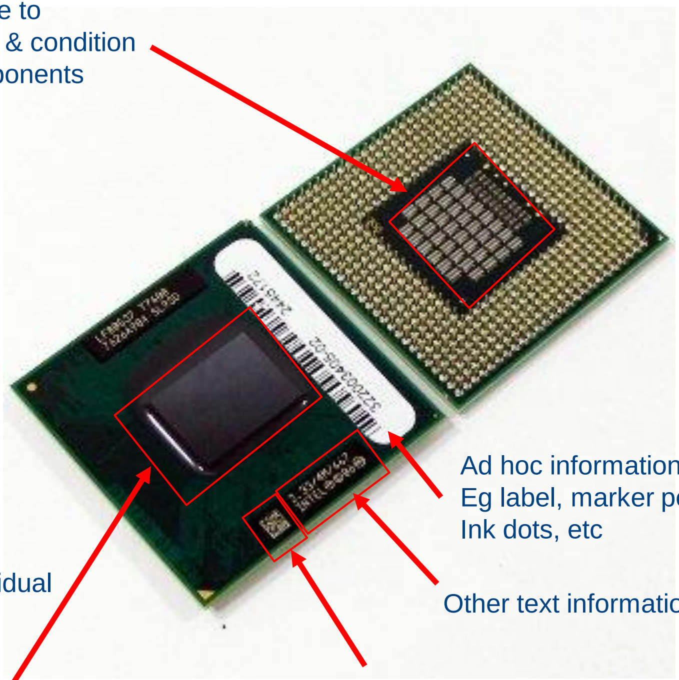


Use CV software to
check presence & condition
of passive components

Use CV software to
check condition of individual
pads / solder balls

Other text information

2D barcode contains
Product information



Ad hoc information
Eg label, marker pen,
Ink dots, etc

Other text information

2D barcode contains
Product information

Inspect backside of die
For damage like scratches,
Cracks, chips, etc

Overview of the check-in station

The system will be a small, light-tight box containing 2 x ~$100 USB cameras and controlled illumination. The cameras can be moved in +/-Y direction by an off-the-shelf stepper motor and drive screw. They are to be capable of manual macro-focus and will be focussed by software-controlled movement in the Z direction.

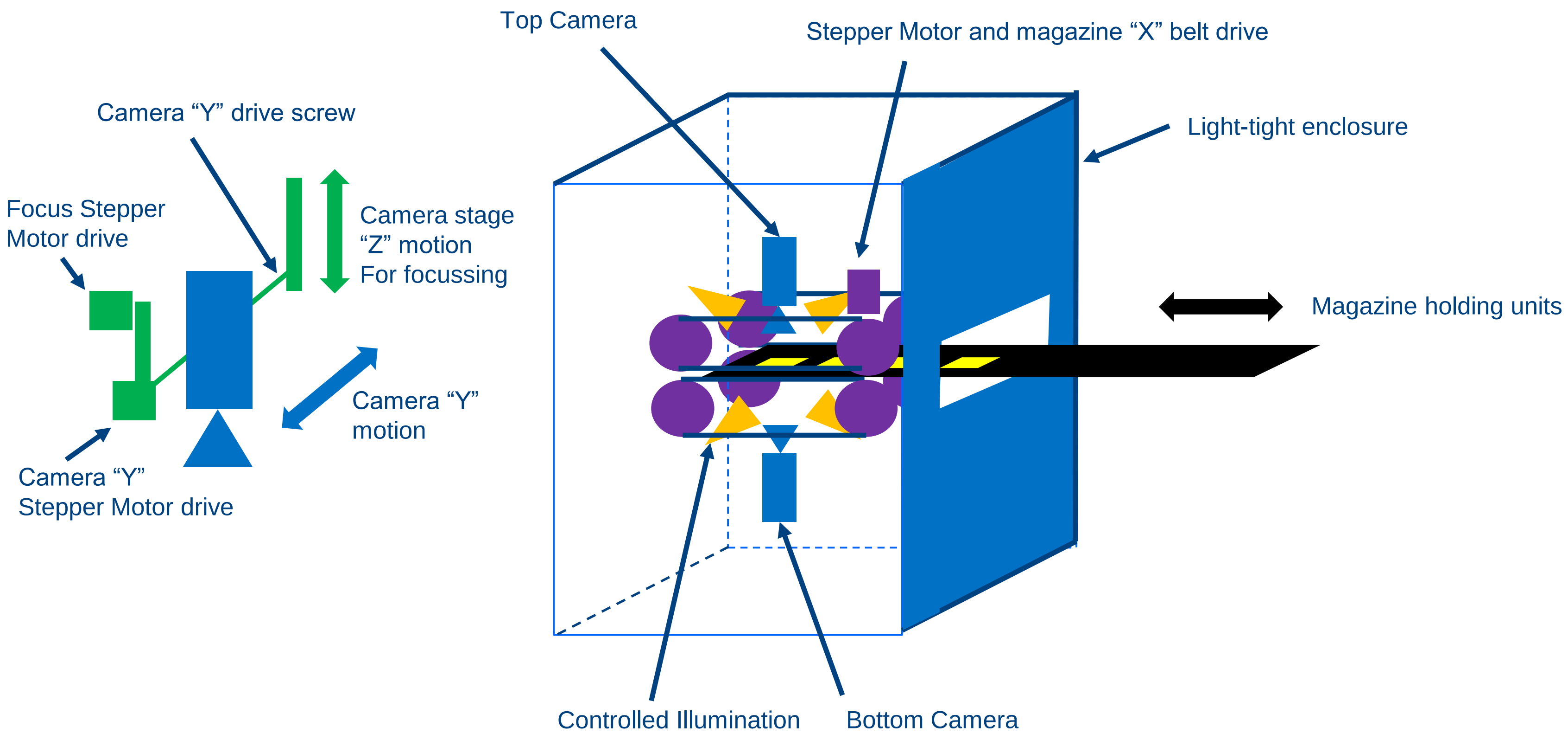
The box will have entry/exit slots through which you can insert a magazine containing an array devices to be checked in. As you insert the magazine, a simple, low cost stepper motor and sensor system will draw the tray into and through the box in the +/- X direction, like a Compact Disc drive does

The magazine must hold devices only around their edge so that the top and bottom surfaces can be positioned under the camera and are maximally visible.

The software will use the cameras to take a set of overlapping photograph of the device top & bottom that will then be analysed by CV functions to check for visual defects (solder, contamination, cracks, etc). The software will save the individual tiles and also stitch the tiles together to form a complete high-res picture which can then be saved as a single file.

The CV software should use openCV or equivalent off-the-shelf solution and should initially use simple template-matching rather than any more advanced training-based or AI solution (this can be a stretch goal once template matching has been implemented successfully)

Concept Design



Hardware

All components should be low cost and off-the-shelf where possible and the system should be easy to assemble and maintain using only basic tools.

The frame can be made from standard 20mm extruded aluminium profile utilizing off-the-shelf fittings. The system should weigh no more than 5kg and must be able to easily fit on a standard workbench.

Attention should be paid to minimize weight and to make the system robust enough to ship internationally without damage (especially from shocks in the Z direction). Shipping straps and stays should be considered.

The system must be robust and safe to use and prevent harm to any user. Safety interlocks and cut-outs must be implemented in such a way as to prevent them from being easily overridden by an operator. Eg door switches must prevent operation when access doors are open.

The use of non-conducting plastics that might cause electrostatic potentials (ESD) is not permitted. Industry practice requires that semiconductor devices must be protected from damage by ESD.

System Software control of hardware features

The system software must :

1. sense insertion/removal of a magazine and control movement in the X direction according to information in a system configuration file.

2. Be able to positively identify a device and select the appropriate configuration file containing the parameters for that device

3. be able to set the Z-height of each camera according to the config file.

4. Be able to position the camera at various pre-defined positions on the device in order to take the image array, according to data read from the config file.

5. Control the illumination

6. Manage interlocks and safety features

Ideally this would be done through a USB link from a controller PC to an Arduino device embedded in the check-in station that ran a simple control program and command set to control motion.

Cameras and Arduino should link to a USB2 hub also embedded in the station

The station should have its own power supply which may be internal or an external power brick.

Application Software CV Features

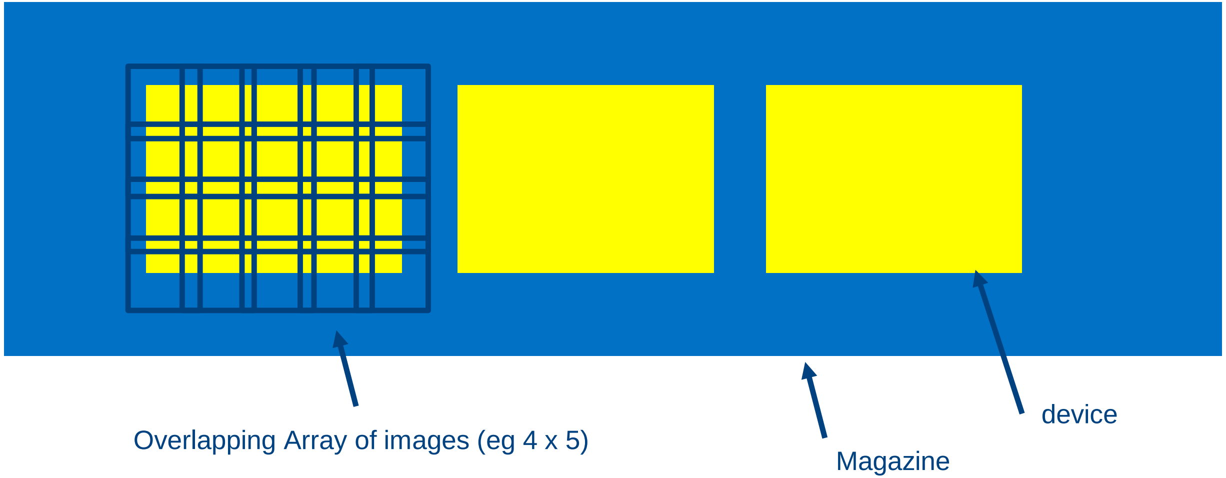
The main application software will :

- be written in Microsoft C# using Microsoft Visual Studio and run on a Microsoft Windows PC (win7 or win10)
- Output results to XML ‘text’ files and images to JPG compressed image files
- Use openCV libraries for vision functions:
  1. Detect device presence and orientation; is it rotated or inverted? Adjust s/w behaviour to accommodate this. The software should be designed to allow the operator to place devices in any reasonable orientation.
  2. Identify and read 2D barcode / VISID and all expected package information using existing software
  3. Accommodate ad-hoc marking on units (marker pen, sticky labels, ink dots, etc). Reject devices are often manually marked in some way. It should at least be able to either reject them as ‘*not correctly prepared for check-in*’ or ignore them and should ideally be able to identify and capture the ad-hoc information as an image.
  4. Check package contacts match the expected template image. Each pad shall have an associated ‘gold template’ image which will be used to determine the degree of matching. Multiple pads can reference the same template if appropriate. This check will result in a pass/fail decision for each pad and any failing pads will have their images recorded.
  5. Similar to the above pad check, also check package passive components for presence and damage by template matching
  6. If applicable, check die ‘backside’ looking for damage, cracks, contamination, etc. Again, use template matching against gold images.

Composite images from X & Y motion

Macro-camera should take close up pictures of the package. You need to determine:-

- The necessary image size and resolution in order to meet the various optical inspection requirements
- The amount of overlap required to 'seamlessly' stitch images together allowing for camera lens effects
- The degree of compression used along with its impact on image CV processing and interpretation by eye
- The best image size w.r.t. speed of image processing, storage requirements and transmission requirements over relatively low bandwidth communications links.



Illumination

A big part of the project is to solve the illumination problem. The units are made of different materials with different reflectivity and possibly even different/varying colours.

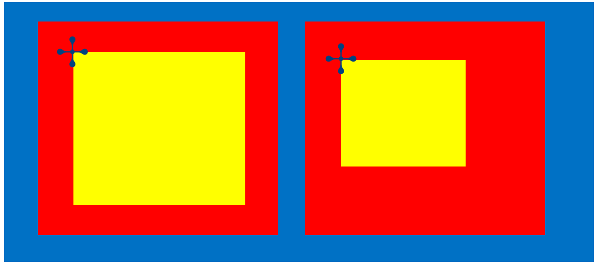
It will be necessary to conduct experiments to determine the optimal light levels & angles for both lighting and cameras.

Appropriate use of selective & angled lighting and shadows will greatly assist detection of contamination and defects that protrude from the device surface (eg solder residue)

Magazine Design Options

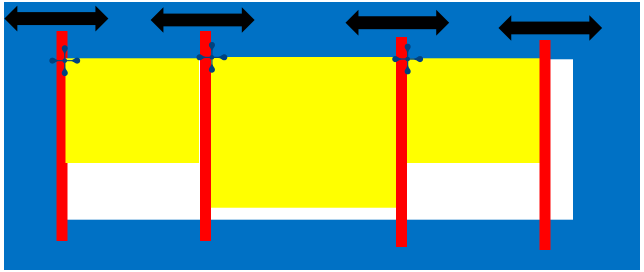
The magazine design has some aspects that need to be worked out by the students.

- The design must allow the operator to load the magazine with different types of devices and should allow for a capacity of at least 10 devices.
- The design could involve a single line of devices or parallel lines, but bear in mind the design constraints on minimizing station volume, desktop footprint and weight.
- The devices should have a designated datum position that the vision system can utilize. In the examples below it is the upper-left corner.
- Option A involves individual carriers that are specific to each package design. The carriers could be secured into the magazine but must be easily changeable if the operator wishes. The downside is there are more individual parts involved and there is a cost to producing carriers for new package types (machining costs, shipping costs & delays, etc)
- Option B is a universal design with sliding support rails that are moved to accommodate differing package sizes. Although this may be mechanically more complex it has advantages in terms of flexibility, units per magazine and reduced costs to adding new package types. If this design can be made reliable then it is the preferred option.

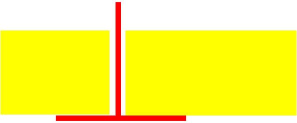


Option A – Selectable Carriers in Wells

=datum



Option B – Sliding Supports



Cross section
Through sliding
support

Error Handling

The system software and application software should contain a sufficient amount of diagnostic messages and logging in order to allow any problems to be identified quickly.

The software must be stable in the event of all error conditions. An FMEA should be conducted and a report written to explain the approach used to determine likely system failure modes, risks and effects.

To succeed the system must operate reliably.

Success

The project will be deemed “***successful***” if either:-

- The prototype station can reliably process devices
  - ‘reliably’ means able to successfully process the same unit 99 times out of 100 taking no more than 10 seconds per attempt. An attempt may involve multiple re-scans & decodes within the 10 sec window.
  - ‘process’ means repeatedly physically moving the device, capturing an image & decode the barcode in order to simulate real-life use across multiple different devices.
  - ‘identify’ means at least being certain about knowing the type of the device and being able to find & capture an image of the 2D barcode.
  - In use, failures due to corrupted or obscured barcodes don’t count against the reliability. These may be rejected as ‘*2D barcode unreadable due to obstruction*’
- or sufficient evidence and reasoning is presented to show that this is actually unachievable within the design constraints

The project will be deemed “***very successful***” if either the 2D-barcode decode or the CV template matching can be demonstrated. If both can be shown to work reliably then the result will be “***exceptionally successful***”