This practical exercise consists in developing a machine vision system to perform measurements in a metal part. Each group will have a different measuring task, all with similar difficulties. The measuring tasks are defined in the specifications provided to each group.

The following is expected from your proposed solutions:

- You should work in a calibrated measurement plane.
- You need to perform experiments to assess the performance of your system quantitatively. This should at least include determining the accuracy and repeatability of your system. Optionally you can consider determining the constraints in the object's position and orientation, or any other interesting aspect you might want to consider.

The following aspects will be considered for the evaluation:

- Proposed solution and implementation.
- Analysis of the obtained results.
- Documentation. It must be clear and concise and must include the sections detailed below.
- Code readability and efficiency (do not aim for perfection, but for reasonable quality code).

Documentation must include the following sections:

- **Introduction**: describe the designated inspection task.
- **Method**: describe your proposed solution.
    - Hardware system description. Explain what devices you are using and how they are arranged and configured. Detail all the employed geometric transformations.
    - Software design. Explain the logic and structure of your solution. Imagine a colleague needs to maintain the machine you have developed; this section should provide a roadmap of how to understand your code. Note that no code should be included unless strictly necessary or relevant. Diagrams with logical blocks and images obtained in intermediate operations should suffice. The most important parameters (if any) should be specified.
    - Constraints: Specify conditions/limitations in which your solution will work (if any).
- **Experiments**:
    - Calibration (camera intrinsic and extrinsic parameters) setup and results.
    - Experimental design used to evaluate your systems performance.
- **Analysis**: this section should provide a quantitative assessment of the performance of your system. If there were problems that you could not solve, or factors influencing the performance of your system explain them here.
- **Conclusions & future lines**: what would you conclude from the previous analysis? What would you do to improve your system?

Some remarks

- Performance evaluation

The accuracy and repeatability of the measurements are two parameters commonly evaluated in industrial inspection systems. The following definitions have been taken from the "Guide to the expression of uncertainty in measurement" (JCGM 100:2008):

Accuracy of a measurement*: closeness of the agreement between the result of a measurement and a true value of the measurand.*

Repeatability *(of results of measurements): closeness of the agreement between the results of successive measurements of the same measurand carried out under the same conditions of measurement.*

Although the previously mentioned guide provides more complex methods to carry out an evaluation of the performance of your measurement system, in this work a simplified approach will be considered. You can perform a series of N repeated measurements considering the variability of your system (e.g., positioning constraints). For each measurand, the individual observations x_i will differ in value because of random variations in the influence quantities and because of systematic errors in your measurement model.

You can consider the difference between the arithmetic mean or average of the repeated measurements and the measurement obtained from an external source (e.g., a caliper) as an estimation of the accuracy of your system. Note that this implies that the external measurement is considered as the true measure, and this will probably be incorrect because this measurement has its own sources of error (especially if you are using a caliper). However, this is the best you can do with the available resources. Thus, you can consider the accuracy as

$$Accuracy \approx \bar{x} - x_{external} \text{ ,}$$

where $x_{external}$ corresponds to the "true" measure and $\bar{x}$ corresponds to the average measurement, given by

$$\bar{x} = \frac{1}{N}\sum_{i=0}^{N-1} x_i,$$

where x_i corresponds to each measurement and N represents the number of repeated measurements.

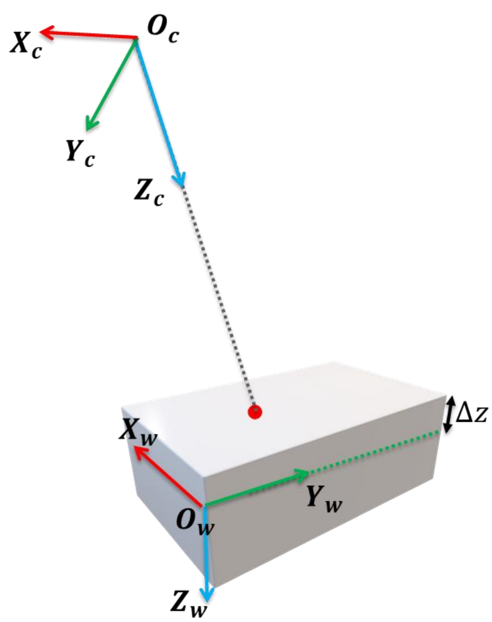
In order to assess the repeatability, you can consider the dispersion of the measured values measured as their standard deviation:

$$\text{repeatability} \approx \sqrt{\frac{\sum_{i=0}^{N-1}(x_i - \bar{x})^2}{n-1}},$$

where $\bar{x}$ corresponds to the average measure and x_i corresponds to each measurement.

- Calibrating the measurement plane

Note that your calibration plate has a non-negligible thickness and so does your metal object. You might need to compensate their differences in thickness by considering an extra parameter Δz when computing the extrinsic parameters of the camera.



- Image enhancement

You might benefit from working with an image that highlights the features required to perform the measurements and removes details from non-relevant features, as it will simplify the image processing operations. This can be achieved using the techniques we have seen in class, but also adjusting your camera settings!