Assignemnt 1 - Assembling Lego kits

Group of two (up to three) persons.
Submission of the Colaboratory file (.ipynb) must be made via Moodle and should include:

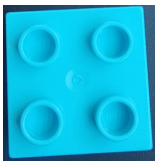
1. *working code file. The dataset import must be automated, and the Colab notebook should be saved after executing all program cells;*
2. *report providing commentary and analysis of all implemented components.*

The Lego production factory needs to select the appropriate parts to include into different kits. Visual data acquired from the production line must be analyzed to classify the types of blocks. The factory relies on a computer vision system to automatically extract the following properties:

- Identification of the **size** of each brick (e.g., **2x1**, **2x2**, etc.);
- Calculation of the average shape area of all bricks, in square millimeters, categorized by color;
- Determination of the distribution of brick sizes and colors within the sample (e.g., total number of red, blue, etc., and quantity of each size such as 2x1, 2x2).
- Verification of completeness: if any size or color required for kit assembly is missing, the system must generate a warning in the format "Color (Size) XPTO is missing".

Table 1 presents the standardized dimensions of Lego bricks in millimeters. The set of colors considered includes white, blue, red, yellow, green, among others. The configuration of the production line inspection system is illustrated in Figure 1.

Table 1: Summary of brick sizes.

Brick	Sample	Length (mm)	Width (mm)
2x1		32	15
2x2		32	32
2x4		32	64
2x6		32	95
R2x2		32	47

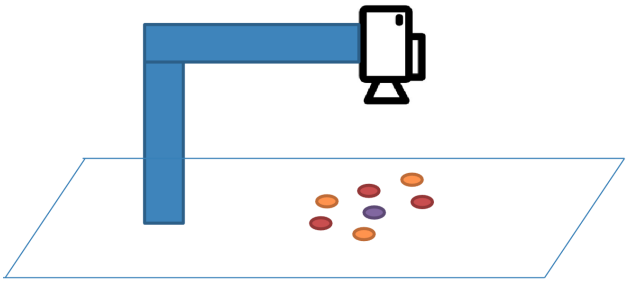


Figure 1: Setup of the imaging system.

The assignment is organized into the following tasks:

1. ***Calibration* images**:

   (a) Three intrinsic calibration attempts were made to determine the intrinsic parameters and lens distortion of the camera. The calibration attempts are contained in folders *Calib1*, *Calib2* and *Calib3*. For each attempt, present the intrinsic matrix, the lens distortion coefficients and the re-projection error. Select the best calibration and justify (in 2 sentences). ***Note**: A chessboard with configuration 12x9 and square size 15 mm was used.*

   (b) The image *"final_setup.png"* represents the final inspection arrangement. Calibrate the extrinsic parameters of the camera setup. Present the extrinsic matrix and specify the pixel-to-millimeter conversion factor applied.

2. ***Isolated* brick images**:

   (a) Define a ROI (region of interest) for the image.

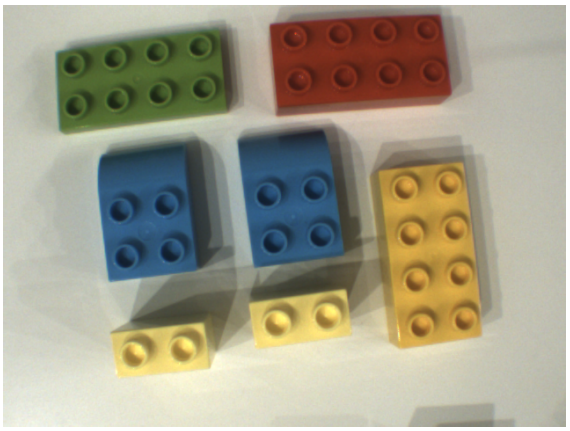
   (b) For image *"colored_bricks.png"*, count the number of bricks grouped by color.

   (c) Consider images *"blue.png"*, *"green.png"*, *"red.png"* and *"yellow.png"*. Group the bricks by size and compute the **average area** and **standard deviation** of each brick size in millimeters. Show the result in a table similar to Table 2.

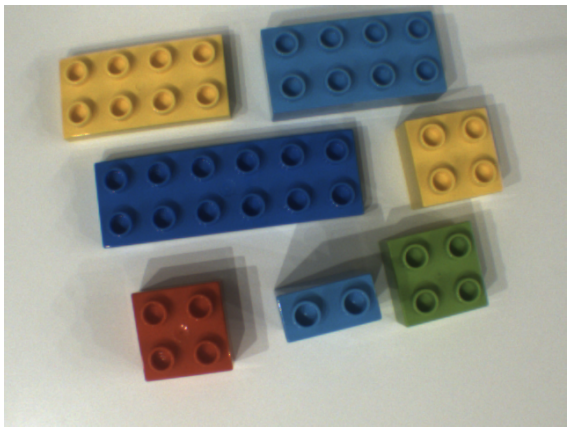
Table 2: Result table for question 2c.

Size	**Avg Area (pixel)**	**Avg Area (mm)**	**Standard deviation (mm)**
2x1			
...			

3. ***Kit* images**. The Lego factory manufactures multiple kits, each consisting of bricks of specific colors and sizes required to assemble different products. Figure 2 illustrates the three complete kits that need to be prepared for packaging and delivery. A kit is considered complete only if it contains the **exact** number of bricks specified for that kit, distinguished by both color and size. ***Note:*** *Assume that the data collected by the inspection system on the assembly line corresponds to a complete kit.*



(a) Kit 1 package (*kit1.png*).



(b) Kit 2 package (*kit2.png*).

(c) Kit 3 package (*kit3.png*).

Figure 2: Pre-defined Kits for package assembly.

(a) Display the bricks detections and their centroids for each image.

(b) Count the number of bricks by size and color for all images. Show the result in a table similar to Table 3.

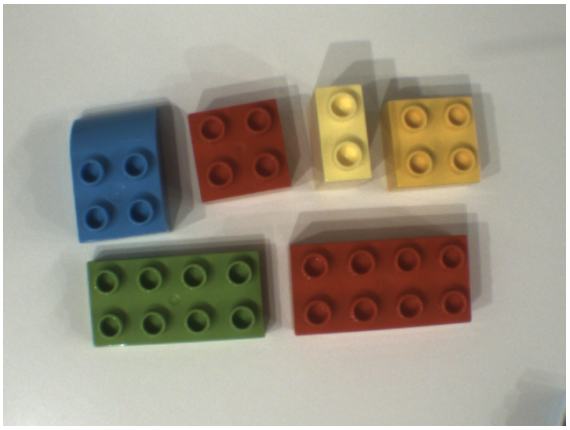
Table 3: Result table for question 3b.

Image	**Size**	**Color**	**Quantity**
ImageA_kit.png	2x1	Blue	#
		...	#
	...	Blue	#
		...	#
ImageB_kit.png	2x1	Blue	#
		...	#
	...	Blue	#
		...	#

(c) Determine which pre-defined Lego kit (see *Figure 2*) corresponds to each image.

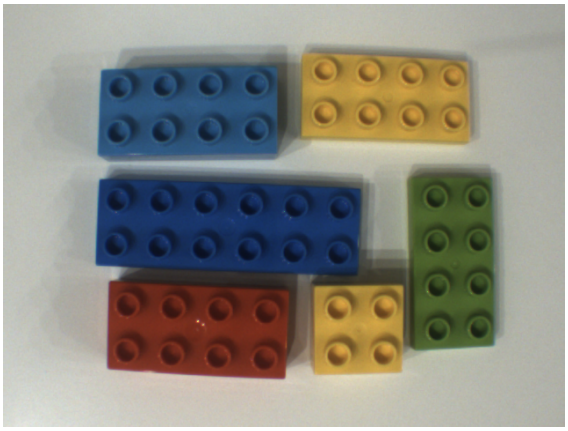
(d) Provide some recommendations that the Lego factory should take into consideration to improve the performance of the sorting process based on image processing (e.g., imaging setup, calibration process and photometric effects), in 4 sentences.

4. ***Fault* images** (3 points). Consider the kits shown in Figure 3. Using the **Fault** image set, assign each image to its corresponding kit or classify it as a Faulty kit. A kit is deemed faulty if it does not match any of the predefined kits, either due to a missing or surplus number of parts, or the inclusion of bricks that are not specified for that kit. In the case of a fault, automatically identify the cause.



(a) Kit A package (*kitA.png*).

(b) Kit B package (*kitB.png*).



(c) Kit C package (*kitC.png*).

Figure 3: Pre-defined Kits for package assembly.

Notes:

- **Calibration** - contains images for intrinsic and extrinsic calibration;
- **Isolated** - contains isolated brick images categorized by color;
- **Kit** - contains production line images for assembling kits. *Each image contains all the required bricks, and every image corresponds exclusively to a single kit*;
- **Fault** - contains production line images for an assembling kit. *Some required bricks can be missing.*