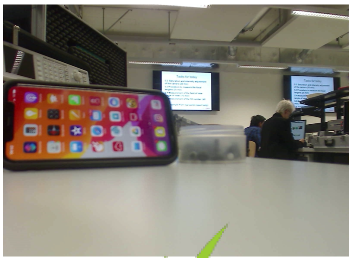
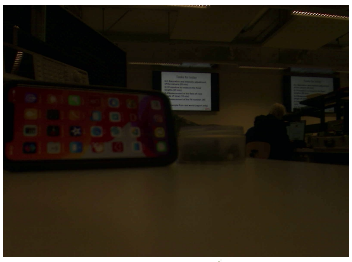
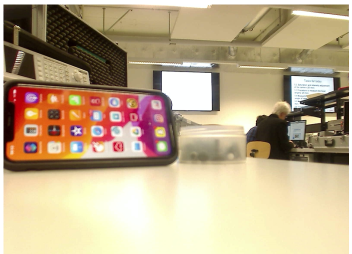
Introduction - Imaging

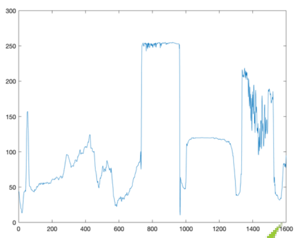
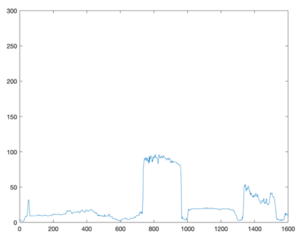
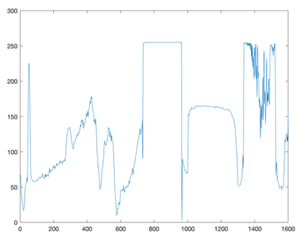
5. Summary of tasks of the experimental work

5.2. Saturation and intensity adjustment of the camera

Take an image of the same scene at different exposure levels: one with automatic exposure, one with no saturated pixel, one with only a few saturated pixels.

Picture 1 - automatic exposure	Picture 2 - no saturated pixel	Picture 3 - few saturated pixel
		

Make line plots at areas were automatic exposure gave saturation and compare the plots for the three exposure conditions.

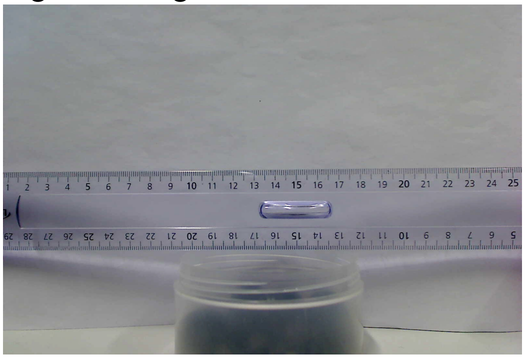
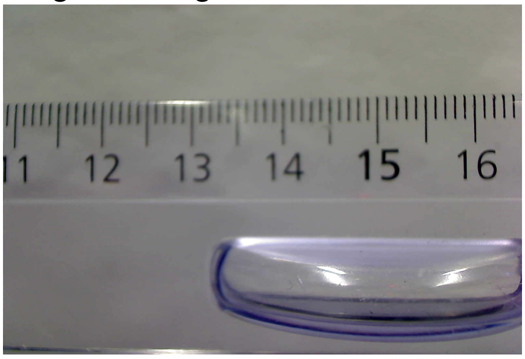
Line plot 1 - automatic exposure	Line plot 2 - no saturated pixel	Line plot 3 - few saturated pixel
		

Comments: We can manipulate the exposure time through the webcam software. The longer it is, the more likely the pixel detectors, constituting the camera, are to accumulate too much energy and saturate.

In the above tables we observe this saturation where bright screens are located. In Picture 3 in particular, we can't even distinguish the content on the TV. Picture 1 saturates a little too because the automatic settings' calibration algorithm is not adequate for this particular case. Obviously, the hardware is able to avoid the saturation, as proven by Picture 2.

5.3 Procedure to measure the focal lengths

Show your two images with different magnifications.

Image with magnification one A	Image with magnification two B
	

Determine the focal length and show the numbers used for the calculation.
(**d_{IB}-d_{IA} = 0.333mm** for one turn of the objective, which we did)

First, we determine the magnification $m = \frac{d_I}{d_o}$, with $d_I = 4.536\ mm$ the image to lens distance and d_o the object to lens distance.

$$m_A = \frac{4.536}{246} = \mathbf{0.018} \qquad (d_o = 24.6\text{ cm})$$

$$m_B = \frac{4.536}{56} = \mathbf{0.081} \qquad (d_o = 5.6\text{ cm})$$

Then, we compute the focal distance:

$$f = \frac{d_{IB} - d_{IA}}{(m_B - m_A)} \Rightarrow \boldsymbol{f} = \frac{0.333}{0.081-0.018} = \mathbf{5.286\ mm}$$

Make an error estimation for the case that we assume no error on d_{IA}.

Errors can be due to imprecise manipulation of the lens position, angle of the photograph, ruler reading errors and orientation as well as varying judgment of the focal positions.

Based on these factors, for our distance measurements we estimate ±10mm precision in case A and ±4mm in case B and calculate the error as follows:

$$\frac{\Delta m}{m} = \frac{\frac{d_I}{d_o - err_{max}} - \frac{d_I}{d_o + err_{max}}}{\frac{d_I}{d_o}} = d_o\left(\frac{1}{d_o - err_{max}} - \frac{1}{d_o + err_{max}}\right)$$

Which yields:

$$\frac{\Delta \mathbf{m_A}}{\mathbf{m_A}} = 246 * \left(\frac{1}{236} - \frac{1}{256}\right) = \mathbf{0.081}$$

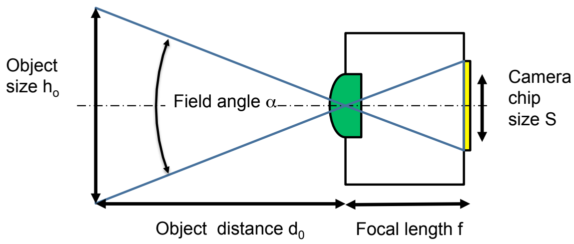
$$\frac{\Delta \mathbf{m_B}}{\mathbf{m_B}} = 56 * \left(\frac{1}{52} - \frac{1}{60}\right) = \mathbf{0.144}$$

So, the error on the focal distance is:

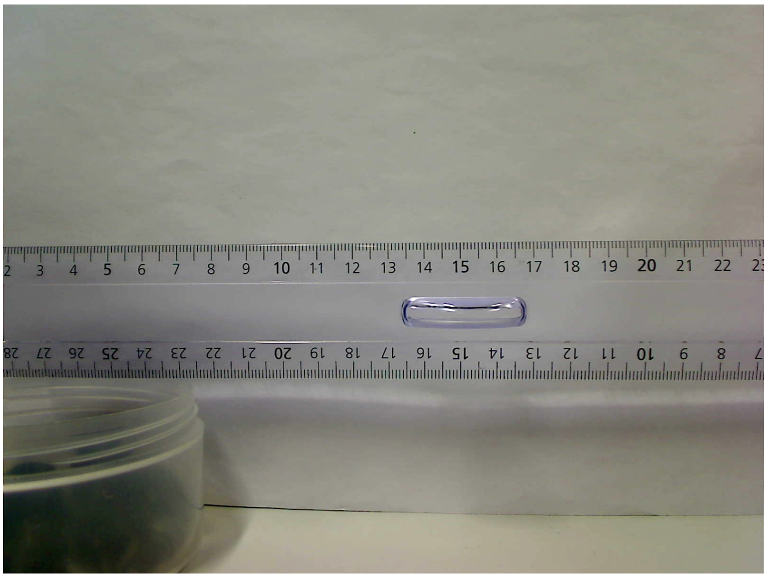
$$\frac{\Delta f}{f} = \left|\frac{\Delta m_A}{m_A}\right| + \left|\frac{\Delta m_B}{m_B}\right| \Rightarrow \frac{\Delta f}{f} = 0.081 + 0.144 = \mathbf{0.225}$$

Result: $f \pm \Delta f = 5.286 \pm 0.225 * 5.286 = \mathbf{(5.286 \pm 1.189) mm}$

5.4 Measurement of the field of view (angle of view)



Measure h_o and d_o. Calculate the angle of view (field of view) and make an error estimation.



The above image was taken at a distance **do = 19cm** and the visible width measured is **ho** = (23.1–1.9)cm = **21.2cm**. Using the below formula, we can compute the viewing angle.

$$\alpha = 2\arctan\frac{S}{2f} = 2\arctan\frac{h_o}{2d_o} \approx \frac{h_o}{d_o} \Rightarrow \boldsymbol{\alpha} = \frac{21.2}{19} \approx 1.12\, rad \approx \mathbf{64}^{\circ}$$

Now, taking into account some errors, we aligned the ruler well, parallel to the camera, and measured the distance more or less precisely, let's suppose we have a ±5mm error on d_o and ±2mm error on h_o.

We then compute:

$$\frac{\Delta \mathbf{do}}{\mathbf{do}} = \frac{0.1}{19} = \mathbf{0.053}$$

$$\frac{\Delta \mathbf{ho}}{\mathbf{ho}} = \frac{0.4}{21.2} = \mathbf{0.019}$$

So, the error on the viewing angle is:

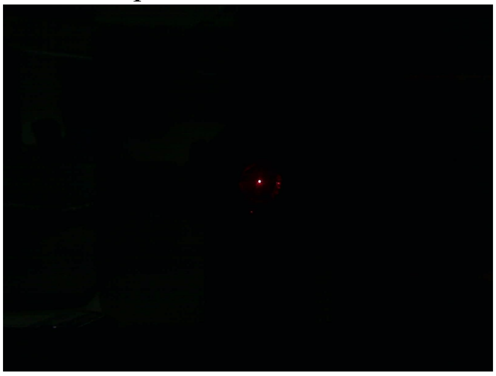
$$\frac{\Delta\alpha}{\alpha} = \left|\frac{\Delta h_o}{h_o}\right| + \left|\frac{\Delta d_o}{d_o}\right| \Rightarrow \frac{\Delta \boldsymbol{\alpha}}{\boldsymbol{\alpha}} = 0.019 + 0.053 = \mathbf{0.072}$$

Result: $\alpha \pm \Delta\alpha = (64 \pm 0.072 * 64)^{\circ} = (\mathbf{64} \pm \mathbf{4.6})^{\circ}$

5.5 Measurement of the F# number.

A picture of the smallest spot size.

Smallest spot size –



A table of luminous disc size versa relative focusing position (min 5 measurements).

The relative position changes represent quarter turn increments, which is more or less 0.25*0.333mm = 0.0825mm for every measure.

No.	absolute position	relative position in mm	Spot size in pixels (from image) (diameter)	Spot size in micron (1px=2.835um)	Angle u (demi-angle) in degrees	NA (sin(u))	F# (0.5/NA)
1	?	0	10	28.35	16.9	0.29	1.72
2	-	0.0825	18	51.03	11.17	0.19	2.63
3	-	0.165	36	102.06	13.55	0.23	2.17
4	-	0.2475	60	170.10	16.13	0.28	1.79
5	-	0.33	80	226.80	16.76	0.29	1.72

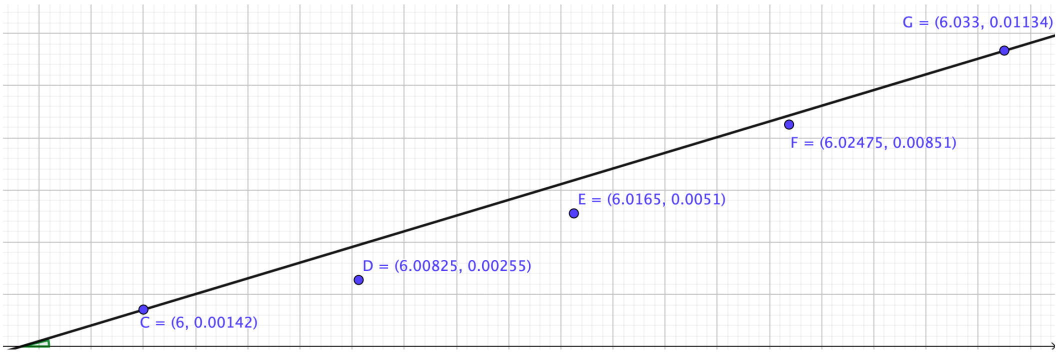
Calculation of averaged

$$u = 14.9^{\circ}$$

$$\mathrm{NA} = 0.25$$

$$\mathrm{F\#} = 2$$

Comments: The half angles were computed using GeoGebra. We plotted the measured points and applied some decent approximations to try and triangulate the position given the lack of an absolute position measure.



Here is our plot, we start with point C at the absolute position of 6 cm on the horizontal axis and add the displacement of a quarter turn to the following points. The vertical axis represents the spots' radii, in centimetres as well, used for the half angle calculation.

5.6. Example from real world

Find an example in the internet of **one photographic lens** with small F# number. Try to find something what not all your classmates have. You might look at websites of well-known lens produces such as Nikon, Canon, Leica, Zeiss, Rodenstock, Fuji….. You can also include c-mount lenses (used for automated machine vision) in your search. Add a photo of the objective!

“The lens aperture is usually specified as an f-number, the ratio of focal length to effective aperture diameter. A lens typically has a set of marked "f-stops" that the f-number can be set to. A lower f-number denotes a greater aperture opening which allows more light to reach the film or image sensor. The photography term "one f-stop" refers to a factor of $\sqrt{2}$ (approx. 1.41) change in f-number, which in turn corresponds to a factor of 2 change in light intensity.” - https://en.wikipedia.org/wiki/Aperture

The larger is the aperture, the smaller is the F# so we look for lenses with a big aperture.

Photo of your objective

Brightin star 50mm F1.4 Large Aperture Manual Focus fixed Lens mirrorless camera Lens for Panasonic Olympus M4/3 mount cameras

Ref: https://www.aliexpress.com/i/4000028010081.html

Personal feedback:

Was the amount of work adequate? No, the workload was not expected for a first session but we had plenty of time to actually finish the "in lab" work.

What is difficult to understand? At first we had some trouble making our way through the document and finding some given values wasn't easy.

What did you like about it? The search for the lens was quite interesting, found out about other things too browsing the internet for it. Also liked getting a first contact with the tools used.

How can we do better? We had a big problem accepting the vague measurement method in the first place and also a little trouble finding out how to calculate the errors as our results seemed abnormal. Maybe you could include those in the slides or give a range for the expected/acceptable values. I think we would redo at least some of our measurements to double check, knowing these things better.

Index of comments

5.1 Should not be able to get angle u, NA, F# for the first row. But others are correct.