Close-Up, Macro and Micro Photogrammetry and Image Perspective: A Comparative Studio on Different Lenses at Work with Small and

Close-Up, Macro and Micro Photogrammetry and Image Perspective: A Comparative Studio on Different Lenses at Work with Small and Medium Size Objects

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Abstract:

The digital photogrammetry has renewed the approach to measurement for archaeologists, architects and many researchers, students, professionals in Cultural Heritage. Thus, most of the troubles coming from the more and more advanced software for photogrammetry processing came from purely photographic mistakes or poor knowledge about photographic tools. Here the focus will be on *perspective* and its influence in the result coming from medium and small size objects and finds. The study will present the results from the use of four different lenses for the same professional DSLR camera body: a Nikon D800e full frame 36 Megapixels, mounting the AF Micro-NIKKOR 60mm f/2.8D with 1:1 reproduction ratio (RT) (one of the best macro lens on the market), the Venus Laowa Micro 15mm f/4 with 1:1 RT (a quite economical super wide lens), a Nikkor Zoom 24-85mm AF with "macro" function (a classic in common set of lenses) and the classic Micro Nikkor 55mm F/2.8 with extension ring to reach the 1:1 RT (a piece of history of photography, the predecessor of the 60mm here in test). The full processing and procedure of matching the data will be presented to bring a useful contribution and reference for other scholars and operators.

Keywords: Photogrammetry; Close-up; 3d modeling; Digital photography; lenses;

Introduction

What does it mean macro photography? Macro photography is simply photographing small items, often insects and flowers, but also still life like jewelry and small household objects. Today it is also possible to consider the macro photography as an advanced survey instrument, which can become fundamental to museums or archaeological purposes. In the days of film, the answer to "what is macro photography" was a little stricter and required much more equipment. Shooting with a film camera, an image that captured something that was at least 1/10th of the original size on a piece of 35mm film was considered macro. Images that captured the object life-size, or at a 1:1 ratio, were considered micro. This can lead to some confusion between the micro and macro words, but commonly define macros all lenses that are able to focus very closely objects. Today, macro photography does not require special equipment; just think that some compact cameras have the macro function and are able to return quality images. It is unnecessary to add that a DSLR is the perfect choice because it's possible choose and use of extremely high-quality lenses. The macro capabilities of a camera can be written in two different ways. The first is using ratio. A 1:1 macro image means that lens will capture a life-sized image of an object. A 1:2 ratio captures a small object at half of its original size, and vice versa. On DSLRs, macro capability is dependent on the lens, not the camera. Lenses with macro capabilities can get closer to a subject. A macro lens usually lists both a minimum focusing distance and a macro ratio in the technical specifications. A 1:1 is a great ratio for a DSLR lens, and many photographers consider anything less than 1:1 not a true macro. Macro lenses aren't limited to just close-ups, either. They can also focus to infinity, meaning they can also snap non-macro photos too. More commonly, a camera or lenses macro capability is measured in the distance the object can be from the front of the lens. Precisely these factors led us to create a direct comparison between lenses using an archaeological find, 58mm high and 39mm wide. Furthermore, to make the test, we wanted more interesting to compare different types of lenses, mainly attracted from the exit on the market of a particular lens for its unique flow characteristics: the Laowa 15mm. This lens is very special: first, the wide focal is unused in macro photography, as preferred with smaller focal lenses; the 1:1 ratio reached as focus, indicates a good quality of the lens construction; also has the possibility to shift the lens to correct any problems of perspective. Now we are going to see how we structured the workflow and the characteristics of the of selected lenses.

Close-up, macro and micro photography

The maximum magnification ratio is the minimum focus of the lens. 1: 1 means that the image is the same sensor size as it is. So, with a full frame sensor of 36x24 mm the width of the frame would be 36 mm. A 1: 2 the width of the frame filling the sensor would be 72 mm. The reproduction ratio is the reciprocal of the magnification that is, 1 divided by magnification.

We used full size of the frame sensor because they are standard, considering APS-C has different size depending on the manufacturer. However, in 1: 1 the image size is the same size of the sensor regardless of the size of the sensor. So, with APS-C image it would be more tightly framed. Whereas with average size, to 1: 1 more of the fractions would be in the frame.

How much of an advantage the maximum reproduction ratio or enlargement of a lens is, it all depends on what is the smallest thing is that you want to fill the frame. It has no real effect on a target to be used for portraiture, because you are usually some way off the minimum focusing distance, when taking a portrait photograph.

All lenses can be made to focus close with additional components such as extension tubes or close-up lenses, which increases the magnification. Thus, for example, with a 1:1 lens it is possible to lead something as large as 2: 1 (2x) using addons.

Fig. 1 – Macro ratio shooting (Copyright: G.Author, P.Author, F.Author, S.Author)

Fig. 2 – Controlling the correct ratio 1:2 (Copyright: G. Author, P. Author, F. Author, S. Author)

Calibrated vs non-calibrated lenses

Nowadays there are several software applications (*i.e.*, Photo modeler, Agisoft Lens, iWitness, *etc.*), mainly produced by the computer vision scientific community, that can automatically perform camera self-calibration. They also offer the possibility to work with several cameras and sensors to obtain dense point clouds or 3D models suitable for different fields of application.

In the wide panorama of consumer grade devices (including nowadays even smartphones or other similar mobile devices), the photogrammetric use though has not been easy since they could not supply high resolution still images and additionally their geometry is far away from the theoretical model of central projection due to their wide angle or fisheye lenses.

First, it is important to take into consideration distortions caused by the lens of camera; these can be divided into two types: geometrical distortions (radial and tangential) and chromatic aberrations. Radial distortion is a type of aberration causing straight lines to appear curved in the picture. It is caused by the misalignment of rays of light when crossing the group of lenses composing the entire lens. In the case where straight lines (referring to the middle of the picture) appear like concave curves, the radial distortion is so called "barrel distortion". When those straight lines generate convex curves, the radial distortion is so called "pincushion distortion". It is produced by the lens misalignments during construction phase, causing a shift of centers of the lenses from the main optical axis. Tangential distortion generates a compound deviation from radial and tangential component at the same time, being the latter orthogonal to the first component. However, in modern lenses this defect is negligible. Another lens defect is the Chromatic aberrations which causes red, blue, green, cyan, magenta or yellow halos, more noticeable in high contrast zones. They are caused by the different refraction index of the lens, according to the wavelength of light passing through the lens.

The testing grounds

Lenses used with a Nikon D800E - FF 36 Mpx:

Nikon AF-S 60mm Micro f/2.8G. One of the best lenses on market for macro-photography, at the same price of the 24-85mm tested. With 1:1 reproduction ratio.

Nikon 24-85mm f/2.8/4-AF-D-IF. Not a high-quality lens but a good one and not expensive for this kind of test. Versatile lens for any situation: landscape, portrait and macro-photography. With 1:2 reproduction ratio.

Nikon Micro-Nikkor 55mm f/2.8 + Nikon Extension ring PK-13 27.5mm. Old lens but good one, with a ratio of 1:2. With this extension ring the lens can reach the ratio of 1:1. Useful for macro-photography and for this kind of test.

Laowa 15mm f/4 Wide Angle 1:1 Macro Lens. This peculiar lens is very particular because it is at the same time wide angle and Macro with a RT up to 1:1, with also the possibility to shift. All these features in the same lens for a reasonable price in comparison with other better-known brands.

How to read the MTF chart

MTF (Modulation Transfer Function) is one of the measurements that evaluate a lens' performance; it shows contrast reproducibility of the lens using characteristic spatial frequencies. Spatial frequencies indicate the number of lines per mm.

In the MTF the horizontal axis is in millimeters and shows the distance from the center of the image toward the edges, and contrast value (highest value is 1) is shown in the vertical axis, with fixed spatial frequencies of 10 lines/mm and 30 lines/mm.

The MTF chart for each lens is based on the value at the maximum aperture of the lens; the red line shows the spatial frequency of 10 lines/mm and the blue line, 30 lines/mm.

In the off-axis field, contrast reproducibility of the lens for sagittal direction and meridional direction varies with astigmatic affection. The path of 10 lines/mm indicates the contrast reproducibility of the

Fig. 3 – Lenses and Modulation Transfer Function (MTF) diagram (Copyright: G. Author, P. Author, F. Author, S. Author)

lens (the higher and straighter is better). The higher and straighter the 30 lines/mm-path is, the higher the resolution of the lens. Note that the lens performance cannot be measured only with MTF chart. Softening or blurring of color also governs measurement.

Photographic set, lighting and object:

The object analyzed is a small artifact (58mm x 39mm), a fragment coming from a Saudi Arabian ancient vase.

Fig. 4 – The small artifact (Copyright: G. Author, P. Author, F. Author, S. Author)

For a better framing, the object was put on the top of a tripod with a black backdrop behind.

Fig. 5 – Photographic set (Copyright: G. Author, P. Author, F. Author, S. Author)

The use of the tripod under the object was useful also for the possibility to keep very close the camera to the subject; the lamp, a Helios Biglamp 430 Ring 65W, with a folding stem, was the best choice because of its maneuverability and the opportunity to be close to the object without creating deep shadows.

Fig. 6 – The object on the top of a tripod (Copyright: G. Author, P. Author, F. Author, S. Author)

Shooting on a tripod, we had the possibility to use a long-time exposure; the condition of shooting was the same for every lens: At f/11 S 1/50 ISO 400. The fact to use a f/11 was required to have a good depth of field. We decided to shoot at ISO 400 to not have an excessive time of exposure, and because of the high quality of the Nikon D800E, in facts the sensor of this camera produce almost noiseless images with this setting.

As we can see from the situation during the shooting the distance between the object and the focal plane was different for every lens. During the use of the Nikon AF-S 60mm Micro f/2.8G the distance was 24,4 cm; for the Nikon 24-85mm f/2.8/4-AF-D-IF the distance was 21,8 cm; instead for the Nikon Micro-Nikkor 55mm f/2.8 + Nikon Extension ring PK-13 27.5mm the distance was 26,5 cm and last the distance of the Laowa 15mm f/4 was just 12,1 cm, the shortest between all the lenses.

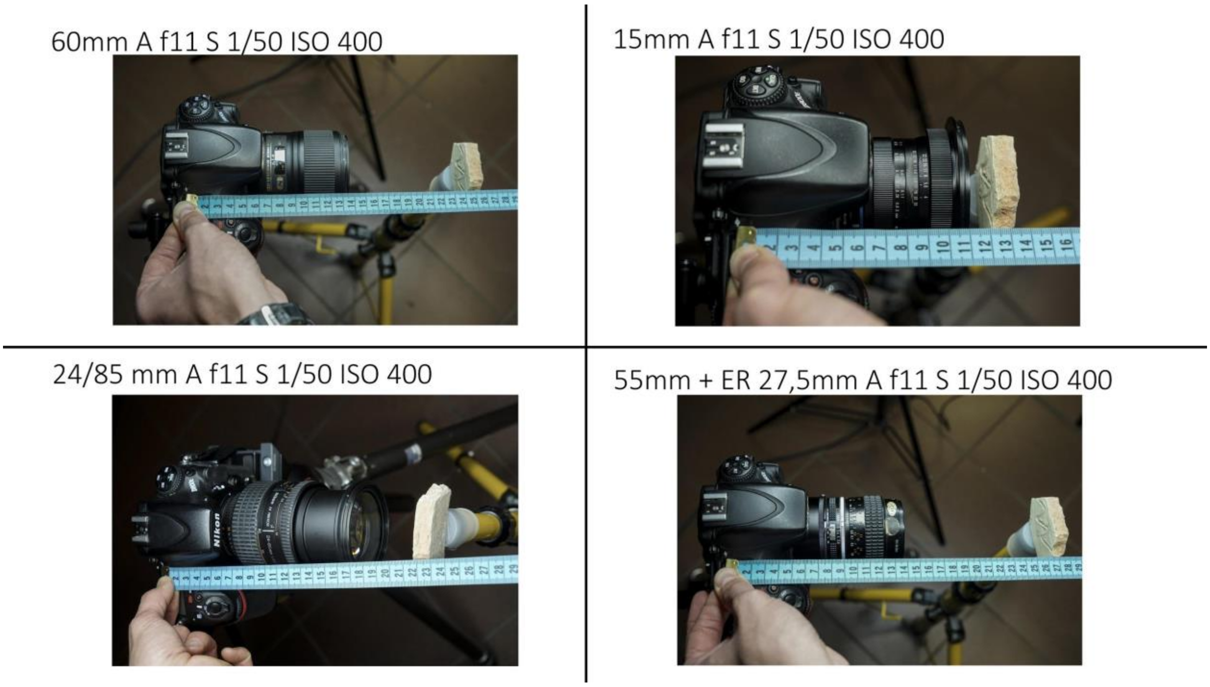

Fig. 7 – Distance between the object and focal plane for every lens (Copyright: G. Author, P. Author, F. Author, S. Author)

First results

Our first result has been to build, using software Agisoft PhotoScan, a series of four dense points clouds that would allow us to obtain a comparison between the results of the various lenses.

Among the four lenses choices, undoubtedly the best in terms of quality is to be the NIKON AF-S 60mm Micro f/2.8G. This aspect has led us to choose this lens as a reference model to compare the other

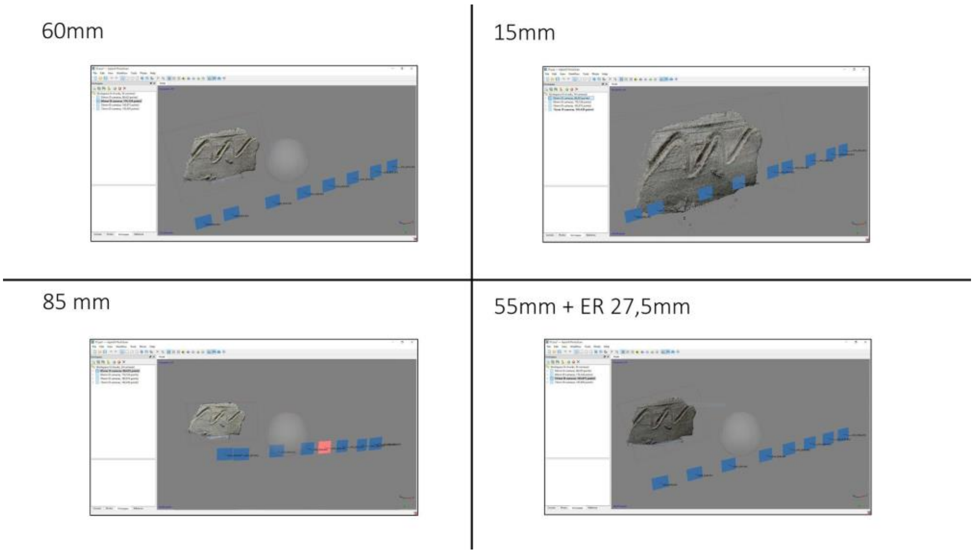

Fig. 8 – Alignment of the pictures for every lens (Copyright: G. Author, P. Author, F. Author, S. Author)

lenses.

After performing the alignment of the pictures for every lens, operation that has not created problems in any of the four cases examined, we proceeded to the creation of dense and raw cloud in order to start the comparison. As we can see from the pictures above the next comparison about the points recognised for every lens highlights some differences on the correct distribution of points on the surface of the object.

As we expected the lens NIKON AF-S 60mm Micro f/2.8G gave a distribution of measured points on the surface homogeneous and widespread. This aspect is the first confirmation of the choice made about the reference lens.

The second lens that we used is a Laowa 15mm f/4 Wide Angle 1:1 Macro Lens. In that case the widespread is good but we have some parts, on bottom left corner, that has not detected points.

The dense clouds present a total of 9.723.781 points overall.

In the dense cloud of the Nikon 24-85mm f/2.8/4-AF-D-IF we can see a suboptimal distribution of the points and their absence in various parts of the object.

The dense clouds present a total of 9.723.781 points overall.

At the end we used Nikon Micro-Nikkor 55mm f/2.8 + Nikon Extension ring PK-13 27.5mm.

Analyzing the data extrapolated from the dense cloud of this lens we can see a good density of the points recognized and a widespread distribution over all the surface.

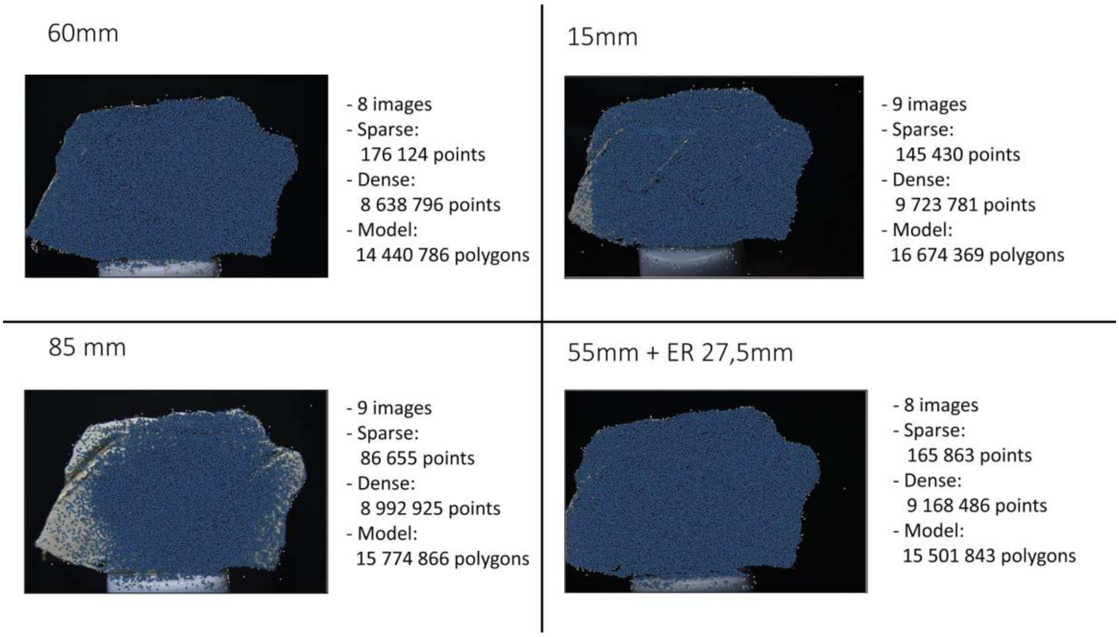

Fig. 9 – Points recognised for every lens (Copyright: G. Author, P. Author, F. Author, S. Author)

The total number of recognized points for this lens is 9.168.486.

Glancing at the final models can be an initial confirmation of the impressions we had from. While all models have a rather homogeneous although not totally collimating, the 85mm lens generates a cloud of points insufficient to accurately reconstruct the actual appearance of the object.

After these preliminary considerations we try to analyze the models obtained through the support of software "Raindrop Geomagic Qualify" for a more detailed analysis of the models.

Fig. 10 – 60mm model from Agisoft (Copyright: G. Author, P. Author, F. Author, S. Author)

Fig. 11 – 55mm + ER27,5mm model from Agisoft (Copyright: G. Author, P. Author, F. Author, S. Author)

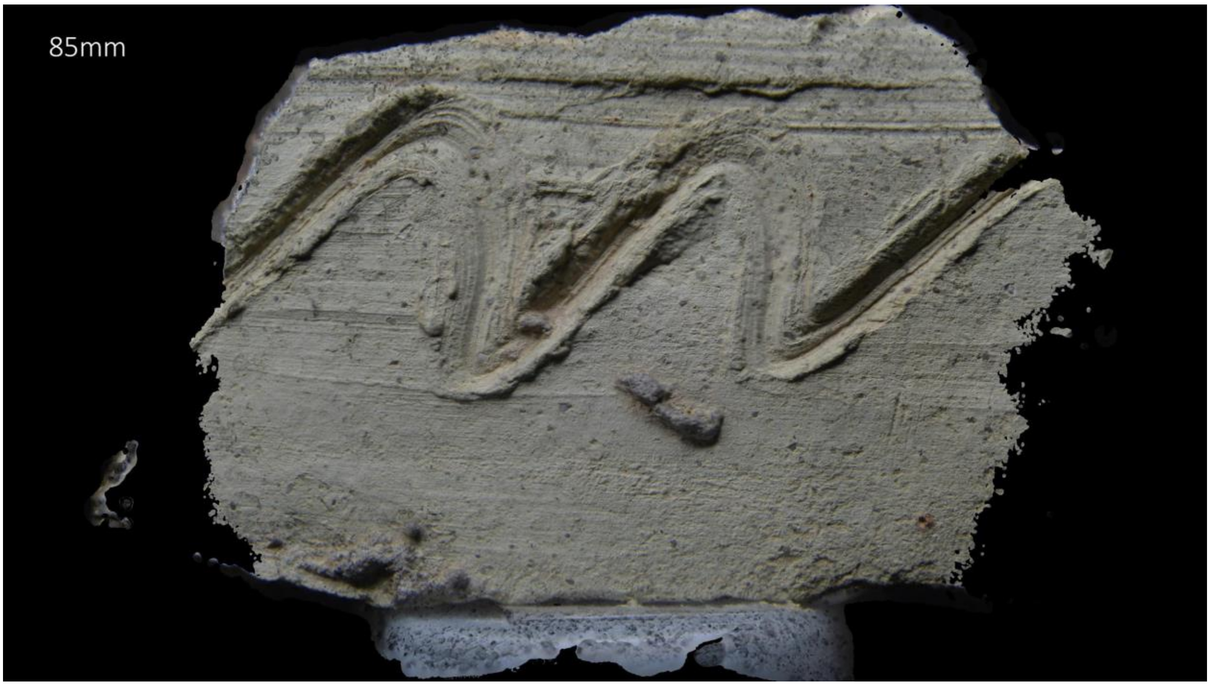

Fig. 12 – 85mm model from Agisoft (Copyright: G. Author, P. Author, F. Author, S. Author)

Fig. 13 – 15mm model from Agisoft (Copyright: G. Author, P. Author, F. Author, S. Author)

The final benchmarks

After digital scanning and three-dimensional reconstruction of the object, the 3D models were compared to analyze the differences and the quality of the survey.

The first impression was positive, because all three lenses have produced results not too dissimilar from the reference model, that is the Nikon 60mm.

For the comparison of the 3D models, we used the Geomagic Qualify software that, using a color scale, makes a clear view of the differences between the models.

In detail, all three lenses have generated a good result but what has left us surprised was the quality achieved by 15mm. As it is possible to see from the graphs results obtained (fig. 14), the 15mm has produced the closest result to 60mm, with an average deviation of 0.037mm.

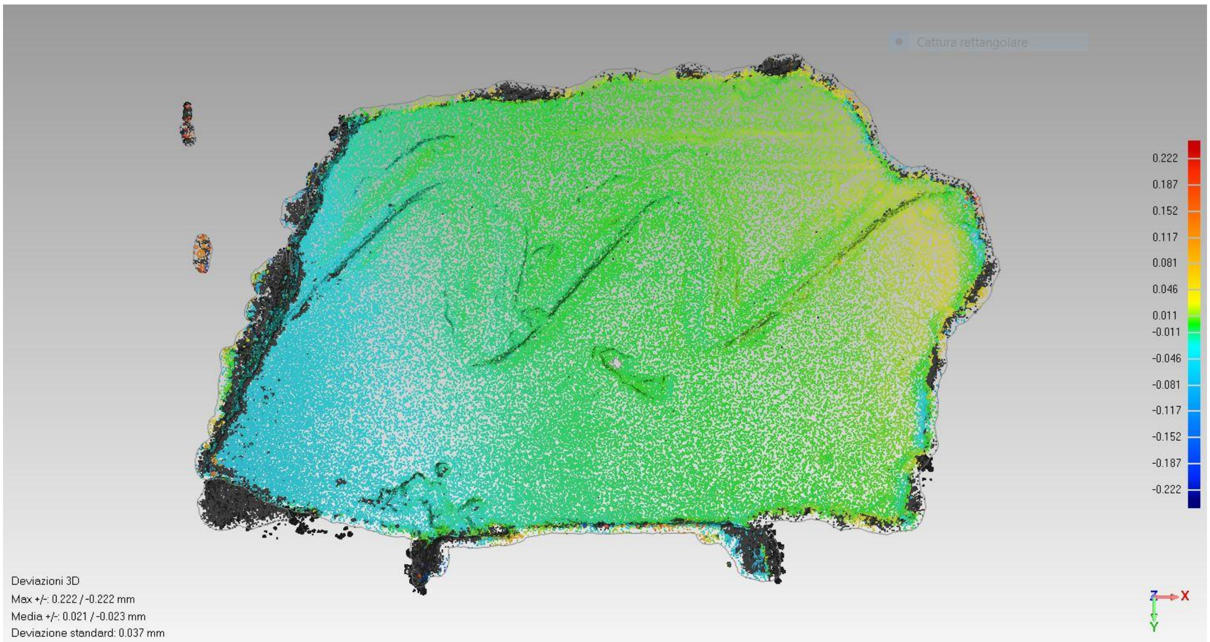

Fig. 14 – Qualify Geomagic between 60mm and 15mm models (Copyright: G. Author, P. Author, F. Author, S. Author)

Good results have also been obtained with the 24-85mm that generated an average deviation equal to 0.04mm, that is very close to 15mm (fig. 15).

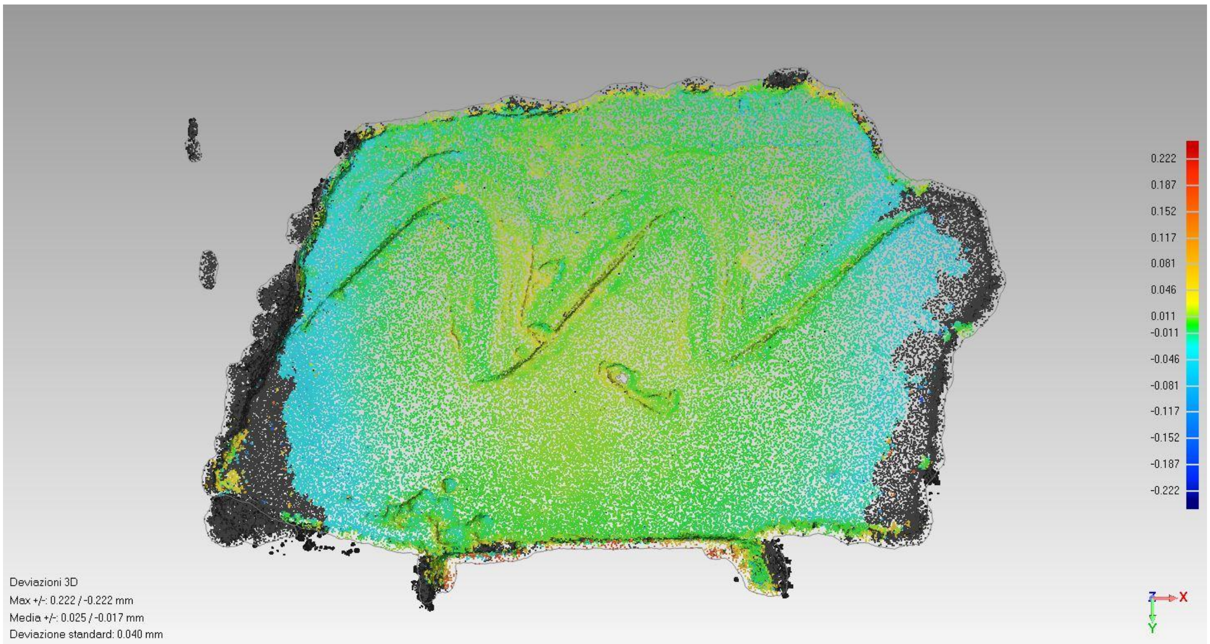

Fig. 15 – Qualify Geomagic between 60mm and 85mm models (Copyright: G. Author, P. Author, F. Author, S. Author)

The 55mm, however, produced the worst results, with a gap of 0.062mm, probably due to the use of the extension ring (fig. 16).

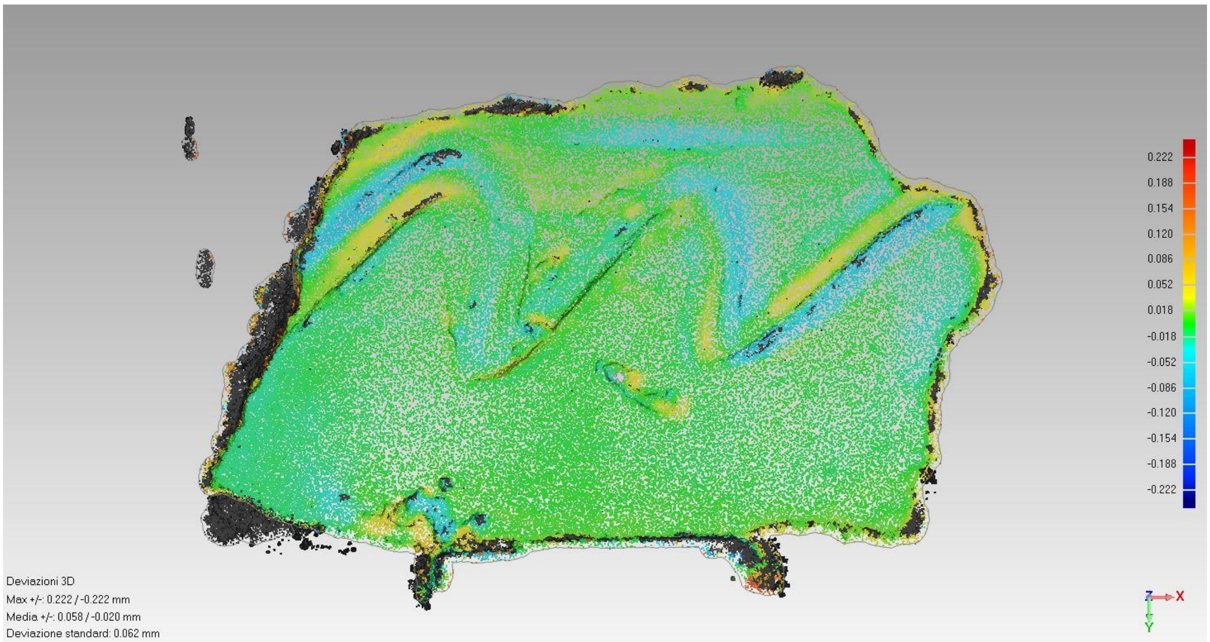

Fig. 16 – Qualify Geomagic between 60mm and 55mm models (Copyright: G. Author, P. Author, F. Author, S. Author)

It is important to note that the lower part of the model is very similar to the original and the main differences are in the parts in relief of the object.

Conclusions

The lenses we considered have shown different results that can induce some considerations about the quality in relation to accuracy in image reproduction, price and versatility**:**

Nikon Micro-Nikkor 55mm f/2.8 + Nikon Extension ring PK-13 27.5mm

Despite the contingent need of shooting conditions to bring the macro ratio to 1:2, this lens has proved to be the best from the point of view of homogeneity of the scan. Also, the result of points measured on the individual pictures of the scan revealed a large quantity of information. Due to an excessive prospective crushing if the limited range extension has been most lacking in raised dots.

Nikon 24-85mm f/2.8/4-AF-D-IF

Despite the zoom versatility that makes it suitable for all types of uses, from the calibration, this lens has managed to achieve good results both on flat surfaces and in those in relief. Unfortunately, the number of surface covered by aligned points is very low compared to the other lenses. As it can also be deduced from the decay of the MTF curves in the diagram.

Nikon AF-S 60mm Micro f/2.8G

This lens, with a focal length of 60mm, is the reference lens for macro photography with a focusing distance of 18.5cm from the focal plane. Thanks to the quality of the lenses, the Nikon 60mm is able to capture the finest details with no distortion and chromatic aberration. In our case, this lens has been used as a reference point for the other lenses, as it was assumed before the tests that could give better results due to its specific characteristics for the macro survey. The scan result has confirmed first impressions (due also to the MTF diagram), creating a cloud of points of quality and a subsequent mesh rich in detail, with around 14 million faces. It is noteworthy that in the scanning step, the results differ mainly for the different number of points of the cloud spread, which attests to the degree of correct points surveyed.

Laowa 15mm f/4 Wide Angle 1:1 Macro Lens

During this test we couldn’t use this lens at the ratio of 1:1 because of the excessive proximity of the lens to the object, just few millimeters from the top of the lens to the artifact, also the light couldn’t come in. Because of this situation the photos were taken at the ratio of 1:2 for all the lenses: in the case of the Laowa the object was just 2,4 cm from the lens. The decay of the MTF curves in the diagram of the Laowa is very similar to the 24-85mm, but about the aligned points it has behaved better than the other lens. This is an interesting lens and due to its versatility is to be appreciated more according to the results obtained, especially compared with other lenses.

This test has helped us to build a strong foundation to create a comparative database that we will push for a thorough comparison of professional lenses and entry level lenses.

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