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Research Report

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**Photogrammetry
with application to
fresco documentation**

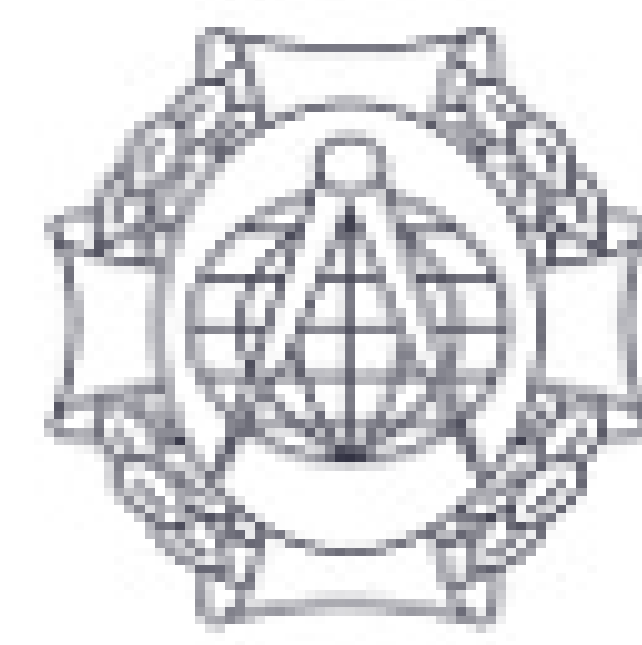
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Photogrammetry with application to fresco documentation.



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Abstract-Close range photogrammetry has great potential for development as a tool for architecture analysis, especially through the use of low-cost image acquisition tools. Low-cost sensors allow for the creation of reliable and accurate three-dimensional models of investigated objects, while the data collected in the course of the documentation can serve for an advanced analysis. This poster presents the results of an investigation carried out in a baroque residence of Otwock Wielki near Warsaw, Poland using low-cost sensors for photogrammetry.

1. INTRODUCTION- PHOTGRAMMETRY AS AN ANALITICAL TOOL

The method of photogrammetry is based on the concept of collecting a set of photos and orientating them as to create a high accuracy representation of the documentet object or space. As a tool it is appreciated for being easy and fast, requiring little additional work and tools when compared to traditional methods, especially drawing. Since the generated documentation, in the form of images, is orthorectified, any necessary measurements not recorded previously can be taken directly from the documentation. This eliminates the need to refer to the original object for such additional measurements, which might be costly or simply impossible (as it is very often the case in archaeology).

The data gathered for photogrammetrical documentation, most notably the point cloud, **can be used itself as the entry data for detailed analysis.** Such analysis include for example angles of structures and surface flatness. This in turn allows the investigation of geometrical properties of structures.

2. THE CASE STUDY

For the purpose of our investigation we have chosen a fresco-decorated room in The Bieleński Palace in Otwock Wielki, a great example of late baroque noble residence (Fig.1). The frescos cover entirely the walls of a room of 11,5 x 5,5 m. The investigated room is located in a wing of the palace dating to the second phase of the structure. Since little documents survive concerning the rebuilding and remodeling of the palace only very general information are available. One of the goals of the carried out investigations was to establish how the SE end of the palace looked like before the remodeling. Since the walls of the added room are covered with frescoes no invasive method could have been applied.



Fig.1. The Bieleński Palace in Otwock Wielki, near Warsaw.

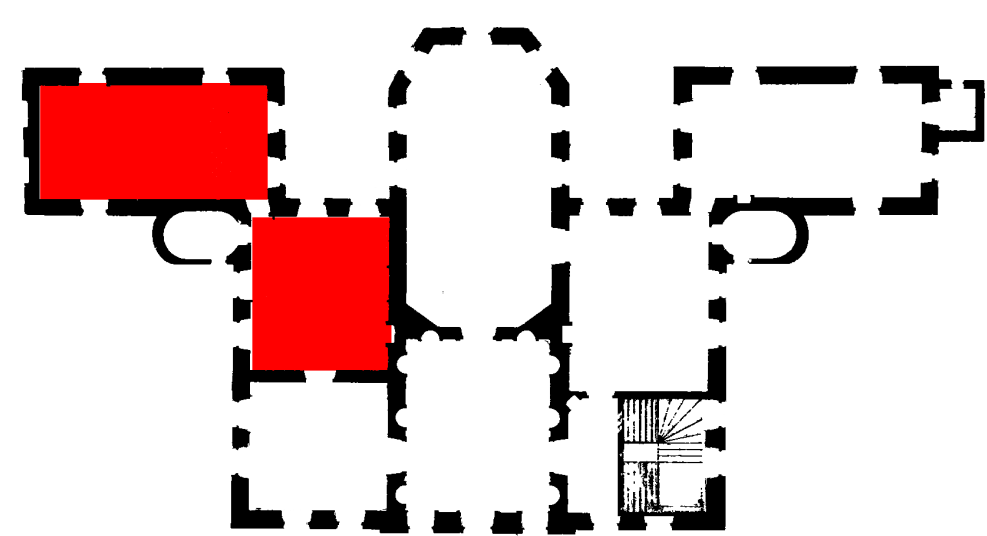


Fig.2. The Bieleński Palace floor plan. The investigated rooms shown in red.

3. METHODOLOGY

The goal of our investigation was two-fold: 1) First of all we wanted to verify if it is possible to use data gathered for photogrammetry to investigate the complexity of a construction; 2) and second, we wanted to look into the possibility of using low-cost cameras for high precision documentation.

In order to achieve the first goal we have col-

lected data on the room through geodesic measurements and photos. A series of geodetic measurements was conducted in the investigated room as well as an adjacent room, in order to establish the ground control points, used for the orientation of the close-range images (Fig.2). As a result



Fig.3. Gathering of the data.

of the observation's alignment the accuracy of 1,5 mm for control and check points calculation was achieved. In the course of the investigation the geometrical quality of the results was analyzed as well as the radiometric quality. After processing of the photos acquired, photogrammetric documentation in the form of orthoimages, point cloud and 3D models were obtained for the investigated room.

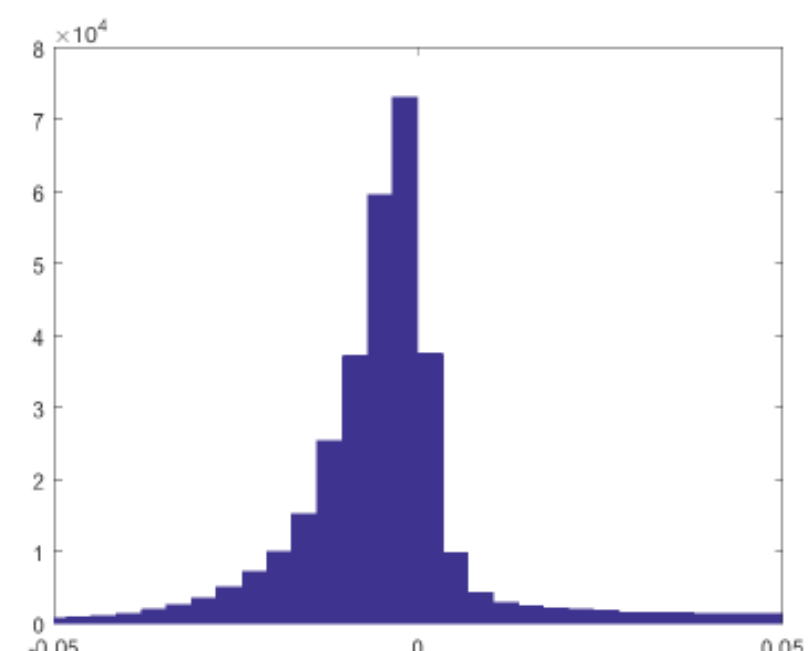
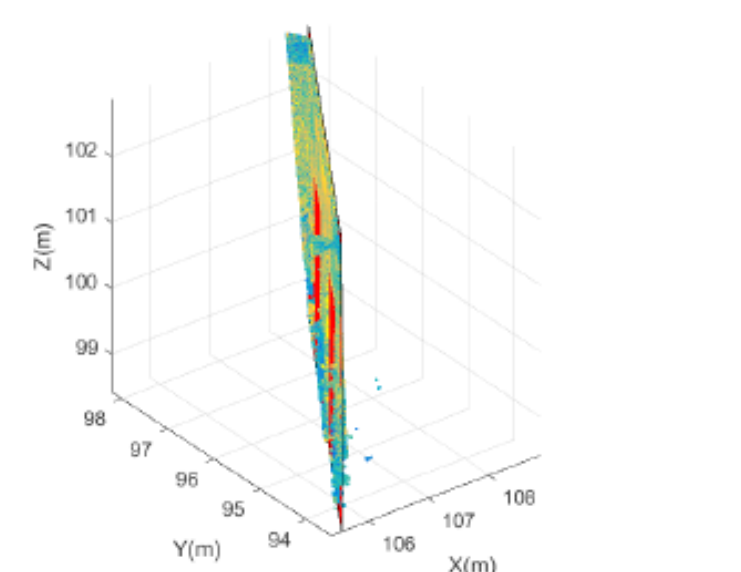
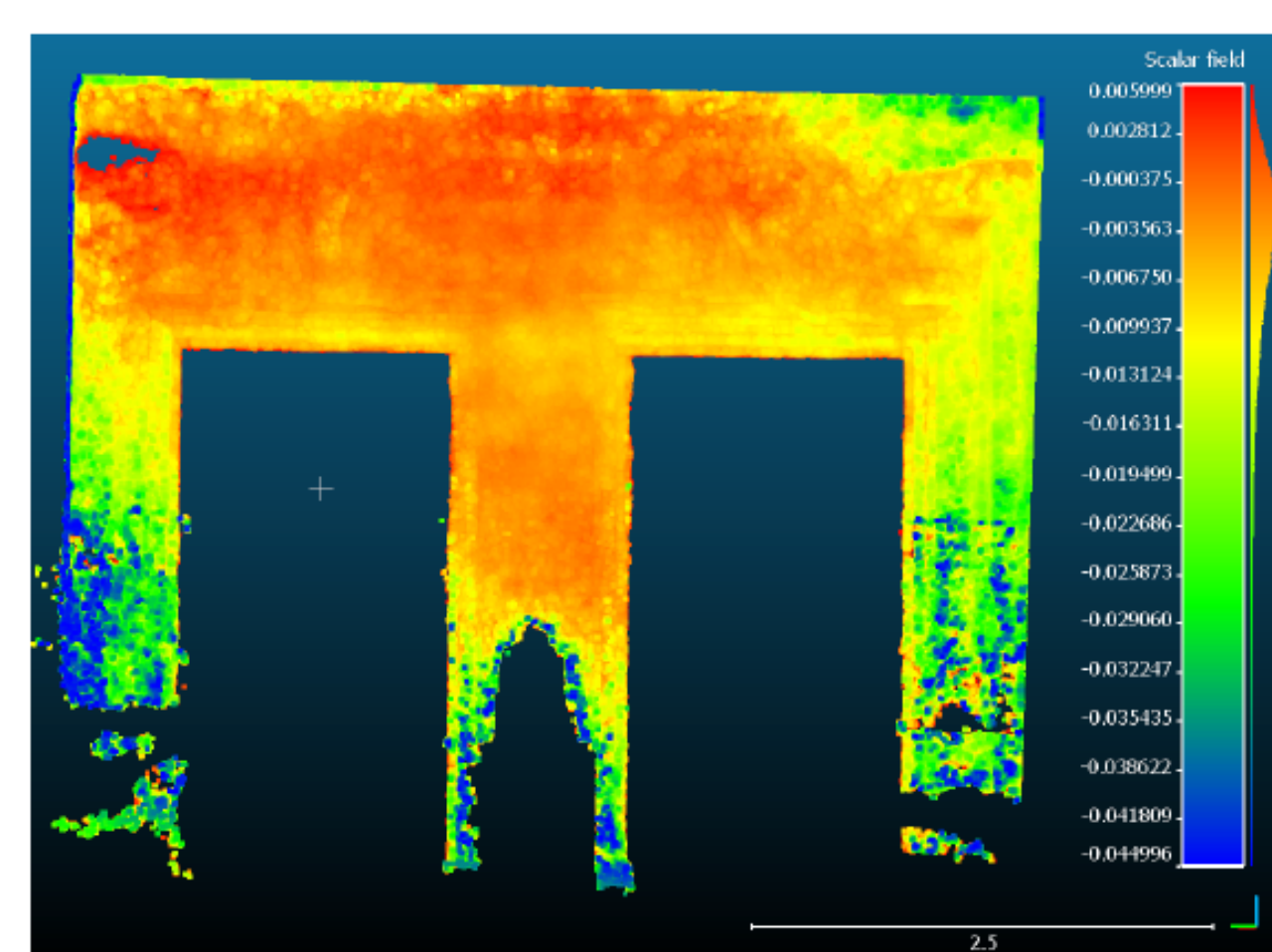


Fig. 4. A) Map of point deviation from a fitted plane, B) Point cloud with fitted plane, C) Histogram of point deviations from a plane- Xiaomi Yi 4k

We decided to use the point cloud to perform the analysis of the wall flatness. To that aim an application has been created in the MatLab program allowing the automatic fitting of a plane into a point cloud. In order to achieve that the function `pcfitplane` was used. Figure 3 shows a visualization of the results, where the colours show the distance of the points from the fitted plane.

In order to achieve the second goal two different sensors were used to acquire images: a low-cost Xiaomi-camera, and a Canon 5D Mark II - a full-frame format camera. In order to check how the results obtained from the two sensors differ

the following parameters were analysed:

- The accuracy of the orientation of the ground level photos on the control and check points,
- The total orientation error,
- The distribution of appointed distortion in the self-calibration process,
- The flatness of the walls,
- The discrepancies between point clouds from

Kamera	Control (mm)	Control (px)	Check (mm)	Check (px)	Total Error (mm)
Yi 2K	9.1	3.1	6.4	2.2	9.2
Yi 4K	8.3	3.5	7.8	1.4	8.4
Canon	6.4	2.2	2.2	1.3	6.6

Tab.1. The accuracy of orientation of photos on control and check points according to sensors.

the low-cost cameras and references data,

- The discrepancies in the quality between orthoimages generated based on the photos from the Xiaomi cameras and the reference data.

Additionally the point clouds, generated from the two sets of images, were compared. As it is shown below, we have concluded that the proposed low-cost tools produced satisfying results in most cases. For the purpose of gaining a rough outlook, the accuracy of the described products is more than acceptable. However, in cases where an exact and detailed registration of architectural monuments is important, using the cameras discussed is it might be an insufficient solution.

4. RESULTS

During the analysis of the flatness of the walls of the investigated rooms patterns in the deviation begun to emerge prompting us for a more detailed investigation of the issue. By mapping the points deviation on the North wall of the room we discovered an outline of an earlier door, now blocked and covered with the frescoes. This outline is clearly visible not only on the point cloud generated from the Canon 5D Mark II camera, but also the one from Xiaomi Yi 4k and 2k (Fig.4)). The height of the door opening clearly coincides with the height of the existing doors and the outline of a tympanum crowning the doors is visible. This proves the usefulness and scientific value of low-cost camera photogrammetric documentation of architecture.

The results of the non-invasive examination allowed us to identify a door that led to the tower in the first phase of the palace, and which was later blocked and covered by the frescoes. The effects of the project show how digital documentation methods can be applied to the analysis of architecture and subtle changes on the surfaces of walls that are often invisible to the naked eye, and that might be evidences of remodeling. If it wasn't for the digital documentation the information about the remodeling would have been inaccessible for us, without the use invasive methods. Such information enriches our knowledge about the architectural objects, and their history.

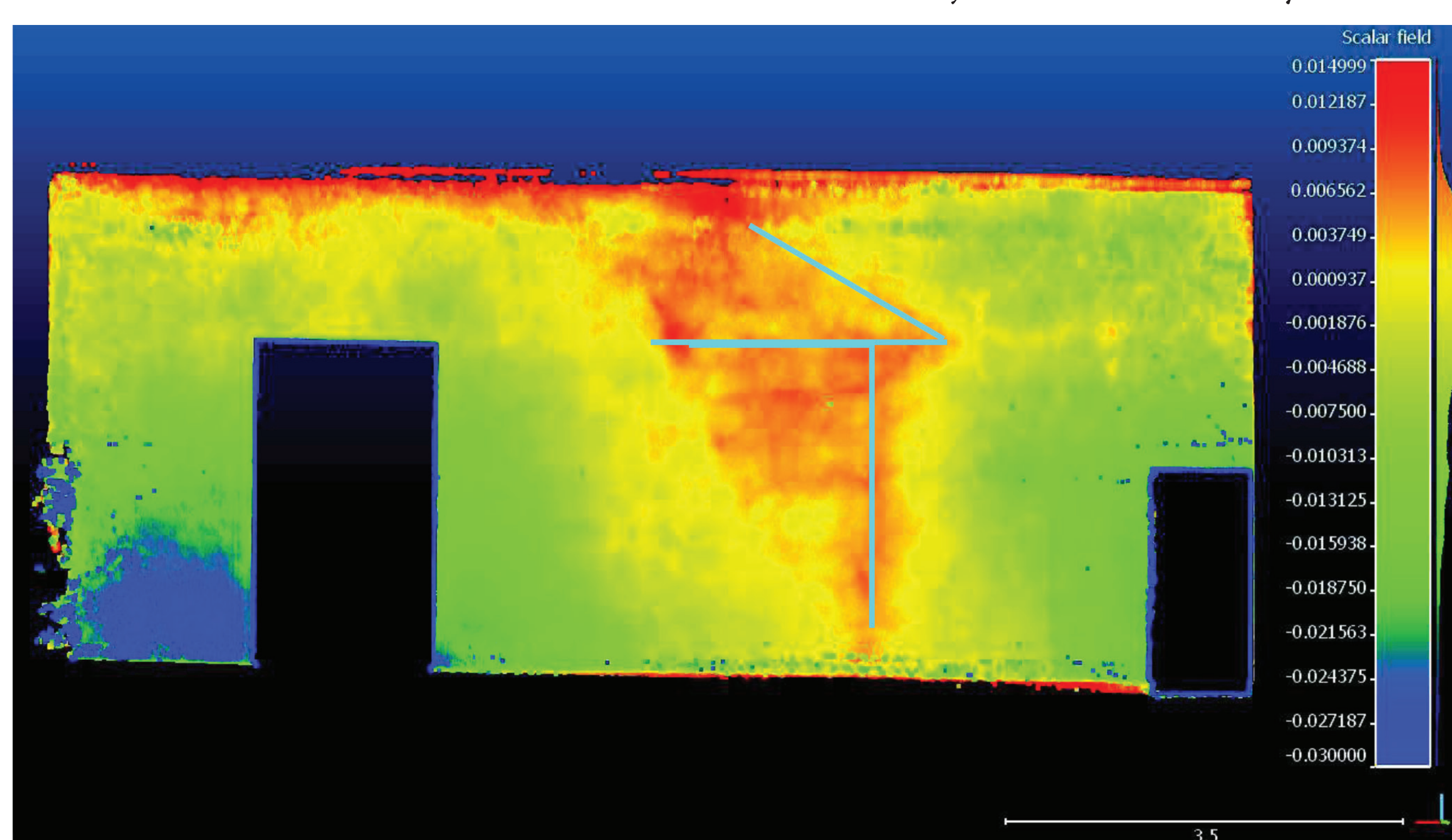


Fig.5. The analysis of the wall flatness with a blocked door clearly showing under the frescoes. Data for the analysis gathered with the low-cost camera Xiaomi Yi 4k.



Fig. 6. The fragment of the fresco, behind which the blocked door is located.

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