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Analysis of selected parameters of partial 3D models obtained by gradual reduction of the number of photo frames

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Abstract – Photographs of the object are used to create 3D models using photogrammetry. However, it is not always possible - especially for time or technical reasons - to obtain sufficient photographs. It is even often only possible to obtain photographs for the creation of partial 3D models. In such cases, the use of video seems to be a suitable solution. Instead of lengthy photography, we create a short video and get the appropriate number of photo frames by separating them from the video. In our paper, we focus on the description of the characterization parameters of the 3D models, created by gradually reducing the photo frames that we obtained from the video. The parameters describing the quality of a 3D model are generally accepted and known. We have chosen a few basic parameters that we observe, such as The median of keypoints per image, Number of 2D Keypoint Observations for Bundle Block Adjustment and so on.

Keywords – Pix4Dmapper, Photogrammetry, 3D models, partial 3D models, OPPO Reno 5z

I. INTRODUCTION

If we mention the creation of 3D models using photogrammetry, we often imagine the protection of cultural heritage. Yes, it is one of the typical areas of its use. But sometimes we don't have the possibility to create a complete 3D model, so the solution is to create partial 3D models. Photogrammetric procedures, especially close-up photogrammetry, can also be used to create partial 3D models, not only in architecture or construction, but due to its applicability, it has also found its place in other sciences, even biology. [1][5-7]

3D models are characterized by many indicators. In principle, these indicators can be divided into two groups: subjective indicators and objective indicators, i.e. indicators of a statistical nature. Among the indicators of a statistical nature, we can mention a few of the following. First, we must mention Keypoints. Keypoints are characteristic points that can be detected in the images. They form the basis for the creation of 3D models and are also the starting point for Point Cloud. The parameter "Number of 2D Keypoint Observations for Bundle Block Adjustment" is The number of automatic tie points on all images that are used for the AAT/BBA. It corresponds to the number of all keypoints (characteristic points) that could be matched on at least two images. The parameter "Number of 3D Points for Bundle Block Adjustment" is The number of all 3D points that have been generated by matching 2D points on the images. "Mean

Reprojection Error [pixels]" is The average of the reprojection error in pixels. The next parameter can be "re-projected error". Each computed 3D point has initially been detected on the images (2D keypoint). On each image, the detected 2D keypoint has a specific position. When the computed 3D point is projected back to the images it has a re-projected position. The distance between the initial position and the re-projected one gives the re-projection error. Often appears in cases of using GPS supported photos. [3-4]

Models obtained by photogrammetry often contain realistic textures that are directly derived from the photographs, which is their great advantage, which is why we choose this method. Also, Photogrammetric 3D models can achieve a high level of detail, allowing complex and detailed models to be created without the need to manually model every detail. Although the disadvantage is that creating a 3D model from photographs involves intensive computation, and processing can take a long time depending on the power of the computer and software, modern means are slowly eliminating this disadvantage as well. Photogrammetry is a method suitable for creating models of small objects, such as coins, to large sceneries, such as buildings or even entire landscapes. In the latter case, we cannot do without UAVs or aerial photographs, while small objects can be processed even in domestic conditions. This makes it possible to use photogrammetry also in the educational sphere, where it is also gaining its place. [8-11]

II. Materials and Method

The starting point for the creation of 3D models is the acquisition of photo images of the real object. Since photogrammetric software can also obtain the appropriate number of photo frames from video, we also used this possibility. We created a short video of a vertical formation on a tree. The method of obtaining the video is presented in Figure 1. We used a mobile phone Oppo Reno 5z which created a video with the following parameters:

- Frame width/Frame height: 1920/1080
- Datarate: 20177 kbps
- Total bitrate: 20436 kbps
- Frame rate: 29 frames/second
- Video type: MP4
- Size: 122 MB

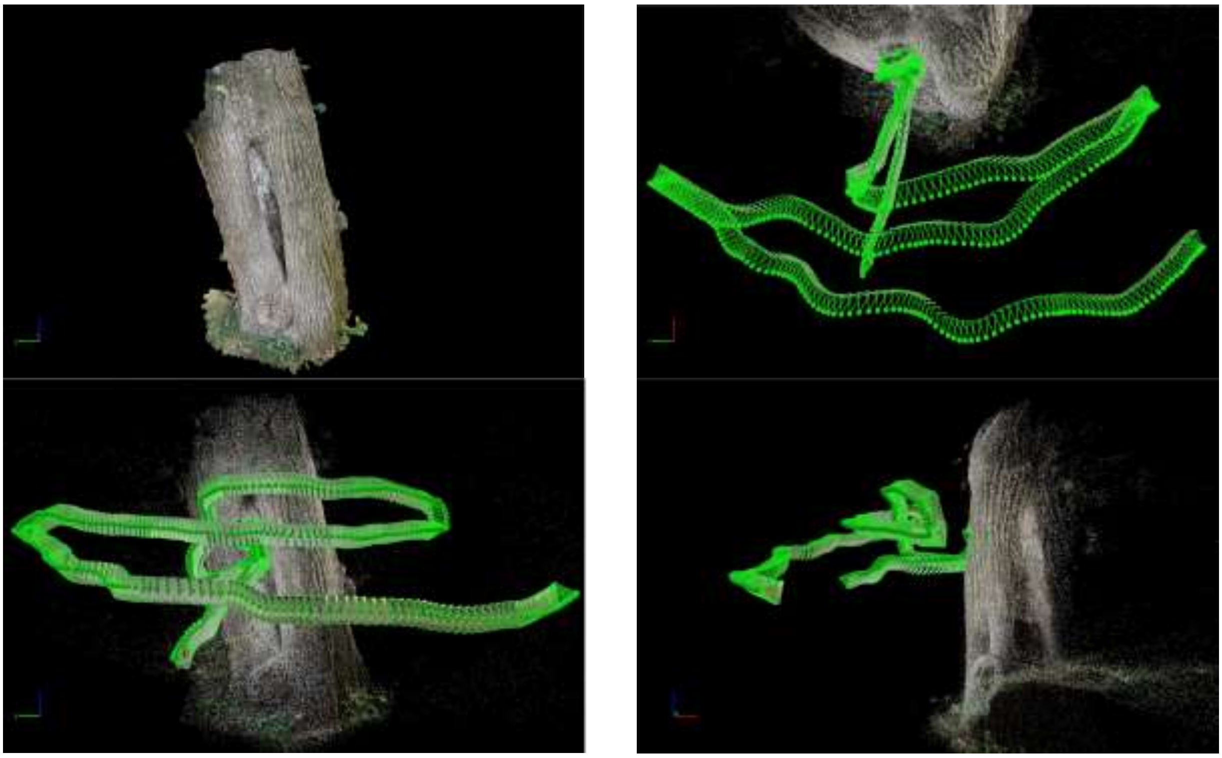


Fig. 1 Capturing a real formation on a tree trunk (top left) and the camera movement while capturing: top view (top right), front view (bottom left) and side view (bottom right).

Then we create a series of 3D models from a decreasing number of photo frames. Specifically, from the number of 1472, 749, 501, 376, 301, 215, 188, 167, 151, 137, 126, 116, 108, 101, 94, 89, 79, 69, 61, 51, 40, 30, 13 and 7. To create the 3D models, we use the photogrammetric software Pix4Dmapper Pro, 2.0.104 - 64bit, with which we have achieved good results in the past and which has proved its worth, for example see [2]. For each 3D model we create, we collect descriptive parameters, namely:

- Number of Calibrated Images.
- The median of Keypoints per image.
- The median of matches per calibrated image.
- Number of 2D Keypoint Observations for Bundle Block Adjustment.
- Number of 3D Points for Bundle Block Adjustment.
- Mean Reprojection Error [pixels].
- Median, Min, Max and Mean for Number of 2D Keypoints per Image.
- Median, Min, Max and Mean for Number of Matched 2D Keypoints per Image.
- Number of 3D Densified Points

We present the observed parameters in tabular form. For selected combinations of parameters we also create graphs.

III. Results and Discussion

Table 1. Parameters of 3D models obtained during the gradual frame reduction in the selection process from the source video. The calculated values are shown in thickly highlighted text and italics. The difference parameter is determined by subtracting the maximum and minimum values in the case of Number of 2D Keypoints per Image and Number of Matched 2D Keypoints per Image (Difference = Max – Min)

	Number of Calibrated Images	1472	749	501	376	301	215	188	167
	The median of keypoints per image	12223	12219	12189	12280	12257	12301	12236	12201
	The median of matches per calibrated image	6685,6	6885,75	7027,11	6903,1	6996,66	6781,33	6464,12	6256,12
	Number of 2D Keypoint Observations for Bundle Block Adjustment	9875292	5153777	3468838	2605229	2055688	1418820	1217489	1048531
	Number of 3D Points for Bundle Block Adjustment	1453345	943837	721316	596461	496449	377252	338398	303512
	Number of 2D Keypoint Observations - Number of 3D Points	***8421947***	***4209940***	***2747522***	***2008768***	***1559239***	***1041568***	***879091***	***745019***
	Mean Reprojection Error [pixels]	0,271318	0.273939	0,271833	0,27117	0,267256	0,264093	0.262643	0.258694
Number of 2D Keypoints per Image	Median	12223	12219	12189	12280	12257	12301	12236	12201
	Min	7507	7507	7656	7656	7656	7507	7900	7922
	Max	15193	15193	14591	14737	15193	14328	14737	14390
	Mean	11978	11986	11975	12008	12031	12023	11989	11963
	DIFFERENCE	***7686***	***7686***	***6935***	***7081***	***7537***	***6821***	***6837***	***6468***
Number of Matched 2D Keypoints per Image	Median	6686	6886	7027	6903	6997	6781	6464	6256
	Min	2736	521	1235	772	649	1106	1545	323
	Max	10386	10385	10672	10853	10579	10819	10491	10416
	Mean	6709	6881	6924	6929	6830	6599	6476	6279
	DIFFERENCE	***7650***	***9864***	***9437***	***10081***	***9930***	***9713***	***8946***	***10093***
	Number of 3D Densified Points	6299062	4869346	4031834	3522212	3103288	2615953	2423598	2244379

	Number of Calibrated Images	151	137	126	116	108	101	94	89
	The median of keypoints per image	12313	12189	12214	12223	12255	12208	12213	12066
	The median of matches per calibrated image	6447,99	6103,67	5614,69	5666,94	5656,2	5498,63	5355,13	5278
	Number of 2D Keypoint Observations for Bundle Block Adjustment	944780	823626	733722	666369	613408	550601	502449	461558
	Number of 3D Points for Bundle Block Adjustment	280834	252164	231258	214036	201620	186400	171339	159614
	Number of 2D Keypoint Observations - Number of 3D Points	***663946***	***571462***	***502464***	***452333***	***411788***	***364201***	***331110***	***301944***
	Mean Reprojection Error [pixels]	0.258172	0,255754	0.254399	0,253487	0,252654	0,248569	0,246622	0,24676
Number of 2D Keypoints per Image	Median	12313	12189	12214	12223	12255	12208	12213	12066
	Min	7656	7692	7656	8332	7507	7656	7900	7656
	Max	15193	14198	14408	14291	14328	14542	14408	14086
	Mean	12069	11923	11889	12005	12032	11962	12033	11849
	DIFFERENCE	***7537***	***6506***	***6752***	***5959***	***6821***	***6886***	***6508***	***6430***
Number of Matched 2D Keypoints per Image	Median	6448	6104	5615	5667	5656	5499	5355	5278
	Min	279	333	414	565	212	369	748	564
	Max	10337	10132	9819	9649	9727	9586	9507	9354
	Mean	6257	6012	5823	5745	5680	5451	5345	5186
	DIFFERENCE	***10058***	***9799***	***9405***	***9084***	***9515***	***9217***	***8759***	***8790***
	Number of 3D Densified Points	2107315	1979425	1855345	1752432	1656520	1558847	1484579	1428767

	Number of Calibrated Images	79	69	61	51	40	30	13	7
	The median of keypoints per image	12218	12195	12118	12143	12140	12301	11997	11413
	The median of matches per calibrated image	4709,54	4459,17	4438,21	3717,87	3293,84	2793,91	1573,28	1307
	Number of 2D Keypoint Observations for Bundle Block Adjustment	386218	309258	262587	182235	135121	86136	19035	8174
	Number of 3D Points for Bundle Block Adjustment	139484	114153	102226	73608	57238	37608	9087	3964
	Number of 2D Keypoint Observations - Number of 3D Points	***246734***	***195105***	***160361***	***108627***	***77883***	***48528***	***9948***	***4210***
	Mean Reprojection Error [pixels]	0,240514	0,250934	0,241076	0,243185	0,235679	0,219279	0,184423	0,15975
Number of 2D Keypoints per Image	Median	12218	12195	12118	12143	12140	12301	11997	11413
	Min	7696	8218	8406	7656	9481	9557	7725	10532
	Max	14542	14000	15193	14408	14737	14291	13381	13296
	Mean	11993	11905	11883	11814	12037	12053	11798	11841
	DIFFERENCE	***6846***	***5782***	***6787***	***6752***	***5256***	***4734***	***5656***	***2764***
Number of Matched 2D Keypoints per Image	Median	4710	4459	4438	3718	3294	2794	1573	1307
	Min	345	196	814	327	700	713	386	197
	Max	9325	8586	8979	7146	6181	5554	3818	1736
	Mean	4889	4482	4305	3573	3378	2871	1464	1168
	DIFFERENCE	***8980***	***8390***	***8165***	***6819***	***5481***	***4841***	***3432***	***1539***
	Number of 3D Densified Points	1295736	1154105	1030759	832725	663159	443045	129881	42994

In Table 1 we show the results of the observed parameters depending on the Number of calibrated Images. As we expected, the larger the number of keypoints per image and matches per calibrated image, the better the quality of the model. We can support this dependence by Figure 2, where we can clearly see that the group of parameters forming the quality models forms a cluster in one part of the graph. The blue points represent the parameters of all the created 3D models, the red points represent the cluster of quality 3D models. It can be argued that the boundary is located between the 3D models created from 13 and 30 photo images.

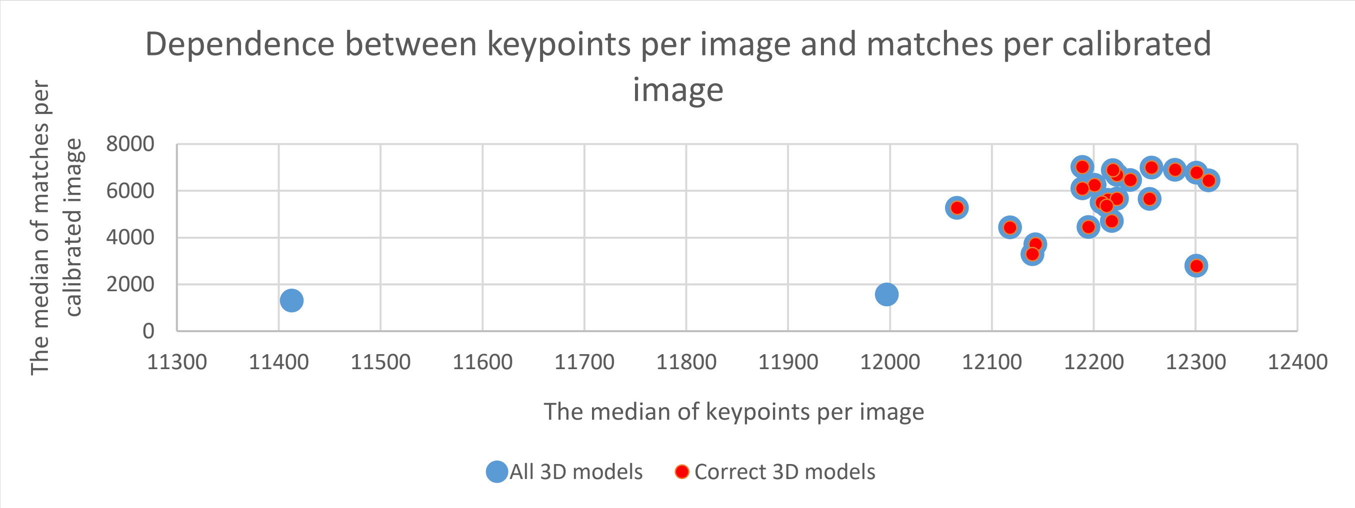
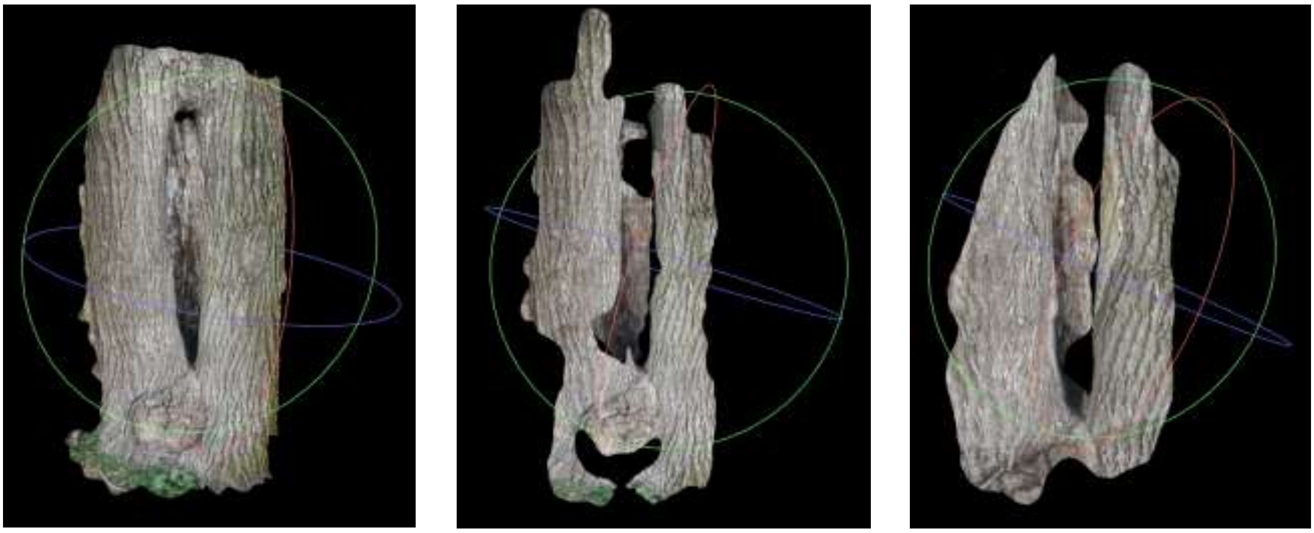


Fig. 2 Dependence between median of keypoints per image and median of matches per calibrated image

Thus, the last two 3D models presented in the table are not of sufficient quality. On the contrary, they are of poor quality. Such a number of photos and the number of corresponding points on them is not sufficient. See Figure 3.



30 images	13 images	7 images

Fig. 3 3D models created from 7, 13 and 30 photo frames.

The second group of monitored parameters was Number of 2D Keypoint Observations for Bundle Block Adjustment and Number of 3D Points for Bundle Block Adjustment. We show the dependence of these parameters on the Number of Calibrated Images in figure number 4. The gray color shows the values obtained by the difference of the mentioned parameters. All three parameters are characterized by a great similarity in terms of the waveform of the values. Nevertheless, we did not find any of the basic regressions that describe these waveforms with a sufficient R^2 value to suit our needs. Specifically:

- Number of 2D Keypoint Observations for Bundle Block Adjustment:
    - $y = 8E+06e^{-0,214x}$ – $R^2 = 0,8757$
- Number of 3D Points for Bundle Block Adjustment:
    - $y = 7E+06e^{-0,232x}$ – $R^2 = 0,8837$

- Difference between Number of 2D Keypoint Observations and Number of 3D Points:
  - y = 2E+06e-0,174x – $R^2 = 0,8355$

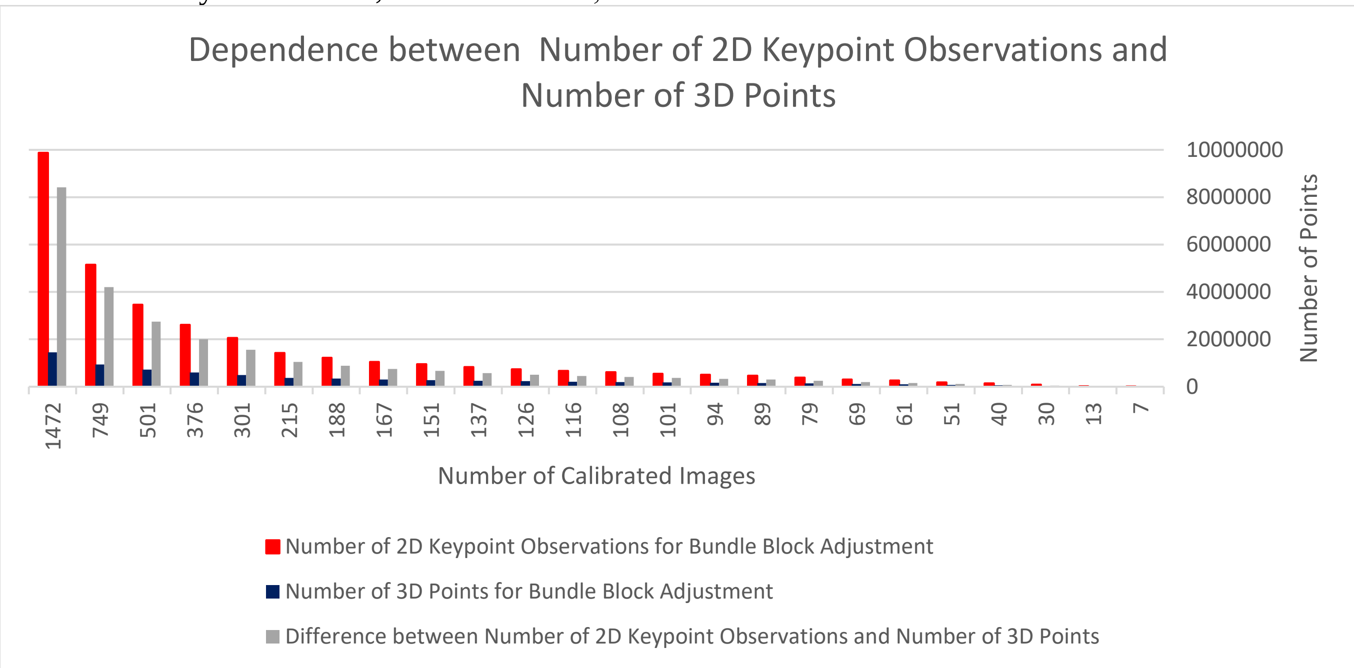


Fig. 4 Dependence between Number of 2D Keypoint Observations for Bundle Block Adjustment and Number of 3D Points for Bundle Block Adjustment

Therefore, to confirm our conjecture regarding similarity, we used the dependence of the difference of these values and the Number of Calibrated Images. We report the result in Figure 5. An almost linear dependence is visible. The small deviation is in turn only in the region of very low values, probably caused by poor quality 3D models.

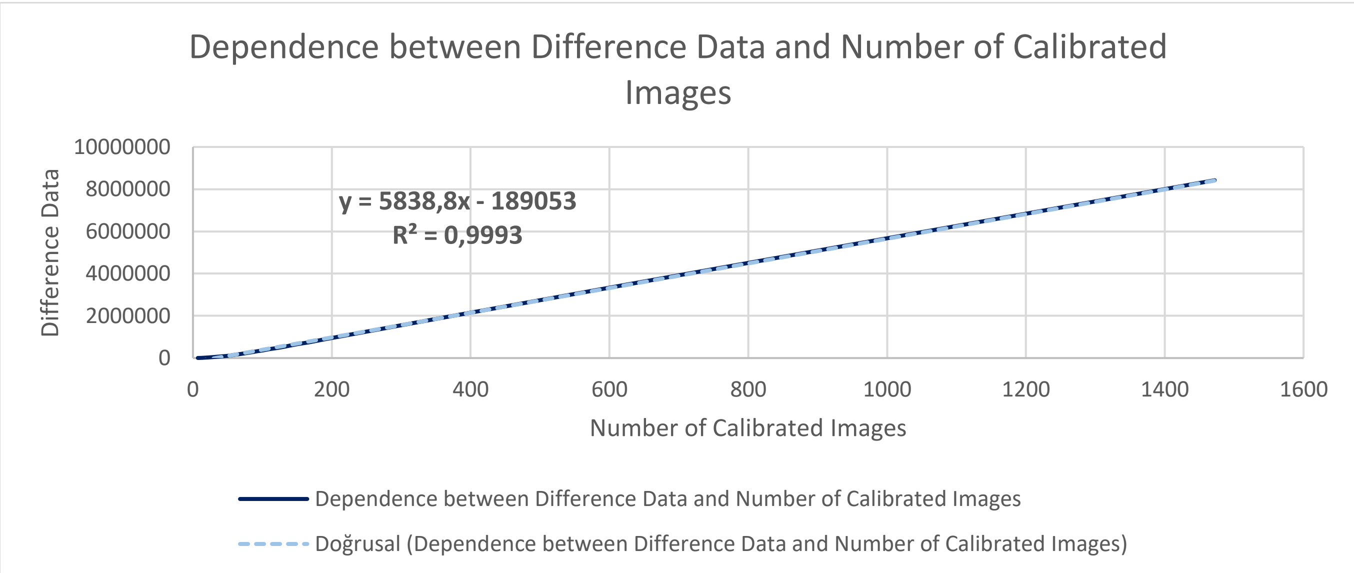


Fig. 5 Dependence between Difference Data (Difference between Number of 2D Keypoint Observations and Number of 3D Points) and Number of Calibrated Images.

The median of keypoints per image parameter depending on the Number of Calibrated Images varies very little. We can see this in Table 1. Also, only poorer quality 3D models cause a more significant change.

IV. CONCLUSION

When creating 3D models, we don't always have the option of creating complete models. Therefore, we depend on creating partial 3D models, where we only take into account the part of the object that interests us. In our paper, we have tried to describe the different parameters and their variations with respect to the number of photographs from which the 3D models were created. When combining the parameters, we also showed the structure of two well identifiable clusters. One cluster belonged to good quality 3D models and the other to poor quality 3D models. In general, we also confirmed the statement that the more photo frames from which a 3D model is created, the better the quality of the 3D model.

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