

## DIRECT LINEAR TRANSFORMATION BASED PHOTOGRAMMETRY SOFTWARE ON THE WEB

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### ABSTRACT:

Internet offers a new direction for software development and also for photogrammetry. The affordable commercial digital cameras are widely available and their geometrical resolution is good enough to perform photogrammetric measurements. Seeing this, a widely accessible, web based photogrammetry application could be a new development direction for photogrammetry. For photogrammetric calculations Direct Linear Transformation is a well useable method as it does not need calibrated camera. The potential users are in the lack of experience, therefore the calculation method should be prepared to help them to achieve high accurate results. For example, gross errors in measurements cannot be avoided but the impacts of gross errors should be avoided. This study shows a technique how to reduce effects of gross errors with Huber-method and discusses the investigation for results.

### 1. INTRODUCTION

Availability of classical photogrammetry was limited due to expensive devices for example special cameras and stereocomparators. Nowadays everybody can afford a commercial camera with relatively high geometric resolution. Photogrammetric post-processing could be performed on a simple PC. Remaining limiting factors for users are the lack of experience and affordable software. This paper presents a solution to avoid these difficulties. A web based photogrammetry application was developed that allows to access the software by a single web browser. For calculation Direct Linear Transformation (DLT) is used, which enables the use of non calibrated digital cameras. The lack of user's expertise has to be considered during the calculation method. For example, gross errors have bad effects for classical least squares method, and inexperienced users can easily cause gross errors during digitizing. The effect of gross errors is minimized by Huber-method. The developed photogrammetry application can be a spatial measurement system not only for professionals, but for the wide public. To achieve an inexpensive, reliable, and widely available application, only opensource and free software were used. Another goal was to apply all web standards to make the web application available in all graphical web browsers. In addition to the mentioned goals, accuracy issues should be assessed as well.

#### 1.1 Practical uses

There are two major reasons that motivated the software development. First, if somebody wants to buy or rent a real estate, he takes photo and the decision is made at home. These photos can be used for spatial measurements, why aren't they used? With photogrammetry the 3D model and a base plan can be created.

The other application area is education. For students it is an impressive application, they can try it at home, and also the calculation algorithm can be presented. Photogrammetry can be

presented in practice without the "black-box" calculation effect that usually can be experiences in case of the commercial software.

The web based photogrammetry is not a new idea, Grussenmeyer developed a web based photogrammetry application in Java programming language and discussed the possibilities of an internet based photogrammetry software (Grussenmeyer et al, 2001). However, this software still have limitations on software environment.

### 2. WEB BASED APPLICATION

Even more software is available in a web based version. For example many e-mail, office, route planning applications working on the internet. These applications usually are free to use, don't need software installations and available everywhere; that's why they are getting even more popular. This inspired the development of a web based photogrammetry application. The advantages and disadvantages of a web based application are shown in the Table 1.

Advantages	Disadvantages
No limit of operating system (multiplatform)	Broadband internet connection required
No need of software installation	Large data amount causes high network traffic
No specific rights are needed	Browser limitations
No need to upgrade, always the newest version is available	Private data handling (images)
Location and time independent	No 3D engine available
Regular user interface	
Inexpensive	

Table 1. Advantages and shortcomings of web based applications

On the development side there are some difficulties. In digital photogrammetry images have large size that must be transmitted over the internet in case of the web based approach. The transfer has to be well planned without data and resolution loss. For example, at the beginning of the work, only minimal part of

the images should be transferred, the other ones should be downloaded in the background while digitizing is made.

Another difficulty is the variety of browser types (i.e. Firefox, Internet Explorer, Opera, Google Chrome, etc.). They all work in a different way, it's not easy to create a browser independent web application. However, it would be beneficial, if one can work in the same user interface, even if he has to use Internet Explorer in the office, but Firefox is installed at home. This difficulty exist also in the classical desktop applications, it's difficult to develop a program that works on Windows, MacOS or Linux.

For development, the main issue was to use free and open source programs to reduce costs, and to ensure a dynamically developing programming background. This is true for the frontend and calculation part of the application too. The web page parsing is made by PHP, database backend is MySQL. The user interface is done with HTML, Javascript, SVG and VML and all sites apply the W3C web standards. The processing is done with Octave mathematical programming language that is similar to Matlab. The processing is done on the server, but in order to reduce server load, as much calculation as possible is processed on the client side. For example, 3D visualisation is done in the browser with SVG/VML and Javascript.

### 3. CALCULATION

#### 3.1 Direct Linear Transformation (DLT)

The commercial digital cameras are not calibrated. Neither the internal calibration data, nor the optical distortions are available that has negative effect on the final accuracy. The DLT enables performing calculations with high accuracy without calibration data (Abdel-Aziz and Karara, 1971). DLT describes a direct connection between 3D coordinates and image coordinates. Another advantage of DLT is the application of linear equations, which make the calculation algorithms more efficient. DLT defines 2 equations in each point, and has 11 parameters that means minimum 6 control points are needed for successful calculation. If all optical distortions are omitted, the equations are as follows (Karara, 1989):

$$\begin{aligned} L_1X + L_2Y + L_3Z + L_4 - xL_9X - xL_{10}Y - xL_{11}Z - x &= 0 \\ L_5X + L_6Y + L_7Z + L_8 - yL_9X - yL_{10}Y - yL_{11}Z - y &= 0 \end{aligned} \quad (1)$$

where  $L_i$  = DLT parameters  
 $x, y$  = image coordinates  
 $X, Y, Z$  = 3D coordinates

The calculation is processed in two steps, first the DLT parameters are estimated by control points for each image (orientation), then the unknown points can be calculated if they appear on more than 2 oriented image. Least Squares Method (LSM) is used (Detrekői, 1999) for adjustment with some modifications.

#### 3.2 Huber-method

If gross errors are present in measurements (image coordinates), LSM is not a good choice for adjustment. Gross errors cannot be avoided in photogrammetry, especially by inexperienced users. The main reason for gross errors is the false point identification on images. Estimations, which reduce the effect of gross errors are named robust estimations. A way for reducing

effects is to modify weight matrices, gross errors weight should be reduced. The algorithm is follows: first an initial adjustment is done with a unit matrix. A new weight matrix is defined based on the residual vector of previous adjustment, and this step is iterated.

The question is, how new weight matrix is defined. Several object functions were developed for an efficient filtering. The developed application uses Huber-method, since its object function is convex (Huber, 1981), what ensures, the estimation will be convergent. The object function is:

$$\rho(v) = \begin{cases} \frac{v^2}{2} & , |v| \leq a \\ a(|v| - \frac{a}{2}) & , |v| > a \end{cases} \quad (2)$$

where  $\rho(v)$  = object function  
 $v$  = residual  
 $a$  = threshold

The weight function is the derivation of object function and divided by  $x$ . As shown in Figure 2., the residuals smaller than the threshold get 1 for weight (this means, normal distribution is supposed), others get smaller values. During iterations gross error's weight decrease, and will have minimal effect on final result.

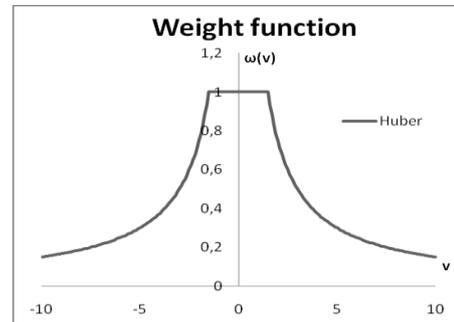


Figure 2. Huber-method weight function

The threshold value is  $1.5\sigma$  according to Huber (Huber, 1981), but it can be changed for a suitable value, for example  $3\sigma$ , as in geodesy usual. The photogrammetry web application uses the value 3 pixels and the number of iterations is 6. Experience proved that this is appropriate.

$$\omega(v) = \begin{cases} 1 & , |v| \leq a \\ \frac{a}{|v|} & , |v| > a \end{cases} \quad (3)$$

where  $\omega(v)$  = weight function  
 $v$  = residual  
 $a$  = threshold

Huber-method makes LSM a robust and widely applicable estimation. Using the Huber-method, the previously used algorithms can be kept, and calculation time doesn't rise exceptionally.

DLT describes one equation for x and one for y image coordinates. The coordinate pairs are not independent, thus if one of them has gross error, the other coordinate is also wrong. The weight must be the same for coordinate pairs.

### 3.3 Huber-method in practice

The performance of the calculation was tested in practice. A critical point of estimation is the first adjustment, if gross errors are dominant, the residual vector will be false. In this case the users have to be warned. It can be done if the RMS values of the first adjustment are high.

If RMSs are low, the calculation can be done, and Huber-method can be tested. In the particular test 4 images were used. The DLT parameters were determined by 20 control points and one unknown point were determined based on the DLT parameters. This process was performed several times, with different level of gross errors (test 1-3) on one point. The results were compared with that of without gross errors. A comparison was made also for extremely gross errors with and without Huber-method (test 4). Table 2 presents the image coordinates of point 8, in different tests, first column is without artificial values (clean measurements), others with gross errors (errors are in the last two rows).

[pixel]	clean	test 1	test 2	test 3	test 4
x	455.0419	475.0419	475.0419	575.0419	575.0419
y	588.4174	588.4174	548.4174	948.4174	948.4174
$\Delta x$	-	20	20	120	120
$\Delta y$	-	0	-40	360	360

Table 2. Test coordinates and differences [pixel]

Table 2 shows the final weights of measurements, the point 8 is with gross error, it has in test 1,2,3 very low value. The test 4 is without Huber-method. The weights of clean measurements are unchanged, the highest change is 0.141. Here are x and y coordinates are handled as independent values in order to see the real effect of Huber-method.

	clean		test 1		test 2		test 3		test 4	
1	0.207	0.865	0.217	0.942	0.207	0.724	0.198	1	1	1
2	1	1	1	1	1	1	1	1	1	1
3	1	1	1	1	1	1	1	1	1	1
4	1	1	1	1	1	1	1	1	1	1
5	1	1	1	1	1	1	1	1	1	1
6	0.584	1	0.583	1	0.606	1	0.516	1	1	1
7	1	0.587	1	0.569	1	0.613	1	0.519	1	1
8	1	1	0.152	1	0.15	0.079	0.026	0.009	1	1
9	1	0.802	1	0.821	1	0.863	1	0.756	1	1
10	1	1	1	1	1	1	1	1	1	1
11	1	1	1	1	1	1	1	1	1	1
12	0.761	1	0.739	1	0.686	1	0.818	1	1	1
13	0.367	0.548	0.363	0.528	0.363	0.584	0.405	0.529	1	1
14	0.506	1	0.480	1	0.470	1	0.462	1	1	1
15	0.494	0.602	0.482	0.575	0.453	0.545	0.464	0.545	1	1
16	1	0.484	1	0.471	1	0.515	1	0.465	1	1
17	1	1	1	1	1	1	1	1	1	1
18	0.56	0.461	0.539	0.455	0.606	0.459	0.579	0.415	1	1
19	0.184	1	0.182	1	0.187	1	0.179	1	1	1
20	1	0.252	1	0.249	1	0.245	1	0.265	1	1

Table 3. Weights of image coordinates

The maximum change of DLT parameters with Huber-method is 7% for  $L_4$ , but all other values remain under 1%. Without Huber-method changes can be 158% (294% for  $L_4$ )! The  $L_4$  and  $L_8$  are special parameters in the DLT equations, they represent a constant image coordinate offset.

	clean	test 1	test 2	test 3	test 4
$L_1$	7.130589	7.121748	7.128731	7.079486	4.995442
$L_2$	0.996978	0.998059	0.995439	0.97812	0.261669
$L_3$	-6.81928	-6.82449	-6.83241	-6.83772	-7.51298
$L_4$	-101.799	-100.813	-100.529	-94.4567	191.6648
$L_5$	-0.45804	-0.46	-0.45406	-0.46558	-0.80934
$L_6$	-7.66184	-7.65652	-7.66018	-7.62773	-6.26042
$L_7$	-4.71138	-4.71009	-4.70971	-4.70847	-4.90712
$L_8$	2568.476	2567.238	2567.051	2559.208	2213.25
$L_9$	-0.00047	-0.00047	-0.00047	-0.00048	-0.0007
$L_{10}$	0.000312	0.000312	0.000312	0.0003	-0.00018
$L_{11}$	-0.00312	-0.00313	-0.00313	-0.00315	-0.00442

Table 4. Changes of DLT parameters

While DLT parameter changes are around 1%, the unknown point determination with Huber-method is very accurate; changes are under 0.025 mm. That means, the method can be well applied for photogrammetry, and the effect of gross errors can be reduced. (Test images had 3888x2592 pixels, object distance was ~3m.)

[mm]	clean	test 1	test 2	test 3	test 4
X	158.117	158.117	158.117	158.124	158.455
Y	204.591	204.582	204.568	204.585	205.446
Z	-0.12	-0.11	-0.095	-0.128	-2.316
$\Delta X$	-	0	0	-0.007	-0.338
$\Delta Y$	-	0.009	0.023	0.006	-0.855
$\Delta Z$	-	-0.01	-0.025	0.008	2.196

Table 5. Changes of unknown point coordinates [mm]

### 3.4 Accuracy

The final accuracy of measurements depends on multiple factors. An important one is the accuracy of control points' spatial coordinates. The critical factor is the digitizing accuracy. In digital photogrammetry subpixel digitizing is used to increase accuracy. It means that all pixels are divided to more pixels, and intensity is calculated for all subpixels depending on the neighbour pixels' intensity values. Modern browsers (e.g. Firefox) use this method if a photo is zoomed: the developed application uses the same method if available in browser. The digitizing gross errors are filtered as described above. As mentioned before, the user's experience is also an important factor. It also covers the photogrammetric network planning, i.e. the determination of camera positions and control point positions. The accuracy also depends on the quality of photos, the important factors are: geometric and radiometric resolution, optical distortion, and image sharpness.

## 4. CONCLUSION

With a web based photogrammetry application the number of potential photogrammetric users can be increased. Users only need to have a simple digital camera and a computer with a web browser and broadband internet connection. Measurements can be performed anytime all over the world, since user data are stored on server. Users can work fast and be effective due to well planned data transfer and calculation methods. Accuracy depends on users' experience, but the available accuracy is comparable to that of other photogrammetric methods. DLT offers the opportunity to use non calibrated cameras, and an effective linear equation system for calculation. The effects of gross errors can be reduced with Huber-method, thus the estimation will be convergent. The test shows that the gross errors' effect will be minimized even if false point identification is done. Least Squares Method combined with Huber-method can be reasonably applied for photogrammetric calculation.

## 5. REFERENCES

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