THE PRODUCTION OF A PHOTOREALISTIC DIGITAL TERRAIN MODEL (P.D.T.M.)

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ABSTRACT

This research introduce an efficient and easy method to superimpose or merge an available digitized aerial photo on the common wireframe digital terrain model D.T.M. for a specific region, and to finally produce what is called photorealistic digital terrain model P.D.T.M. with the aid of Matlab programming language.

الخلاصة

يقدم هذا البحث طريقة فعالة وسهلة لدمج صورة جوية رقمية متوفرة مع النموذج التضاريسي الرقمي الترسيمي الشائع ولمنطقة معينة لكي ينتج في النهاية مايسمى بالنموذج التضاريسي الرقمي الصوري وبالاستعانة بلغة Matlab البرمجية.

KEY WORDS

D.T.M. – P.D.T.M. – Matlab – L.L.S. – G.C.P - Stereomodel

INTRODUCTION

With the rapid and amazing development of computers and programming languages facilities, many fields in surveying and photogrammetry are now become applicable like the production of photorealistic or photo texture digital terrain model P.D.T.M.

This research introduce a simple and efficient procedure for producing P.D.T.M depending on the superior facilities available in Matlab technical programming language ,and so it provides with a high quality PDTM performance and at the same time a low cost one when compared with others produced by any universal software like ERMapper and other costly software.

General Procedures

The general outlines of the project performance is by building a mesh or wireframe DTM by one of the many known methods of DTM interpolation techniques and then by superimposing or merging the digital aerial or satellite photo over that DTM properly to produce the PDTM.

Constructing a D.T.M

Much software is available now days to build a wireframe digital terrain models or surfaces which depend on some suitable interpolation techniques like:

- Kriging method.
- Inverse distance method.
- Polynomial method.

– Linear least square method.

One of the most common software that construct a D.T.M is the well-known *Surfer* program, and in spite of the existence of such technique in Matlab language by the *griddata* command, but it was preferred to build our own D.T.M with one of the above techniques and then merge it with the digitized aerial photo of that area.

Since all the interpolation methods gives an identical shape results, the linear least square interpolation method (L.L.S) was chosen .The mathematical approach of this method is illustrated in the following section.

<u>Linear Least Square Interpolation Method (L.L.S)</u>

There are many methods of interpolation and one of the most common methods is the linear least square interpolation which uses the mathematical series of the form:

$$\hat{f}(x) = \sum_{l=1}^{n} b_l s(d_l) \qquad (1)$$

Where s, being a function of distance d, $d_l = (x - x_l)$, may be a parabola $s(d) = d^2 + c$ or Gaussian function $s(d) = e^{(-cd^2)}$ or hyperbolic function, or quadric function.

One can interpret $\hat{f}(x)$ as summation of elementary curves –for instance:

$$s(d) = e^{-cd^2} \rightarrow \hat{f}(x) = \sum_{l=1}^{n} b_l . e^{\{-c(x-x_l)^2\}} \qquad (2)$$

i.e. bell shaped curves at the reference points as in **Fig. 1**

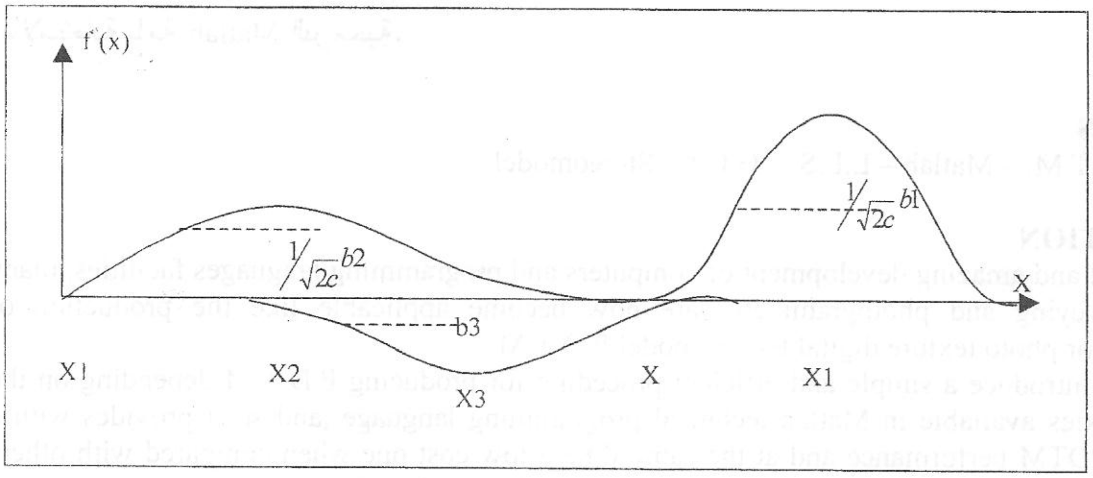

Fig. (1)

The mathematical form in matrix notation:

$$B = \begin{bmatrix} b1 \\ b2 \\ . \\ . \\ bn \end{bmatrix} \qquad S = \begin{bmatrix} s(d1) \\ s(d2) \\ . \\ . \\ s(dn) \end{bmatrix} \qquad \hat{f}(x) = S^T B \qquad (3)$$

Using as stochastically form an exact fit, the parameters B can be determined by:

$$F = QB$$

$$F = \begin{bmatrix} f(x_1) \\ f(x_2) \\ . \\ . \\ f(x_n) \end{bmatrix} \quad Q = \begin{bmatrix} S_1^T \\ S_2^T \\ . \\ . \\ S_n^T \end{bmatrix} = \begin{bmatrix} s(d_{11}) & s(d_{12}) & . & . & . & s(d_{1n}) \\ s(d_{21}) & s(d_{22}) & & & & s(d_{2n}) \\ . & . & . & & & . \\ . & . & . & . & & . \\ s(d_{n1}) & s(d_{n2}) & & & . & s(d_{nn}) \end{bmatrix} = \begin{bmatrix} q(d_{11}) & q(d_{12}) & . & . & . & q(d_{1n}) \\ q(d_{21}) & q(d_{22}) & & & & q(d_{2n}) \\ . & . & . & & & . \\ . & . & . & . & & . \\ q(d_{n1}) & q(d_{n2}) & & & . & q(d_{nn}) \end{bmatrix}.$$

Where

$d_{11}=/x_1-x_1/=d_{11}=0$

$d_{12}=/x_1-x_2/=d_{21}$

$d_{k1}=/x_k-x_1/=d_{1k}$

$d_{nn}=/x_n-x_n/=d_{nn}=0$

$s(d)=q(d)$

$B=Q^{-1}F$

The Merging Between Digital Photo and Graphical DTM

To merge the DTM constructed by the L.L.S technique and the digital aerial or satellite image, a Matlab programming language have been used ,the Matlab has a variety of superior commands to represent a surface graphically by providing a regular grid (matrix) of interpolated elevations for the region like in the **Fig. (2)**

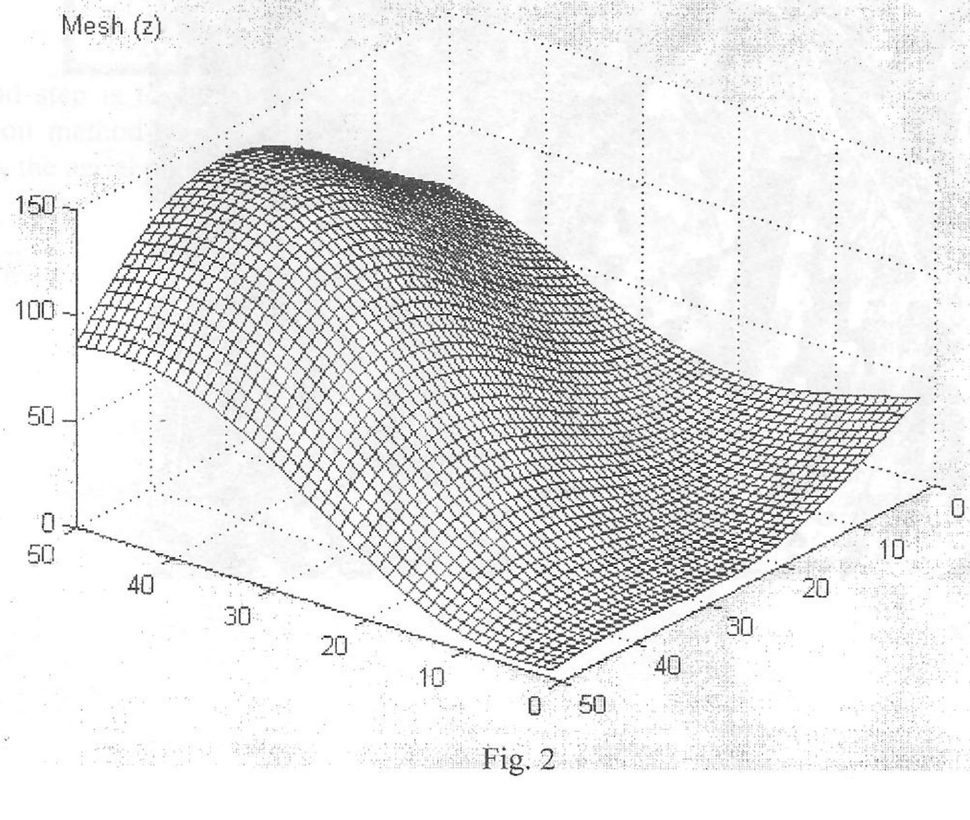

Fig. 2

Then by calling the directory of the stored digitized photo, the surface command will merge the photo and the mesh together and produce the P.D.T.M, and it must be noted that the Matlab deals with four types of images as follows:

1- R.G.B image
2- Index image.
3- Intensity image.
4- Binary image.

Also any image format may be used like Bitmap (bmp) format, Jpeg, Tiff, Gif, etc., so the suitable kind of image and format must be selected, and for more information return to the available manual of Matlab and any image processing reference.

Experimental Test

An aerial photo was selected which is used for academic studies and covers a hilly area of the Swiss countryside, this image was scanned to have a digital format and the chosen number of cells was (5441*5030) pixels as in the **Fig. (3)**.

The photo was provided with a scattered twenty ground control points (GCP) whose rectangular coordinates (X, Y, Z) are known and premarked on the photo clearly.

The photo coordinates of these GCPs were measured and listed as follows in **Table (1)**

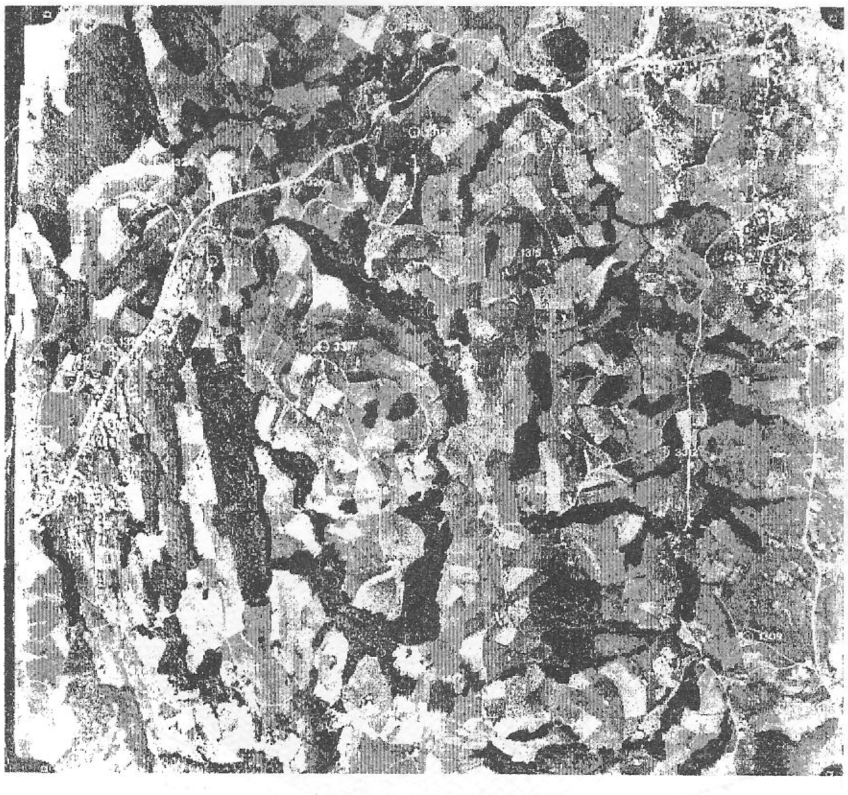

Fig. (3)

Table (1)

POINT	Digital Photo coordinates (pixels)		Ground rectangular coordinates (meter)		
	Ln	Sn	X	Y	Z
1219	4728	1025	747771.40	250789.19	857.21
3311	5123	1685	748069.65	251150.41	891.87
1310	5223	3043	748804.71	251540.33	880.00
1309	4820	4111	749510.46	251574.21	895.60
1315	3273	1610	748458.34	250110.92	918.24
3312	4273	2903	748945.82	250987.05	862.87
1314	3366	3143	749295.85	250516.03	972.68
3414	3586	4685	750093.51	250998.89	973.83
1417	2758	4416	750104.01	250474.21	1026.52
1316	2276	3160	749541.44	249935.06	976.96
3317	2066	2219	749079.15	249584.82	914.11
1318	2648	825	748138.82	249571.11	862.76
1319	1182	3229	749839.91	249342.48	964.33
1422	719	4350	750640.96	249326.54	887.05
1323	671	2191	749403.02	248738.37	818.95
1324	1004	1031	748635.83	248657.23	828.54
1421	1439	4340	750366.36	249760.49	1021.93
1425	444	3228	750069.60	248865.33	872.03
2425	344	3255	750113.67	248812.88	826.85
1320	1856	1147	748503.37	249177.61	811.97

The second step is to establish the mesh surface or DTM (50*50) cells, by applying the L.L.S. interpolation method as described previously .The following DTM were obtained for the region covered by the aerial photo, **Fig. (4)**.

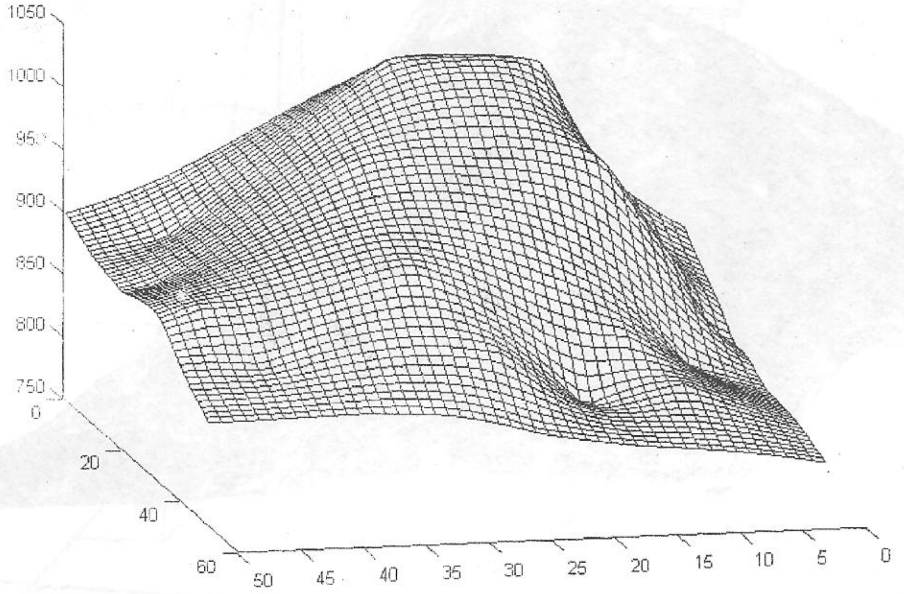

Fig. (4)

Five points were selected as check points and the predicted relative error for the elevations was about 10 %.A (10*10) sample for the interpolated elevations in the mesh is listed as follows:

868.98	874.69	880.88	887.63	894.99	903.04	911.80	921.19	931.09	941.24
866.08	871.75	877.93	884.71	892.21	900.54	909.78	919.91	930.75	941.99
863.00	868.58	874.68	881.40	888.91	897.43	907.11	918.02	929.95	942.52
859.79	865.26	871.20	877.75	885.12	893.63	903.65	915.38	928.61	942.76
856.56	861.89	867.65	873.92	880.95	889.16	899.26	911.84	926.65	942.69
853.39	858.64	864.24	870.23	876.75	884.22	893.82	907.31	924.17	942.38
850.38	855.64	861.22	867.10	873.25	879.75	887.46	902.20	921.92	942.11
847.56	852.98	858.78	864.92	871.34	878.04	885.52	900.94	921.52	942.27
844.91	850.64	856.90	863.69	871.11	879.49	890.00	904.81	923.24	942.88
842.33	848.47	855.34	863.03	871.70	881.70	893.74	908.44	925.43	943.54

The final step is to superimpose the digital photo over the obtained DTM by using the *surface command* in Matlab, and the result is a P.D.T.M as in **Fig. (5)**.

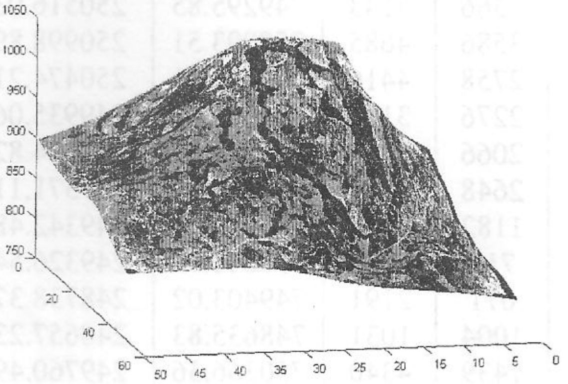

Fig. (5)

Different views could be attained through the three dimensional rotation facilities available in Matlab, and **Fig. (6)** illustrates a different view.

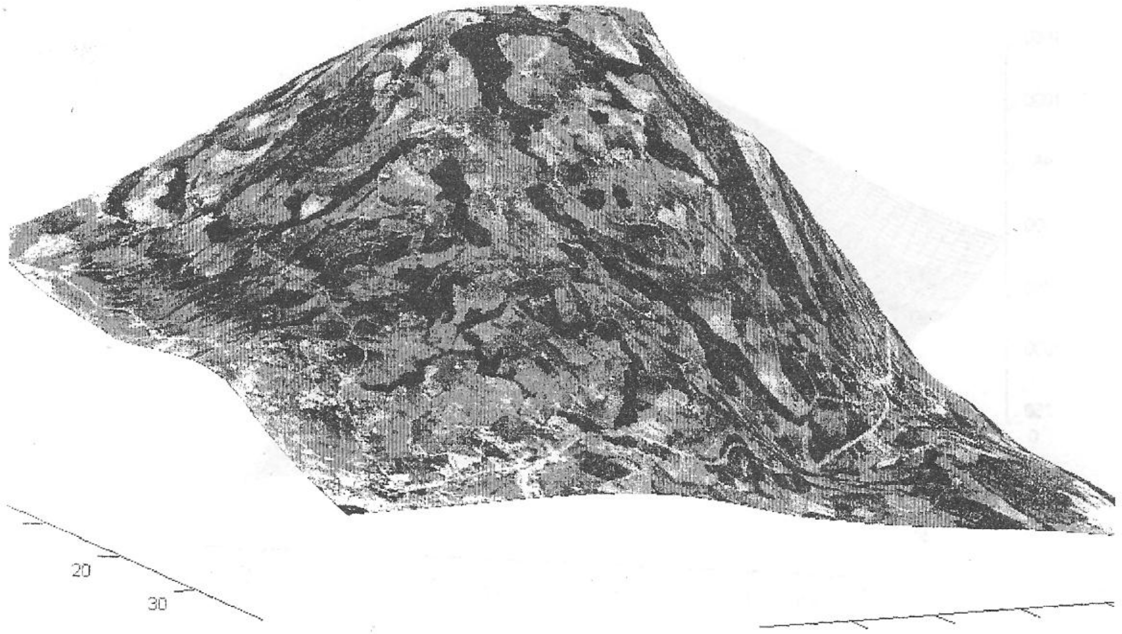

Fig. (6)

EXPERIMENTAL TEST FOR A STEREOMODEL

In many cases the ground control points GCPs are not available or it's densification in the photographed area is costly and tedious way ,so the availability of an overlapped photos will provide us with an accurate and accepted way to build a stereomodel for the overlapped area ,and then applying the proposed method of PDTM .

The technique of constructing a stereomodel for the overlapped area is achieved by using the well-known *relative orientation* procedure; there are two ways to perform this procedure:

1- Dependant relative orientation (one projector method).

2- Independent relative orientation (two-projector method)

In this research the first one are chosen to accomplish the analytical relative orientation, which depends on the concept of fixing the left photo vertically (rotation angles $\omega_1=0,\varphi_1=0,k_1=0$) and orienting the right photo relatively to it, so it is necessary to compute the orientation angles (ω_2,φ_2,k_2) and the base components (by,bz) since the bx is chosen unity or some value to fix the scale of the model **Fig. (7)**.

The mathematical way to compute these five orientation parameters (ω_2,φ_2,k_2, by, bz) and the model coordinates (x_m,y_m,z_m) for each point appearing in the overlapped area could be achieved by either coplanarity or collinearity equations.

It is known that the chosen points must be well distributed to achieve a better accuracy, but for the aim of how to produce a PDTM, so only the pre-marked points on the photos will be used.

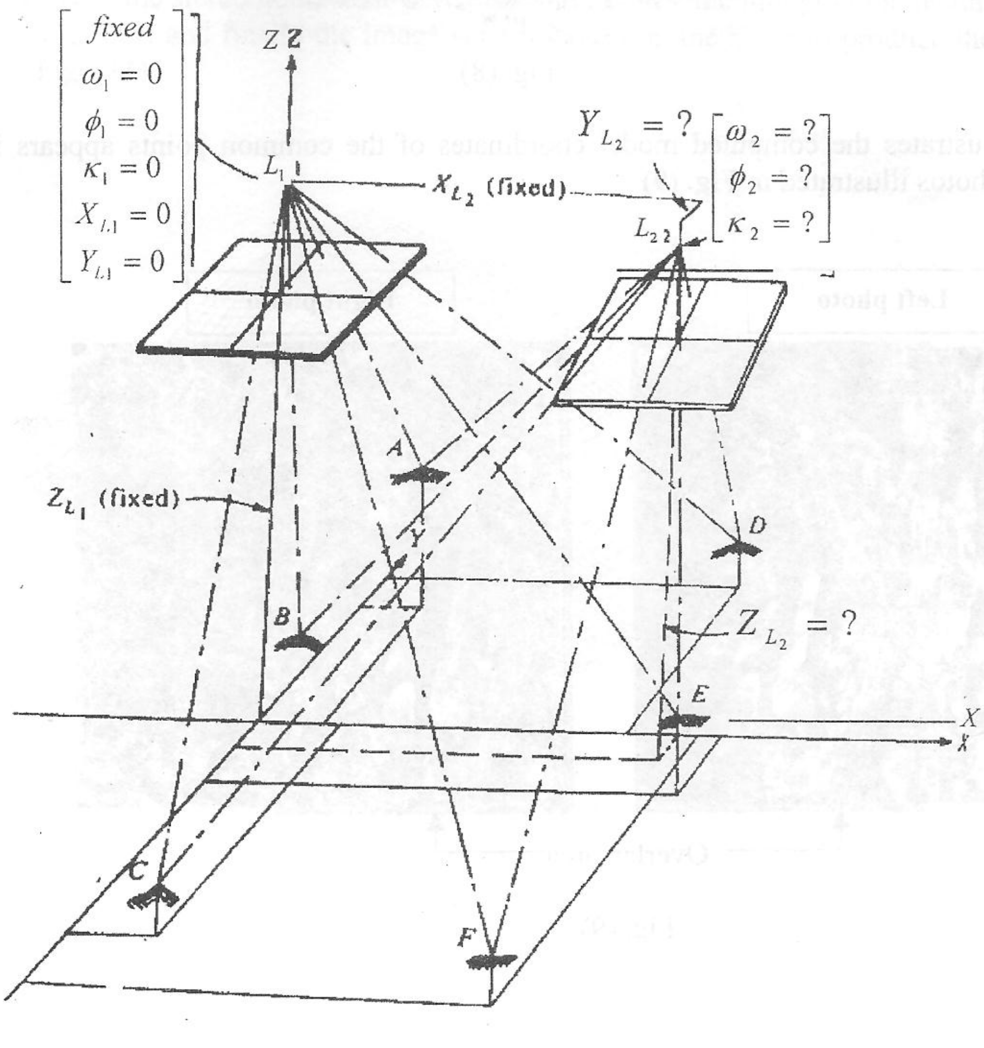

Fig. (7)

The exterior orientation parameters for the right photo computed by the analytical relative orientation technique using collinearity equations are listed as follows:

omega = -0.021977 rad.
phi = +0.001740 rad.
kappa = +0.009084 rad.
b_Y 7.070 mm.
b_Z = -0.678 mm.

Fig. (8) illustrates the sparsity pattern of coefficient matrix (48*40) necessary to solve the problem.

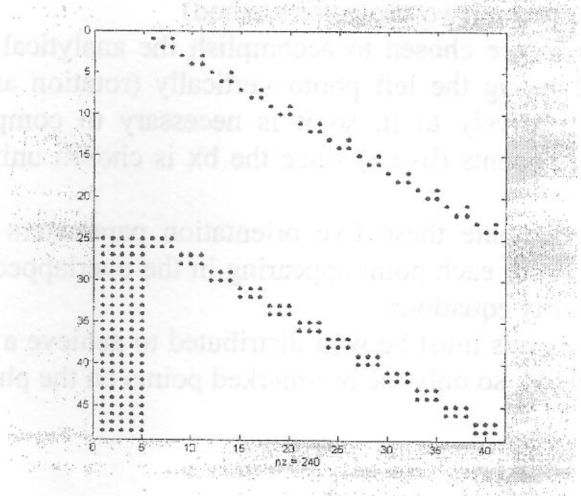

Fig. (8)

Table (2) illustrates the computed model coordinates of the common points appears in the two overlapped photos illustrated in **Fig. (9)**

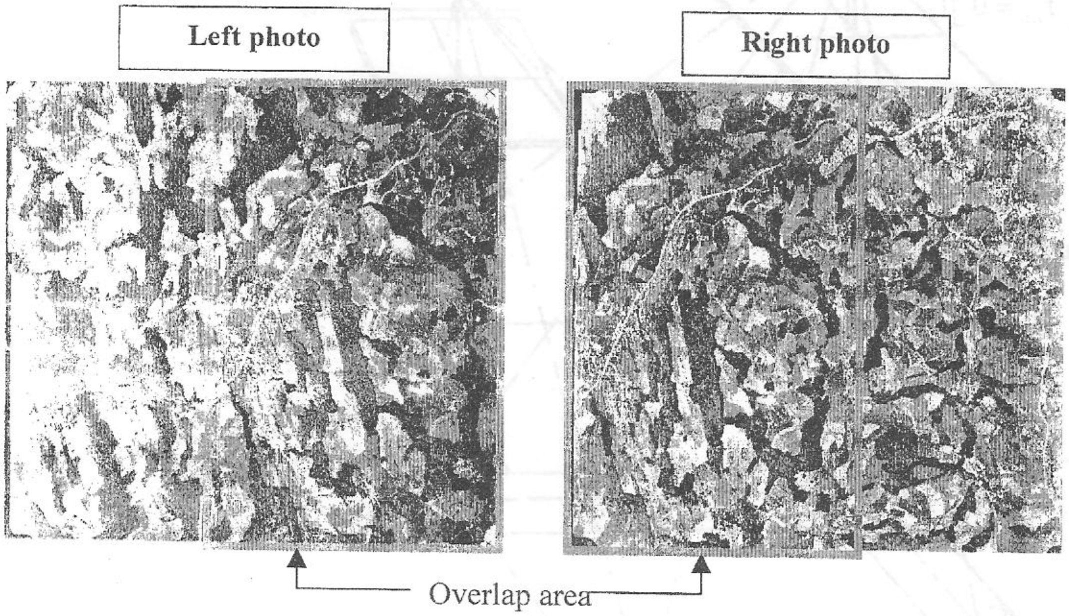

Fig. (9)

Table (2)

Point NO.	Model coordinates (cm)		
	xm	ym	zm
1422	5.80	-70.82	145.33
1421	38.41	-66.54	139.57
1425	-8.05	-25.50	149.91
1318	81.72	73.91	148.68
1319	27.08	-22.66	136.86
1316	69.32	19.83	139.82
1228	74.80	102.86	149.93
3317	59.19	16.28	143.07
1323	0.35	17.22	149.85
1321	29.41	37.57	144.10
1324	14.12	64.62	148.52
1320	48.58	60.81	151.27

The final PDTM of the stereomodel area were prepared in the same interpolation technique L.L.S as illustrated in **Fig. (10)** and finally the image superimposed on the mesh to produce the P.D.T.M as illustrated in **Fig. (11)** .

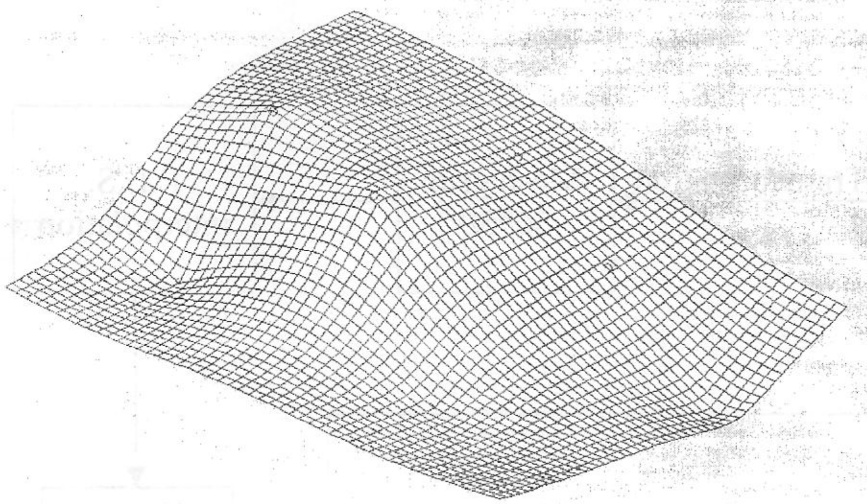

Fig. (10)

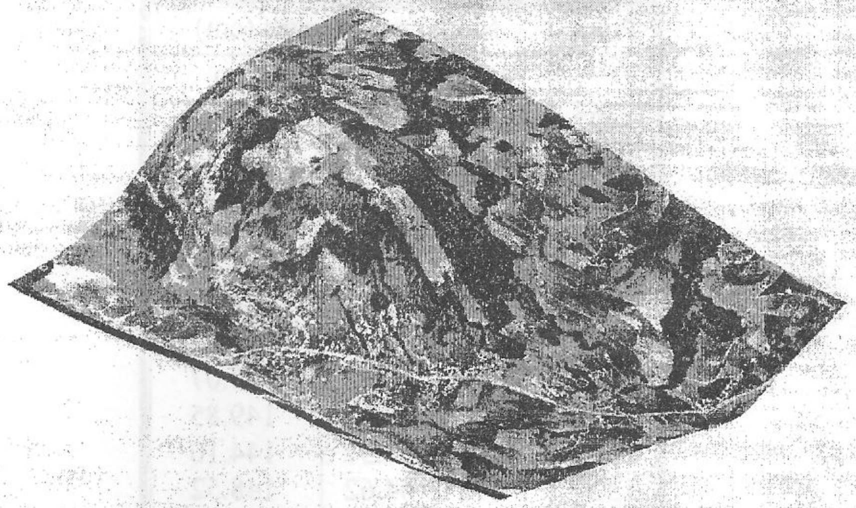

Fig. (11)

SUMMARIZED PROCEDURE

The introduced procedure in this paper could be summarized by the following diagram as in **Fig.** (12)

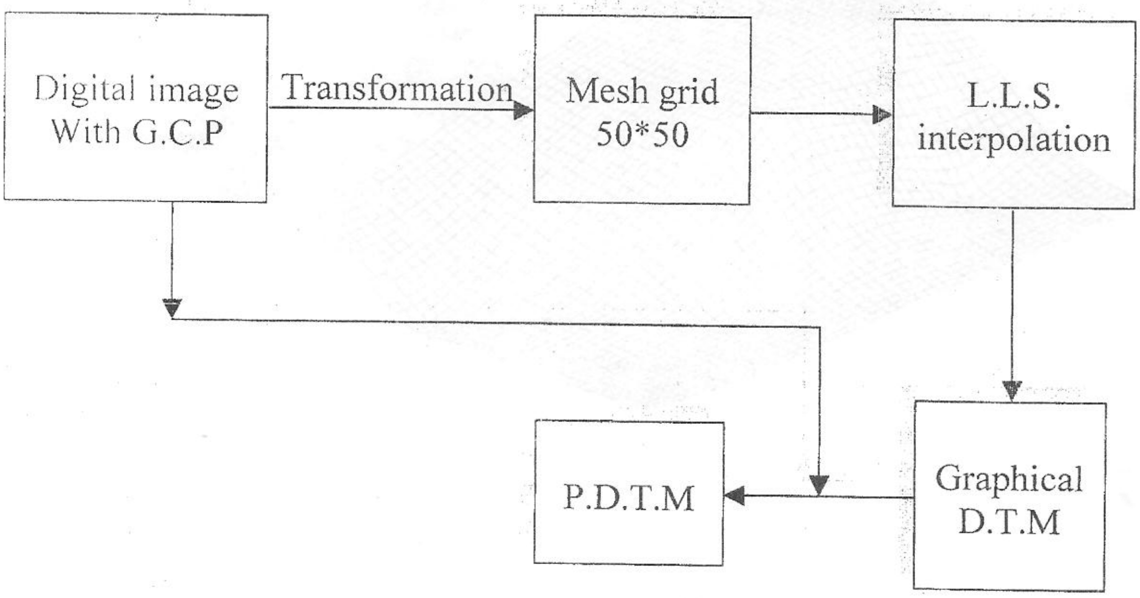

Fig.(12)

CONCLUSIONS AND RECOMMENDATIONS

From the proceeding discussion it is obvious that it is so easy to build a PDTM for any region covered by photos even if there are no ground control points available.

It represents a low cost work and accurate production method of photorealistic digital terrain-model P.D.T.M.

The proposed method is a future promising technique and it opens a wide range of applications to be achieved in the fields of interpretation, geology, highway engineering, military applications, etc.

It is recommended that the procedure also tested for our national photographed lands and then compared with real seen, and also to apply the proposed method on a satellite images to produce the P.D.T.M.

REFERENCES

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