Utilization of Existing Elevation Data Base to Improve Correlation on Kern DSR-11 Analytical Plotter.

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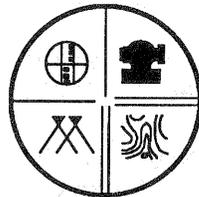
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Abstract:

This paper documents the study of a strategy in order to improve the efficiency of the correlator of Kern DSR-11 analytical plotter. In particular the measurements of digital elevation models are considered. Initial values for the correlation process derived from existing elevation data base and by interpolating operator-measured height data are introduced. Especially for relatively large point spacing of the elevation model, the number of successfully correlated points are significantly increased.

1. Introduction

It is a fact that a 'good' initial value for presetting the height before correlation always plays an important role. Firstly, the approximation will shorten the search length which means saving on correlation time. With some of the algorithms, which have only poor "pull-in" range, this seems to be the only way to help the correlation. Secondly, this approximation will be able to make a limitation, so that the blunders can be eliminated to some extent and the quality of the correlation is therefore improved.

This approximation for correlation is not difficult to obtain. In the following experiments two different presettings have been used to support the Kern's VLL correlation and the effects of these will be discussed.

2. VLL correlation concept

The Vertical Line Locus (VLL) is a discrete correlation method introduced first by Kern & Co.AG. Some changes of the original version have been made before the experiments were carried out. Briefly, the algorithm can be described as following: (See also Cogan and Hunter 1984).

To find the height on the ground, the operator can define some horizontal, rectangular "windows" which are equally spaced and centered on a specified vertical line. The middle window is set on the floating-mark's position, which has the best estimation of height before the correlation. The projection on both left and right image of these windows can be derived and correlated. The correlation principle used here is cross correlation. With a predefined acceptance-threshold the correlation coefficients can form a criterion for finding the desired height. The process can be repeated and by changing window-size, the wished for accuracy can be expected.

One difficulty with this method is that the windows on the vertical line must be chosen close enough to each other, so the maximum is able to be detected (not jumped over). That means, with a finite number (usually 5 or 7) of windows, the whole search region is quite limited ("pull-in" range is poor). In order to solve this problem it is very natural to support the correlation with the approximate height settings.

It is also very difficult to define the acceptance-threshold. In Kern's original programme 0.40 is normally used. But this value is not sufficient if the high-precision is taken into account, (Ackermann, Schneider & Vosselman 1986). On the other hand, with poor texture/contrast images, or around forests, grassland and farmfield areas, though the maximum is only about 0.3 - 0.4, the correlation could be arrived at correctly (because here the obvious maximum is truly found). Having chosen the acceptance-threshold, then, if it's too low, the accuracy is sometimes not satisfied, and, if it's too high, the number of correlated points will decrease. In the modifications the value 0.60 is used as the main acceptance-threshold and combined with this a secondary threshold (0.25) has also been introduced to separate obvious maximum of correlation coefficients from no maximums at all.

We now have the following situations for the correlation coefficients within one trial:

1) only increasing or decreasing (maximum is beyond the search region).
2) the maximum is less than 0.25 (no obvious maximum).
3) the maximum is between 0.25 - 0.60.
4) the maximum is above 0.60.

With 1): keep the window spacing, change center and re-correlate.

With 2): make the window spacing larger to see if the maximum

lies in the neighbouring regions (until the largest
spacing is reached).

With 3): first make the window spacing smaller (find the top),
and then use the largest window spacing to indicate
that there is no higher maximum in this specified
region.

With 4): If the window spacing is suitable for accuracy then
accept the correlation.

This approach has several disadvantages:

- based on testing of Kern's programme we can not re-use the
data from the frame-buffer. Mechanical movements of image
stages and resampling of grey-tone values must be done for
every trial.

- with the concepts described before, the window-size must be
the same for the different retries.

- time consuming. (Because of 1: time for this work is
limited, 2: a small computer PDP-11 has been used.)

3. Supporting DEMs and Ground-truth.

For practical reasons only a regular grid form is used with a
grid-distance equal to 50 metres in all experiments.

The main supporting digital elevation model is from an
existing elevation data base. This data base has a regular grid
form of 50 m and is made by digitizing the 1:50,000 topographic
maps which has 5 m equidistance contours. This is a non-accurate
DEM (the RMS of the database is approximately 1.8 m. The histo-
gram of the comparison is shown in fig. 1). This DEM was deve-
loped for The Danish Posts and Telegraphs (P&T). (Frederiksen,
1987).
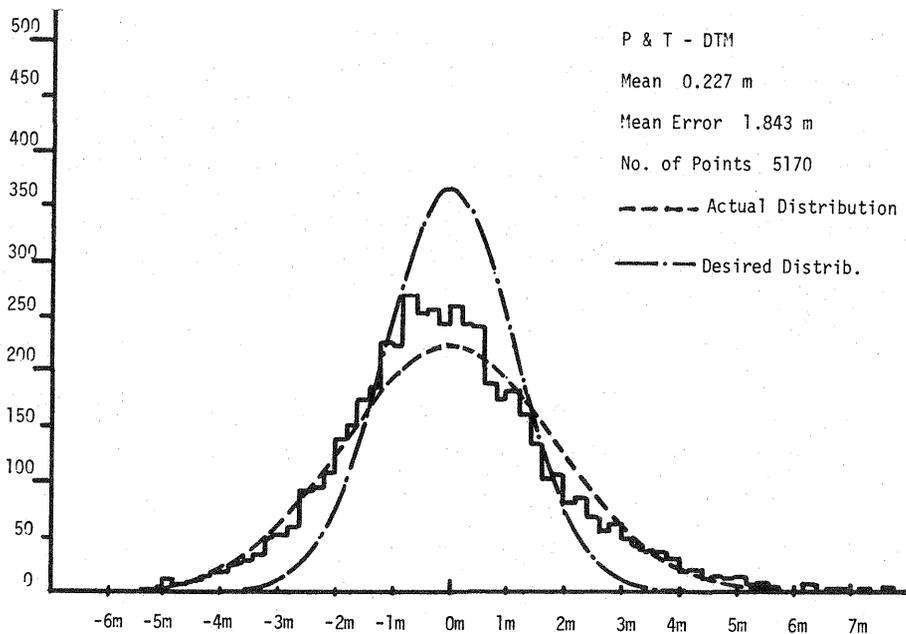
Figure 1. The histogram of comparison between P&T data
and Ground-truth. The desired distribution is
what we could have got, based on the theory.

As another supporting DEM, a "Rough-gridded" DEM of 150 metres
was measured by the operator. A bilinear interpolation is taken
for every 50 m setting. This DEM is called "150m".

Ground-truth is measured by the operator for every 50 metres.
The same photogrammetric model was used both for this purpose
and for the correlation.

Since there is no doubt about the skill of the operator, the
RMS could be estimated at not worse than 0.6 metre (0.15 per-
mille of the flying height – 3,800 m).

4. Results of the experiments

The project is a collaboration of The Danish Geodetic Insti-
tute and The Technical University of Denmark. The aim is to in-
vestigate the reliability and accuracy of correlator measured
DEM.

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The test area is in North-West Zealand, Denmark. It consists of town (concentrated building areas), roads and other break-lines, farmfields, grassland and forests. The landscape is moraine and relatively flat. The photo scale is 1:25,000.

With 50 m grid-distance, 5170 points in total have been counted in the whole model. 4 different correlations were implemented and the results are shown in table 1.

No.	Sup.DEM	Total	uncor.	%	Rest	Time
1.	–	5170	1448	28.0	3722	21:36'
2.	P & T	5170	781	15.1	4389	–
3.	150 m	5170	1056	20.4	4114	22:32'
4.	Operator	5170	770	14.9	4400	22:16'

Table 1. Results of correlation.

Notice that:

- no. 1 is made without supporting DEM.
- percentage of uncorrelated points in No. 3 is slightly higher than no. 2 and no. 4. It is probably because the image brightness was set too high.
- in no. 4 "Operator" means that we have simply used the ground-truth as supporting DEM.

We Have:

Conclusion 1: With the supporting DEM it increases the successful correlation significantly.

In the   without DEM, uncorrelated points are 28.0 %
cases: with   DEM, uncorrelated points are 15.0 %

5. Statistics and Blunders:

Limitation of blunders:

Within all the correlated points a great deal of gross errors (largest up to 15-16 m) were found when correlation results were compared with the ground-truth. To set the limit for these blunders, a histogram was calculated and drawn in fig. 2. Based on this histogram it seems very reasonable to take 4 m as the candidate, so if:

absolute value of difference > 4 m   =>   blunder.
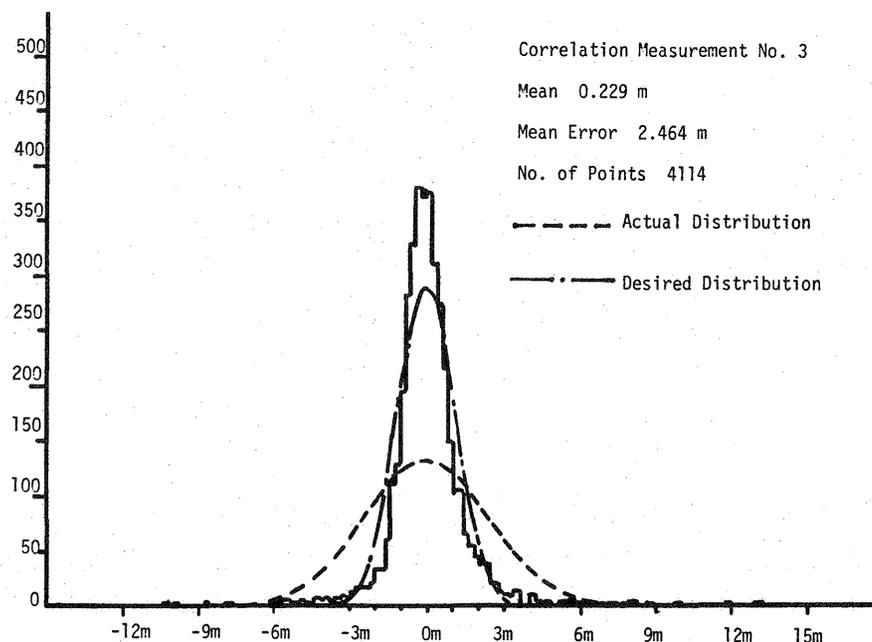
Figure 2   It seems reasonable to use 4 m as the limit for blunders.

Results:

In table 2 the statistical results of the experiments are illustrated. The different symbols mean:

Sb : standard error in metre before eliminating the blunders.
Sa : standard error in metre after eliminating the blunders.

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No.	Sup.DEM	Total	corrl.	>4m.	%	Sb	Sa
1.	−	5170	3722	699	18	9.7	1.6
2.	P & T	5170	4389	471	11	3.2	1.2
3.	150 m	5170	4114	205	5	2.5	1.1
4.	Operator	5170	4400	431	10	3.1	1.2

Table 2. Results of Statistics.

Table 1 and table 2 together conclude following:

Conclusion 2: Supporting DEM is not demanded to be
             very accurate.

In the case: Operator DEM has a mean error: 0.6 m.
             P&T DEM has a mean error: 1.8 m.

6. Substitution of the uncorrelated points and blunders with P&T DEM points.

This part of the work is only concerned with retrieving the
uncorrelated points and blunders. The analysing correlation here
is no. 3 (uncorrelated points = 1056). We replace first all the
uncorrelates with P&T DEM points and then compare this mixed DEM
with the P&T data set. If there any differences found greater
than the blunder-limit, we substite the points as well. The
limitation of blunders is taken as a variable in range from 4 to
8 metres (table 3).

In the table 3 "bad choice" means that the actual correlation
measurement is better than the replacement of P&T data when we
compare the substitution-DEM with the ground-truth.

Limit	*No. sub.	Bad choice	mean	st. dev
> 8 m.	1142	6	0.25	1.61
> 7 m.	1171	11	0.24	1.54
> 6 m.	1199	22	0.38	1.51
> 5 m.	1269	49	0.45	1.47
> 4 m.	1425	161	0.56	1.55

* The number includes 1056 uncorrelated points.

Table 3. Substitution of uncorrelated points
and blunders with P&T Data.

Table 3 shows that the no. of "bad choice" from "greater than 8m" to "greater than 5m" grows linearly, but to choose 4 metres as the limitation causes a blind substitution.

Fig. 3 shows the comparison of the substitution and the ground-truth, when the 5m limit is used.


Hybrid DTM
Subst/Uncorr 1269/1056
Measured Points 3901
Mean/Mean Error 0.245/1.473 m
Subst.limit 5.0 m
Bad choices 49
— — — Actual Distribution
————·— Desired Distribution
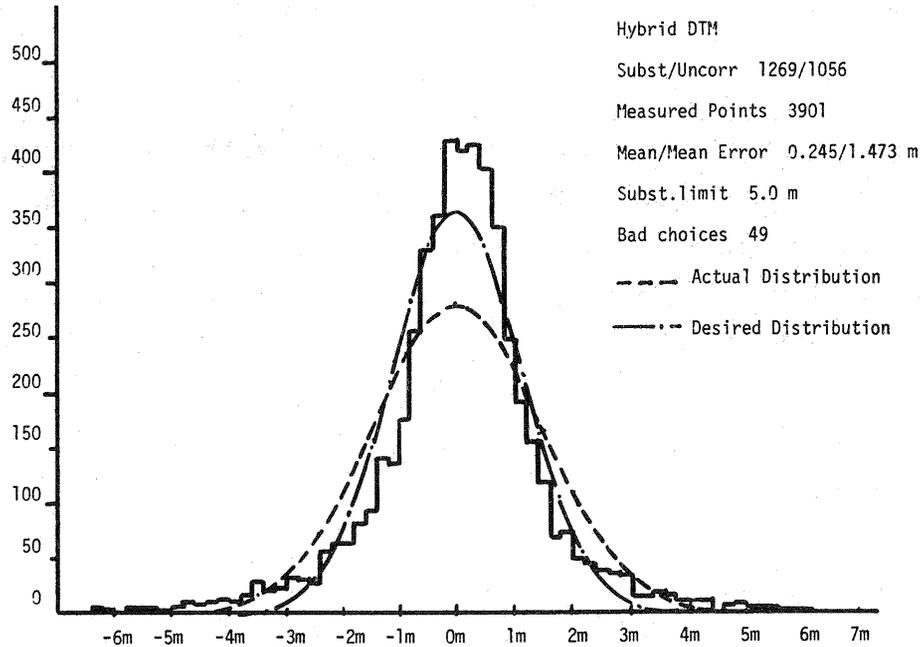
Figure 3   The comparison between "Hybrid" DEM and
the ground-truth.

7. Summary of the results.

In this work we have the following results:

a) The VLL correlation principle can be improved significantly by introducing a supporting DEM as the initial values.

b) The quality of this DEM is, however, not critical for the correlation.

c) The supporting DEM could be used to set up a limitation for blunder detections. In this case, of course, the accuracy of the DEM must be known.

8. References

Cogan, L. & D. Hunter, 1984: DTM-Collection and the Kern Correlator for Kern DSR1/DSR11.

Ackermann, F., W. Schneider & G. Vosselman, 1986: Empirical Investigation Into the Precision of Digital Image Correlation. ISPRS-Proceedings of International Symposium "From Analytical to Digital", Rovaniemi, Finland.

Frederiksen, P., 1987: A Digital Elevation Model for Radio Communication. ISPRS-Proceedings of the International Colloquium "Progress in Terrain Modelling" WG III/3, Lyngby, Denmark.

Li Mengxiang, 1986: A Comparative Test of Digital Elevation Model Measurement Using the Kern DSR-11 Analytical Plotter. ISPRS-Proceedings of the International Colloquium "Progress in Terrain Modelling" WG III/3, Lyngby, Denmark.