ORIENTATION TESTS ON YZERMAN APY INSTRUMENT

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ABSTRACT

As part of a continuing programme of research in map revision, experiments have been carried out using the Yzerman APY Analytical Plotter. The accuracy of the orientation procedure when carried out using control points obtained from existing graphic maps has been investigated for models of different terrain types and of different scales. It has been shown that it is possible to obtain orientations suitable for subsequent plotting within normal graphical accuracy of ± 0.3mm, but only if high quality control points are available.

KEY WORDS: Revision, Analytical Instruments.

1. INTRODUCTION

Map revision by photogrammetric means has been attempted by many methods over the years, using a wide range of photogrammetric equipment (Walker, 1984). One common feature of almost all photogrammetric revision methods is that the central operations have had to be carried out on an instrument which was not specifically designed for revision, but for new mapping and from this fact stems many of the difficulties of these methods.

As the swing from analogue to analytical instrumentation has intensified, several low cost analytical plotters have been produced and some are claimed to be optimized for revision, in that they satisfy a series of requirements recognized as being necessary in a revision instrument (Tait, 1991). One instrument satisfying these requirements is the Yzerman APY (Yzerman, 1987). Around 30 units have been sold world-wide to various users, mainly for use in thematic mapping operations where specialist information is easily added to an existing topographic base map, which supplies the control for the orientations.

This paper discusses some aspects of the metric properties of the APY instrument, an instrument which without doubt satisfies all the other main requirements for a revision instrument to some degree.

2. OBJECTIVES, METHODOLOGY AND MATERIALS FOR THE TEST

The tests investigated the metric qualities of the instrument, both with respect to the claims made by the manufacturer and to the needs of revision at the larger scales. Since this instrument is very different from conventional analogue photogrammetric instruments, a specific series of tests had to be devised.

The metric quality of the output of any photogrammetric system will depend on the intrinsic accuracy of the instrument; the manner in which the model is formed (i.e. the orientation); the accuracy with which the observer makes the measurements; and the ease with which new data can be interpreted, followed and plotted. Full details of these tests have been reported in Turker (1991). Only two of the tests will be discussed here, namely

(a) the testing of the digitizer tablet, which provides the basic input to the instrument;
(b) the testing of the orientation procedure and its accuracy.

2.1. Test of Digitizing Tablet

All measurements carried out on the APY involve the tablet digitizer over which the measuring mark or cursor is moved.

A stable plastic sheet containing a millimetre grid was placed on the digitizer table and a series of grid intersections were measured, both at the largest and at the lowest map magnification. This test allowed an investigation of the operator setting error and a determination of the absolute accuracy of the coordinates which are output by the digitizer. Diagrams were produced to show the errors occurring over the working area of the tablet digitizer.

2.2. Tests Using Stereo-Models

A series of tests involving stereopairs of aerial photographs taken at different scales over test areas with differing terrain characteristics (eg.flat/hilly terrains, etc.) were carried out.

3. TEST AREAS

The test areas have been divided into two main groups:

(a) those with comparatively flat terrain; and
(b) those with hilly terrain.

The overall accuracy tests and the compilation tests were carried out for models of these two kinds of terrain. Four models with mainly flat terrain and two with hilly terrain were used. Of these, four (2 flat and 2 hilly terrain) utilized large scale photographs in the scale range

1:3,000 to 1:5,600. The remaining two tests employed much smaller scale photographs taken at approximately 1:20,000 and 1:40,000 scale respectively. Maps were available for all areas and were used to provide control data.

Table 1 gives a summary of the main characteristics of the various test models.

4. USE OF DIFFERENT INSTRUMENTS

In addition to the APY instrument installed in the Department of Geography and Topographic Science, University of Glasgow, other instruments were used for the tests. These were:

- the APY of the Economic Forestry Group, Moffat;
- the APY at the Dublin College of Technology, Dublin, Eire;
- the Kern DSR 11 at the University of York;
- the Wild BC-2 of Mason Land Surveys in Dunfermline.

The other two APY instruments were used to allow a comparison of the results achieved from measuring the same models in three different APY instruments.

The two mainstream analytical plotters were used to measure the Llandudno and Rorbas models to give terrain coordinates (E, N and H) of the control points and to provide comparative data that could be used in the analysis of the measured APY data.

5. ORIENTATION AND ACCURACY TEST RESULTS

5.1. Test of the APY Digitizing Tablet

This test aimed to establish the accuracy of the tablet digitizer of the APY. The quoted resolution is 0.025mm., and the quoted accuracy ± 0.1mm. Since the map which is being revised is placed on and measured by this digitizer, the accuracy of its output is very important, as the tablet digitizer generates the X, Y coordinates which are the input to the analytical photogrammetric solution based on object coordinates primary.

The grid intersections of a stable gridded plastic sheet were digitized. The test was carried out twice, once for the lowest magnification (20mm spacing; 154 points) and again for the greatest magnification available in the map viewing channel (10mm spacing; 42 points). The positions of the grid intersections were measured three times.

The standard deviations of a single observation (stdev) were computed with the following results:-

For 154 points	For 42 points
stdevx= ±0.067mm.	stdevx= ±0.038mm.
stdevy= ±0.069mm.	stdevy= ±0.053mm.

These are measures of the pointing accuracy in the X and Y directions for the lowest and greatest magnifications.

The standard deviation values found for the greatest magnification are greater than the quoted value of ±0.025 but part of the difference might be due to the errors in the observations made by the operator.

FLAT TERRAIN					
Area	P.D.	Height	B:H	Ph.Scale	Map Scale
Kelvingrove	152.57	840	0.6	1: 5,400	1: 2,500
Llandudno	304.77	1,510	0.3	1: 5,000	1: 2,500
Greystoke	152.05	2,950	0.6	1:18,000	1:10,000
HILLY TERAIN					
Area	P.D.	Height	B:H	Ph.Scale	Map Scale
Greenock	152.40	585	0.6	1: 3,700	1: 2,500
Rorbas	152.35	900	0.6	1: 5,600	1: 4,000

Table 1. Model Summary Table.

The residual error at each grid intersection was then computed. The root mean square error values for each of the three sets of measurements at the two viewing magnifications were as follows:-

Highest Magnification	Lowest Magnification
± 0.08mm.	± 0.14mm.
± 0.12mm.	± 0.11mm.
± 0.15mm.	± 0.18mm.
AV. R.M.S.E. Value	
± 0.12mm.	± 0.14mm.

The quoted accuracy of the digitizing tablet incorporated in the APY instrument is 0.1mm. which is rather better than the actual results found from the test, but these results include both observation errors and any errors present in the stable gridded plastic sheet. Obviously these two factors could have affected the results of this test.

In production, it is likely that control points, even pre-marked or artificial points, will be more difficult to measure than the grid intersections used in this test. The rmse value of ±0.12mm. must therefore be regarded as the best that could be achieved and, for planning purposes, a value of ±0.15mm, or even ±0.20mm, might be more realistic.

5.2. Orientation Tests

Testing the orientation of the APY continued using aerial photographs, starting with the Kelvingrove model. The control points were digitized on the map during the measurement of the model. Numerous orientations were carried out at different times. The root mean square error values for planimetric and height and the values of the orientation elements (XO, YO , ZO , omega and phi) for each photograph are shown in Table 2.

The maximum r.m.s.e. value in planimetry (mpl) obtained is ±1.00m, the minimum value is ±0.29m. The mean r.m.s.e. value in planimetry (mpl) for the 12 orientations listed is ±0.48m, equivalent to ±0.2mm at the map scale of 1:2,500 and is twice the quoted value of the accuracy of the tablet digitizer (0.1mm), which is equivalent to ±0.25m at this particular map scale.

Turning next to the height errors, the r.m.s.e. value (mz) is ±1.02m for a flying height of 840m which is equivalent to ±1.21 per mil of the flying height (H). This figure seems surprisingly

Ornt No	No of Pt	Control Points R.M.S.E. values (±) mx	my	mpl	mz	Left Photograph Proj. Centre Coordinates XO	YO	ZO	Rotation Values Sin w	Sin v	Right Photograph Proj. Centre Coordinates XO	YO	ZO	Rotation Values Sin w	Sin v
1	4	0.24	0.36	0.42	0.94	56,598.30	66,275,85	857.57	0.0187	-0.0057	57,064.33	66,229.32	820.52	0.0558	-0.0304
2	4	0.43	0.13	0.45	2.45	56,597.76	66,300.00	884.34	-0.0046	-0.0121	57,094.76	66,286.08	846.94	-0.0074	0.0048
3	4	1.00	0.14	1.00	2.05	56,600.26	66,284.53	879.73	0.0085	-0.0158	57,075.95	66,252.66	840.30	0.0266	-0.0273
4	4	0.05	0.60	0.60	0.57	56,610.25	66,293.11	852.67	0.0023	-0.0020	57,085.22	66,279.07	843.80	-0.0021	-0.0080
5	4	0.37	0.23	0.44	1.15	56,598.83	66,315.63	848.61	-0.0205	-0.0083	57,109.75	66,295,77	850.87	-0.0172	0.0172
6	4	0.13	0.26	0.29	0.50	56,610.27	66,290.00	900.50	0.0173	0.0061	57,094.66	66,267.71	854.36	0.0223	0.0086
7	4	0.61	0.06	0.60	0.59	56,612.75	66,292.28	866.67	0.0037	0.0034	57,086.54	66,326.05	852.63	-0.0551	-0.0060
8	4	0.48	0.08	0.48	0.51	56,608.72	66,283.10	862.38	0.1220	-0.0031	57,090.16	66,313.75	855.36	-0.0390	-0.0024
9	4	0.31	0.13	0.34	1.06	56,611.69	66,281.13	866.62	0.0146	0.0013	57,088.33	66,285.27	844.92	-0.0070	-0.0044
10	4	0.41	0.38	0.55	0.55	....	....	......	....	....	....	....	.....	......	......
11	4	0.23	0.21	0.31	1.07	56,601.22	66,279.42	847.94	0.0162	-0.0201	57,060.55	66,254.27	854.85	0.0092	-0.0162
12	4	0.36	0.06	0.36	0.86	56,600.73	66,289.39	845.84	0.0008	-0.0155	57,069.33	66,260.02	856.62	0.0021	-0.0085
Average		0.39	0.22	0.48	1.02	56,604.62	66,289.49	864.81	0.0163	-0.0065	57,083.60	66,277.27	847.38	-0.0011	-0.0066

Table 2 Summary Table for Kelvingrove Model

low when one considers that a standard topographic stereo-plotter will regularly achieve height accuracies of 1/5,000 to 1/10,000 of the flying height - equivalent to 0.2%. to 0.1%. of H.

The results show a large spread in the recorded values of the orientation parameters. The r.m.s.e. for the X value of the left projection centre has the smallest value (±5.7m) with the Y and Z values considerably larger at ±10.6 and 16.5m respectively. On the right photograph, the r.m.s.e. of ±27.0m for the Y value is much larger than the corresponding values for X (±14.1m) and Z (±9.9m). These figures show the very poor repeatability of the orientation.

Coordinates measured by the APY digitizer will have a limited accuracy and the operator is likely to make some observational errors during the measurement of these control points. These errors will affect the accuracy of the whole solution. As a result, the r.m.s.e. values will almost certainly be larger than the quoted or expected values, which are given in the APY literature and appear to be based only on the accuracy of the digitizer itself.

In order to orient a stereomodel, the APY instrument needs at least four control points at which x and y parallaxes have to be eliminated. However, the operator will make observational errors in the elimination of these parallaxes and with the observations of the planimetric positions of the control points. These are the two most probable errors affecting the r.m.s.e. values obtained in a test.

The conclusion must be that the quoted r.m.s.e. value mpl for planimetry (called md in the APY literature) of 1:10,000 of the map scale number, equivalent to ±0.1mm on the table, is not realistic for practical purposes. A value of at least ±0.15mm., and probably larger, would be more reasonable.

Orientation tests were carried out on the four other models listed in Table 1, using the same procedures as described above. Detailed results are given in Turker (1991); only a summary is presented here.

5.3. Summary of Results of the Accuracy and Orientation Tests

The results from the various models have been summarized and are presented in a series of tables below.

	mX	mY	mPL	mZ
Kelvingrove	0.39	0.22	0.48	1.02
Llandudno (2)	0.27	0.25	0.37	1.37
Greystoke	0.70	0.56	0.90	2.70
Greenock (1)	0.32	0.40	0.52	0.82
Greenock (2)	0.33	0.44	0.56	1.19
Rorbas	0.43	0.17	0.46	1.31

Table 3. Summary Table of the Absolute R.M.S.E. Values in metres for mx, my, mpl and mz at the Control points.

Table 3 gives a summary of the absolute values in metres of the r.m.s.e. values for mx, my, mpl and mz. The planimetric values (mpl) for the Kelvingrove, Llandudno and Greenock models all lie within the range ±0.37 to 0.52m for a common map scale of 1:2,500. In the case of Greystoke, the mpl value is ±0.90m which is only twice greater than the previous three models, although the photo scale (1:18,000) and map scale (1:10,000) are both four times greater.

In the case of the three models Kelvingrove, Llandudno and Greystoke with fairly flat terrain, the my values are all substantially smaller than the mx values. Only in the model with hilly terrain - Greenock - is this situation reversed. In the case of the absolute height values, the values for the three larger scale models (Kelvingrove, Llandudno and Greenock) are lying in the range ±0.82 to 1.37m.

	PLANIMETRY				HEIGHT		
	Photo Scale	Map Scale	Nominal mpl	mpl (m)	Ht. (H)	mz	mz %.H
Kelvingrove	1:5,400	1:2,500	0.25	±0.48	840	±1.02	±1.21
Llandudno (2)	1:5,000	1:2,500	0.25	±0.37	1,510	±1.37	±0.91
Greystoke	1:18,000	1:10,000	1.0	±0.90	2,950	±2.70	±0.92
Greenock (1)	1:3,700	1:2,500	0.25	±0.52	585	±0.82	±1.40
Greenock (2)	1:3,700	1:2,500	0.25	±0.56	585	±1.19	±2.03
Rorbas (1)	1:5,600	1:4,000	0.40	±0.46	900	±1.31	±1.45

Table 4. Summary Table of Planimetry and Height

For the Greystoke model, the value is approximately twice larger, as also occurred with the planimetry noted above.

Table 4 attempts to standardize the results, giving mpl results in comparison with the expected accuracy - 0.1mm at map scale - quoted in the APY literature. Also the height values (mz) have all been expressed in terms of per mil (%.) of the flying height (H).

It can be seen that the mpl value (±0.09mm) for Greystoke is the best encountered in the tests, amounting to just under the 0.1mm target figure. The Llandudno mpl value (±0.15mm) is 1.5 times greater, while the Kelvingrove and Greenock mpl results (approximately ±0.20mm) are twice the target. These can all be regarded as reasonable results in that the specifications for the planimetric accuracy (r.m.s.e.) of well-defined detail in most topographic map series is set at ±0.3mm.

Turning to the height accuracy (mz) figures, the best results, 0.92 %.H, were obtained with the Llandudno and Greystoke models. The figures for the Kelvingrove and Greenock models were substantially poorer at 1.2.% and 1.4%.H. It must be said that none of these results can be regarded as really satisfactory, given the expected accuracy - 0.1 to 0.2 %.H - of heights measured with topographic plotters. While the quality and accuracy of the elevation values of the control points must have played a part in these disappointing figures, nevertheless a question must also be raised against the present provision for height measurement in the APY instrument which gives the operator a very poor control of the Z-movement. Provision of a properly designed foot wheel or thumb wheel control of the mark rather than the present use of press buttons would seem to be an alternative well worth investigation. The use of an illuminated measuring mark would also make parallax measurement easier, especially in darker parts of a model.

A good initial orientation on the APY system requires that at least half the stereo-model be in the field of view. This results in the operator having to measure in a much smaller scale model than would be the case in a conventional photogrammetric plotter or indeed in other low cost analytical plotters where only a small percentage of the model is viewed at one time. This situation is inevitable because of the manner in which superimposition of the model and map is achieved.

The mean r.m.s.e. values of the projection centre coordinates (X ,Y and Z) and rotation values of each model were examined but it was difficult to make generalizations which are useful, given the large variations in the recorded values. The variation in the values of the rotations phi and omega are very large throughout which points apparently to a very unstable solution. However, variation in the tilt values are accompanied by variation in the projection centre coordinates; these combinations were found to lead to similar coordinates for check points in the compilation tests (not reported here).

5.4 Use of new version of APY Program

The orientations discussed so far were carried out using an early version of the APY software. Early in 1992, an updated version of the software became available.

In this new version, again four points are required for the orientation. However, after an initial orientation is computed, the height residuals at these four points are used to determine corrections to the omega values to eliminate the height residuals at the control points. If the four points are measured twice in two rounds of observations (eight points being the maximum which the program can accept), the residual height errors for each pair of observations will be equal but opposite in sign. The magnitude of the residuals can then be used to detect errors in observations, which can be repeated or an alternative control point chosen.

A number of orientations have been carried out using this version of the software. For good control, any error in the observations can easily be detected. However, this orientation procedure can mask errors in the ground control, giving an apparently good result in height but a poor one in planimetry. These problems are currently under investigation.

6. CONCLUSIONS

It would appear that the APY is a reasonably capable low cost analytical photogrammetric instrument, especially for topographic map revision. The availability of a three - way superimposition comprising the stereo-model, the map to be revised and the graphics screen, is a particular advantage especially for topographic map revision.

The operator can eliminate any local parallaxes during plotting, thus maintaining coincidence of the map and the stereo-model in the field of view.

The APY instrument can obtain both the planimetric and height information needed for control purposes from the map which is set on the table. This method is convenient and there is no need for a knowledge of aerial triangulation or ground surveying. However, this method gives rather moderate results in terms of accuracy which may still be good enough for thematic mapping. It is important to realise that accurate height values are needed for the control points used for orientation, if high quality output is required. The heights interpolated from an existing map may be insufficient for this purpose.

From the test results, it can be said that the planimetric accuracy of the APY instrument was better than its height accuracy. However, the planimetric accuracy of well-defined detail is still within the figure of ±0.3mm which is used by many national topographic mapping agencies and therefore the orientation procedure using an existing graphical map for control does satisfy the accuracy requirements for map revision.

It has been demonstrated that it is possible to incorporate into a low cost analytical instrument the features necessary for a revision instrument. Attention should now be given to the task of improving the existing systems and it is to be hoped that, in the near future, other manufacturers will enter this field with new solutions, based on analytical principles, which are optimized for the revision of maps at a variety of scales.

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