PC-TAS: PC-TOOLED ANALYTICAL STEREO-MODELLING

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ABSTRACT:

A basic understanding of the principles of analytical photogrammetry is commonly regarded as essential for every student in the photogrammetric area. However, analytical stereoplotters are quite expensive, they require a certain space, and there can only be one operator working at the same time. Normally, a university or institute does not have access to more than a few analytical stereoplotters, while the students may be numerous - especially in the earlier courses.
The Department of Geodesy and Photogrammetry at the Royal Institute of Technology, Stockholm, Sweden, has developed an educational aid in this field, called **PC-TAS** (PC-Tooled Analytical Stereo-modelling). PC-TAS is a concept which uses simple hardware and software available at almost any university: A cheap digitising table and an ordinary PC with MS Windows, MS Excel 5.0 (or higher) and Software Wedge (a TAL Enterprises software for linking the digitising table output to the Excel sheet. Similar softwares may be equally good to serve this linking purpose). However, the real tool in the PC-TAS concept is the 350 kb Excel sheet where all input, calculations and output are done.
With this relatively simple and inexpensive equipment the students can sit down at the PCs and explore the basic principles of analytical photogrammetry in their own pace and with their own hands. The number of exercises on the analytical stereoplotter can be reduced drastically (normally there are more PCs and digitising tables available than there are stereoplotters). In addition, the PC-TAS Excel sheet is designed for beginners and is easy to use with its different colour codes indicating where to digitise and where to look for different kinds of results.

1. THE DEVELOPMENT OF PC-TAS

1.1 Background

Faced with the fact that 100 students were to be given a basic course in photogrammetry, the Department of Geodesy and Photogrammetry at the Royal Institute of Technology realised that a single analytical stereoplotter would not be sufficient for their needs. The thought of developing an easy-to-use analytical software for educational purposes arose.
It should be noted that the idea of using a digitising table together with some software for analytical photogrammetry is not new - there have been commercial systems available since 1983 at the very least. (WB Geomap and Leica, to mention a few). Those systems perform well, but they have a minor drawback: the software can only handle a certain type of input data, restricting the number of possible digitising tables. PC-TAS uses Software Wedge (from TAL Enterprises) as a link and "interpreter" between the digitising table and MS Excel. It is easy to change the configuration to suit almost any kind of digitising table.

1.2 Why using Microsoft Excel?

There were several reasons behind the decision to use Microsoft Excel in the PC-TAS concept. Most important, the time for program development was sparse and it would be easier to use an existing software than to develop a new one. Another important factor was that the students were already familiar with this software from other applications. It is also an advantage that it is fairly easy to get an overview of the calculations on an Excel sheet, to see how the equations are built up and to trace the dependants of a variable.

2. THE PARTS OF PC-TAS

2.1 Hardware requirements

PC-TAS uses an ordinary PC capable of running MS Windows 3.1 and MS Excel 5.0 (or higher versions). You will also need a digitising table which is possible to connect to the computer. The digitising table could be of any make, as long as it is capable of transmitting output data (x and y coordinates) in a single output string. A high resolution table is preferable, but not necessary.

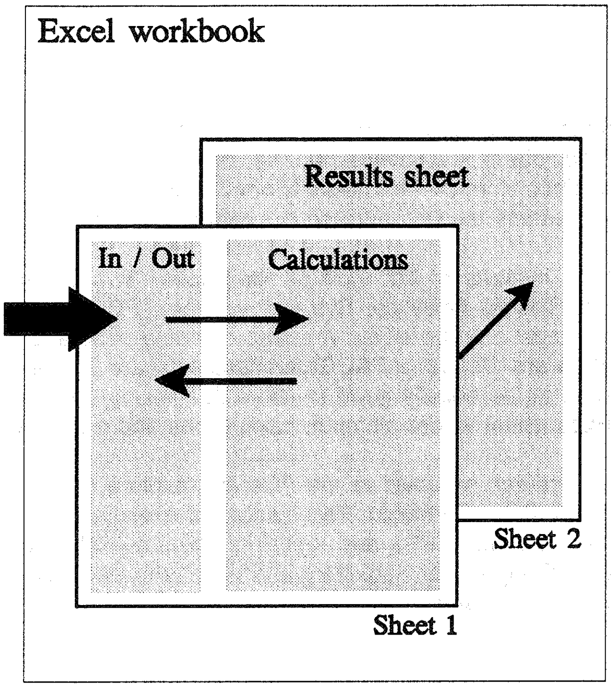
2.2 Software requirements

Apart from the PC-TAS 350 kb Excel sheet, you will need MS Windows 3.1 (or higher versions), MS Excel 5.0 (or higher) and some software to analyse and link the digitising table output data to MS Excel. We use

Software Wedge for Windows from TAL Enterprises, but similar software from other vendors may work as well.

2.3 PC-TAS Excel sheet

The PC-TAS Excel sheet is divided into several parts: input/output part, calculation part and a results sheet. Normally, the students will only notice the input/output and the results sheet parts unless they really want to study the way the calculations are done.



It is possible to gather all calculations and formulas on a sheet of its own, effectively linking it to both an input/output sheet and the results sheet. However, tests have shown that this will slow down the program significantly. The current version of PC-TAS thus have an Excel sheet in common for input/output and calculations, as can be seen in the illustration above.
The PC-TAS input/output part is in turn divided into five subsections. The Excel sheet is too large for a total screen view, so the user will have to scroll from one section to the next. The subsections are:

1. Inner orientation/Transformation
2. Object measurement
3. Relative orientation
4. Absolute orientation
5. Object coordinates

Interactive interface. Unlike most Excel sheets where calculations are automatically performed immediately after the input, PC-TAS has an interactive user interface in the meaning that the user must click at indicated "buttons" to view the results from the different calculations. The purpose of this is to allow the students enough time to follow and understand the calculations and to check the intermediate results.

3. USING PC-TAS

3.1 Preparations

In order to run PC-TAS, the user first has to connect the digitising table to the computer and set the configurations in Software Wedge (or similar software) to match the settings of the digitising table. These configurations includes baud rate, input port, parity, number of data bits, input string length etc. This is done only once, i.e. when the Software Wedge is installed. The settings are stored for future use.
To set up a stereo model, the user places a pair of paper print stereo images on the digitising table, making sure that as many fiducial marks as possible will fit inside the digitising area. The user will now continue to work with the PC-TAS Excel sheet, as will be explained below.

3.2 Operation

Section 1 - inner orientation. This establishes the affine transformation parameters for the transformation from digitiser coordinates (xD yD to image coordinates (x' y', x" y"). Since PC-TAS uses a two-dimensional affine transformation to determine the transformation parameters, at least three fiducial marks must be digitised in each image, and they must not be in a straight line. The user will digitise the fiducial marks into the Excel sheet in their respective cells by activating the correct cell and digitise. On the user's command (triggered by clicking at a button), Excel will calculate the affine transformation parameters. These parameters will be used from here on to transform all indata to the image coordinate systems. Presently no corrections are made for radial distortion or atmospheric refraction, but it would be easy to include them at this stage of computation.
If the solution of the transformation is not satisfactory, the user can easily re-digitise some (or all) of the fiducials. To help in this judgement, PC-TAS also displays the residuals from the comparison of known fiducial coordinates and the transformed digitised coordinates.

Section 2 - Object measurement. In this section the user will digitise the objects he/she wants to measure. In its current form, PC-TAS allows for 25 such object points to be digitised.
Digitisation is performed as mono-measurement separately for left and right image. It is possible to equip the digitising table with a stereoscope, thus enabling stereo vision while digitising. The measurement is, however, done in one image at a time as there is only one cursor.
The object measurement is followed by computation of model coordinates, using the normal case parallax equations.
The reason that this step precedes the relative orientation is to facilitate a later comparison of model coordinates (x y z) and parallaxes (px, py) before and after the relative orientation has taken place, in order to give the students some understanding of the importance of relative orientation.

Section 3 - Relative orientation. In this step, the user will digitise at least six well-distributed, corresponding cardinal points in both images. With these and the digitised object points as indata, PC-TAS will calculate the relative orientation using the coplanarity equation. This is an iterative process which is supervised by the user.
The new model coordinates and the parallaxes will be displayed (upon command) and the user will be able to compare the values with those generated before the relative orientation.

Section 4 - Absolute orientation. The user will now enter the ground control point coordinates and finally identify and digitise the points in the two images and perfom the absolute orientation. In its current form, PC-TAS allows for a maximum of 10 control points to be digitised. After some possible re-digitising and/or exclusion of points, the absolute orientation parameters will be calculated. The absolute orientation is performed in two steps:
- Helmert transformation in planimetry.
- Levelling in elevation.

Section 5 - Object coordinates. Simply by pressing a button, the model coordinates (x y z) of the digitised object points will be transformed to the ground coordinate system (X Y Z).

Results sheet. To view all significant results from the analytical measurements, the user may switch to the Results sheet. This sheet is also a good help for gross error detection, or for the assisting teacher when evaluating the measurements.

4. TEACHING EXPERIENCE

The Department of Geodesy and Photogrammetry has been using PC-TAS as a part of the exercises since December 1994. At least 200 students have already tried this system, and their opinion is that PC-TAS is easy to use, much because of the differently coloured Excel cells, telling the user where to digitise and where to look for specific results. The most common reaction is, however, a fascination over how much you can do with a simple Excel sheet.
Our experience with PC-TAS shows that it performs well and that it is well suited for our needs. The only drawback is that, due to the nature of the Excel sheet, it is impossible to write-protect the cells where the digitisation is done. An enterprising student can easily destroy the links if he/she starts to copy and paste cells without knowledge of the correct procedures.
It should be noted that PC-TAS is **not** a complete substitute for the stereoplotter exercises, it is merely a way for the students to get some basic practice and knowledge **before** trying the analytical stereoplotters, thus reducing the time spent at those exercises. It should also be mentioned that the quality of the measurements with PC-TAS is not as good as with analytical stereoplotters. This is not surprising because of the digitiser resolution, paper print stability and viewing magnification.