Creating seamless digital maps from Survey of India topographic sheets

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Abstract

It is possible to create seamless digital maps from Survey of India topographic sheets, by separately georeferencing each N-S strip of sheets which share the same projection to a separate metric grid, back-projecting from the separate metric grids to geographic coordinates on the Everest 1956 elipsoid, and then joining the strips. This method can also combine maps from different scales. The procedure is explained in detail using Arc/Info terminology, and outlined for ILWIS 2.1 for Windows.

Introduction

In his informative article ‘Abandon Polyconic Projection’ [1], Dr N K Agrawal makes a very persuasive case that Survey of India (SOI) should produce topographic maps on a common metric grid. However, he states that since each sheet is projected individually on its own central meridian, “we can not have seamless data in a rectangular coordinate system”, and further, “It will not be possible to compile a 1:250,000 sheet from sixteen 1:50,000 sheets using digital mapping procedures”. On the contrary, digital techniques can in fact be used to create seamless data, both for adjacent sheets of the same scale and for larger-scale sheets within a smaller-scale sheet, albeit with more difficulty than if Dr Agrawal’s suggestions were adopted. In this article I outline a procedure for creating seamless digital coverages from adjacent SOI topographic maps, even of different scales. The procedure is explained in Arc/Info terminology because of this GIS’s wide use, but users of other systems with the same facilities for georeferencing should have little difficulty adapting the procedure for their use. In fact procedures are easier in ILWIS 2.1 for Windows, as outlined later. Although the procedure is a bit tedious, it illustrates very well the power of a true GIS, that is, one that is able to georeference in any defined coordinate and projection system, and convert among systems. The basic idea is as follows; I then explain each step in more detail:

1. A **separate grid coordinate system** is created for **each N-S strip of map sheets in a single map series** (i.e., scale), each using its **own central meridian** but otherwise the same projection parameters;
2. Corner tics corresponding to the Lat/Long graticule for each strip are projected into that strip’s grid coordinates;
3. Maps from each strip are registered to the digitizer using the corner tics from that strip’s grid coordinates;
4. Coverages from each strip are **separately digitized in that strip’s grid coordinates**;
5. Coverages from each strip are **separately projected back to geographic coordinates**;
6. Coverages from adjacent strips are **merged in geographic coordinates** to create a seamless, single coverage.

At this point, coverages can be used directly in geographic coordinates (as is preferred by ArcView, for example), or projected into any defined grid system, including Dr. Agrawal's proposed Andhra Pradesh Grid [2]. I now explain each step in more detail.

(1) Create a separate grid coordinate system for each N-S strip

For each map series (1:250,000 [1°x1°], 1:50,000 [15'x15'], and 1:25,000 [7'30"x7'30"]) in the digitizing project, organize them in N-S strips sharing the same limiting meridians. For each strip, create two Arc/Info projection files, one from geographic to grid, and inversely. Name the files for the map series and the central meridian. Here is an example file named '250773p.prj' meaning '1:**2**,**50**,000, **77**°**3**0', to **p**rojected', and its inverse, named '250773g.prj', with the same meaning, except suffix 'g' meaning 'to **g**eographic'.

Projection File '250773p.prj' **geographic to projected**	**Projection File '250773g.prj'** **projected to geographic**

`input`
`projection geographic`
`units dd`
`spheroid everest1956`
`parameters`
`output`
`projection polyconic`
`spheroid everest1956`
`units meters`
`parameters`
`77 30 00`
`00 00 00`
`0.0`
`-1000000`
`end`
	`input`
	`projection polyconic`
	`spheroid everest1956`
	`units meters`
	`parameters`
	`77 30 00`
	`00 00 00`
	`0.0`
	`-1000000`
	`output`
	`projection geographic`
	`units dd`
	`spheroid everest1956`
	`parameters`
	`end`

The key points here are: (1) the central meridian in DD MM SS, which is different for each N-S strip, (2) an optional false origin for Y, so that grid N coordinates will not be numerically too large; (3) the spheroid. Now each N-S strip at each scale has its own, separate, grid coordinate system with (X,Y) origin at the central meridian and approximately 9° N (since 90° ≈ 10,000km, each -1,000,000m of false northing brings the origin north about 9°). If the study zone is further north or south, you can adjust the false northing accordingly.

For the N-S strip to the E of this one, the two files would be named ‘250783p.prj’ and ‘250783g.prj’, with the only difference from the above example being the central meridian, which would be ‘78 30 00’ instead of ’77 30 00’.

This example is for maps using the Everest 1956 spheroid; for older maps, the Everest 1930 spheroid must be used. Arc/Info can perform a datum transform between these, as explained in the documentation of the ‘project’ command.

(2) Create a geographic grid and projected tics

For each N-S strip, create a new line coverage, again named for the map series and central meridian, e.g. ‘250773g’. Using command ‘generate’ (which allows entry of coordinates from the keyboard or a text file), directly enter the bounding meridians and intermediate parallels, in geographic coordinates. For example, for a project covering two adjacent N-S sheets, the lines would be the bounding box (77,12), (78,12), (78,14), (77,14), (77,12) and the cross parallel (77,13), (78,13). Don’t use the digitizer, rather, enter exact coordinates from the keyboard. Create polygon toplogy using command ‘clean’ and, if you wish, label the polygons with the map sheet names; this can itself be a useful coverage. Do the same for adjacent N-S strips. For example, the strip to the E of the one already created would have the bounding box (78,12), (79,12), (79,14), (78,14), (78,12) and the cross parallel (78,13), (79,13). You now have *exact geographic limits* for each map sheet, organized by N-S strips.

Each polygon coverage should already have four georegistration points, known in Arc/Info as ‘tics’, i.e. the strip corners. Add tics (again, using the keyboard and ‘generate’) at the intermediate corners, so that each Lat/Long intersection has its own tic. Make a note of the correspondence between tic numbers and geographic coordinates. In the example, tics would have to be added at (77,13) and (78,13) in the western N-S strip, and at (78,13) and (79,13) in the eastern N-S strip.

Now, project *each* N-S strip of map sheet limits into its *own* metric grid, using the ‘to **p**rojection’ projection file; in the example above: **project cover 250773g 250773p 250773p.prj**. The tics will also be projected. Viewing the projected coverage, you will see X=0m on the central meridian, minimum (negative) X at the lower left corner (the widest parallel), e.g. –54,451m, maximum (positive) X at the lower right corner, e.g. 54,451m. Y values will be positive, and cover a range of about 110,856m per 1:250,000 sheet (the exact range depends slightly on latitude).

In the example above, the corners of the W strip would be: (-54444.09m E, 327033.86m N), (54444.09m E, 327033.86m N), (54009.79m E, 548285.30m N), (-54009.79m E, 548285.30m N). Note that the extreme X values are the same with changed sign; this is because the central meridian is X=0. Also note the different widths: going from 12 to 14°N reduces the width of a parallel of 1° by [(54444.09 - 54009.79) $\times$ 2) = 868.6m, from a total of (54444.09 $\times$ 2) = 108,888.18m at 12°N. These results will of course vary with latitude. The corners of the E strip are exactly the same, but in its own coordinate system.

(3) Register maps to projected tics

To create a new coverage from a paper map, first create the new (empty) coverage, copying the tics from the appropriate N-S strip and map series in the same step. Indicate in the coverage name that it is projected, e.g. with a ‘p’ suffix.. For example, to create a coverage of roads (prefix ‘r’), you could use command **createcov r250773p 250773p**. Then, register the paper map (command ‘coordinate digitizer’) to the digitizer using the corner tics. The RMS error of digitizer registration will be expressed in digitizer units, and should be converted to map scale. For example, with a good quality map, a high-resolution digitizer, and careful operation, a RMS error of less than 0.005” = 0.127mm is expected. At 1:250,000 this is equivalent to 31.75m ground resolution. This is an order of magnitude smaller than the gap between adjacent strips at their N end of 417.86m on the ground = 1.67mm on the map sheet, for a 1:250,000 sheet based at 12°N. The further North one goes, the worse this problem becomes, as illustrated in Dr. Agrawal’s [1] Figure 1, which shows an map sheet gap of ≈3.2mm, equivalent to 800m (actually, 801.64m) on the ground for the N end of a sheet based at 24°N. This shows why it is inadvisable to use an affine digitizer transformation directly on the geographic, rather than the projected, coordinates.

At larger map scales, the gap is smaller in ground meters but very similar on the map sheet. For example, on a 1:50,000 map (15’ x 15’) based at 24°N, the gap between adjacent strips at their N end (24°15’) is 197.52m on the ground = 3.95mm on the map sheet.

(4) Digitize

The digitizer should now read out directly in meters. Digitize the coverage. Do *not* digitize the neatlines, since on SOI toposheets they are not correctly drawn (see below). A well-defined point should be digitized to 0.01” ≈ 0.25mm = 62.5m ground resolution at 1:250,000; this is the acceptable printing error of the original map.

(5) Project coverages to geographic coordinates

This is the reverse of step (2). Indicate in the unprojected coverage name that it is in geographic coordinates, e.g. with a ‘g’ suffix.. Use the inverse ‘to **g**eographic’ projection file created in step (1), e.g. **project cover r250773p r250773g 250773g.prj**. Viewing the unprojected coverage, you will see geographic coordinates; in particular, the tics at the map corners will again be exact Lat/Long. Reversing the example of step (2), we can see that the geographic point (78°E, 14°N) is equivalent to grid point (54009.79m E, 548285.30m N) in the grid system centered at 77°30’, *as well as* to grid point (-54009.79m E, 548285.30m N) in the grid system centered at 78°30’. If this, or any other point on the boundary between the two strips were digitized in both grid systems, it back-projects to the same geographic coordinate, as required, subject of course to human error during digitizing and to digitizer resolution.

(6) Join coverages into one seamless map

Once you have done this for adjacent N-S strips, all coverages will be in a common coordinate system, i.e. uprojected geographic. Combine them with standard map joining procedures (command ‘mapjoin’ for polygons, ‘append’ for lines, using a snap tolerance of 0.01” ≈ 0.25mm converted to map scale). However, there is a slight complication. As explained by Dr Agrawal [1], SOI toposheets in fact are printed with straight rather than curved neatlines. Thus, features (e.g. a road) will not *exactly* match at the printed neatlines, although the sheet corner points will match precisely. This is solved by adjusting the snap tolerance during the map joining procedure to a value a bit greater than the error, as just explained. It is also possible, but tedious, to manually correct undershoots or overshoots, e.g. using command ‘edgematch’.

The error due to drawing straight rather than curved *parallels* is a maximum at the central meridian of each sheet, and is greater than digitizer error at all scales, e.g. at 12°N it is 49.40m for 1:250,000 scale maps. This error increases as one goes North; e.g. at 24°N it is 90.27m. At the top of a sheet a bit too much is shown (i.e., the neatline is above its correct position), at the bottom a bit too little. Two adjacent sheets in a N-S strip almost exactly match, even though the neatline is not drawn correctly on either sheet, therefore map joining in the N-S direction (across parallels) should be easy.

The error due to drawing straight rather than curved *bounding meridians* is much smaller, because the complex curve of the polyconic projection is very close to a straight line. For example, at 12°30'N, 78°E, the difference between the true projected point and the point on the straight line from (12°N, 78°E) to (13°N, 78°E) is only (2.055m, 1.305m) in (X, Y) at 1:250,000 map scale, much lower than digitizer error. The straight line is a very slight overshoot on both sides. The error becomes slightly smaller in X and slightly larger in Y as one goes North. So, there is no problem with map joining in this direction either.

If you would like neatlines surrounding the study area, add them at this stage, as in step (2). If you would like an overprinted geographic graticule, use the coverage created in step (2); the separate N-S strips may be merged into a common coverage.

Finally, the coverage may be projected into any defined coordinate system, e.g. UTM, using an appropriate projection file.

Variations

Other GIS packages may handle this problem a bit differently from Arc/Info, but should be able to achieve the same goal. For example, procedures are much simpler in ILWIS 2.1 for Windows [3], produced by my institute. ILWIS is able to register a projected map to the digitizer directly in geographic coordinates, if the projection is known (see Help topic 'Map Referencing (1)'). In effect, the ILWIS programmers have combined projection into the digitizer referencing procedure. Then the coverages are from the first produced in unprojected geographic coordinates and may be combined (using commands 'glueseg' or 'gluepnt') without problem. The ILWIS command 'TransfCrd' is also a useful calculator for transforming coordinates between projection systems and with unprojected geographic coordinates, and in fact I used it to make all the calculations in this paper. In ILWIS, one must create a Coordinate System file, with the appropriate parameters; this is simpler than in Arc/Info, because the parameters are requested in a Windows dialog box with on-line Help.

Discussion

The procedure explained in the paper is not worth the trouble unless one has good quality maps, a high-resolution digitizer, and careful operation. Any problem with these will make the registration error on the digitizer greater than the error due to using unprojected coordinates. If the RMS error of map registration is greater than about 0.05" (vs. the ideal 0.005" or less), all benefit is lost.

It would certainly be ideal if SOI would create seamless digital coverages on a conformal projection and make them available to the public at cost. However, considering SOI's track record in this matter, the Indian GIS community can not afford to hold its collective breath that long. Meanwhile many GIS projects, especially in natural resource evaluation and management, must by necessity use SOI toposheets as the most reliable map georeference. The procedure outlined in this article should allow any study area, no matter how large, to share a seamless, correct digital map in geographic coordinates, and moderately wide areas (e.g. the size of a UTM zone, 6°) to share a seamless, correct digital map in a common grid.

Postscript: geo-referencing maps with no coordinates

Often one is presented with a thematic map supposedly drawn on a SOI base, but with no coordinates or geographic grid. To incorporate such a map in a GIS, the correct procedure is:

1. Prepare a projected grid covering the area, as explained in this article.
2. Identify common control points on the thematic map and SOI toposheets. Examples are road junctions, railways, and sharp corners of political boundaries.
3. Register the SOI toposheet to the digitizer using corner tics, as explained in this article, and digitize a point coverage of these points from the SOI toposheets, in grid coordinates.
4. List the points to a text file, e.g. with 'ungenerate'.
5. Create a coverage for the thematic map, copying the tics from the projected grid.

6. Add the control points as tics from the keyboard or a text file, using ‘generate’. They will be in projected meters.
7. Register the map to the digitizer using the projected control point tics (*not* the corners, since you don’t have these on the thematic map).
8. Digitize the thematic coverage, in projected meters.
9. Unproject the thematic coverage to geographic coordinates.

Good luck! And write up your experience for this magazine.

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References

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[2] Agrawal, N K. 1998. “Andhra Pradesh Grid for Cadastral Surveys”. GIS India 7(2): 18-20

[3] The Integrated Land & Water Information System (ILWIS 2.1) for Windows. March 1998. International Institute for Aerospace Survey & Earth Sciences (ITC), P.O. Box 6, Enschede, Netherlands. e-mail: ilwis@itc.nl; URL: http://www.itc.nl/ilwis

Figure 1
Unprojected Geographic Coordinates

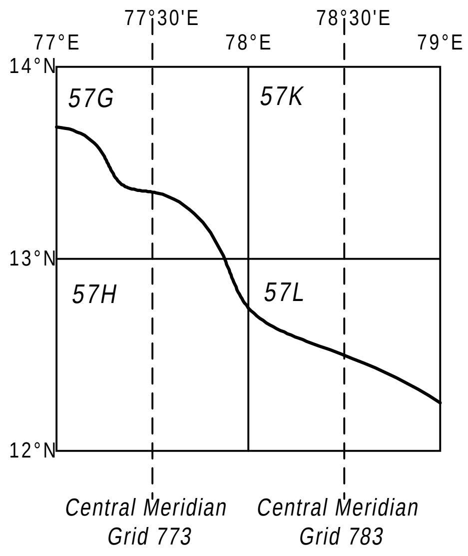

Figure 2
Projected Metric Coordinates