Chapter 13.
Topographic Mapping and Spatial Data Collection

13-1. Introduction

- Mapping, and/or spatial data collection for GIS databases, can generally be categorized into either *planimetric* or *topographic* methods

- Planimetric methods involve determining only the horizontal positions of features
  - ⇨ The locations of these features are normally referenced in an XY coordinate system that is based upon some selected map projection

- Topographic methods, on the other hand, include not only the location of planimetric details but also provide elevation information
  - ⇨ Elevations are often given in digital form; that is, Z coordinates are listed for a network of X, Y locations
  - ⇨ This is particularly the case when data are being collected for GIS applications
  - ⇨ This digital representation of elevations is called a *digital elevation model* (DEM)

- The purpose of the mapping, or spatial data collection, will normally dictate the level of detail required in representing features and the required level of accuracy as well

13-1. Introduction

- A map used for the design, construction, and operation of a utility, on the other hand, would generally be compiled from low-altitude photos, having a much larger scale
  - ⇨ Thus **compilation scale would be larger**, and features and elevations would be shown in much greater detail and to a higher level of accuracy

- The concept of map scale and its relationship to level of detail that can be shown was well understood throughout the era when hard-copy maps were being compiled manually
  - ⇨ That was the case because as map scale decreased, the number of features and contours that could be shown also had to decrease; otherwise, the map would have become congested to the point of being unreadable

- Now, however, with the advent of digital mapping systems, the concept of mapping scale versus level of detail that can be shown is often not so obvious
  - ⇨ With these systems, map products created from digital data can technically be plotted at any scale, and congestion can readily be removed by simply using the system's zoom feature
  - ⇨ Nonetheless, the intended purpose of the mapping will still guide the level of detail presented, and this in turn will dictate photographic scale, compilation scale, and hence the positional accuracy of features shown

13-2. Direct Compilation of Planimetric Features by Stereoplotter

❖ Either of two basic methods may be employed in compiling topographic information with stereoplotters:
  (1) direct tracing from stereomodels to create hard-copy maps
  (2) compiling digital files of topographic data from which computer-generated maps are prepared

❖ Prior to the existence of digital mapping systems, photogrammetric map compilation was accomplished exclusively by direct tracing of topographic features and contours from stereomodels
⇨ This process, although still occasionally performed, now has almost completely given way to digital mapping

❖ In the direct tracing process, to locate a "point" feature such as a utility pole, the floating mark is placed on the object in the stereomodel, and the corresponding location of the tracing pencil marks the point's map location

❖ "Linear" features such as roads and streams, and "area" features such as lakes and buildings, are drawn by placing the floating mark on the feature at some starting point, and then tracing the feature by moving the floating mark continuously along or around the object

13-2. Direct Compilation of Planimetric Features by Stereoplotter

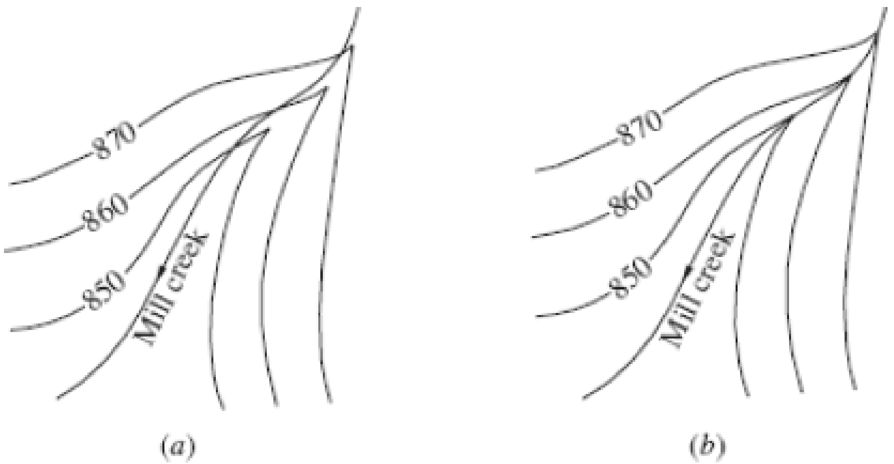

Figure 13-1. (a) Inconsistencies between planimetry and contour locations. (b) Consistent renditions of planimetry and contours.

- As a general rule in direct compilation, planimetric details are traced first, followed by contouring
- This is so because natural and cultural features have a very significant effect on the location and appearance of contours

- An example of carelessly compiled contours or planimetry is shown in Fig. 13-1a, while its corresponding correct rendition is shown in Fig. 13-1b
- Also in direct compilation, it is advisable to plot all features of a kind at once, before proceeding to another feature, as this reduces the likelihood of omissions

13-3. Direct Compilation of Contours by Stereoplotter

- Direct compilation of contours is a difficult operation that takes considerable skill and experience on the part of the operator
- To trace contours, the floating mark is set at the elevation of a desired contour and is moved within the model until the mark coincides with the apparent terrain surface in the model ⇨ This will occur at any point where the desired contour elevation exists
- The operator then moves the floating mark about the stereomodel as necessary to keep it constantly in contact with the terrain, while the tracing pencil simultaneously follows the movement and records the contour
- During the tracing of a contour, the operator must continuously look ahead to properly determine the direction in which to proceed

13-3. Direct Compilation of Contours by Stereoplotter

- ❖ In direct tracing of contours, it is recommended that all contours be completely compiled within a local area of the model, rather than attempt to trace a single contour across the entire model
- ❖ To facilitate accurate contouring, the operator should become acquainted with the general shape of the terrain within the entire model before proceeding
  - ⇨ This is usually most conveniently accomplished by viewing prints of the stereopair in three dimensions, using a stereoscope
- ❖ Generally, contouring can be approached in much the same way as the assembly of a jigsaw puzzle
- ❖ Easier areas and prominent features are compiled first, and the more difficult detail is filled in later
- ❖ It can be helpful to initially locate and trace apparent drainage lines (ditches, swales, etc.) in order to guide the contouring operation
- ❖ If necessary, these drainage lines can be subsequently erased during the map editing stage

13-3. Direct Compilation of Contours by Stereoplotter

- ❖ Some terrain areas such as flat expanses, regions of shadow, and areas of minimal image texture present particular difficulty when tracing contours
  - ⇨ In these areas, it is sometimes necessary to determine "spot elevations" and interpolate contours from them
  - ⇨ This is helpful because spot elevations can be read to significantly greater accuracy than direct contour tracing

- ❖ In areas covered with trees or tall vegetation, it may be impossible to plot continuous contours
  - ⇨ In these areas broken contours (contour lines plotted in open areas only) may be drawn;
  - ⇨ Otherwise, spot elevations can be plotted and contours interpolated
  - ⇨ Densely vegetated areas occasionally must be field-surveyed

13-4. Digitizing Planimetric Features from Stereomodels

- ❖ Features that are typically depicted in topographic mapping are many and varied
- ❖ In general, however, in digital mapping any feature can be represented as consisting of: (1) a *point*, (2) a *line* (straight or curved), or (3) a *polygon* (closed shape)
- ❖ Horizontal and vertical control points, utility poles, and fire hydrants are examples of features that can be represented by **points**
- ❖ Roads, railroads, streams, etc, can be shown as **lines**, while parcels of different land ownership or land-use types, large buildings, etc., can be represented by **polygons**
- ❖ Map compilation scale dictates the level of detail of the features to be included
  - ⇨ This in turn may affect the manner of representing a particular feature
  - ⇨ For example, on a 1:24,000-scale map, an 8 m-wide road would be plotted only 0.3mm wide, and therefore it would be appropriately represented as a single line
  - ⇨ On the other hand, the same road shown on a 1:600-scale map would be 13 mm wide, and therefore both edges of the road could be clearly shown without congestion

13-4. Digitizing Planimetric Features from Stereomodels

- In practice, features can be graphically represented by using different base-classes and sub-classes
  - ⇨ This way, users can either select from predefined classes associated with specific features, or create their own

- For example, a building sub-class is a type of rectangle base-class, and inherits its properties
  - ⇨ That is, it can be represented by two perpendicular pairs of parallel lines and requires only three points to be defined
  - ⇨ Thus, the user can simply select the building class to digitize rectangular buildings

13-4. Digitizing Planimetric Features from Stereomodels

- In addition, the user may choose the rectangle base-class to digitize some other rectangular feature—such as an outdoor basketball court—that may not be a defined sub-class in the software
  - ⇨ Further division is also possible beyond a two-class hierarchy
  - ⇨ For instance, the rectangle class could be a sub-class of a polygon base-class

- Predefined sub-classes typically have different graphical depictions depending on the features they represent in order to allow differentiation on the map
  - ⇨ For example, while points can be used to define light poles, manholes, signs, and hydrants, each is assigned its own unique identifying symbol
  - ⇨ While the classes described here refer to the shapes that are drawn during digitization, the features themselves may be grouped by category without regard to the type of drawing class

- The category only relates to the database representation of the feature- such as in GIS- while the class is used mainly for the digitizing process

13-4. Digitizing Planimetric Features from Stereomodels

- In digital mapping, code identifiers are used to keep track of the many different features that can be digitized from a stereomodel
- Normally all features **within one category** are given **a specific identifying code**
- Then within that category, <u>individual features may be further labeled with an additional identifier</u>
- Many different coding systems have been developed for categorizing map features based on type
  - ⇨ These systems, while fundamentally similar, differ according to the primary purpose of the map product

13-4. Digitizing Planimetric Features from Stereomodels

- The following feature categories (with typical individual features listed within each category) are presented only as a general guide
- The list is not all-inclusive and may need to be supplemented on a project-specific basis

1. *Nonimage data*: coordinate grid, property boundaries, horizontal and vertical control points
2. *Streets, highways, and related features*: edge of pavement, centerlines, curbs, medians, barrier walls, shoulders, guardrails, parking lots, alleys, driveways
3. *Other transportation*: railroad tracks, abandoned railroads, airport runways and taxiways, unpaved roads, trails, sidewalks, port facilities, locks
4. *Structures*: buildings, bridges, water towers, dams, fence lines, stadiums, retaining walls, antennas, concrete slabs, swimming pools
5. *General land use*: cemeteries, parks and recreation areas, agricultural areas, quarries, stockpiles, landfills

13-4. Digitizing Planimetric Features from Stereomodels

- The following feature categories (with typical individual features listed within each category) are presented only as a general guide
- The list is not all-inclusive and may need to be supplemented on a project-specific basis

6. *Natural features*: lakes, ponds, rivers, streams, beaches, islands, wetlands, wooded areas, individual trees, bushes and shrubs, meadows
7. *Terrain elevation*: contours, spot elevations
8. *Drainage features*: ditches and swales, retention basins, culverts, headwalls, catch basins, curb inlets, storm sewer manholes, flared end sections, berms
9. *Utilities*: utility poles, power lines, telephone lines, transmission lines, substations, transformers, fire hydrants, gate-valve covers, sanitary manholes
10. *Signs and lights*: traffic signals, streetlights, billboards, street signs
11. *Project-specific*: varies

13-5. Representing Topographic Features in Digital Mapping

- Traditionally most maps were traced directly from stereomodels and reproduced in hard copy by some type of printing process, while today the vast majority of maps are developed using computers and topographic data that have been compiled by digitizing from stereomodels

- Many **advantages** accrue from the **digital method of extracting topographic information**
  - ⇨ Perhaps the foremost advantage is that databases of geographic information systems require data in digital form
  - ⇨ In most cases, if proper formats and procedures are employed during the process of digitizing stereomodels, the resulting files can be entered directly without further modification into a GIS database

- Other advantages are that digitized data afford greater flexibility of use

- Furthermore, maps can be plotted using any desired scale and/or contour interval, and the topographic data can be instantaneously transmitted electronically to remote locations

- Because the information is collected according to feature category or "layer" in the digitizing process, individual layers can be plotted and analyzed separately, or overlaid with other layers for analyses

13-5. Representing Topographic Features in Digital Mapping

- The process of digitizing planimetric features from stereomodels is fundamentally the same, whether the operator is using a digitized mechanical projection *stereoplotter*, an *analytical plotter*, or a *softcopy plotter*
- In digitizing data from stereomodels the instrument must be completely and accurately oriented prior to commencement of the digitizing process
- To digitize an object within a stereomodel, the operator must bring the floating mark in contact with that object, enter the feature code, and then either push a button or depress a foot pedal
  - ⇨ This causes the feature code and its X, Y, Z coordinates to be instantaneously stored in the computer

13-5. Representing Topographic Features in Digital Mapping

- ❖ When digitizing linear or area features, a number of points along the line or polygon are digitized
  - ⇨ This can be done very rapidly, since after the first point on any specific feature is identified and digitized, no further feature codes need be entered on that feature
  - ⇨ On these types of features, most operators will pause momentarily when the button or foot pedal is depressed to ensure that the floating mark is on the desired object when the digitizing occurs
- ❖ CAD systems associated with modern plotters provide for grouping of similar features into a specific layer in the drawing file
- ❖ Generally, features are compiled in descending order of prominence
- ❖ Point features that would appear smaller than about 1 mm at the intended map scale should be represented by appropriate symbols
- ❖ Any notes or labels that the compiler feels are necessary to avoid later misidentification should also be made
- ❖ Again, a set of paper prints and a stereoscope are essential to the compiler as an aid in identifying features

13-6. Digital Elevation Models and Indirect Contouring

- Digital representation of elevations in a region is commonly referred to as a *digital elevation model* (DEM)
- When the elevations refer to the earth's terrain, it is appropriately referred to as a *digital terrain model* (DTM)
- When considering elevations of surfaces at or above the terrain (tree crowns, rooftops, etc.), it can be referred to as a *digital surface model* (DSM)
- Any of these models can be represented as a regular grid or as a *triangulated irregular network* (TIN)
- While a DEM can technically be an elevation model of anything, in this book the term DEM will be used for elevation models of the earth's terrain in either regular grid or TIN form, unless otherwise specified

13-6. Digital Elevation Models and Indirect Contouring

- In a **regular grid DEM**, spot elevations are determined for a uniformly spaced array of ground cells or groundels
- The elevations (Z values) are digitally stored in a computer array
- Figure 13-2 shows a three-dimensional representation of a rectangular DEM
- In this figure, lines are drawn to connect the center points of the groundel array, which, by virtue of their varying Z values, appear as undulating terrain
- Since the z values are stored as an array of numbers, they are compatible for computer processing using various algorithms
  - ⇨ These algorithms include contour generation, volume and slope calculation, orthophoto generation and depiction of three-dimensional views

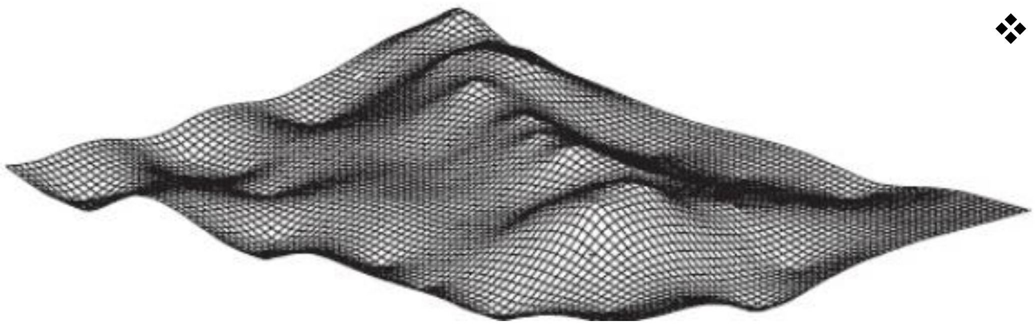

Figure 13-2. Three-dimensional representation of a rectangular DEM.

- Computer algorithms applied to rectangular arrays of elevations tend to be very straightforward in their implementation
  - ⇨ They readily lend themselves to investigations such as frequency analysis and finite element analysis

13-6. Digital Elevation Models and Indirect Contouring

- In a regular grid DEM, spot elevations are determined for a uniformly spaced array of ground cells or groundels
- The elevations (Z values) are digitally stored in a computer array
- Figure 13-2 shows a three-dimensional representation of a rectangular DEM
- A **disadvantage** associated with regular grid DEMs is that for large areas of level or uniformly sloping terrain, a great deal of computer memory is wasted storing highly redundant elevation information
- More complex data structures such as quadtrees can be used in lieu of arrays to reduce storage requirements of regular grids
  ⇨ However, their implementation is far more complicated

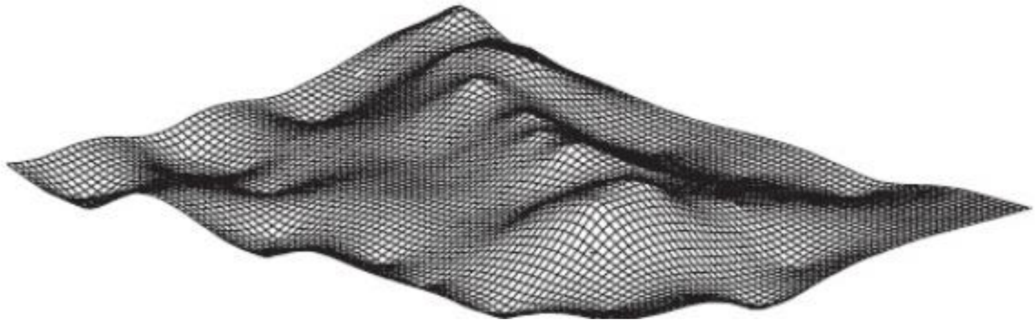

Figure 13-2. Three-dimensional representation of a rectangular DEM.

13-6. Digital Elevation Models and Indirect Contouring

- A **TIN** affords a more efficient representation of terrain in terms of data storage
- With a TIN, spot elevations can be acquired at *critical points*, which are high points, low points, locations of slope changes, ridges, valleys, and the like
- Once these spot elevations have been collected, together with their X, Y coordinates, lines are constructed between the points forming a system of triangles covering the surface
- The triangles can be assumed to be planar facets which are sloped in three-dimensional space
- Each triangle side has a uniform slope, and the system of triangles is called a TIN model. The method generally used to construct the TIN is known as a *Delaunay triangulation*
- In a **Delaunay triangulation**, the lines are drawn between points in closest proximity to each other, without any lines intersecting
- The resulting set of triangles has the property that for each triangle, the circle that passes through the three vertices contains no vertices of any other triangles

13-6. Digital Elevation Models and Indirect Contouring

- A further generalization of a TIN allows the inclusion of *breaklines*
- Breaklines are lines which have constant slope and are used where there are discontinuities in the terrain surface, such as streams, retaining walls, and pavement edges
- Within the TIN, a breakline will form the sides of two adjacent triangles and will have no other lines crossing it
- By using breaklines in a TIN, the terrain surface can be more faithfully represented, and contours generated from the TIN will give a more accurate portrayal of the surface features

13-6. Digital Elevation Models and Indirect Contouring

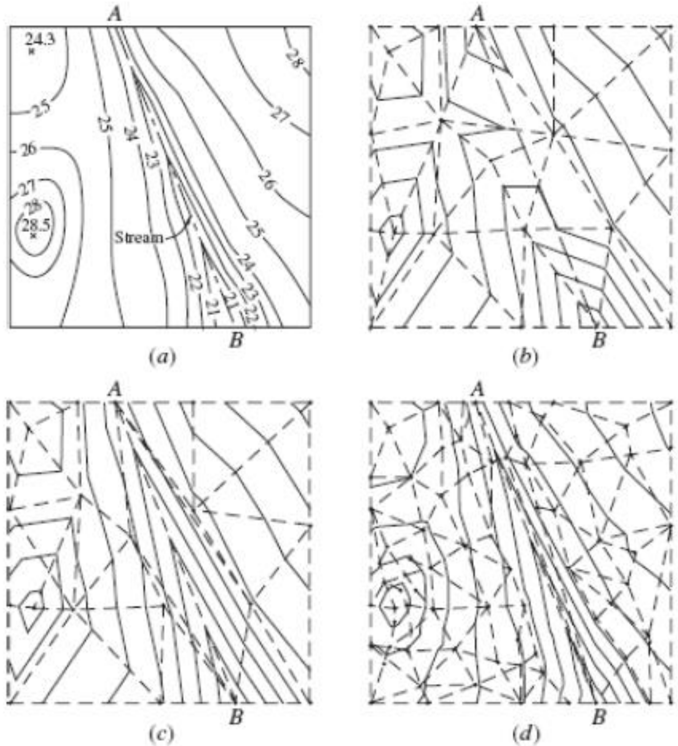

Figure 13-3. (a) Contour map showing accurate representation of terrain in an area. (b) Contours of the same area based on a TIN created from 20 data points, but without a breakline along stream AB. (Note the erroneous contour representations, especially in the area of the stream.) (c) Contours of the same area based on a TIN with 20 data points, but identifying stream line AB as a breakline. (Note the improvement in the contours in the area of the stream.) (d) Contours of the same area based on a TIN created from 72 data points, and with stream line AB identified as a breakline. (Note how well these contours agree with the accurate representation of (a).)

- ❖ Figure 13-3 illustrates the concept of using a TIN as a DEM in order to determine contours
- ❖ Figure 13-3a shows a contour map, which for purposes of illustration is assumed to accurately represent a particular terrain area
- ❖ Note that the figure includes a hill near the left edge, a depression at the upper left, a steady rise to the upper right, and a stream (AB) which runs from the upper left to the lower right
- ❖ Figure 13-3b shows a TIN (dashed lines) formed from a sample of 20 spot elevations (shown as black dots at all triangle vertices) along with the set of interpolated contours (solid lines)
- ❖ The contours are formed by interpolating along the sides of the triangles and connecting the interpolated points with straight lines (Smooth curves can also be used to approximate the straight-line contours)

13-6. Digital Elevation Models and Indirect Contouring

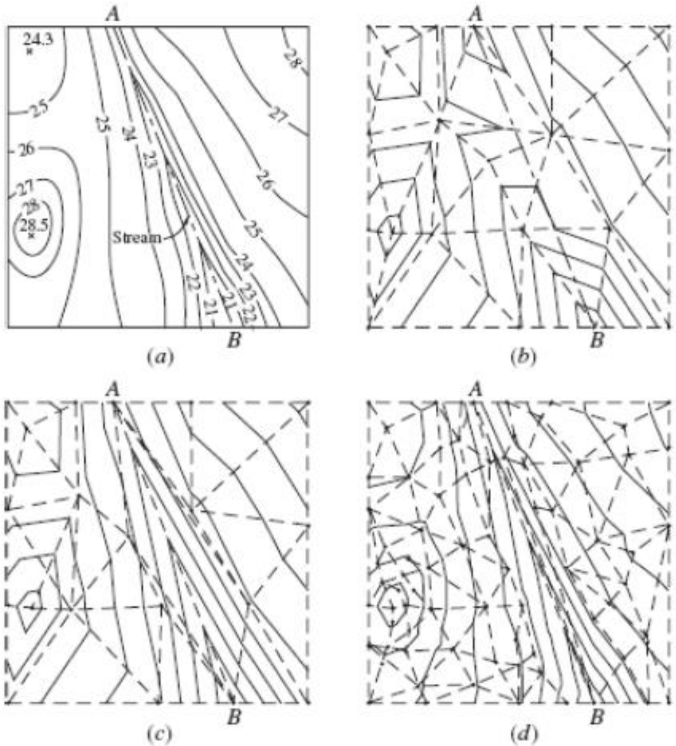

Figure 13-3. (a) Contour map showing accurate representation of terrain in an area. (b) Contours of the same area based on a TIN created from 20 data points, but without a breakline along stream AB. (Note the erroneous contour representations, especially in the area of the stream.) (c) Contours of the same area based on a TIN with 20 data points, but identifying stream line AB as a breakline. (Note the improvement in the contours in the area of the stream.) (d) Contours of the same area based on a TIN created from 72 data points, and with stream line AB identified as a breakline. (Note how well these contours agree with the accurate representation of (a).)

- Although the figure gives a nominal depiction of the hill, depression, and rise, the contours associated with the stream (AB) are not properly represented
- In the TIN shown in Fig. 13-3c, the original 20 spot elevations are still shown, but a breakline has been added to connect the endpoints (A and B) of the stream
- Note that in this figure, none of the TIN lines cross the stream as they did in Fig. 13-3b
- As such, the contours associated with the stream give a much better representation

13-6. Digital Elevation Models and Indirect Contouring

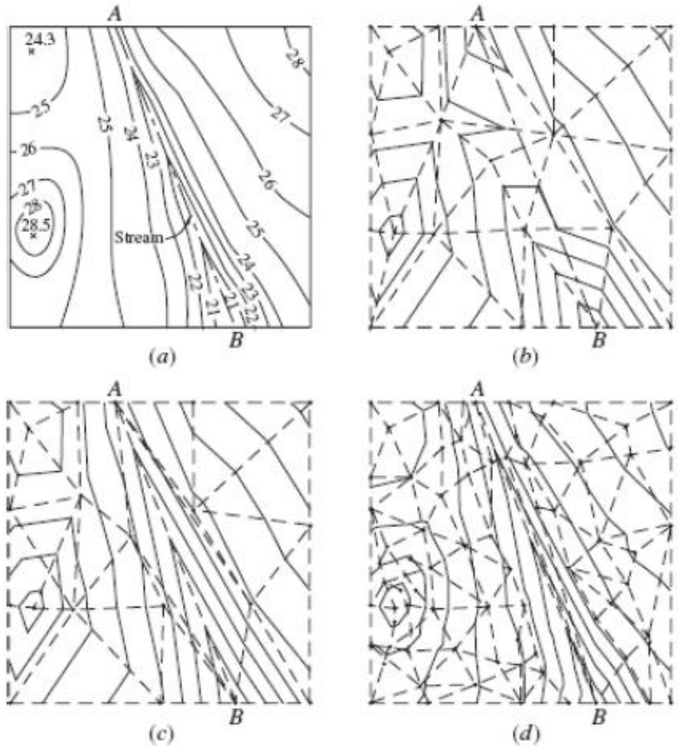

Figure 13-3. (a) Contour map showing accurate representation of terrain in an area. (b) Contours of the same area based on a TIN created from 20 data points, but without a breakline along stream AB. (Note the erroneous contour representations, especially in the area of the stream.) (c) Contours of the same area based on a TIN with 20 data points, but identifying stream line AB as a breakline. (Note the improvement in the contours in the area of the stream.) (d) Contours of the same area based on a TIN created from 72 data points, and with stream line AB identified as a breakline. (Note how well these contours agree with the accurate representation of (a).)

- An even more accurate terrain representation is shown in Fig. 13-3d
- In this figure, 72 spot elevations are used, in addition to the stream breakline
- Note that the shapes and spacings of the contours in this figure are much closer to those in Fig. 13-3a, although some minor inconsistencies remain

13-6. Digital Elevation Models and Indirect Contouring

- Because certain computational algorithms require the use of regular grids, it is sometimes necessary to convert a TIN to a regular grid DEM
- This can be done by interpolating elevations between the TIN vertices at the centers of each grid cell
- Various methods are available for performing this interpolation, including ***nearest neighbor, inverse distance weighting***, *moving least squares, surface splines*, and *Kriging*

the nearest-neighbor method	the inverse distance weighting approach
▪ As its name implies, the nearest-neighbor method simply assigns the elevation of a grid cell to that of the nearest spot elevation in the TIN	▪ In the inverse distance weighting approach, elevations at the grid cell locations are computed by a weighted average of spot elevations, where each weight is inversely proportional to the horizontal distance between the grid cell center and the spot elevation point ▪ By this approach, spot elevations that are nearer to the grid cell will contribute more heavily to the weighted average.

13-6. Digital Elevation Models and Indirect Contouring

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the moving least squares approach	Surface splines
▪ In the moving least squares approach, a local polynomial surface $z = f(x, y)$ is fitted to a small set of points nearest the grid cell being interpolated ▪ Once the polynomial coefficients have been computed by least squares, the z value (elevation) is computed at the given x, y of the grid cell ▪ The procedure is repeated for every additional grid cell, with different polynomial surfaces being computed for each	▪ Surface splines are mathematically defined functions that generate a smoothly-varying surface that is forced to pass through each of the spot elevation points

13-6. Digital Elevation Models and Indirect Contouring

❖ Various methods are available for performing this interpolation, including nearest neighbor, inverse distance weighting, moving least squares, surface splines, and Kriging

Kriging

- Kriging is a statistical method which involves spatial correlation of points
- The spatial correlation is specified a priori through the use of a *variogram* which quantifies the influence a spot elevation will have on points being interpolated
- Proper definition of the variogram is important for generating an accurate interpolation
- Figure 13-4 shows a three-dimensional view of a regular grid which has been interpolated by Kriging, using the spot elevations (and points along the breakline) of Fig. 13-3d

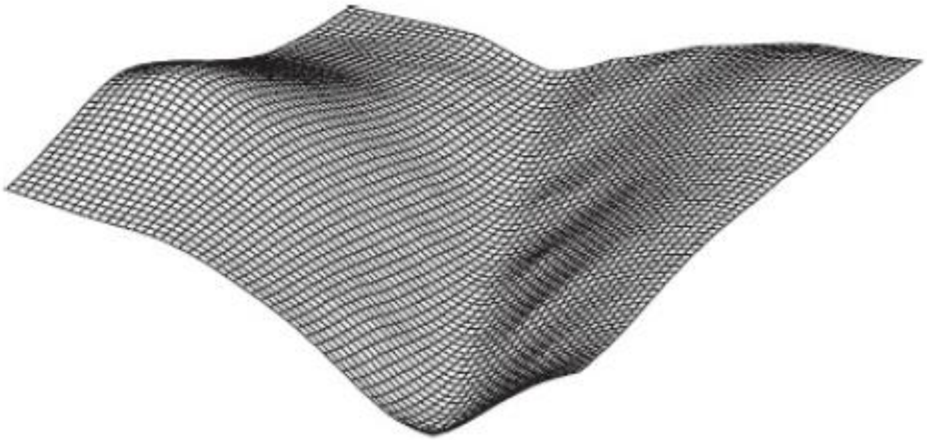

Figure 13-4. Three-dimensional view of a regular grid that has been interpolated from the data points of Fig. 13-3d by Kriging.

13-7. Automatic Production of Digital Elevation Models

- An important application of softcopy stereoplotters, which relies upon **digital image matching**, is the automatic production of digital elevation models
- In this process, a set of image points is selected from the left image and subsequently matched with corresponding points in the right image
- The set of selected points is typically arranged in a nominal grid pattern, which results in a nearly uniform regular grid DEM
- In general, the resulting DEM will differ somewhat from a perfectly regular grid due to tilt and relief displacements which exist in the images

13-7. Automatic Production of Digital Elevation Models

- Figure 13-5 is an illustration of the positions of DEM points within the overlap area of a stereopair of images
- A boundary is chosen for the region in which the DEM points will be selected
- The grid of selected points within the region on the left image is arranged at spacing of d_x and d_y in the x and y directions, respectively

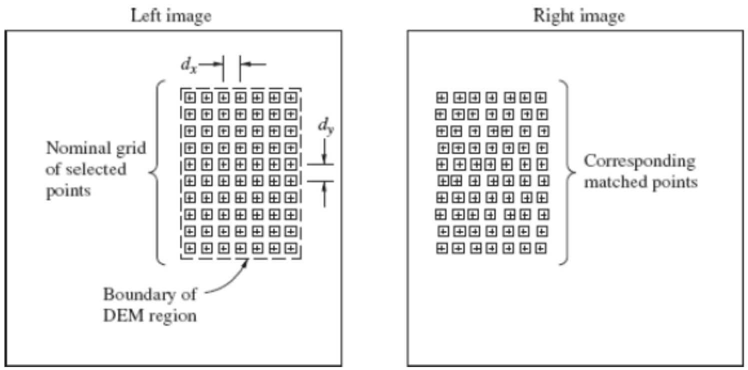

Figure 13-5. Positions of automatically matched DEM points in a stereopair.

- Each of these points is matched with corresponding points from the right image, using image-matching techniques as discussed in the preceding section
- Since the ground is generally not flat, the x parallax of DEM points will not be constant
- As can be seen in Fig. 13-5, this varying x parallax causes the pattern of corresponding points from the right image to differ from a perfect grid arrangement

13-7. Automatic Production of Digital Elevation Models

- Once the full set of DEM points has been matched and their object space coordinates calculated, their three-dimensional positions in the stereomodel can be represented by a set of floating marks superimposed upon the terrain
- If desired, the plotter operator can then view these points in stereo, one at a time, and adjust the positions of points which do not appear to rest on the terrain
- When the operator is satisfied with all vertical positions, the resulting DEM can be stored in a computer file
- This DEM is then available for additional operations such as automatic contouring or the production of digital orthophotos, as discussed next

13-8. Orthophoto Generation

- An **orthophoto** is a photograph showing images of objects in their true orthographic positions

- Orthophotos are therefore geometrically equivalent to conventional line and symbol planimetric maps which also show true orthographic positions of objects

- The **major difference between an orthophoto and a map** is that an **orthophoto** is composed of images of features, whereas **maps** utilize lines and symbols plotted to scale to depict features

- Because they are planimetrically correct, orthophotos can be used as maps for making direct measurements of distances, angles, positions, and areas without making corrections for image displacements
  ⇨ This, of course, cannot be done with perspective photos

- Orthophotos are widely used in connection with geographic information systems, where they serve as planimetric frames of reference for performing analyses, and are also used for generating layers of information for databases

13-8. Orthophoto Generation

- Orthophotos are produced from perspective photos (usually aerial photos) through a process called *differential rectification*, which eliminates image displacements due to photographic tilt and terrain relief
- The process is essentially the **same** as **standard rectification**, **except** that it is performed independently at myriad individual, tiny surface patches or differential elements
- In this way, rather than rectify the photograph to some average scale (which does not correct for relief displacements), each differential element is rectified to a common scale
- Prior to the age of digital photogrammetry, complicated optical-mechanical devices were employed to produce orthophotos from film diapositives
- Modern orthophotos, however, are produced digitally, Softcopy systems are particularly well-suited for differential rectification
- The essential inputs for the process of differential rectification are a DEM and a digital aerial photo having known exterior orientation parameters ($\omega, \varphi, \kappa, X_L, Y_L$, and Z_L)
- It is also necessary to obtain the digital image coordinates of the fiducials so that a transformation can be computed to relate photo coordinates to digital image coordinates
  ⇨ A systematic application of the collinearity equations is then performed to produce the orthophoto

13-8. Orthophoto Generation

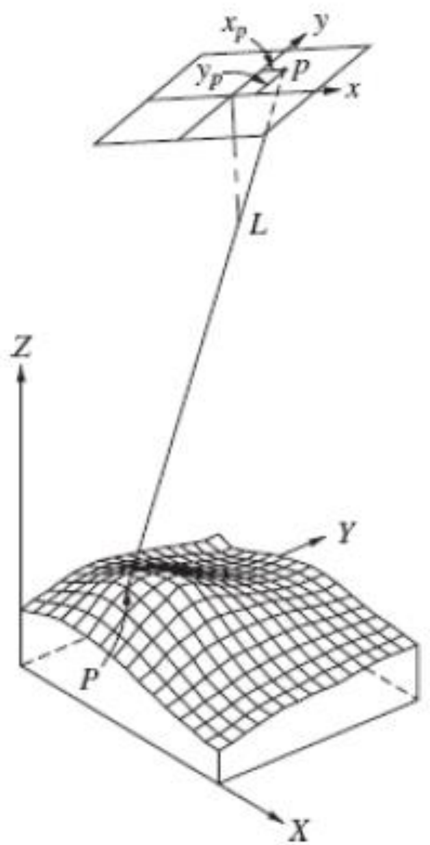

Figure 13-6. Collinearity relationship for a DEM point P and its corresponding image p.

- Figure 13-6 illustrates the collinearity condition for a particular groundel point P in the DEM
- The X and Y coordinates of point P are based upon the row and column within the DEM array, and its Z coordinate is stored in the DEM groundel array at that position
- Given the X, Y, and Z coordinates of point P and the known exterior orientation parameters for the photograph, the collinearity equations can be solved to determine photo coordinates x_P and y_P
- These photo coordinates define the position where the image of groundel point P will be found
- Since photo coordinates are related to the fiducial axis system, a transformation must be performed on these coordinates to obtain row and column coordinates in the digital image
- The transformed row and column coordinates will not be whole numbers, so resampling is done within the scanned photo to obtain the digital number associated with groundel point P

13-8. Orthophoto Generation

- The process of creating the digital orthophoto requires repetitive application of the collinearity equations for all the points in the DEM array
- Figure 13-7 gives a schematic illustration of the process. In this figure, two arrays are shown in vertical alignment, where each of the groundels of the DEM array corresponds one-to-one with a pixel of the orthophoto array
- The orthophoto array is initially empty, and will be populated with digital numbers (shown in the figure as x's) as the process is carried out

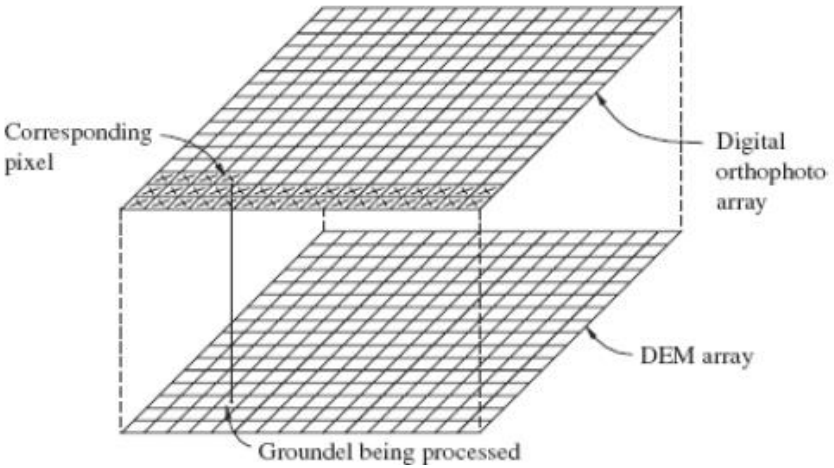

Figure 13-7. Schematic representation of digital orthophoto production process.

- At each step of the process, the X, Y, Z coordinates of the center point of a particular groundel of the DEM are substituted into the collinearity equations as discussed in the preceding paragraph
- The resulting photo coordinates are then transformed to row and column coordinates of the digital aerial photo

13-8. Orthophoto Generation

- The process of creating the digital orthophoto requires repetitive application of the collinearity equations for all the points in the DEM array
- Figure 13-7 gives a schematic illustration of the process. In this figure, two arrays are shown in vertical alignment, where each of the groundels of the DEM array corresponds one-to-one with a pixel of the orthophoto array
- The orthophoto array is initially empty, and will be populated with digital numbers (shown in the figure as x's) as the process is carried out

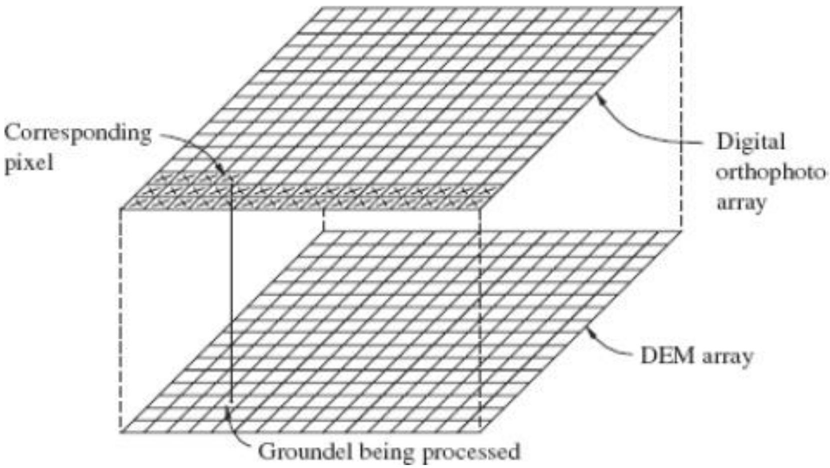

Figure 13–7. Schematic representation of digital orthophoto production process.

- Resampling is performed to obtain a digital number, which is then placed into the corresponding pixel of the digital orthophoto
- The process is complete when all pixels of the orthophoto have been populated with digital numbers

13-8. Orthophoto Generation

❖ If the DEM used does not fully represent features on the ground surface, the resulting orthophoto can be dramatically distorted

❖ Figure 13-8 shows the effect of DEM accuracy on the resulting orthophoto

Figure 13–8. Effect of DEM accuracy on orthorectification.

13-8. Orthophoto Generation

- The original photo, prior to orthorectification, is shown in Fig. 13-8a
- Figure 13-8b shows the photo orthorectified with a DEM that does not include the bridge (i.e., elevation is the ground beneath the bridge)
- Fig. 13-8c is the orthophoto resulting from a DEM that takes into account the height of the bridge above the ground

Figure 13–8. Effect of DEM accuracy on orthorectification.

13-8. Orthophoto Generation

- *Orthophotomaps* prepared from orthophotos offer significant advantages over aerial photos and line and symbol maps because they possess the advantages of both
- On one hand, orthophotos have the pictorial qualities of air photos because the images of an unlimited number of ground objects can be recognized and identified
- Furthermore, because of the planimetric correctness with which images are shown, measurements may be taken directly from orthophotos just as from line maps

Figure 13-9. Three-dimensional pictorial view of terrain obtained by combining a DEM and orthophoto.

- When digital orthophotos are stored in a computer in their numeric form, they can be incorporated with a regular grid DEM having the same ground resolution to produce three-dimensional pictorial views

13-8. Orthophoto Generation

- Orthophotomaps prepared from orthophotos offer significant advantages over aerial photos and line and symbol maps because they possess the advantages of both
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Figure 13-9. Three-dimensional pictorial view of terrain obtained by combining a DEM and orthophoto.

- This is achieved by assigning the brightness values of the orthophoto pixels to corresponding cells of the DEM and manipulating the view angle
- The result is a three-dimensional view of the terrain with the image draped over the top, as shown in Fig. 13-9

13-9. Map Editing

- After map manuscripts have been compiled with a stereoplotter, they are passed on to an editor who provides finishing touches
- Since modern stereoplotter manuscripts are compiled in a CAD environment, the resulting digital files can be used directly by the editor at a computer workstation
- The editor checks the manuscript for completeness and the use of proper symbols and labels
- Endpoints of lines which delineate polygon features are forced to close properly, and buildings are squared up
- Lines which continue between adjacent manuscript sheets are edge-matched so that they will be continuous
- Proper line types (dashed, solid, etc.) are assigned along with appropriate line thickness
- Depending upon project requirements and the features in the mapped area, additional edits may be performed

13-9. Map Editing

- In a CAD environment, many of the editing functions can be achieved through automated processing, particularly edgematching, closing polygons, and building squaring
- After the manuscripts have been edited, the map should be checked to verify its compliance with the appropriate accuracy standards
- When the digital manuscript has been edited to its final form, the original stereoplotter manuscripts form a continuous and seamless composite map of the project area
- The corresponding digital CAD file can be saved on a convenient data storage medium
- When individual map sheets are required, the editor will extract areas of the digital manuscript in a "cookie-cutter" fashion and place them in an appropriate border and title block
- A north arrow, scale bar, legend, notations, etc., are then placed on the map which can be subsequently plotted at the appropriate scale