



By **Kenneth A. Crawford, PE**

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The How-To Guide to Successful Surface Modeling, Part 3

Back for more? Welcome to the third installment in a series where we are discussing the exciting world of digital terrain modeling! As you have experienced in the marketplace, it is no longer enough to simply produce a flat map, although this is something the world has worked on for centuries. We've come a long way, developing such tools and concepts as coordinate system projections, mathematical techniques to minimize the errors inherent in drawing a necessarily rounded surface (the earth) onto a flat piece of paper. While this hasn't and won't go away any time soon, we now are tasked with delivering even more information about that original round or irregular surface, and we can deliver a wealth of value by producing a three dimensional model of the land under study. This is the venerable *terrain model*, and with our modern arsenal of tools, the delivery of choice is of course in digital form. Hence the term *digital terrain model*, or more simply, a DTM.

We've discussed in detail in previous articles some sources of data used to start our model, some techniques to make sure that it will fit our needs, and the necessity to make an accurate model so that the value in that model can be leveraged downstream of our part of the work. We'll now take a look at some of the common errors we find in source data and ways to resolve them so we can be assured that we've modeled our data correctly.

Types of Source Data and Errors

Remember our past discussion about various source data that we can use for our models. This can generally be broken down into the following categories:

- Previous digital and paper mapping (usually contours and spot elevations)
- 3D design data (often for use in automated machine guidance, or AMG)
- Digital files of previous processing (sometimes, nothing more than the resulting triangles of prior triangulation, but we could have more)
- Remote sensing sources such as aerial photogrammetry
- Lists of elevation data, often termed a DEM or Digital Elevation Model, usually text files with a regularly spaced set of coordinate and elevation values
- Occupation and observation of point locations on the ground

We won't have time in this article to discuss all the source data types, so we'll focus on the one that in my experience gives the most trouble: contours.

One of the most common sources of data that we use—sometimes without much choice in the matter—is previous mapping. Since most “mapping” is the end result of a process designed to make something visually understandable, the form this usually takes is that of the familiar contour map. This introduces the most common error in this type of

data, and that is of contours either at no elevation (zero), or some or all the contours drawn at the *wrong elevations*. We must also consider the spot elevations indicated in the mapping, if any.

A second common error we find in contour data is not actually an error, *per se*, but rather a lack of full information. Remember that contours are simply representations of constant elevation and therefore they have no inherent informational content about what happens *between* the contours, although trends can be indicated. For example, we are all familiar with “nose” contours indicating either a valley or a ridge, but this is just an indicator that we use from our experience base that really does nothing to inform the actual digital model about that local condition. We have to supply that “understanding” in digital form.

Errors, OK, Now How to Resolve?

Resolving these potential errors so that our modeling is correct is going to be dependent on a number of factors. One is to ask yourself what the resulting DTM is going to be used for. If you are creating a surface that a hydrologist will use to perform a county-wide drainage study, then you may not need to worry so much about little things like a widely spaced DEM data set, or even whether or not road edges are sufficiently densified to produce a smooth surface. The goal here would be to indicate trends,

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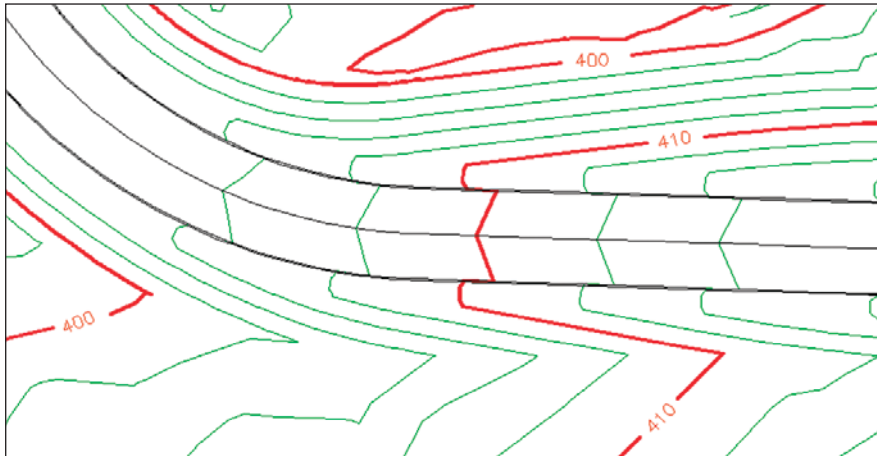


Figure 1 Typical contour map

Crawford, continued from page 64 and you should look more for gross errors such as surface discontinuities, vertical gaps, etc. If on the other hand you are preparing data for automated machine guidance (AMG), you will definitely need much “tighter” surface data to produce the most seamless surface you can. In every case, you obviously want to faithfully reproduce the ground surface as you observed it in the field or as intended by the design.

Other factors will be software-dependent tools that you may have at your disposal. Some applications provide a rich set of manipulation tools to make changes to drawing elements, and I urge you to learn these tools well. They are what make your bread and butter. Others have algorithmic tools that are built into the triangulation process itself, so learn the underlying techniques of these applications, too.

As mentioned above, one of the most common sources of incorrect information from which to build a surface is from previous contour mapping. I always teach my students in all my classes that this is the absolute worst possible source of good modeling data (imagine the shock!), and it is entirely due to the error types discussed above. However, using contour data is quite often “all we have” to work with, so this bears some detailed treatment. If we can minimize these errors, then we should be able to obtain a clean model for others to continue working with our model.

Contour and Spot Elevation Source Data

The most obvious problem when using contour data is when the contours are all

at no elevation (remember, everything we use for our model must be at the required elevation), and this is easily seen using our 3D visualization tools. If all the contours are “flat,” then we know there’s a problem and we need to simply elevate the drawn contour lines we plan to use to their proper elevations. This can be as simple as changing the entity’s elevation property in the CADD system, or “moving” them to a known elevation. Other tools can actually “read” the elevation labels and set the surrounding contours to those values. Not totally foolproof, but a useful tool. Make sure to change the elevations of the intermediate contours as well if they aren’t labeled. Look for tools that change elevations “by contour label” or “change in series” or “by interval.”

Next, if there are spot elevation indicators, make sure that they are available to be used in the modeling data set. Sometimes the spots are actually blocks or cells in the drawing and as such are not typically available for modeling without special pre-processing.

An often overlooked source of error in using contour data is a lack of information between the contour lines. While we may inherently “know” what the shapes of contours indicate, the modeling software doesn’t “know” that same thing. We need to teach it what happens in those regions. We do so by creating supplemental breakline data along indicated features.

Figure 1 shows a typical roadway and contours indicating possibly sidewalks and a ditch, which we immediately recognize as such. However, to the software, the only data being considered are the vertices along the contour lines and the road edges.

While the road edges and centerline are excellent breaklines keeping our points on one edge from “seeing” across the centerline ridge to the opposite road edge, the points along the contours indicating the sidewalks and ditch can easily “see” the points on the opposite side of the missing feature, and triangles will assuredly form across the open space without our intervention. This will cause erroneous “flat” triangles across the ditch top, never creating the ditch bottom. **Figure 2** shows the resulting triangles formed by this condition.

The obvious solution to this is to manually create breaklines along the

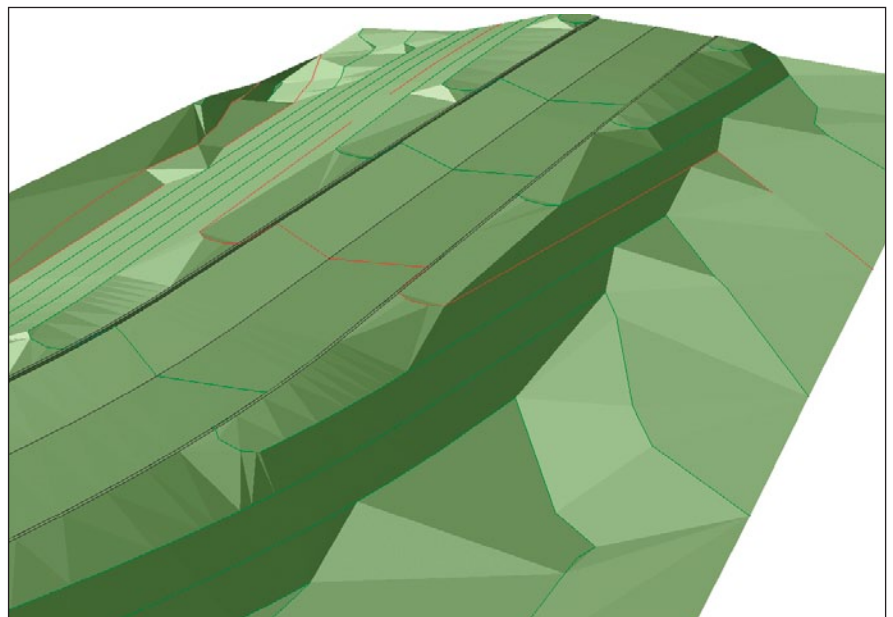


Figure 2 “Flats” formed along ditch and sidewalk areas

ditch bottom (and the top edge as well if indicated by the contour shape), or provide some indication to our triangulation process that there is some special condition occurring here. Notice the flat areas along the apparent sidewalk as well. If we cut a profile along these features, we see a "stair step" effect instead of a continuously sloping feature. This is not an error in the profile, given the surface as formed. The problem is that the surface itself is in error.

In applications such as Carlson's Civil and Survey modules that triangulate by treating *all* drawn geometry as breaklines, we need to supply these missing breaklines. Using tools to draw simple 2D linework along the feature and then "elevate" them to 3D form by intersecting the contour lines they cross is a good way to create them. There is no need to draw them as 3D and "snap" to the contours they cross, although that will work as long as we don't accidentally miss a snap point and generate a zero elevation vertex within the new breakline. This still is somewhat labor-intensive if we don't know our tools thoroughly. Other systems, such as AutoCAD Civil 3D, allow you to "minimize flats," resulting in an algorithmic "switch" that examines the derived flat triangles and reworks them to keep them to a minimum. A really excellent feature of the Bentley Systems' GeoPAK, InRoads, and PowerCivil series of applications is the ability to import drawn linework and tell the algorithm that they are a special class

of data, that of "contour" type. This then algorithmically disallows triangles to form across open space and have the end points lie on the same line. This has the effect of magically producing breaklines along all concave contour features, which is what we are after.

Whatever methods we use to supply the missing indicators to our software, the resulting surface should then form looking like **Figure 3**, which clearly indicates the ditch bottom and the edges of the sidewalks. As we have repeated throughout this series, make sure to evaluate the results of your work using your eyes! Simply not receiving a formal error message when creating a surface from contours does not mean that the surface is correct.

So that brings us to the close of another discussion. If you are following along and incorporating these ideas into your daily workflow, I suspect that you'll start to "see behind" a lot more of the processes you use and will only benefit from that new insight. Use these tools to help sell your services to your client by showing them the 3D graphics and explaining the "better" surface models that you produce compared to the competition. Whether you deliver to the project architect, the design engineer, or the contractor, all will benefit from the more robust nature of your work. So let's talk next time about the various ways to send this information out to other users, making sure that they receive the "model" model. *As*

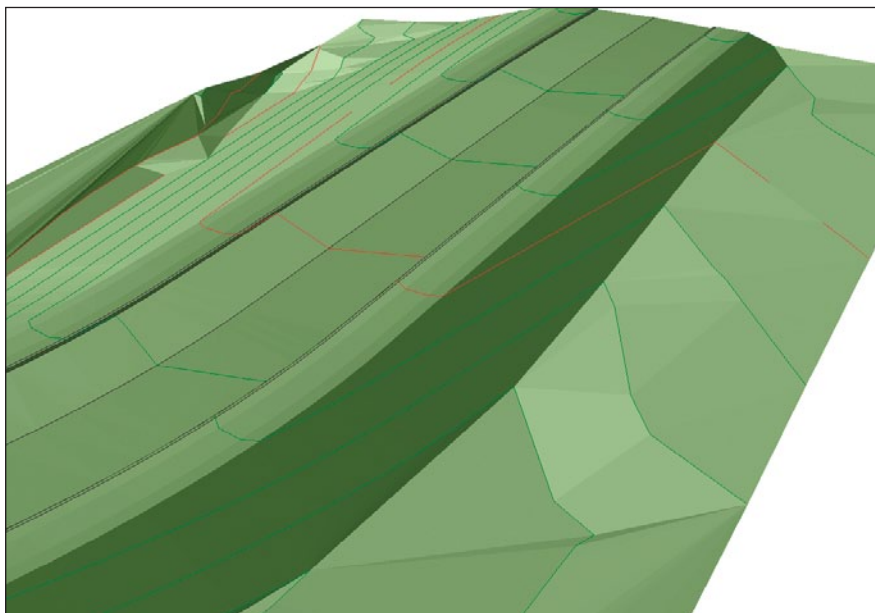


Figure 3 Properly formed triangles using contours and breaklines

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