By Kenneth A. Crawford, PE

Ken Crawford is a Registered Professional Engineer in Pennsylvania and a U.S. Army Corps of Engineers Quality Construction Manager (QCM). Ken's experience includes 25 years in civil engineering, surveying, and construction, with significant background in GIS applications. He is a principal in the firm Harken-Reidar, Inc.

The How-To Guide to Successful Surface Modeling, Part 4

We've been examining some of the pitfalls in surface modeling based on differing source information. The last article [Dec. 2009] dealt with the common errors associated with using drawn contours as source material to describe a surface. Assuming we might want to extend our service offerings to our clients by making highly accurate surface models–particularly for those developers and/or contractors who retain us to generate the proposed design surface for automated machine guidance (AMG)–we'll take a look at elevation information from a design file and how to turn that into a proper surface model.

We'll examine some editing techniques that can more properly reflect design intent. These same techniques can be applied to streamline our data collection process, getting us out of the field sooner, and delivering an accurate existing surface to our clients for use as a design base.

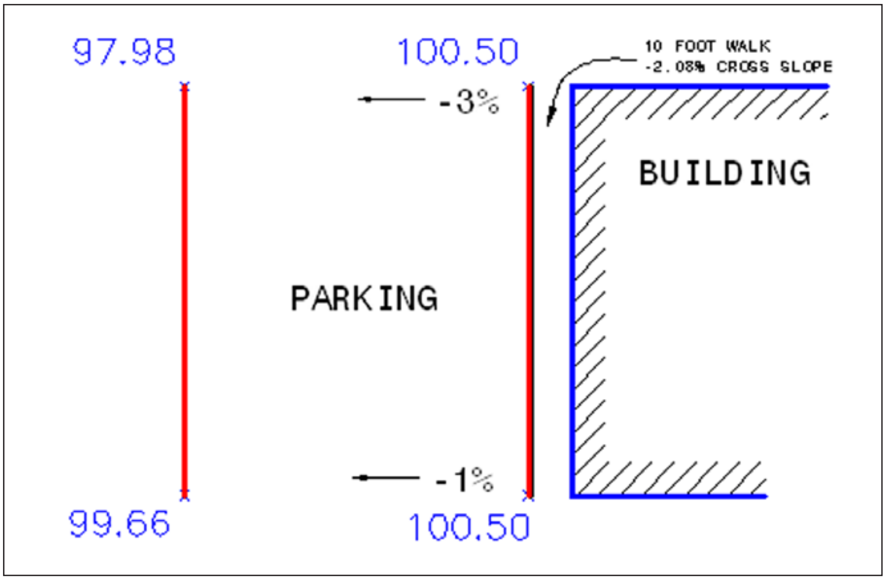

Figure 1 Typical layout

Typical Modeling Process

As we have seen, developing a surface model from drawn contours brings its own set of problems. We need to recall the actual process: TINs are formed by having the computer "occupy" each point and draw triangle edges to nearby points. We've seen how we need to supply breaklines or barriers to interrupt this process where it makes sense to do so, for example, along linear features either found or proposed. Remember, this keeps the points from "seeing" other points that do not lie on a continuous grade from the current point.

Keeping this simple concept in mind will guide us in developing the necessary controls to develop our models. Assume, for example, there is a building either proposed or existing that has basically a constant elevation along one edge. There may be a sidewalk alongside the building that forms the back edge of a parking lot that then needs to gently warp to its lower side having differing slopes from the corners. **Figure 1** illustrates this concept.

If we model the surface as indicated (*i.e.*, using only the four corners), we will get a perfectly valid surface, but one that may not adequately reflect the intent. **Figure 2** shows the resulting contours of this operation. We will see next how to remedy this.

As you can see, without using the "cheat" of contour smoothing, we show

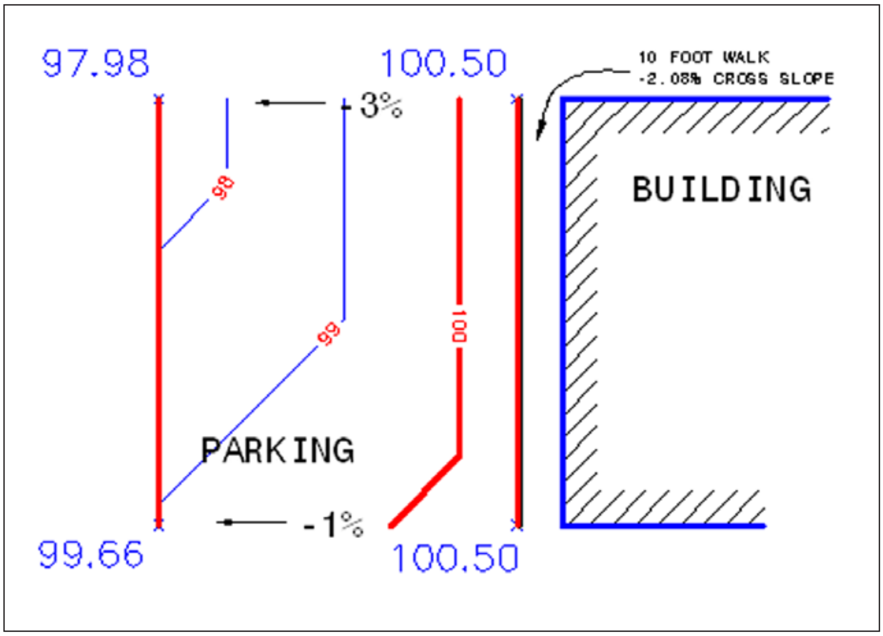

Figure 2 Points at corners only

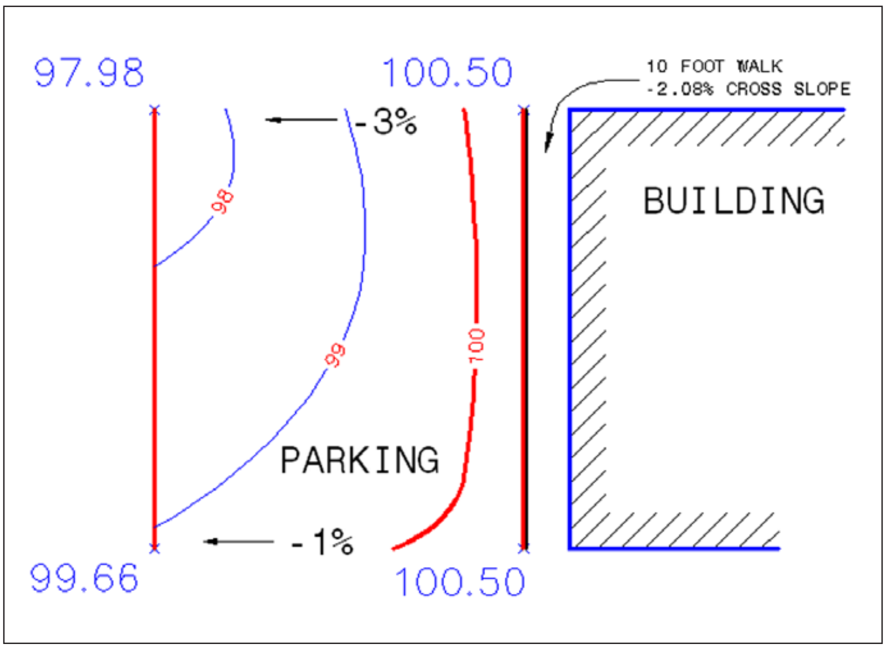

Figure 3 Contour smoothing applied

the resulting contours as formed from the surface triangles modeled from the four corners–notice that they indicate a crease in the surface. Taking a look at contour smoothing which will make nice smooth contours, we see that the surface itself is still unchanged. **Figure 3** shows the resulting smooth contour lines. While the contours appear as we intend them (showing a smooth transition across the parking lot), the surface model itself still contains a valley crease edge across the diagonal. Since it is the model that we need to deliver in its correct form, we need to find some ways to modify our input data to form a surface more reflective of our intent.

The Better Approach

By only using the four corner points of the parking lot, obviously only two triangles will form. Our first instinct might be to start adding a bunch of points, and this is where we can get ourselves into trouble if we aren't careful. If this is an existing parking lot that we survey in the field, we might be tempted to just start grabbing a bunch of extra points along each edge while we're out there to add to our data. While this is certainly a valid approach, we don't really need to spend the time. We can do this back in the office as long as the two edges of the parking lot are captured as breaklines that we will then *densify*.

Densification is simply the process of having edges subdivided into smaller segments, each vertex added at the original polyline's elevation at that location. As you can see, as long as the two edges form a continuous change in slope (linear, with no breaks in grade along the edge), then adding additional points in the office is the same as making our crews observe additional points in the field. Further, as long as the surface of the parking lot is actually a smooth transition with no sudden breaks in grade, such as valley troughs or ridge lines (which we will, of course, observe in the field and return to the office with those features captured as breaklines), then a judicious application of additional CAD data will obtain our main goal, that of a smoothly changing surface, edge-to-edge.

Next, we densify the two edges so that more points appear in our data set, and evaluate the results. **Figure 4** shows the resulting contours in this case, as well as the resulting triangles that form. While there are lots of triangles, the contours are a real mess. As mentioned in previous articles about how triangles form, we now extend that thinking to one further step to smooth out our surface. As you notice in Figure 4, the triangles formed across the lot, edge-to-edge, since there are no other points of data within the interior of the region to "see," and the contours are simply interpolated along each edge of each triangle. Mathematically all is well, but our eyes and our experience tell us differently.

I have come across design procedures that instruct design engineers that this result is acceptable, but that to smooth things out they need to draw smooth polylines over top of the computed contours, then add these new polylines to the surface model as additional line work…obviously the wrong approach! What we need is more data, but some that we can add to our model quickly without resorting to drawing the desired contours. We will do that next.

If you examine closely the horizontal triangle edges in Figure 4, you will note that they represent edge-to-edge linear change across the parking lot, as is our intent. But the only edges that are able to form are exactly that…edge-to-edge. If we could add more points to some horizontal lines that go across our parking lot, we would then have more points closer to each "occupied" point in the modeling algorithm that could form smaller triangles, resulting in a smoother surface. It is perfectly acceptable to "connect the dots" (remember, we densified) from one edge of the parking lot to the other with linework that will become breaklines. This can be done by drawing a 2D polyline at the north end of our lot, array it downward enough times to cover the space, then "drape" these lines onto screen entities (the two edges). Densify all these edges and cross lines, and run the model one last time. **Figure 5** shows these added densified breaklines in 3D, and **Figure 6** shows the resulting contours produced, *without* turning on contour smoothing. These more accurately represent the contours than our "smoothed" contours from the original four-point data set as shown in Figure 3.

Not only do we get smooth contours, we now have a surface that we can deliver to our client or colleague that is accurate at every place within our parking lot. This was fast and easy to construct, judging that there was enough data to begin with using the four corner observations. We simply learned how to densify without having to capture hundreds of points in the field. We can deliver this surface model–the actual DTM data–to anyone, machine control operators included, with full confidence that our surface is fully and accurately represented. This is exactly the kind of process we teach to our students at Harken-Reidar, much deeper than simply which buttons to push. The buttons are only the details, and if you know the process, you can use whichever tool from any given software application is appropriate.

The next article will examine the "field-to-finish" process of capturing the minimum (but sufficient) amount of information in the field, then streamlining the process in the office. As we've discussed before, it's time savings we're after; the hours directly translate to dollars, and we need as much of both as we can get! See you next time.

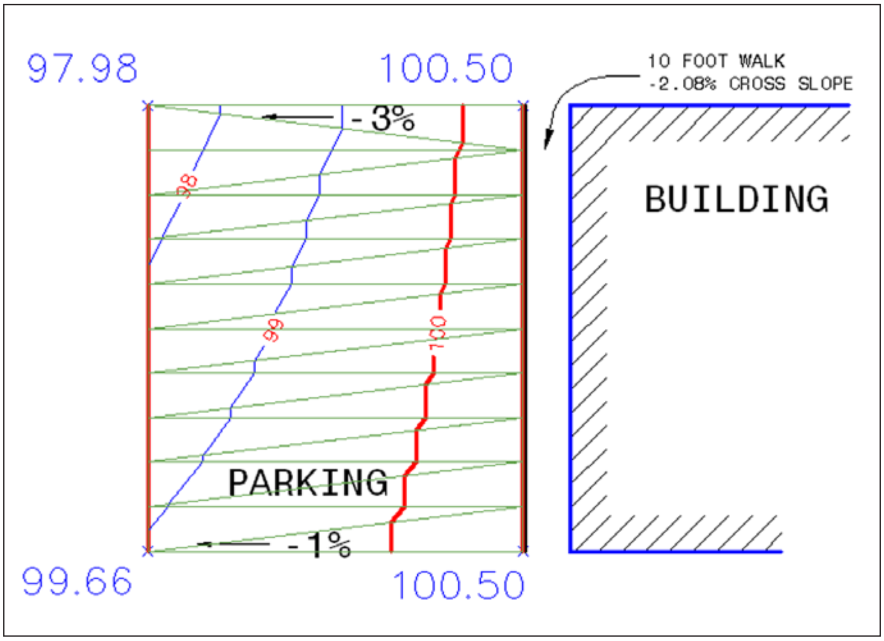

Figure 4 After densifying the edges

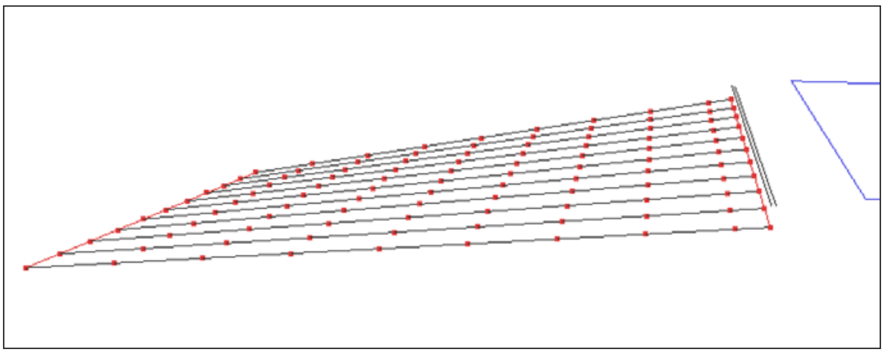

Figure 5 Added cross lines and densified

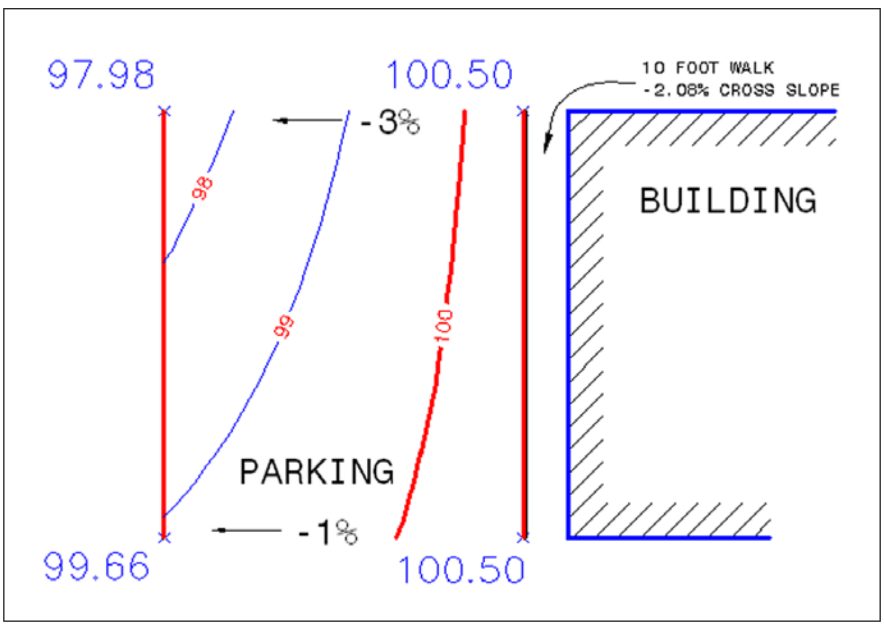

Figure 6 Pleasing contours, smoothing "off"