Software**Review**

By Shawn Billings, LS

Shawn Billings is a licensed land surveyor in East Texas and works for Billings Surveying and Mapping Company, which was established in 1983 by his father, J. D. Billings. Together they perform surveys for boundary retracement, sewer and water infrastructure routes, and land development.

Carlson SurvNet
Network Least Squares Adjustment Software

Many of today's surveyors began their careers with the chain and transit. As many of you will recall, even though electronic distance measuring technology had been around for a while, wide spread acceptance of EDM instruments did not occur until the late 1970s to early 1980s. The chain is simple, easy to understand, easy to implement and easy to explain. The EDM on the other hand was not so easy to understand or explain, but its ease of use, flexibility and efficiency eventually made it irresistible to virtually every surveyor. For most of us, a general understanding of how an EDM works has been sufficient enough for us to perform competent work using EDM instruments, even if we are not able to explain with exact detail how they work.

Similarly, the method of least squares to adjust surveying work has been around for quite a while, but really hasn't enjoyed much enthusiasm from the average surveyor until recently. The compass rule adjustment, like the chain, is simple and functional. I can still remember Dad teaching me how to perform a compass rule adjustment when I was in high school using a scientific calculator, pencil and paper. But, like the EDM, adjustment by least squares is beginning to garner some serious attention from surveyors in all aspects of the field because it offers so much more capability and flexibility than the compass rule. Having said that, least squares adjustment software can be very tedious and difficult to operate.

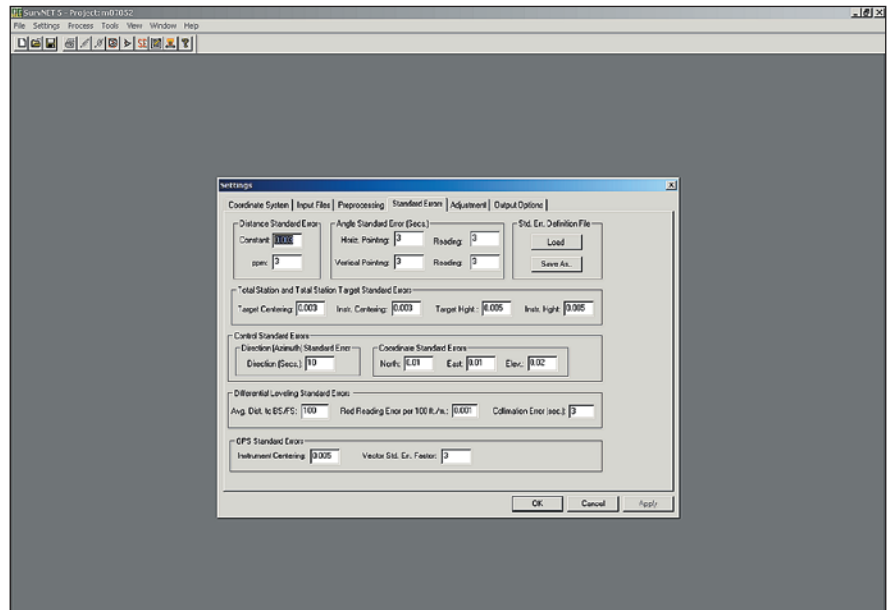Least squares adjustment software has really been making some noise in

Figure 1 Settings

the past two years, due in part to the latest 2005 Minimum Standard Detail Requirements for ALTA/ACSM Land Title Surveys which require surveys to meet a relative positional accuracy that does not exceed "0.07 feet (or 20 mm) + 50 ppm" which can be tested one of two ways. First, you may test your survey for compliance by "(1) comparing the relative location of points in a survey as measured by an independent survey of higher accuracy or (2) the results of a minimally constrained, correctly weighted least squares adjustment of the survey." In light of those two options, least squares begins to look very appealing.

But in all honesty, there are plenty of reasons to consider least squares software for your organization, of which I would place the new ALTA/

ACSM standards at the bottom of the list. Some of the benefits to having network least squares adjustment software include the ability to easily blend GPS vectors and total station work into one project. Next, even though we all know we should have balanced traverse legs, there are certain jobs that just don't allow for equidistant traverse lines due to the boundary geometry, irregular terrain, man-made and natural obstructions, etc. Network least squares adjustment software makes the best of these situations by properly weighting the potential for error in the varying leg lengths (compass rule would place most of the error in the few long traverse lines and very little in the shorter lines). Also, you have greater flexibility in your methodology. You can begin anywhere in the traverse
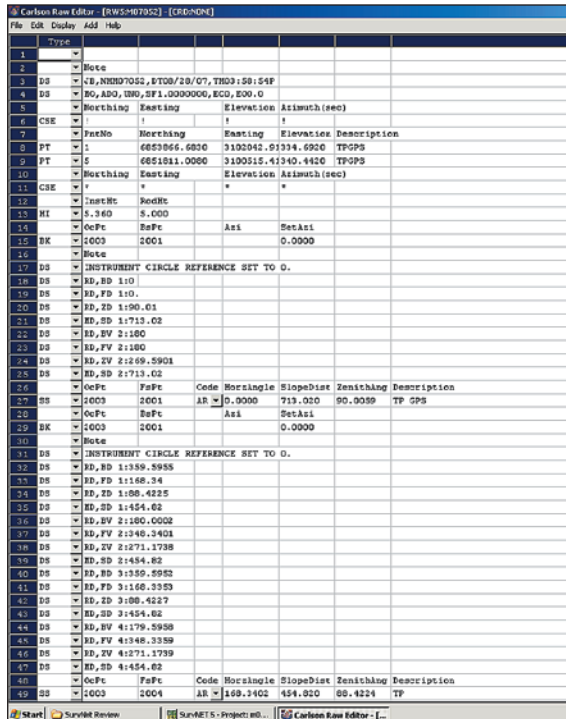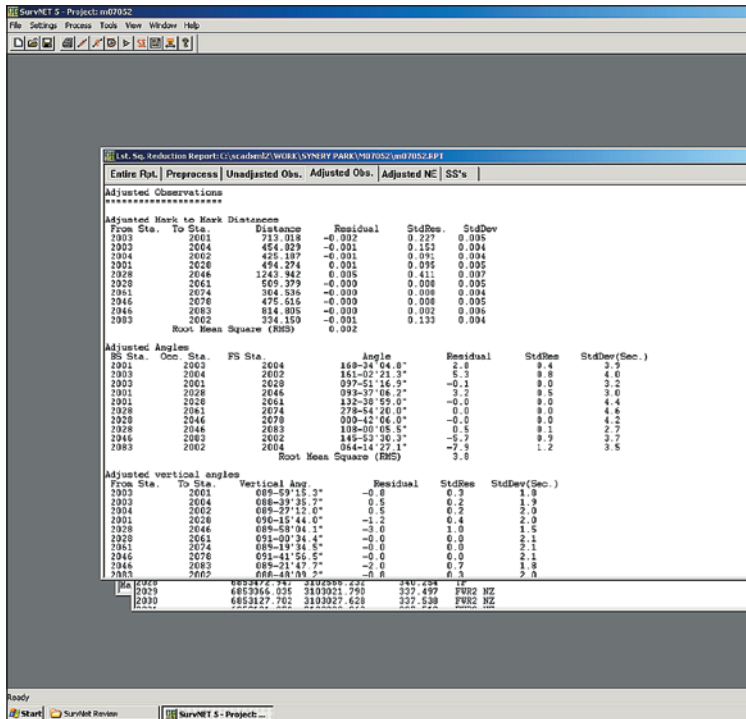
Figure 2 Raw file editor

Figure 3 Report

(not necessarily at a control point) and can skip around any way the project may require. Furthermore, you can do triangulation to remote points such as a distant tower and get accurate results. You also get a realistic idea of what accuracies to expect from your survey and you don't have to try to figure out what to do with redundant data, such as redundant ties, cross brace ties and multiple interconnected traverse loops. You can put those observations into the adjustment as well, building a stronger network. All of these strengths in network least squares are handicaps with the more popular compass rule adjustment.

Enter SurvNet 5 from Carlson Software, Inc. (Maysville, Kentucky). SurvNet is a network least squares adjustment software which originated from the C&G Software Systems, Inc. division of Carlson, and was written by Donnie Stallings, a North Carolina surveyor/programmer and Dean Goodman (the "G" of C&G). The concept began as a personal challenge for Mr. Stallings, who wanted to see if he could write a network least squares program. Mr. Goodman saw the practical application of the software and the two began working it into a commercially viable product. In my discussions with Mr. Stallings, a self-professed average surveyor, he seemed to be a strong advocate of smaller operations, which account for so much of our industry, realizing the benefits of least squares in common surveying work.

With that in mind, SurvNet puts some very surveyor friendly features into a capable adjustment package with an emphasis on simplicity. Once the software is loaded, the user should select the *Project Settings* under the *Settings* pull-down which displays a pop-up with various tabs as shown in **Figure 1**. The first tab, *Coordinate Systems*, directs the user to select the units, type of adjustment, Geoid (either '03 or '99) and coordinate system from the given options of Local, State Plane 1983 and 1927, New Brunswick Survey Control, UTM and User Defined. The *User Defined* option allows you to create a myriad of different projections if the software doesn't already support what you require. It also allows the more advanced user another option in dealing with the grid versus ground issue.

Next, the *Input Files* tab is where you can load multiple .rw5 files or multiple .cgr files (C&G raw data files), no conversions necessary. Optionally, you can load GPS vector data files in several formats and optionally edit ASCII GPS vector data. Although I did not test it for functionality, you can enter differential leveling files for adjustment as well. And finally there is the option to use an NEZ control file which keeps the user from needing to manually enter control coordinates into the raw data file.

The *Preprocessing* tab is next and prompts for curvature and refraction correction, loop closure set up, and tolerances for vertical/horizontal angles and distances. Also a field for *Pt Number Substitution String* is found in this tab. With many data collectors you get to use one point number per field observation. So if you measure point number 10 from traverse point 1 and later shoot point 10 from another traverse point, depending on your data collector, you may not be able to use the same point number for both, even though it is the same point. This is a problem because least squares software requires that the same point be identified throughout the raw data file. That's where the Substitution String field comes in. The user enters a character (such as an "=") that identifies that point as a different point number. So for point number 20, the user could enter =10 in the description and SurvNet would recognize that point 20 is actually point 10 with no office editing required.

Next is a critical part of the setup, the *Standard Errors* tab. It is important to point out here that least squares is not hi-tech "pencil whipping". Poor survey procedures and inaccurate data will still yield poor survey results. Least squares requires realistic estimates of
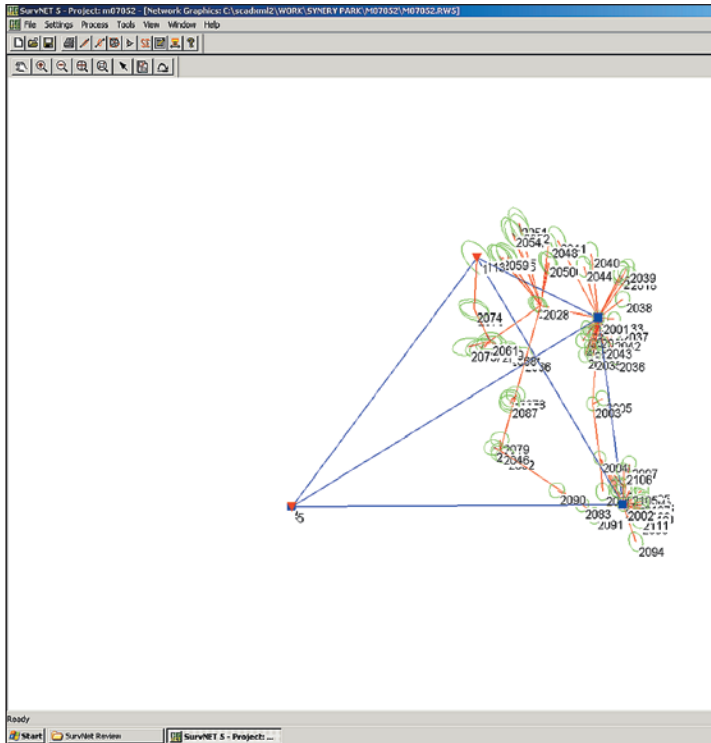
Figure 4 Network map

Figure 5 Inverse routine

various errors in your data. Every measurement type must be considered: angles, distances, set-up errors, height of instrument/rod measurements, etc. Each must be estimated for its likely accuracy. The better the estimates, the better the final adjustment. Once you feel comfortable with your standard errors, you can save the standard error settings to a file so that you can easily repopulate the fields consistently with each new project by retrieving your saved standard errors file.

The *Adjustment* tab allows the user to enter the maximum number of iterations SurvNet is permitted to perform during the adjustment and also the desired convergence threshold. What does all of that mean? In least squares, the software adjusts the data based on some initial estimated coordinate values, and comes up with new coordinates after each adjustment. The software repeats this step until the coordinates change by a value less than the user-specified convergence threshold. Each repetition is called an iteration. Defining the maximum number of iterations is necessary in case the user has a blunder in his data, in which the adjustment may not converge at all. Having a cap on how many times the software will continue to try and find a converging solution will keep

it from running endlessly. A solution that does not converge tells the user he needs to look at his data, a sometimes complicated process we will touch on a little later. In the adjustment tab, the user can also set up ALTA report information, such as which point to point connections to test for relative positional accuracy.

Finally, from the settings tab is the *Output Options* selection that allows the user to set up the number of decimal places for various reporting and the file type and format to be exported after adjustment. Options are given for the proprietary Carlson, C&G, LDD and Simplicity file types. An ASCII file with a .NEZ extension is automatically created.

The user may need to make some adjustments to the raw data file, particularly to erase any coordinates that aren't control coordinates and to add any coordinates that are control coordinates. Unless you are using a control file in the *Input Files* tab, the raw data file is the place to enter known coordinates.

As I mentioned earlier, finding problem entries, *i.e.*, blunders, can be arduous. Before adjusting, SurvNet has some nice blunder searching tools to ease the pain and suffering associated with searching for them. The *Preprocess the Raw Data* option searches primarily for common points that use two
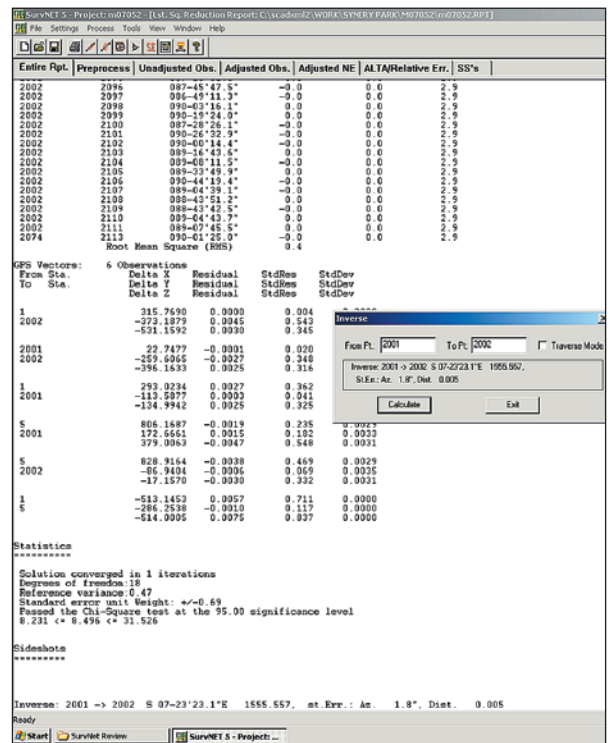
different point numbers and checks for redundant measurements that exceed the user defined tolerances. Next is the option to float one observation. Here the project is adjusted over and over removing one measurement each time. The adjustment with the smallest standard error of unit weight is flagged as suspect. The measurement that was removed from this adjustment is flagged as the likely blunder. Lastly, the program offers the option to *Reweight based on residuals*. Here the project is adjusted several times. With each adjustment, the observations with the higher residuals are considered suspect and are given a higher error estimate. The process then repeats, theoretically isolating the most likely source of blunder. These tools help save possible hours of pouring over a raw data file looking for an error source. Once a blunder is isolated, correcting it is easily done using the built in raw file editor shown in **Figure 2**.

With all of that now done, we are ready to adjust by selecting the *Process>Network Adjustment* option, or by simply clicking the red spider web icon at the top of the screen, at which SurvNet takes over. The adjustment process is quick. On my 2.4 GHz processor with 1 GB of RAM, adjusting my 113-point file, including sideshots and a six vector GPS

file, took about four seconds to generate a report ready for my review.

The report (**Figure 3**) is available as a single document or may be viewed as five separate sections: *Preprocess*, *Unadjusted Obs.*, *Adjusted Obs.*, *Adjusted NE* and *SS*s. The *Preprocess* report is the same as the report available in the *Preprocess* option under the blunder detection tools. The *Unadjusted Obs.* tab displays all of the observations used prior to adjustment. Next, the *Adjusted Obs.* tab, shows the newly adjusted observations with residuals (how much each observation was adjusted). It also reports the standardized residuals and the standard deviation of each point, and at the end of the page it gives some vital statistics on the adjustment itself, such as the number of iterations performed before the solution converged, the degrees of freedom (an expression of how much redundancy was in the network), the reference variance, the standard error unit weight, and the results of the Chi square test (which is an overall test of how well your initial error estimates matched the adjusted measurement residuals). The *Adjusted NE* tab displays the coordinates of the points in the adjustment together with each point's standard error in northing, easting and elevation (excluding or including the sideshots based on the user selection in the adjustment settings). If the sideshots are turned off in the adjustment settings tab (which increases adjustment speed), they will appear in the *SS*s tab instead of the *Adjusted NE* tab.

The graphics view displays a map of the network (**Figure 4**) and is accessed either from the Window pull-down or directly from the eye icon at the top of the screen. The appearance of each element is customizable for easier viewing. This screen shows a graphic representation of the network geometry and relative error ellipses for each point.

An inverse routine found under the Tools pull-down is a great resource (**Figure 5**). For an illustration, consider the closed loop in the network I used to test the program. The loop consisted of seven instrument stations with a total perimeter of 4479.94 feet with a calculated mis-closure of 0.020 foot horizontally and 0.056 foot vertically, giving a ratio of error of nearly 1:220,000. I've been surveying long enough now to know that this ratio is probably optimistic – the inverse of almost any two points in the survey could exceed this calculated

mis-closure. SurvNet's inverse routine gives the user the inverse azimuth and distance between two points along with realistic estimated standard errors of that azimuth and distance.

SurvNet's developers appear to have concentrated on creating a program that offers surveyors a simple to operate and effective least squares adjustment program. They have intentionally stripped away a great deal of extraneous statistical information and leave the user with a trim, easily digested report of the adjustment results. Since the program does enable blended GPS and terrestrial survey adjustments, it must include some geodesy. The complexity of geodesy has been muted, though, and should not be too intimidating to those who are uncomfortable with an abundance of geodetic terms and values.

The geoid files necessary to get orthometric heights, should you use GPS vectors in your adjustment, are available from the Carlson website and are proprietary Carlson grid files (you can't use the NGS Geoid files). The download is huge, at 140 MB of zipped data, making it a bit of an inconvenience, but once loaded, the geoid calculations are completely automatic. Presently only Geoid03 and Geoid99 are supported, although the user may input a project-wide geoid separation value.

If you're riding the fence regarding network least squares, now is a great time to get serious. Carlson offers SurvNet as a free demo so you can check it out for yourself and compare it to the competition before making the decision to purchase. The fully functional program is included with various flavors of their latest CAD software, including Carlson Survey 2008 and Carlson's CG Survey, both for AutoCAD and Standalone, and it is available for separate purchase as well. For the Carlson data collection user, SurvNet is purportedly going to make a debut in the next major release of SurvCE, SurvCE 3.0, a move by Carlson that will potentially make it an early player in the next major progression in field data collection.

One might regard the merging of least squares software with field data collection to be dangerous, considering the complexity of many least squares adjustment programs. Given the simplicity of Carlson SurvNet 5, I think it stands a good chance of making a lasting impression. **A̲s**