CE 511

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GPS Project: April 19, 2004

Introduction:

For this project the group members consisted of Brad Beal, Tim Wrathell, Huilan Lou, and Allan Ng. The purpose of this project was to establish ten centimeter, or better, coordinate accuracy for the photogrammetric control points used in CE 603. In that class, imagery was acquired by Digital Globe's Quickbird satellite sensor (1 meter ground resolution) for the area around Indianapolis Airport in Indianapolis, Indiana. Accurate ground coordinates of these points are needed to enable the recreation of the physical sensor model for the satellite. Previously, "rough" coordinates were obtained using a handheld Garmin G.P.S. receiver. Our goal was to refine those measurements to meet the requirements set by Professor Bethel.

Our group discussed various observation methods. The first option that was discussed was a Class C static survey as defined by NGS. We would have needed three horizontal control points and four vertical control points in addition to the nine photogrammetric control points in order to meet the minimum requirements of a class C survey. For this order of survey, we would have included at least thirty-minute long setups on each of the 13 points. For an NGS class C survey it would have also been necessary to obtain two or more occupations on at least 30 percent of the new stations (photogrammetric control points), 100 percent of the vertical control stations, and at least 25 percent of the horizontal control stations.

NGS also requires that at least 10 percent of all points surveyed be revisited three or more times for a class C survey. Since some of the photogrammetric control points and the other necessary control points were over ten miles apart, the drive time between stations would have been four or five hours. The three hours needed to drive to the project site in Indianapolis and back to Lafayette were not included in this time. These extensive time requirements made multiple occupations of these points unreasonable.

The alternative to this procedure was to use OPUS (Online Positioning User Service). To use OPUS, we would need to obtain approximately two hours of measurements at each of the nine photogrammetric control points. The use of OPUS does not require additional vertical or horizontal control points however, because it uses CORS (Continuously Operating Reference Station) locations as control points. Since the OPUS method would require only having to travel to the nine photo points once and never to any NGS control points, the decision to use OPUS instead of traditional techniques was an easy one.

Data Collection:

The data collection was the most time intensive portion of the project due primarily to the drive time involved. The site of the project is southwest of the Indianapolis International Airport, approximately 60 miles away from Lafayette. The Civil Engineering Department at Purdue University currently owns four survey-grade GPS receivers. In order to occupy the photo control points with efficient use of these four receivers, three observation sessions would be required. Since there are four people in our group, three group members needed to perform the occupation of two points, and one person had to occupy three of the points.

All four of the group members went to the project site on April 3, 2004, and occupied all nine of the points. Data was collected continuously for 2.5 hours at each photo point, with two notable exceptions. The observation time at Point 3 was stopped at 90 minutes due to a battery failure, and the observation at Point 5 was cut-short also at 90 minutes when the receiver was shifted by the wind and had to be repositioned. These observation sessions can be seen on Figure 1.

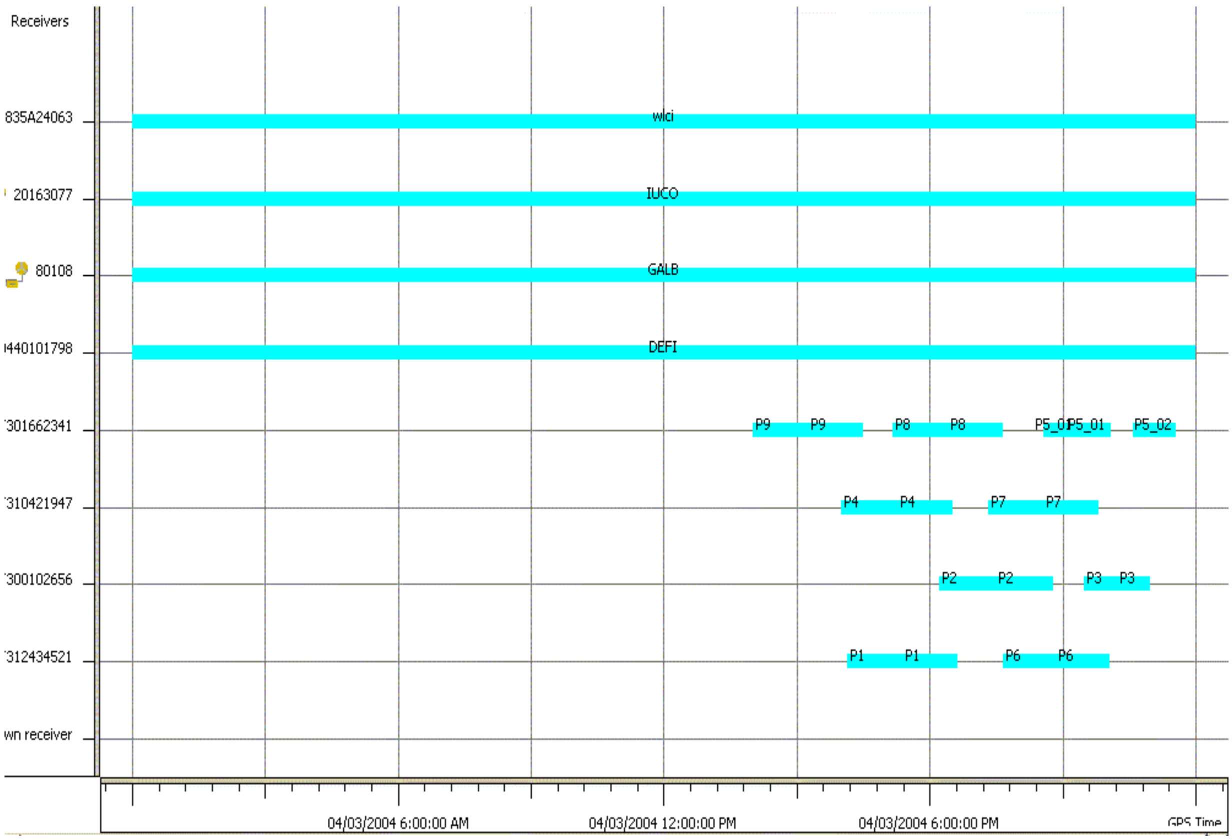

Figure 1: Observation Periods for the 9 Photo Points and 4 CORS locations.

After the observations were made, the data was downloaded using the PC-CDU software and then imported into Pinnacle GPS software. Once in Pinnacle, the data files were converted into the universally recognized RINEX GPS observation files. OPUS requires that the observation files uploaded to the program are in the RINEX format. We then uploaded all nine of our observation files to OPUS through the NGS website (http://www.ngs.noaa.gov/OPUS/). For our solutions, we allowed OPUS to select the CORS to use as the control stations needed for data processing. It should also be noted that our OPUS solutions used only the broadcast ephemeris, not the precise ephemeris. As an independent check, we also decided to use Pinnacle software to process the observed baselines between our nine photo control points and four CORS locations selected by our group.

The observable data obtained by these four CORS points is available for download from the NGS website in 24 hour observation files (see Figure 1). The four points we chose to get the best geometry for our network were DEFI, WLCI, IUCO, and GALB (see Figure 2). After these baselines were processed, Pinnacle used a Least Squares adjustment technique to find the coordinates of our nine photo points. For this adjustment, we held the four CORS points as fixed positions (assumed to be error free) and let the nine photo control points be adjustable locations. The results can be seen in Figure 3.

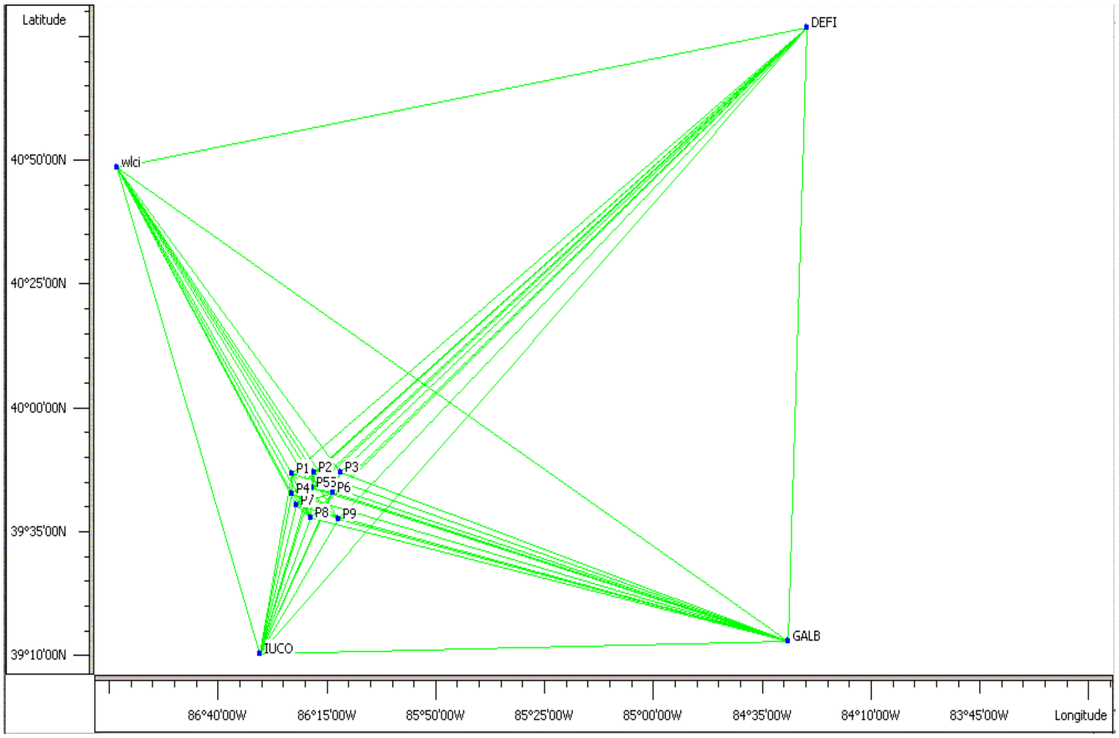

Figure 2: View of Baselines (Zoomed Out to See All 9 Points and All 4 CORS locations)

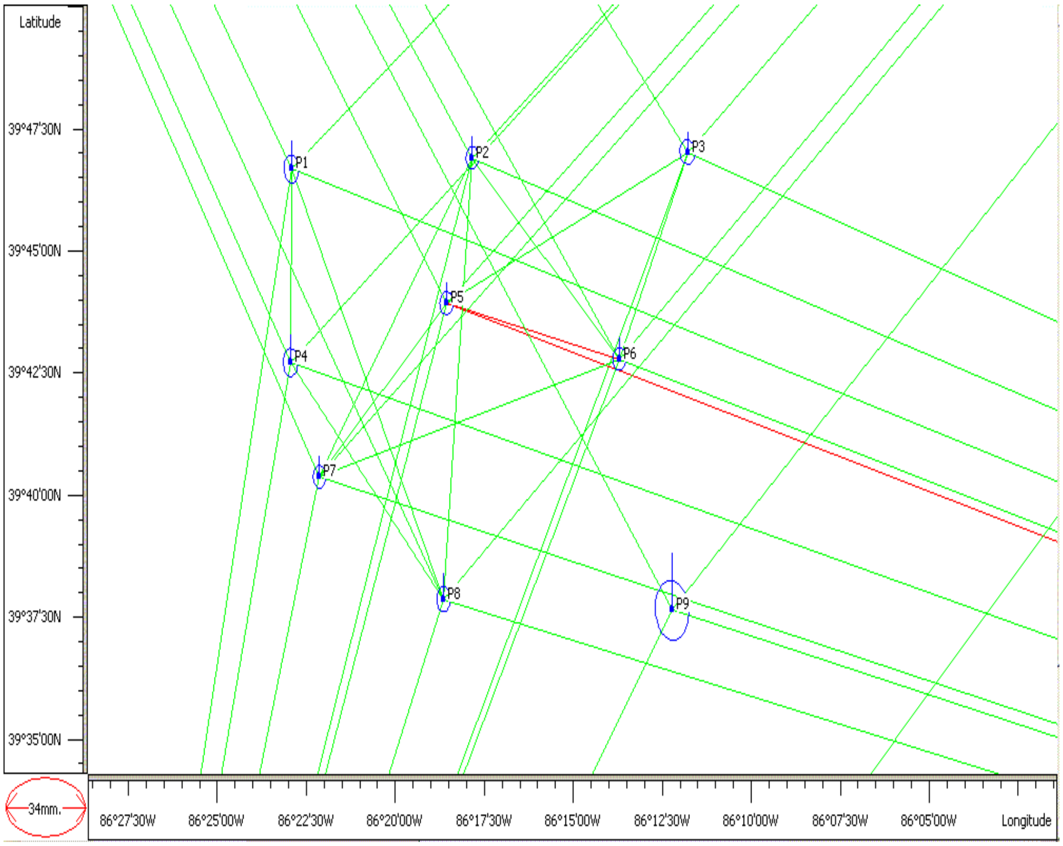

Figure 3: View of Processed Baselines (Zoomed in to See Photo Points and error ellipsoids)

The process of using Pinnacle to process baselines and adjusting data to find the unknown positions of points is essentially the same as that done by OPUS. The most notable exception is that OPUS is automated and allows the use of only three CORS locations. In Pinnacle, however, we could use as many CORS locations as we wanted (in our case four). In addition, with Pinnacle, we had control over all observables and parameters, whereas OPUS performs the operation with the users blind to the process.

As a group we wanted to see how well the coordinates generated from the OPUS solution compared to that of the Pinnacle solution. Four solutions were obtained from Pinnacle for testing purposes. The first approach processed the baselines to the nine points using the broadcast ephemeris and the second used the precise ephemeris (both available at the NGS website). These results were then compared directly to the OPUS solution to determine any discrepancies in positions. The third scheme with Pinnacle was to remove the first 30 minutes from observation files, and the fourth and final technique involved removing the final 30 minutes from the observation files. These results were then compared to the solutions determined with Pinnacle software, with all observations kept in, and with the precise ephemeris used. This comparison was used to determine the internal consistency of the data. The results from each of the four methods, and the differences are displayed on the Microsoft Excel printout included in this report.

Analysis of Results:

Note: All XYZ coordinates used in this project are reported in NAD 83 (an earth-centered earth-fixed system) and in metric units.

The comparison of the OPUS solution vs. the broadcast ephemeris yielded a maximum difference of 4.5 centimeters in the X direction, 6.5 centimeters in the Y direction, and 5.3 centimeters in the Z direction. The comparison of the O.P.U.S. coordinates vs. the precise shows a maximum difference of 4.7 centimeters in the X direction, 6.6 centimeters in the Y direction, and 5.1 centimeters in the Z direction. Taking the square root of the sum of the squares for the "worst" point gives a value of 8.4 centimeters. This is less than the 10 centimeter requirement for the project.

It should be noted that the points that displayed the greatest discrepancy between OPUS and Pinnacle were those points with the shortest observation period used. As expected, these were the Points 3 and 5 mentioned earlier. This is consistent with a study conducted by Purdue graduate student Brian Yentes, in which his experiments showed that consistent sub-centimeter accuracy could only be obtained consistently with CORS data after four or more hours of observation.

Our test to determine the internal consistency of the observation data netted fairly good results. The values computed using the precise ephemeris Pinnacle solution compared to the computed coordinates using the observation files with the first 30 minutes taken out yielded a maximum difference of 1.8 centimeter in the X direction, 2.8 centimeters, and 1.2 centimeters in the Z direction. Inspecting the coordinates obtained using the precise ephemeris vs. the observation files with the final 30 minutes eliminated from showed a maximum difference of 0.8 centimeters in the X direction, 2.7 centimeters in the Y direction, and 1.4 centimeters in the Z direction.

When we were analyzing the results, we also noticed that the standard deviation values for the Y direction were consistently almost three times larger than those of the standard deviation values for the X direction. The standard deviation values for the Z direction were almost twice as large as those for the standard deviation values for the X direction. Our group expected the largest standard deviation values for the Z direction, but the results showed the largest were those in the Y direction.

Conclusion:

Our results show that the OPUS solutions using three fixed CORS were significantly different than the static solutions obtained from Pinnacle using four fixed CORS (plus or minus 8 centimeters maximum in absolute positioning). Although this meets the requirements established by Professor Bethel, the results would not be satisfactory for a high order GPS survey. This is possibly due to the short observation periods (approximately two hours), especially at points 3 and 5. Our internal accuracy was confirmed by removing 30 minute blocks from the front and end of the observation files, which showed less than 2 centimeter differences from the solution using all solutions.

It is our belief that surveyors and others should be wary of many of the pitfalls common with using the OPUS system for determining point coordinates. These professionals should at the very least perform their own experiments to determine which observation methods will be satisfactory for the quality of the results expected by their clients.