# A Comparison of Methods for Mapping Golf Greens

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## ABSTRACT

Several golf greens were mapped using a RTK GPS, Riegl 3D-Laser Mirror Scanner and Trimble S6 Robotic Total Station systems to determine the most appropriate method for this task.

The RTK GPS was the easiest methods for data capture but was insufficiently accurate for mapping at a contour interval of 0.05 m or less in this situation. The laser scanner level data accuracy was slightly more accurate than the robotic total station but both produces results that were suitable for golf green mapping. However, the ease of use of the robotic total station determined this as the preferred methodology for golf green mapping with a 0.05m contour interval.

## INTRODUCTION

Golfers are always looking for a competitive edge to improve their game, whether from a personal challenge to reduce their own handicap, to beat their playing partner, or the chance to win prizes in competitions. Mapping and producing plans of the golf greens can assist all players to improve their game. Providing these plans on the internet can also offer golf clubs a valuable marketing advantage. Surveyors can provide a golf greens mapping service to a suitable standard that will allow informed decisions by both the Club for planning the placement of a green's cup position and by playing members to determine the best putting on the greens.

Various surveying techniques and methods can be used but not all of them are suitable for mapping flat open spaces such golf greens. This project aimed to compare only three specific methods which included digital laser scanning, RTK GPS and robotic total station. Each technique was used to map the shape and slope of a select number of greens at Toowoomba City Golf Course (TCGC) to provide a contour plan of each. The results were then analysed and compared to determine the most effective and efficient surveying method for providing this mapping service.

## METHOD

### *Test Site*

The project was conducted at the Toowoomba City Golf Club because of their interest and access support. The six greens selected represented the broad range of slopes and sizes of the 19 greens.

***Equipment***

The equipment included:

- A Riegl 3D-Laser Mirror Scanner LMS-Z2103D
- A Trimble RTK system comprising a 4700 base station and a 5800 rover
- Trimble S6 is a Robotic Total Station

The 360 degree prism used with the total station was mounted on the rover pole immediately below the RTK receiver. The levelling bubble located on top of the prism was removed to allow the GPS receiver to attach to the same pole for simultaneous use as shown in Figure 1.

The RTK survey was carried out in conjunction with the S6 total station survey. Both the S6 and RTK points were collected at the same point and time to allow for an effective comparison between the digital terrain surfaces derived from each data set. The laser scanner was used at other convenient day and night times.

Figure 1. GPS and S6 prism attached to same pole.

A topo plate (refer to figure 2) was manufactured and attach to the base of the range pole to replace the usual spike. The purpose of the plate was to prevent damage to the green and allow the measurement to properly represent the surface of the green. The ball joint on the topo plate allowed the pole to be held vertical regardless of the slope of the green.

Figure 2. Topo plate

***Establishment of survey control***

A site specific stable control mark was placed and coordinated for use as the RTK GPS base station. Map Grid Australia 1994 (MGA94) coordinates were established on this mark through a Fast Static GPS network involving two first order control points which were also constrained in the adjustments with the new base station. All baselines were less than 2.5km and formed sound network geometry. This survey was carried out in accordance with Standards and Practice for Control Surveys (SP1), version 1.6, 2004 recommendations for class C and included redundant baselines measured in accordance with recommended procedures. Processing and adjustments were carried out in Trimble Geomatics Office with the network observations achieving a 95% Chi square test result. The precision of the final adjusted base station coordinates was calculated to be 0.004m in the easting and northing with 0.006m in elevation at the 95% confidence level. Using the established RTK GPS base station, a further two independent PSM's were measured by RTK to check on the accuracy of the base station coordinates and set up.

RTK was then used to establish intervisible control points near the greens using at least twenty epochs of data before each point was stored. The control marks were existing sprinkler heads; hundred metre markers; signs located on the tee boxes; and other unique fixed marks found around the greens.

***RTK and S6 Total Station Data collection***

A detail survey with both the RTK and S6 total station collected point data around the extremities of the green, string data at the tops and toes of any slopes, and a grid pattern over flat sections to fill in the remaining area. Points were collected at a spacing of 0.5m to 2m with this spacing reduced to 0.2m to 0.3m over the steeper more undulating areas.

The number of observations required for each green varied due to the size, shape and level of undulations over the green. To facilitate accurate contouring, between two hundred and four hundred points were collected at each of the greens. Through areas of greater undulations the point density was increased to approximately 0.3m to improve the accuracy of the final contours.

The S6 was set up at each green in tracking mode with a 360º prism using sprinkler heads as station marks and the one hundred metre markers as backsights As the S6 total station was used in association with the RTK equipment, each detail survey point had both a S6 total station coordinates.

### *Laser Scanner Data Collection*

The terrestrial laser scanner was set over a sprinkler head beside each of the greens, although not necessarily the same one used for the S6, to achieve a single set-up at each green. At each location two targets were placed on coordinated marks beside the green to provide orientation of each scan onto the MGA94 coordinate system to facilitate a direct comparison with each method.

Two 'fine scan setting' scans were completed at each of the six greens. The linked laptop computer contained the I-SITE Studio software to operate the scanner process and store the data.

The scan data files for each green were too large (generally over one million points) for the Terramodel processing software. Hence, the data were filtered of unnecessary data between a variety of distances from 0.1m to 0.5m spacing between retained data points.

### *Processing*

Three-dimensional surfaces and contours from each data collection method were created using Terramodel to establish comparison consistency. A 0.05 metre contour interval was used as the best and most practical interval give the methods used in profile grading of greens. The contours were smoothed using the B Spline option in the software's contour creation settings.

### *Check Observations*

To provide an independent check on the accuracy of each of the survey methods used, a series of twenty-three independent points were collected at random positions over the 8th green using the S6 for horizontal position and a digital level for height. These check points were collected independently of other data collection methods except that common set up and backsight points were used for the S6 positioning of the check points and the initial data collection. The check points were imported into the software and the elevation of each compared against an interpolated height from each of the three-dimensional surfaces created from the three data collecting methods.

## RESULTS AND DISCUSSION

### *Accuracy and Precision*

The graphed height differences obtained from check each point (Figure 3) clearly shows the GPS height to be inconsistent with the check observations by an average +0.03m. While a consistent relative value of +0.03 over a green is acceptable for practical golfing purposes, the height differences range from +0.012m to +0.045m is unacceptable where slope accuracy is critical and the surface contour interval is 0.05m.

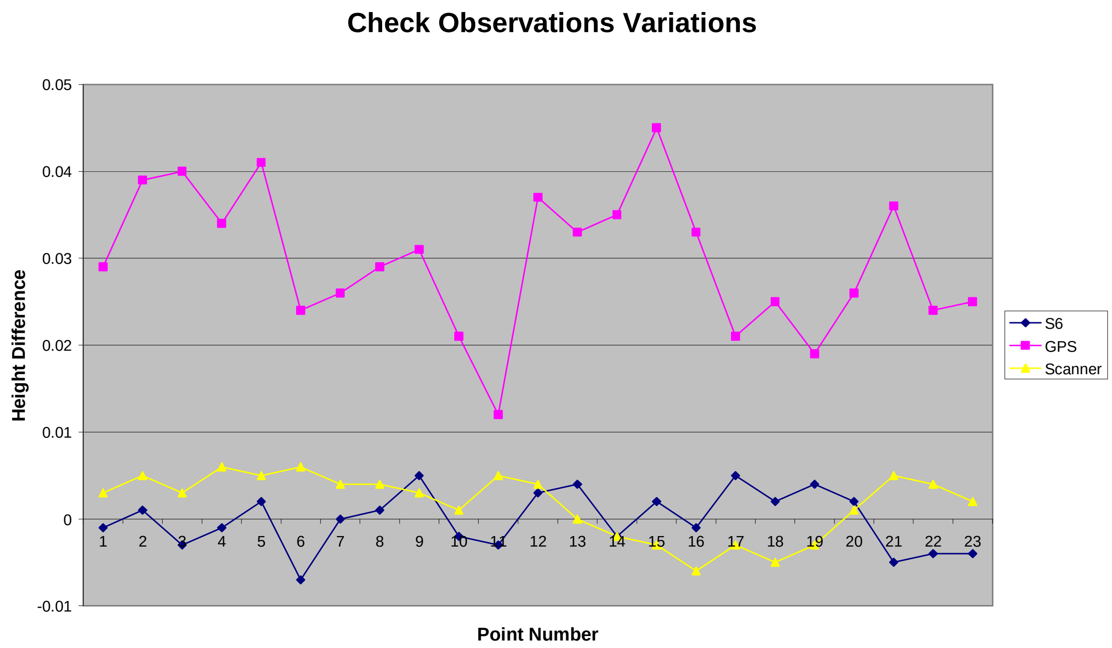


Figure 3. Height Variations on Check Observations

Figure 3 also shows that both the scanner and the S6 measurements were less than 0.01 m from the check observations and mean height variations of only 0.003 m. This difference may be attributed to the length of the grass as measurements with the scanner and S6 observations were a month apart with a further month to the recordings of the check observations. Another possible error source may have occurred from heavy dew that settled on the green during the night scanning of the greens.

Comparison of the interpolated surface levels with the check observations indicate that 95% were within 0.1 of a contour interval (0.005m) for the S6. Similarly, the surface created from the scanner observations provided 86.5% of check observations within 0.1 of a contour interval (0.005m).

A relative comparison of the contours provided similar results. Figure 4 shows contours for all three data collection methods on the 10th green. Due to the contours basically coinciding because of the scale of the output plan, the Figure 4 contours are at slightly different elevations to enable the comparison to be made on shape alone. Comparing the contours of the S6 and the scanner, it can be seen that although the contours themselves do not align perfectly, there is a high correlation in showing the correct fall and shape of the topography.

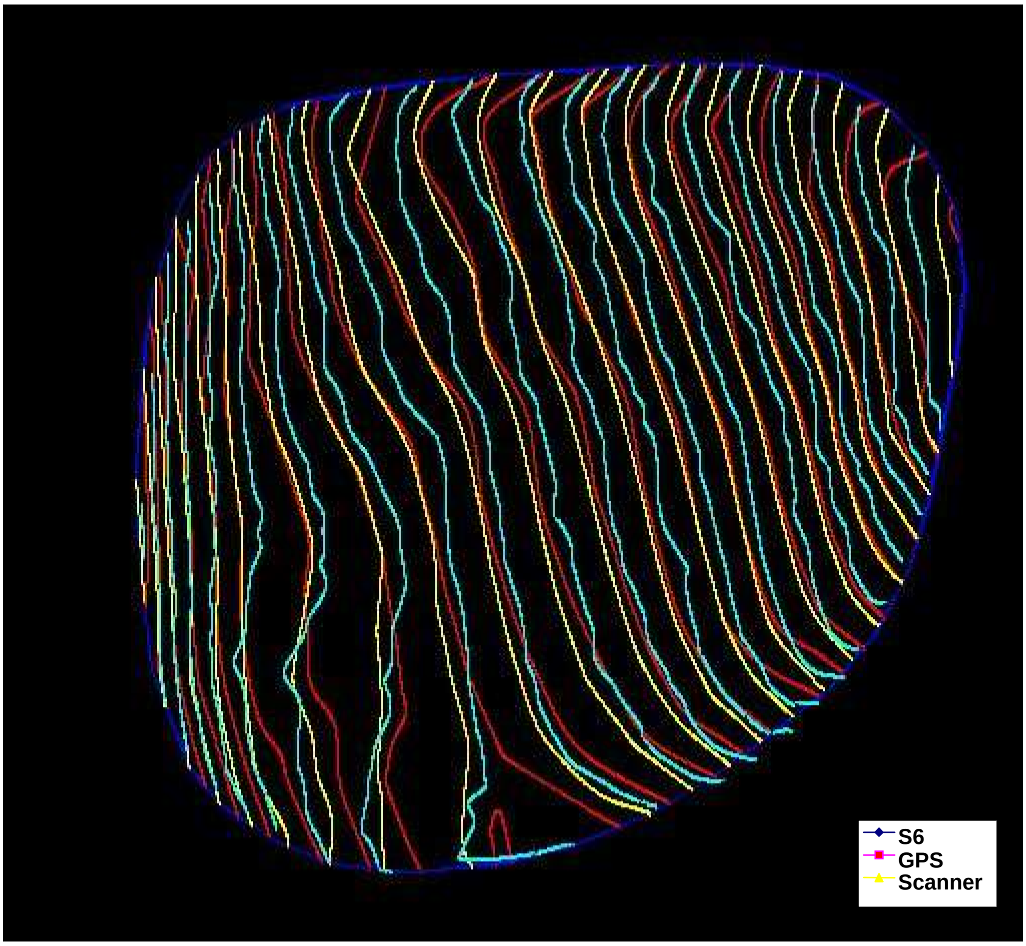


Figure 4.  10th Green, Contour plot of the 3 methods compared.

On the green in Figure 4, and a number of other greens, the GPS contours became erratic and did not match those of the other two methods.  This can also be seen on the 6th green in Figure 5 where the GPS contours are compared with those of the S6.  In parts, the contours are uniform in their shape, in other areas of the green, the contour of each method cross over showing different falls between the two methods.

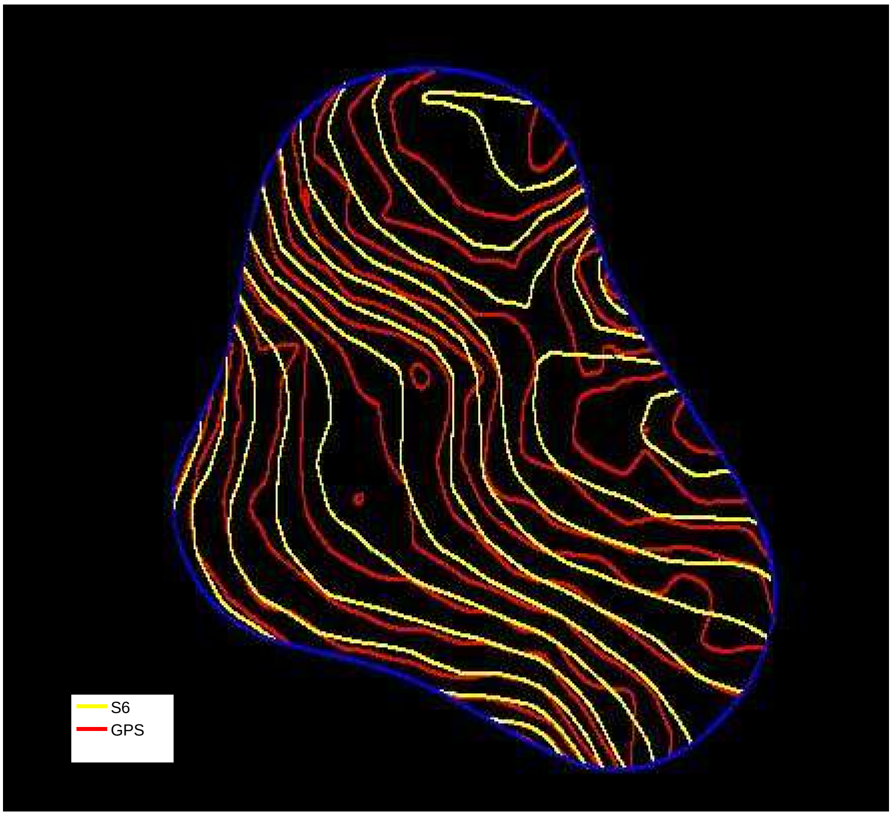


Figure 5. 6th Green RTK and S6 comparison.

The S6 and RTK data were collected simultaneously allowing a direct comparison between the coordinates of each of the points. This time using the 8th green, the differences in easting, northing, and reduced level were calculated. From the three hundred points collected there was an average difference of to 0.027 m between horizontal positions values. These differences could be attributed to a number of factors including: error in levelling of the pole as readings were taken; errors in setup over marks at either the GPS base or at the S6 over a sprinkler head; and other inconsistencies in instrument heights measurement, instrument errors and errors normally associated with the RTK method. The horizontal difference is considered negligible for the purposes of this project as it is relative slope and direction that is critical to the golfer.

***Efficiency***

The RTK GPS proved to be the most unreliable of the three methods due mainly to the problems of maintaining a fixed solution on the available satellites. This was caused mainly by the number, location and size of trees located around many of the greens. Other structures that could have affected the signal at several greens were the powerlines and metal fencing. A stronger radio signal or a second base station set up on the other side of the golf course may have helped with the RTK measurements overcoming some of the problems.

The S6 proved to be the easiest system to operate and the most reliable during data collection. The instrument was able to continuously maintain a lock on the prism allowing for efficient and rapid data collection at all times. Having the RTK control set up at each of the greens facilitated quick and easy transfer between greens as a traverse was not required to transfer control.

Of the three methods used the scanner provided the quickest form of data collection and the most efficient in collecting a large volume of data: however, processing this data proved very time-consuming. Operating the scanner on a fine scan mode and limiting the field of view of the scan to the golf green area, required approximately five minutes to complete each scan. This varied only slightly with the size of the greens and the number of data points collected. This compares favourably with the other two methods where, on average, 40 minutes was required to collect sufficient points to map a green (assuming no interruptions from golfers).

The time required to setup and pack up the S6 and the scanner instruments systems was similar. The exception was for the RTK system as it only required the one setup for the whole course rather than setting up at each green required by the other systems.

Processing of the data for the S6 robotic total station and GPS were comparable since they both provided the same information and file formats. The scanner required a lot more processing due to a lack of knowledge about the processing software, a problem that is partially overcome with increased familiarity. The processing power and the storage capacity requirements of the computer used to run the I-Site software is also a disadvantage, but the scanned data has all the advantages of already being in a 3D colour (day time scanning) image format. The scanner system also suffers from a significantly higher hire rate compared to the other methods, all of which makes it the least preferred method on an economic basis.

**MAPPING SERVICE OUTPUT**

The following two examples (figures 6 and 7) are typical of the maps provided to the Golf Club which can be made available to the players, with or without the cup position, in either hard copy or digital copy format

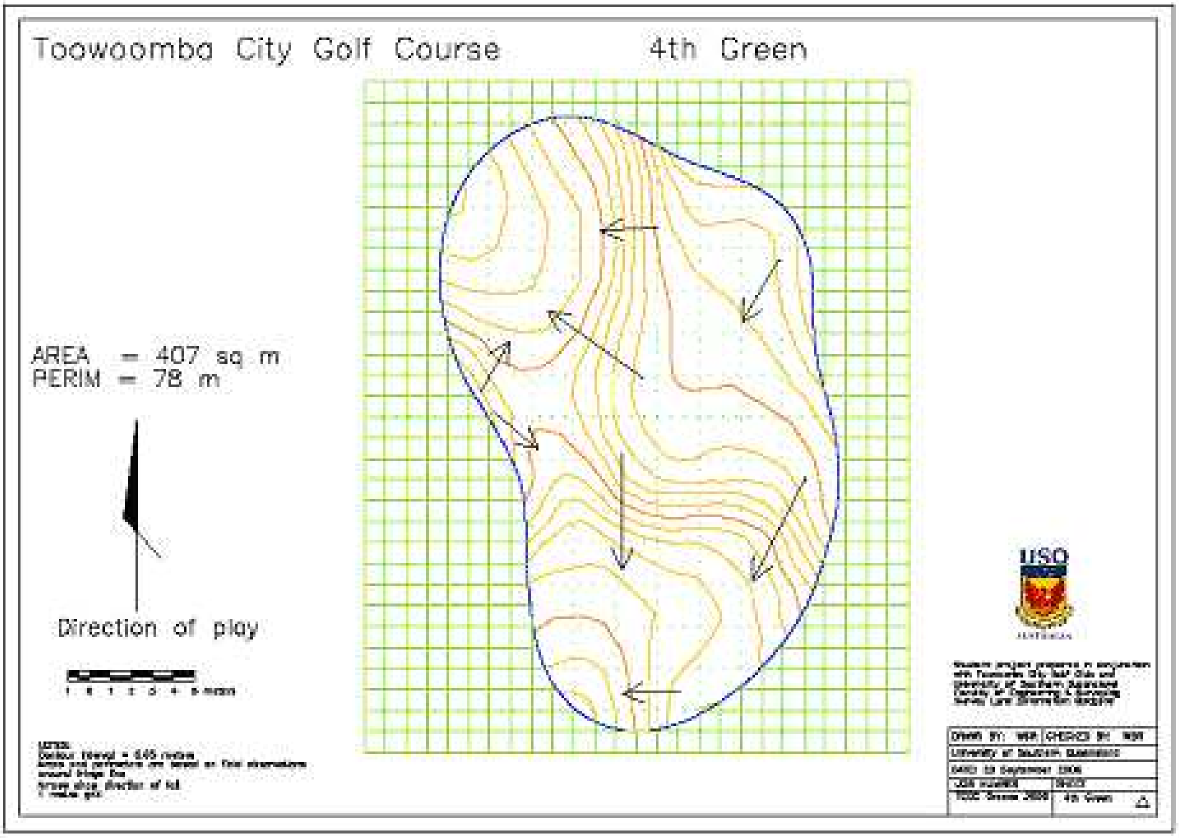


Figure 6. 4th Green map.


Figure 7. 17th Green map.

## CONCLUSIONS

The aim of the project was to compare three different methods for mapping flat areas, such as golf greens, to determine the most appropriate system. The RTK GPS was the easiest of the three methods for data capture with minimal setups required and easy transfer between greens as a line of sight was not required. However, the problems of maintaining a fixed solution, due mainly to the number and size of trees in such an environment, and unreliable height measurements, meant GPS was not sufficiently accurate for the purpose of mapping golf greens at a contour interval of 0.05 m or less.

The laser scanner was the most efficient at collecting data, but the processing of results was very time consuming. The system hire costs made this method the most expensive technique to use, however, the level of accuracy was at least comparable to, and slightly more accurate than, the robotic total station. The S6 robotic total station proved the most time consuming process but also the most efficient and easiest to use method for the capture data. Mapping golf greens by this technique will achieve a 0.05m contour plan within an accuracy range of 0.005m.

## REFERENCES

*Standards and Practices for Control Surveys (SP1) - Version 1.6*, 2004, ICSM Publication No. 1, <http://www.icsm.gov.au/icsm/publications/sp1/sp1v1-6.pdf>.