Using Differential GPS to Determine Range Accuracy and Precision of Terrestrial Laser Scanners

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**Introduction**

Terrestrial Laser Scanners (TLS) use LiDAR (Light Detection And Ranging) technology to create three-dimensional point clouds of surfaces. They operate by emitting a pulse of light that reflects off surfaces and back to the scanner, measuring the time of flight to accurately position the return to 3D coordinates. These data can be used to create high-resolution topographic maps and calculate volumes of land and ice masses. Manufacturers of TLS equipment often only give accuracy and precision measurements for a 100m range, however researches in the field often need to scan areas greater than 100m and must have the ability to repeat scans at these larger distances. As the range increases, beam divergence causes the laser spot size, or beam diameter, to increase which in turn decreases both accuracy and precision. This project builds on the 2015 Geo-LoadShed TLS project in which initial accuracy and precision results were obtained, through a collaborative trend and without the use of an independent measuring device to obtain true point locations. This year the project was expanded to include differentials GPS, a technology capable of sub-centimeter positioning. In comparison with the TLS project to determine the variance in accuracy and precision of the Geo-LoadShed TLS scanner.

**Methods**

1. A GPS station was set up on a 15-foot pole with a hemispherical antenna to provide a stable base with which to derive accurate GPS solutions.
2. The scanner system was centered and leveled over a reflector target on the ground (see Figure 3). This target was capable of accurately measuring beam divergence horizontally to 0.5mm. To accomplish this, the survey was performed on a hillside with a north-south orientation.
3. The target, a reflector, was set on a 15-foot pole, and leveled over a ground truth reflector at 100m intervals from the scanner, with ranges ranging from 100-1000m for a total of 54 data collection points.
4. A Trimble Zephyr Geodetic Antenna was set at the target and, once the scanner warmed up, atmospheric conditions were recorded at the scanner and target locations in order to effectively calibrate the Geo-LoadShed TLS scanner.
5. Scans of the target location were taken 10 times and recorded using the Geo-LoadShed TLS scanner.
6. The target remained stationary for 2 hours to provide an ample GPS observation period. Data was collected in order to reduce errors to 0.01mm.

The process was repeated at 0.5m intervals and again 3 times at the 10cm interval. Each scan produced a point cloud of the target which the scanner then used to calculate center point coordinates. Scanner native coordinates and the GPS global coordinates were compared for each set of scans, which were compared to the same coordinate system using the scanner as the coordinate system origin. This new coordinate system, the scanned coordinates of the target center point, was compared to the GPS coordinates, allowing to determine the accuracy and precision of the Geo-LoadShed TLS scanner.

**Conclusion**

- **Differential GPS can be used to determine TLS scanner accuracy and precision values.**
- A trend may not be obvious; values for precision and accuracy may need to be calculated for each survey using GPS control points to establish the laser measurement.
- **Atmospheric effects** involving particulates such as smoke or dust may reduce the accuracy and precision of the Geo-LoadShed TLS scanner.
- Instruments of the same make and model may have differing internal sources of error; this should be evaluated.

**Spot Size**
- Spot size of scanner diverges by 0.35m.
- At 10m, the spot size is 17.5m, while the target size was only 16.5m. Only 1 point represents a 17.5m area.
- Greater spot size diminishes scanner's ability to distinguish objects.

**Aerosol Effects**
- Speed of light is affected by medium. Differences in temperature, relative humidity, and pressure will affect speed.
- Differences reported between scanner and target each day; these were averaged.
- Measured using LaserWise Weather Station not very precise.
- Temperatures varied from 65 to 100 F.
- Relative humidity from 20% to 65%, pressure by 1-2 mbar due to diurnal cycle, storm patterns, etc.
- Smoke was sometimes collected 1 week after atmospheric conditions were measured.
- Smoke from local forest fire may have impacted speed of light (smoke observation was performed during 1000 and 10000m data collection days).
- Above factors could account for 2-3mm errors.

**Inconsistent Equipment Usage**
- On day of 100m data collection a different Geo-LoadShed TLS scanner was used.
- Further testing with different instruments needed to determine scale of error associated with different instruments.

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