Error Propagation in Directly Georeferenced Terrestrial Laser Scanner Point Clouds for Cultural Heritage Recording

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Introduction

- Terrestrial laser scanners (TLSs) have found application to many cultural heritage recording projects
- However, insufficient attention has been given to point cloud precision, which is often overstated
- Our aim was to construct a random error budget for directly georeferenced TLSs that models all sources
- Many of the contributing random error sources are common to the surveying field
- A new probabilistic model is proposed for the angular uncertainty due to the finite laser beam diameter, which may be significant
- The error budget for a heritage-recording case study undertaken at the UNESCO World Heritage listed Wat Mahathat site in Ayutthaya, Thailand, is presented and analysed

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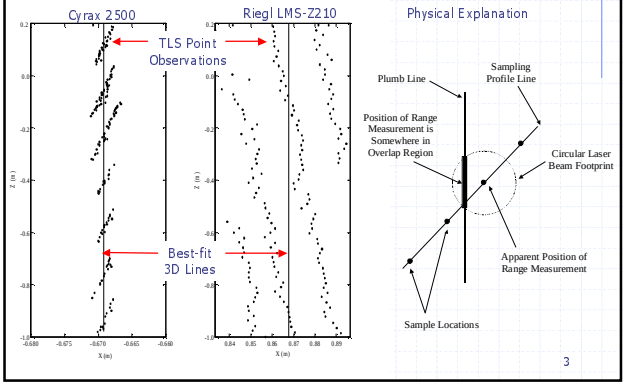
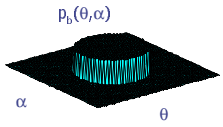
Significance of Beamwidth—Plumb Line Examples



Probabilistic Model

- The probability governing the angular position (θ,α), of the range measurement is assumed to be uniform within the beam's cross-section having diameter δ

$$p_b(\theta,\alpha)=\begin{cases}\dfrac{4}{\pi\delta^2} & \alpha^2+\theta^2<\dfrac{\delta^2}{4}\\ 0 & \alpha^2+\theta^2>\dfrac{\delta^2}{4}\end{cases}$$



- The standard deviation for beamwidth is given by

$$\sigma_b=\pm\sqrt{\int_{-\infty}^{\infty}\int_{-\infty}^{\infty}\alpha^2 p_b(\theta,\alpha)\,d\alpha\,d\theta}=\pm\frac{\delta}{4}$$

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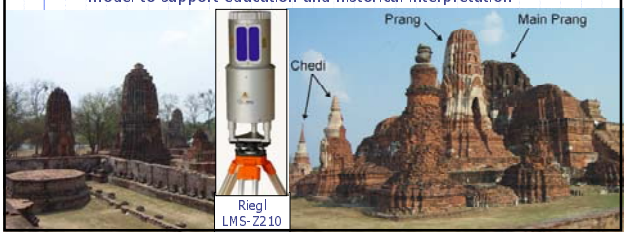
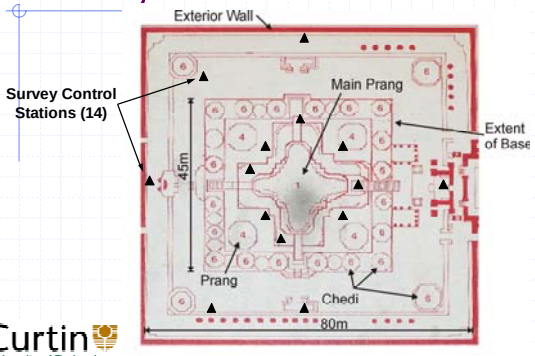
Case Study: Wat Mahathat, Ayutthaya, Thailand

- Located 85km north of Bangkok
- An ancient capital of Siam, Ayutthaya holds UNESCO World Heritage status for the many culturally significant Wats in the city and its environs
- Site was scanned in order to create a three-dimensional virtual model to support education and historical interpretation



Site Layout



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Case Study (cont'd)

- Full error propagation performed on a nominal 0.1 x 0.1 m grid (525,674 points) to assess quality of the full point cloud mosaic
- Budget includes:
  - Setup and backsight station errors from network adjustment
  - Levelling, pointing and optical centring errors
  - Observation errors
  - Beamwidth error
- Some of the relevant parameters (Riegl LMS-Z210)

Parameter	Numerical Value
Range σ	±(25 mm + 20 ppm)
Vertical σ	±0.036° (±130″)
Horizontal σ	±0.018° (±65″)
Laser Beamwidth (δ)	3 mrad (619″)
Beamwidth σ	±155″

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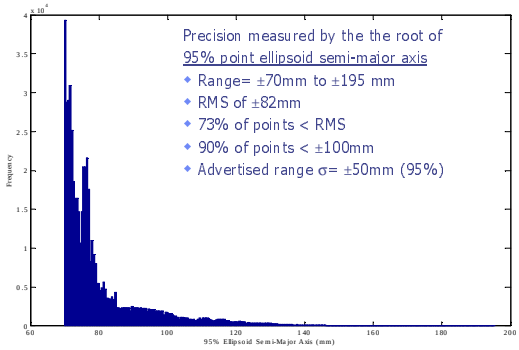
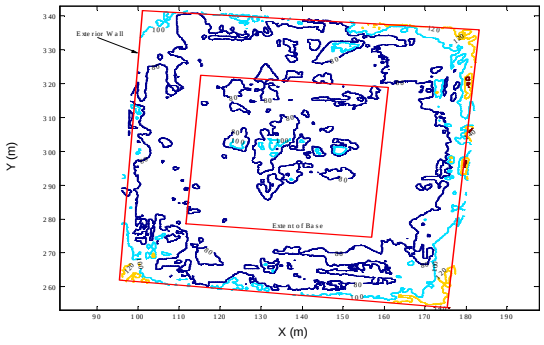
Point Cloud Error Histogram



Precision measured by the the root of 95% point ellipsoid semi-major axis

- Range= ±70mm to ±195 mm
- RMS of ±82mm
- 73% of points < RMS
- 90% of points < ±100mm
- Advertised range σ= ±50mm (95%)

Ayutthaya 95% error surface contours (contours in mm)



Summary

- The subject of error propagation has seemingly been a casualty of the rapid emergence of the very impressive TLS technology
- Many of the error sources in the proposed budget are fundamental to elementary surveying
- A model has been proposed for laser beamwidth uncertainty, which may be significant
- The estimated precision in the Ayutthaya network was much poorer than the advertised range precision—which is often taken to be gospel—for the scanner in question
- However, the attained precision was more than adequate for this type of recording project
- Preanalysis recommended for any recording project in order that realistic project specifications be set and fulfilled.

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