

Iterative Sampling of the Sunlight Field

Huiyu Luo, Xiangming Kong, and Gregory Pottie
Electrical Engineering Department, UCLA

Overview of the problem

Sunlight field under forest canopy

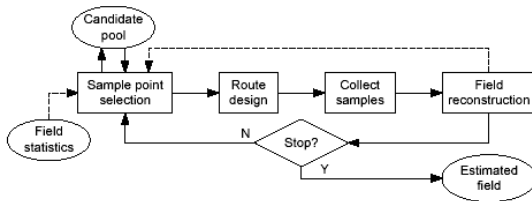
- It influences plant growth in a forest ecological system; is important for energy harvesting applications.
- Provides a good realization of two dimensional random field.
- Reconstruct mean phenomena
 - Reconstruction of instantaneous field is formidable but not necessary in many application
 - Obtain field average over short time interval
- Determine confidence level based on fidelity improvements.
- Optimally allocate limited resource.

Statistical model assisted iterative sampling

- Exploit different level of information
 - Extract statistical model from global information
 - Allocate sampling point based on local derivative information and the statistical model
- Iteratively sample and reconstruct mean field until fidelity requirement is achieved
 - Node mobility enables the iterative sampling approach
 - Determine new sampling location from previous reconstructed field
 - Reconstruct field after each round of sampling process

Overview of the algorithm

Block diagram of the iterative algorithm



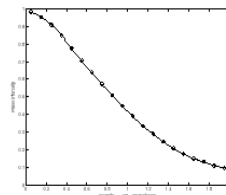
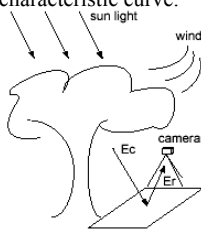
Descriptions of Functional blocks

- Field statistics: build statistical model by exploring field data
- Candidate pool: generate candidates for new sampling points
- Field reconstruction: thin plate spline interpolates scattered data
- Sample point selection: Select sample points based on statistical model and bending energy
- Route design: given a set of sampling point, construct a minimum cost route to cover all of them.
- Collect samples: conduct data measurements.

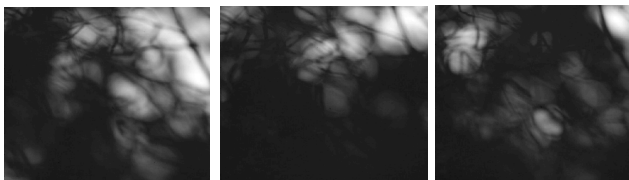
Experiment and simulation results

Multi-scale experiment setup

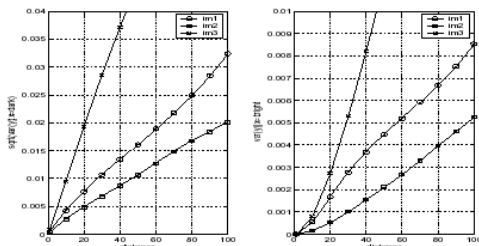
- A homogeneous screen is placed to create a reflection E_r proportional to incident light E_c .
- Camera captures the reflection on its CCD
- The image pixel intensity is transformed to E_r using camera's characteristic curve.



- Global scale field data.

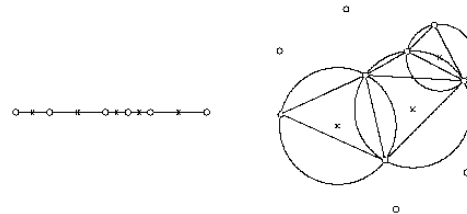


- Statistical model based on the variogram.



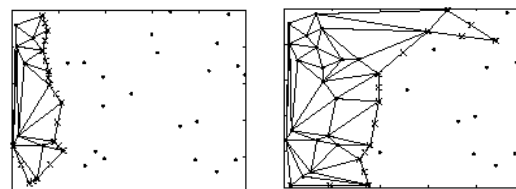
Candidate pool: circle fitting

- Minimum distance from a candidate to existing samples is maximized;
- Distribution follows that of the existing samples;
- Total number of candidates are bounded;
- Efficient algorithm exists – Front-advancing algorithm



- The inscribed triangles form a plane graph
- Use Euler's formula to bound the number of sampling points.

Front advancing algorithm



Sample point selection

- Cost function
 - C1: uncertainty based on source statistical model;
 - C2: local variation based on field derivatives.
- Convergence to the true field: $\|e\| < C \cdot \sqrt{I(f-s)} \cdot h$
- Use bending energy $I(s)$ as the criterion to gauge the gain provided by new new sampling points.