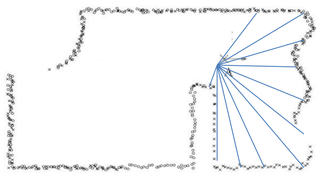
Project 2: A Space-Carving Approach to Surface Estimation

D. Santosh Kumar

What is it about?

- Reconstructing the shape of a general scene from an arbitrary set of points
- Challenge: Efficient solutions that can cope with sparse/missing data yet achieve good surface fit
- Application: Mobile Robotics, Computer Vision/Graphics

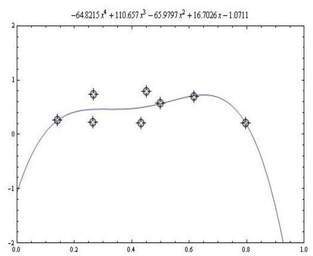


2D Point Set

3D Point Set

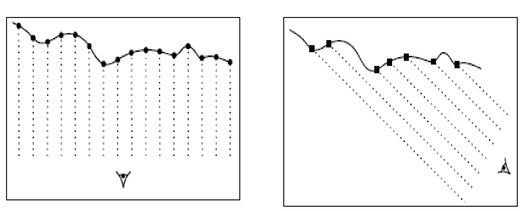
Previous Work

- Most approaches are based on implicit or level set representations
- Involve a least squares formulation
- Number of parameters increases with complexity

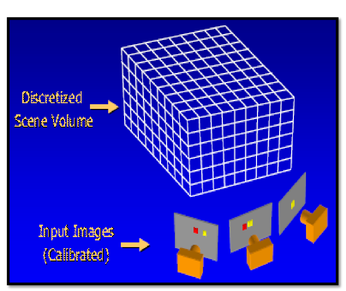


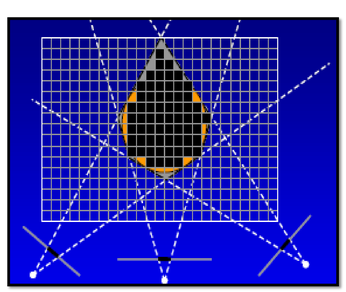
A different way to look at the problem!

- Define interior and exterior points w.r.t the data points
- Formulate it as a two-class data classification problem
- Can do even better by including the ray-information connecting the data points and the sensor location



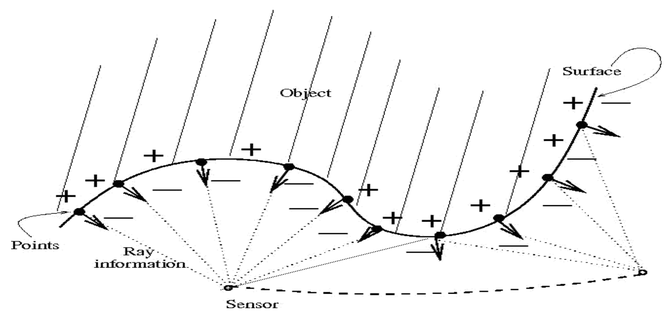
- Idea motivated from 'Space-Carving' technique in computer vision





Max-Margin Formulation

- Similar to a support-vector (SVM) formulation
- Given positive and negative data samples (x_i, y_i), find the max-margin separating hyper plane (w)
- Add ray-information as an infinite set of constraints
- But only need max violated constraint (similar to robust least squares seen in class!)



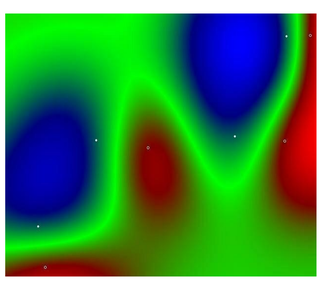
$$argmin_w \ \frac{\lambda}{2}||w||^2 + \frac{1}{N}\sum_i \xi_i \quad subject\ to$$

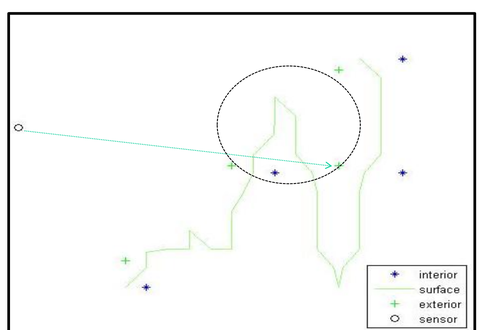
$$w.x_i \geq 1 - \xi_i^+ \quad for\ \ y_i = 1,$$

$$\max\ w.x_i \leq -1 + \xi_i^- \quad for\ \ y_i = -1.$$

Online Sub-Gradient Method

- Above problem is an infinite constraint convex optimization problem
- Could be solved using constraint generation techniques
- Use online kernel-based sub-gradient method as efficient and fast
- Basic Idea: Update current solution by following the negative of the (sub-)gradient at every iteration
- Overall Algorithm is quite simple and easy to implement

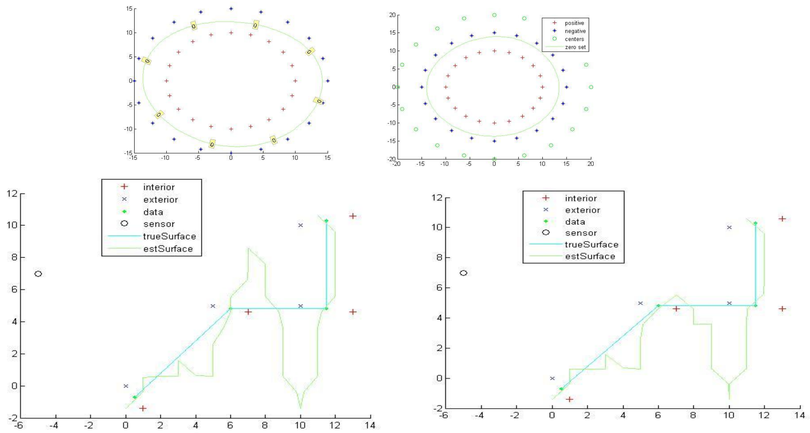




Utility of Ray Information

Results

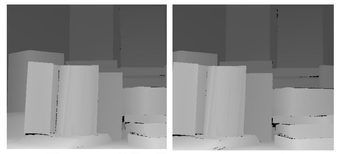
- Performed experiments on simulated, camera, and laser data



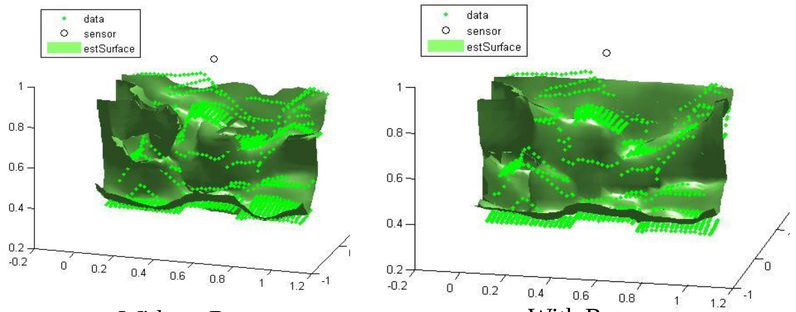
Without Ray

With Ray

Stereo Pair



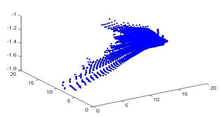
Dense 3D Reconstruction



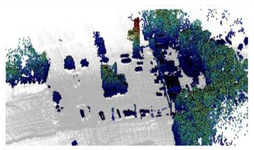
Without Ray

With Ray

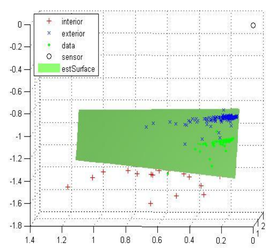
Scene



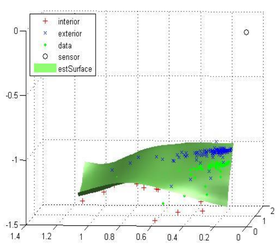
Laser Data



Aerial Data



Without Ray



With Ray

Conclusion - A novel formulation exploiting ray-based information to obtain improved surface estimation result