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SIGNAL & IMAGE PROCESSING LAB

Detection and Tracking of Deforming Objects Using Active Contours

Project Presentation

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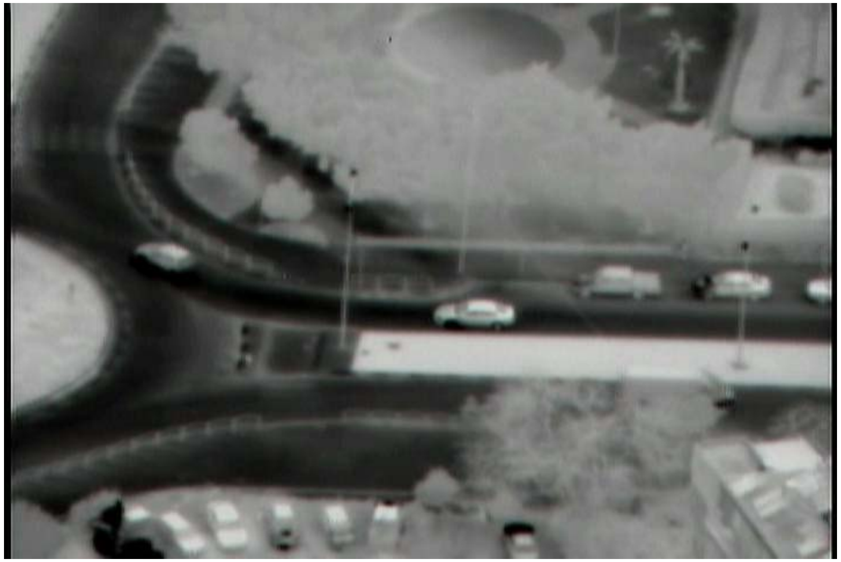
Project Goals

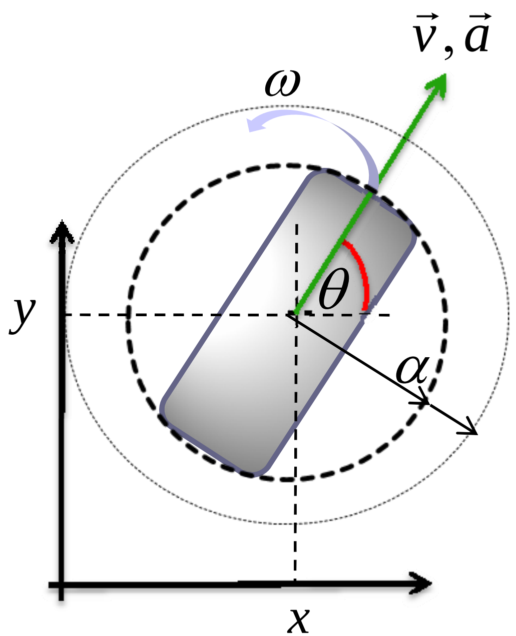
- ***Tracking moving and deforming objects*** in the presence of:
  - Noise & Clutter
  - Occlusions

- The tracking of an object can be separated into:
  - Target acquisition
  - Tracking the object’s parameters evolution



The Object's State

- The object state is represented by a ***contour*** which contains the following information:



$$S_n = \begin{pmatrix} (x, y) \\ (v_x, v_y) \\ (a_x, a_y) \\ \theta \\ \omega \\ \alpha \\ \{LLE_k\} \end{pmatrix} \begin{matrix} \text{Position} \\ \text{Velocity} \\ \text{Acceleration} \\ \text{angle of orientation} \\ \text{Angular velocity} \\ \text{Size} \\ \text{LLE shape coefficients} \end{matrix}$$

- ***Locally Linear Embedding*** is a method which incorporates prior knowledge about the shape.

The Bayesian Model

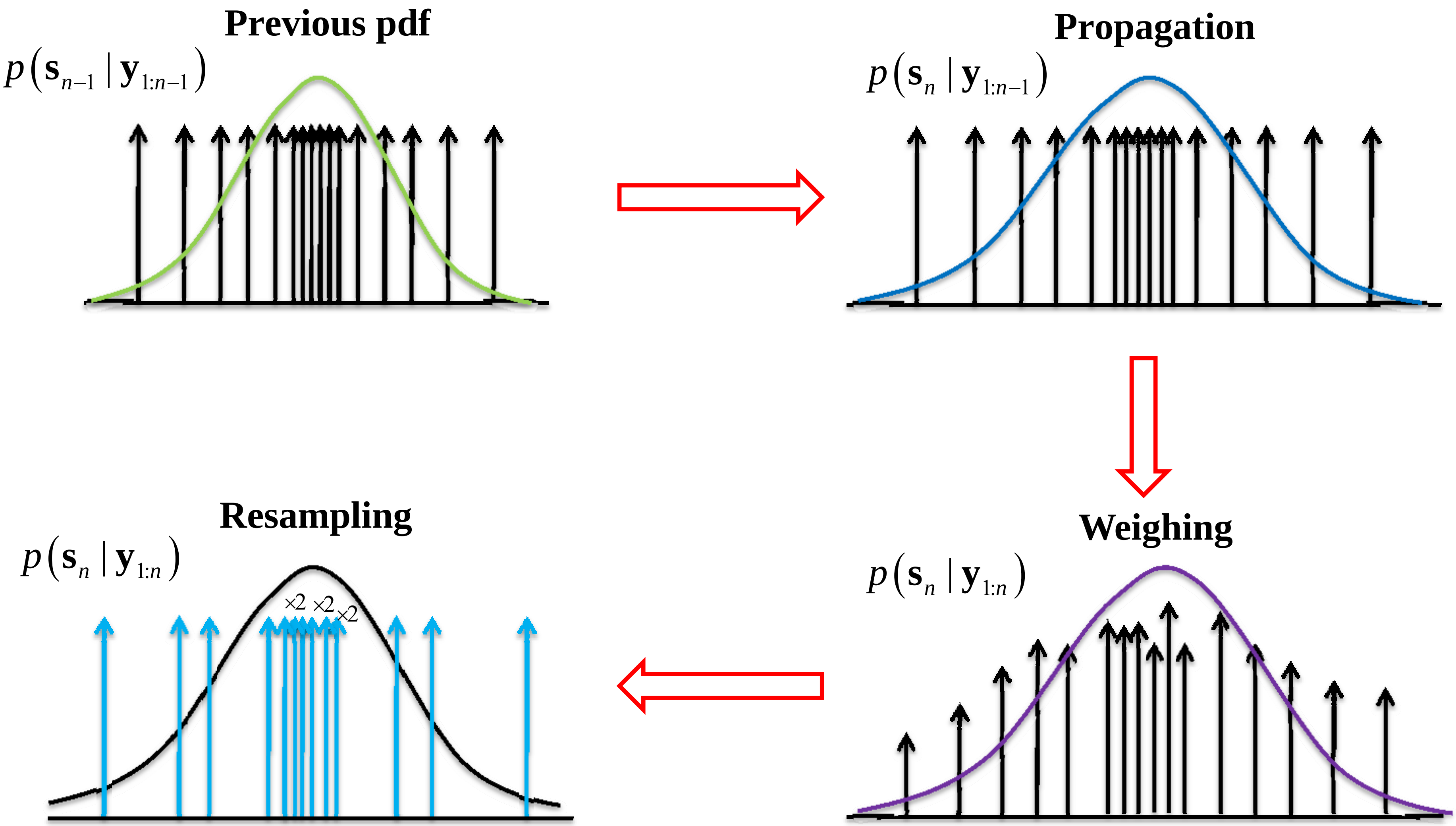
- **Prediction** (propagation):

$$\underbrace{p\left(\mathbf{s}_n \mid \mathbf{y}_{1:n-1}\right)}_{\text{predicted pdf}} = \int \underbrace{p\left(\mathbf{s}_n \mid \mathbf{s}_{n-1}\right)}_{\text{propagation model}} \underbrace{p\left(\mathbf{s}_{n-1} \mid \mathbf{y}_{1:n-1}\right)}_{\text{previous pdf}} \; d\mathbf{s}_{n-1}$$

- **Measurement Update** (weighing):

$$\underbrace{p\left(\mathbf{s}_n \mid \mathbf{y}_{1:n}\right)}_{\text{current pdf}} \propto \underbrace{p\left(\mathbf{y}_n \mid \mathbf{s}_n\right)}_{\text{observation probability}} \underbrace{p\left(\mathbf{s}_n \mid \mathbf{y}_{1:n-1}\right)}_{\text{predicted pdf}}$$

Particle Filter

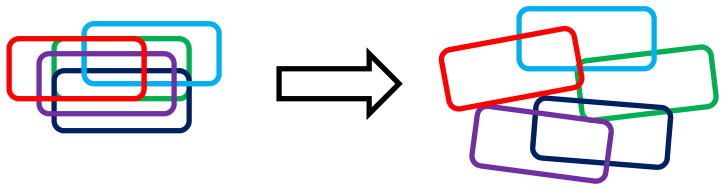


Prediction by Propagation

- We propagate the particles of the previous object state according to a ***dynamic model***

The Dynamic Model

$$\hat{\mathbf{s}}_n^i = \begin{pmatrix} 1 & 1 & & 0 & & & \\ & 1 & 1 & & \ddots & & \\ 0 & & 1 & 0 & & \ddots & \\ & \ddots & & 1 & 1 & & 0 \\ & & \ddots & & 1 & 0 & \\ & & & \ddots & & 1 & 0 \\ & & & & 0 & & 1 \end{pmatrix} \begin{pmatrix} \overline{\mathbf{x}} \\ \overline{\mathbf{v}} \\ \overline{a} \\ \theta \\ \omega \\ \alpha \\ \{LLE_k\} \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ n_a \\ 0 \\ n_\omega \\ n_\alpha \\ 0 \end{pmatrix}$$



Weighing

- The observation probability of each particle is defined by:

1. p_{im} : segmentation quality of the contour using ***"Bhattacharyya Distance"***
2. p_{mot} : amount of ***motion*** of the particle

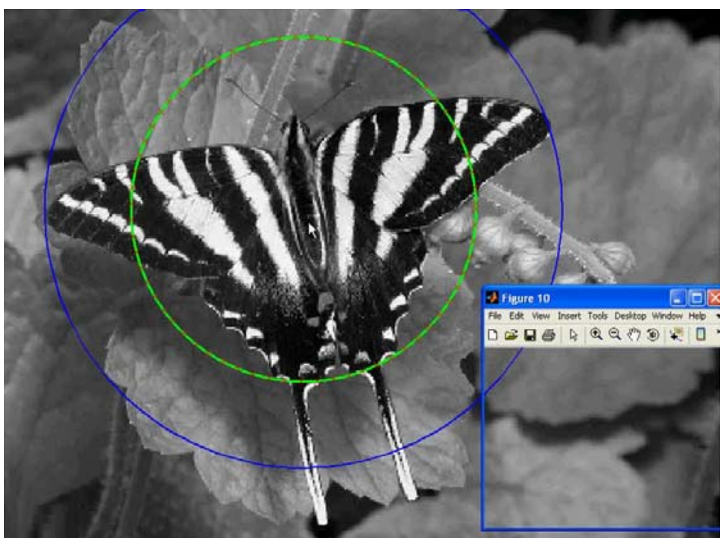
- The total weight assigned to each particle:

$$p(\mathbf{y}_n \mid \mathbf{s}_n) = p_{im}(\mathbf{y}_n \mid \mathbf{s}_n)\, p_{mot}(\mathbf{y}_n \mid \mathbf{s}_n)$$

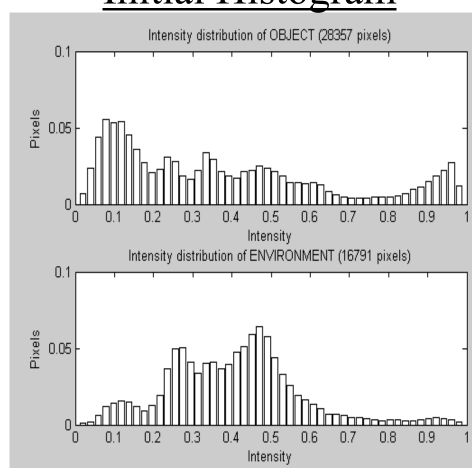
Bhattacharyya Distance

- We measure the segmentation quality of each contour according to the Bhattacharyya Distance: $B = \int_Z \sqrt{P_{in}(z) P_{out}(z)} dz$

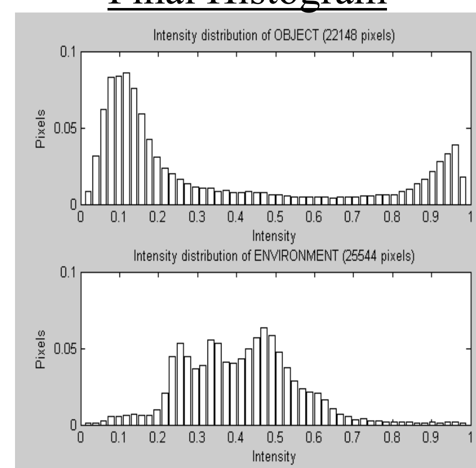
- It is possible to minimize B using variation calculus:



Initial Histogram



Final Histogram

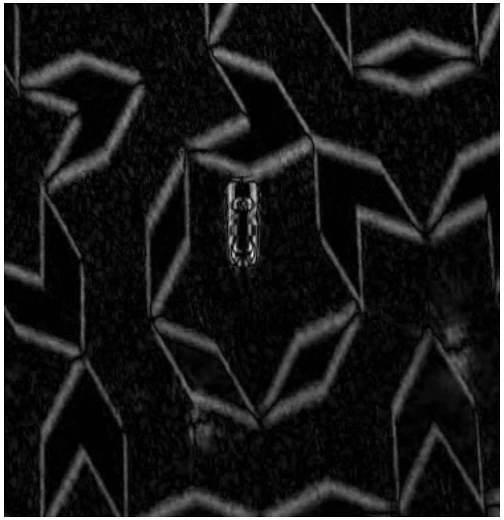


Motion Detection

- We measure the amount of motion of each particle by analyzing the difference image of two consecutive frames.

- It is possible to locate the object using motion detection.

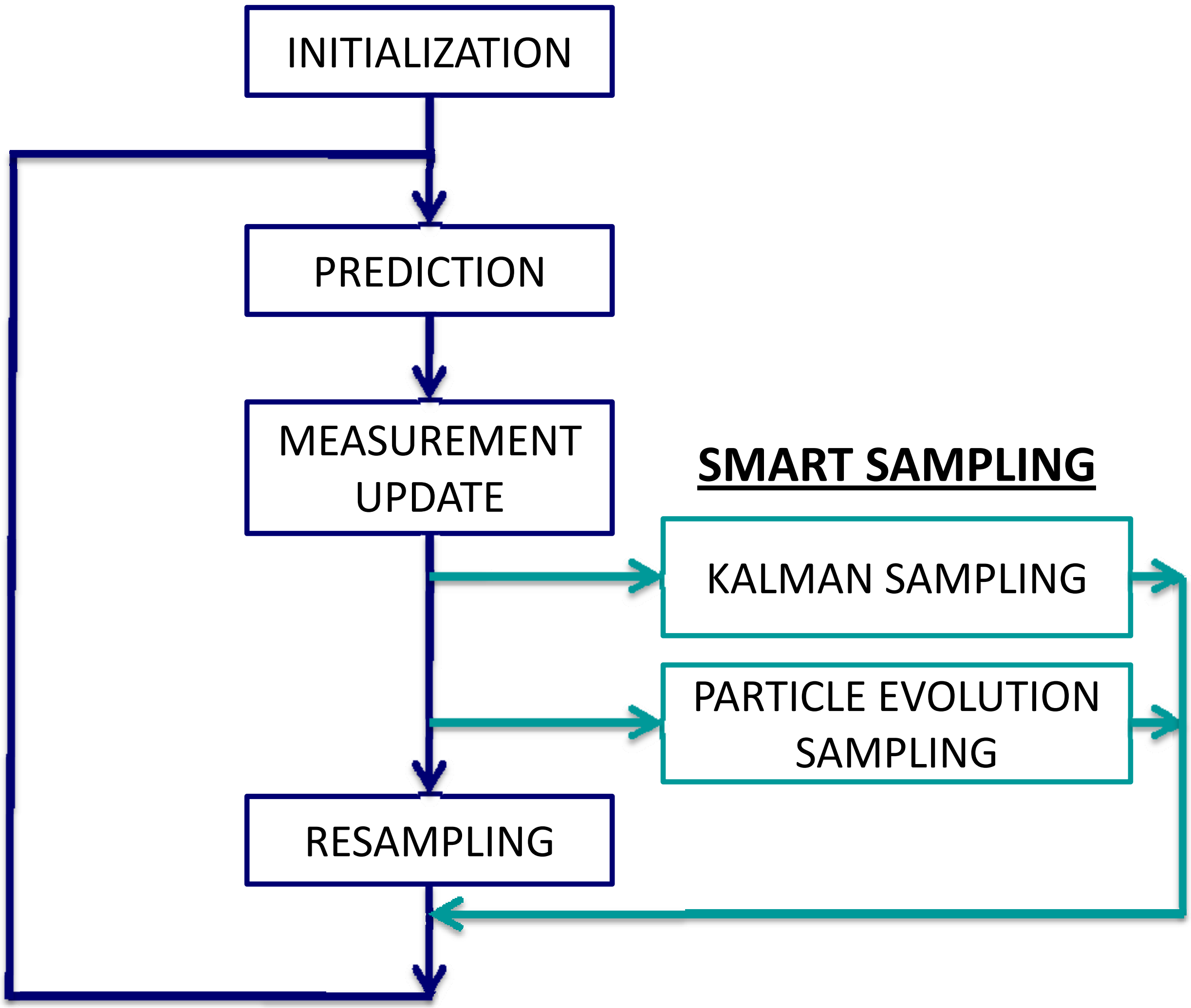
initial difference image



after filtering

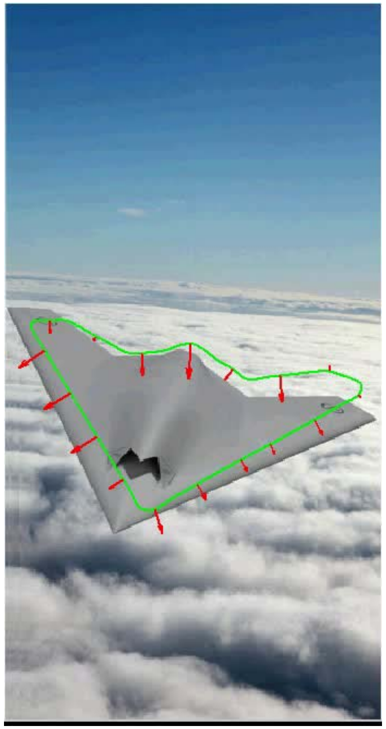
motion detection

Tracking Algorithm Scheme



Evolution

- **First Method of Smart Sampling**:
  Evolution of the best particles by segmentation:



Target Location Smoothing

- The location of the object and its dynamics are estimated by taking the average location and movement of the cloud of particles.

- This noisy observation is smoothed using a ***Kalman Filter***.

- **Second method of Smart Sampling**:

  Sampling a cloud of particles from the Kalman Filter estimation.

Particle Contours

Complete Occlusion

Two Complete Occlusions

Simple Tracking & Complete Occlusion

Tracking a Tractor

Toggle – IR Color Inversion

Future Directions

- Improving the image segmentation

- Integrating prior knowledge about the movement of the camera into the dynamic model & Incorporating image registration

- Real-Time implementation of the algorithm