

# A DISTRIBUTED VISION SYSTEM FOR BOAT TRAFFIC MONITORING IN THE VENICE GRAND CANAL

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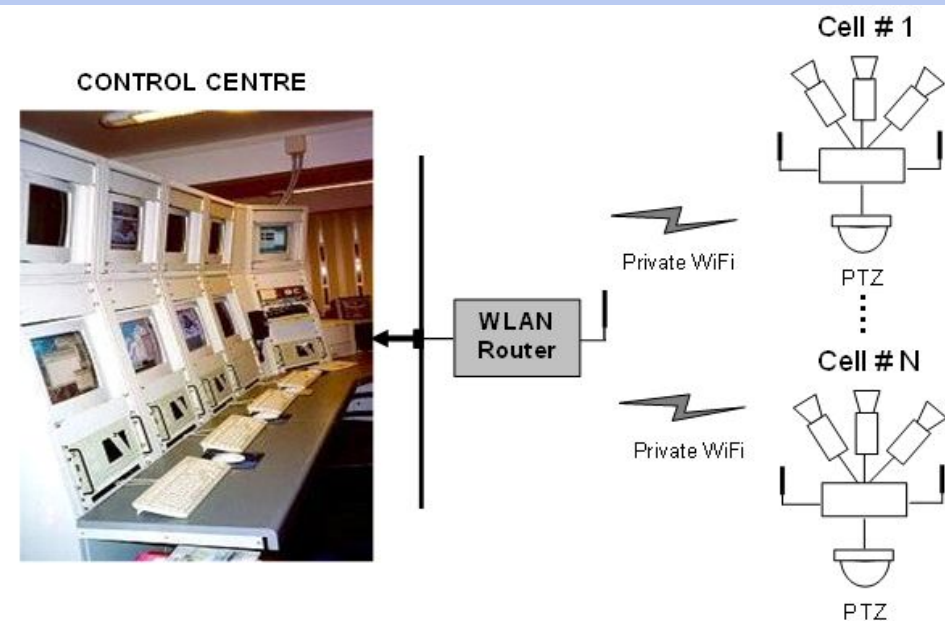
CITTA' DI  
VENEZIA



# ARGOS Project Overview

## Automatic Remote Grand Canal Observation System

The *ARGOS* system is going to control a waterway of about 6 km length, 80 to 150 meters width, through 13 observation posts (Survey Cells).

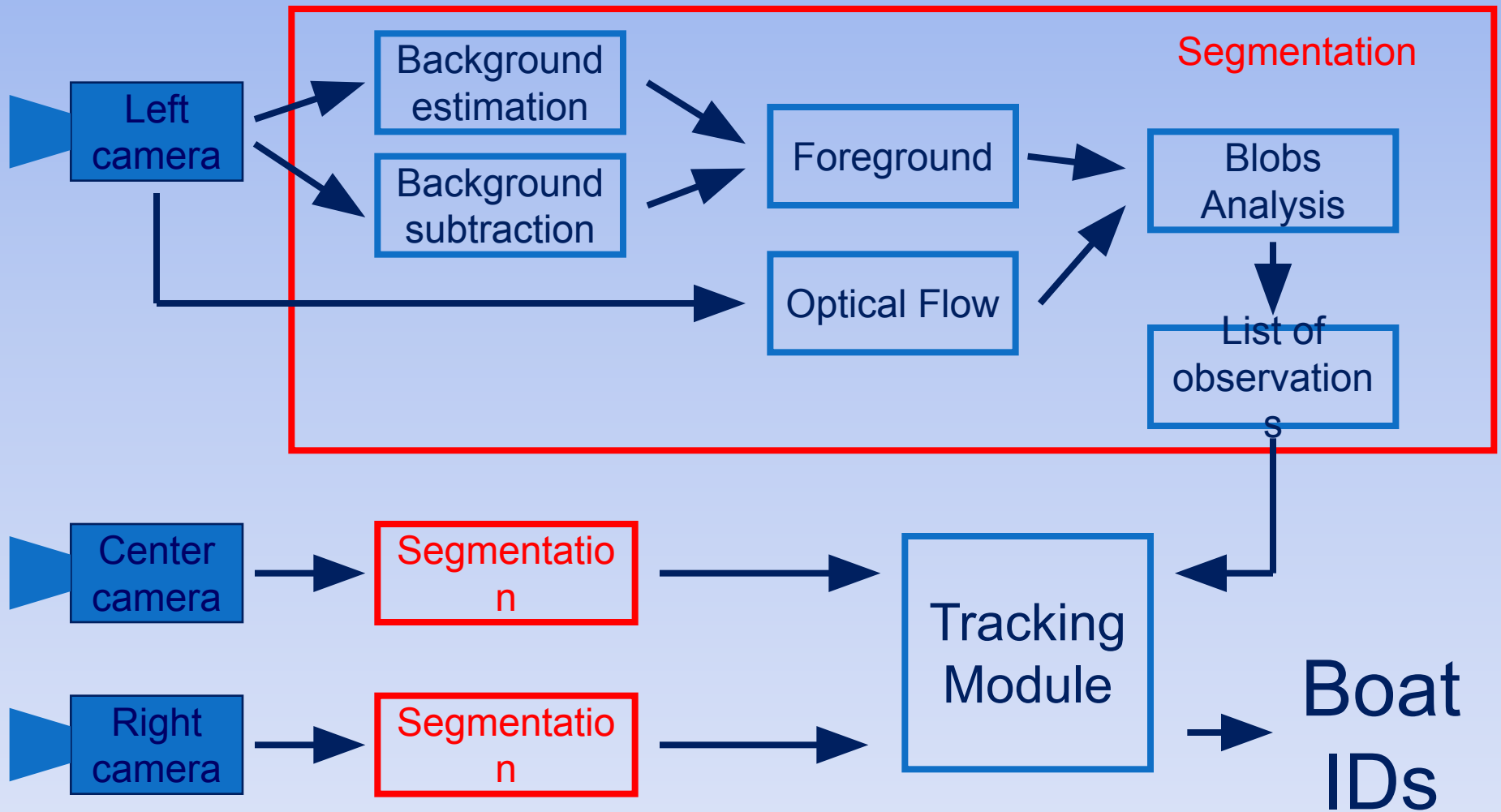




# Survey Cells



# SC Software Architecture



# Background Estimation

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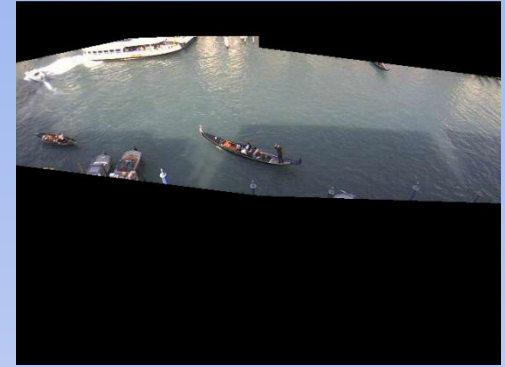
## Problems:

- gradual illumination changes and sudden ones (clouds)
- motion changes (camera oscillations)
- high frequency noise (waves in our case)
- changes in the background geometry (parked boats).

## Approach:

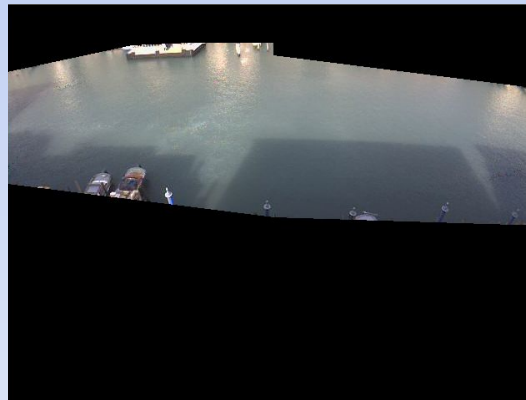
- computation of color distribution of a set of frames
- highest component form the background

# Background Estimation (2)



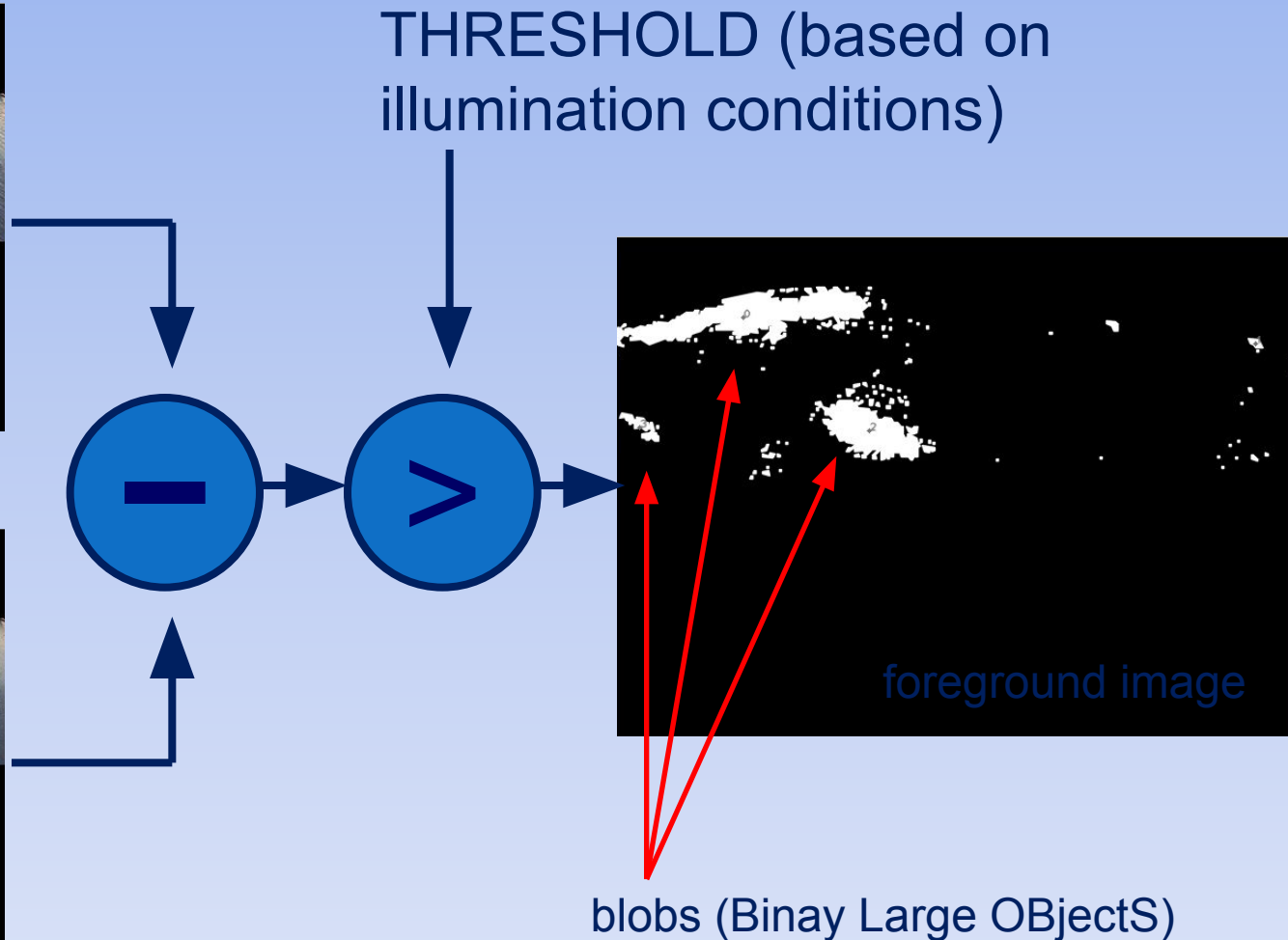
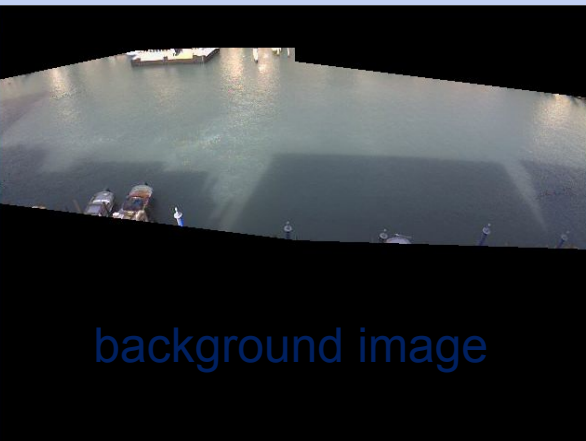
Set S of 20 images from a camera

Mask for cutting off  
buildings from  
computation



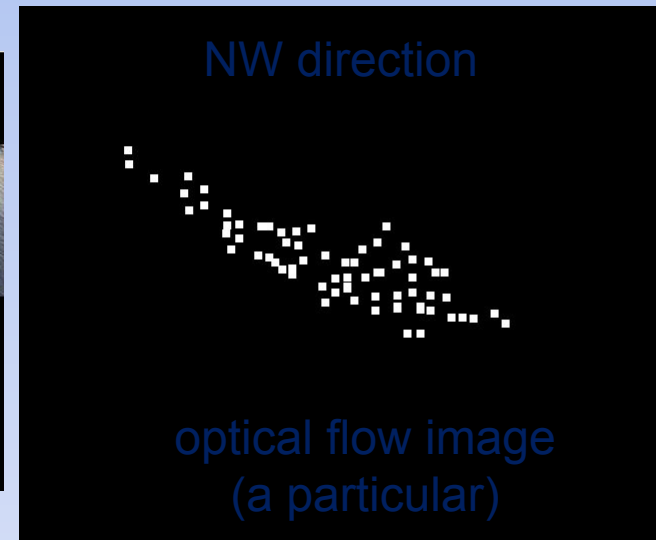
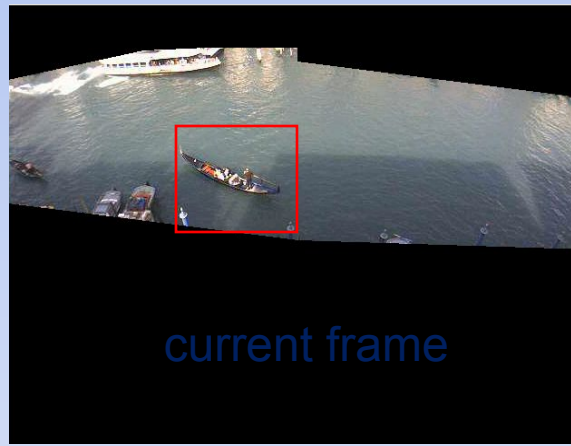
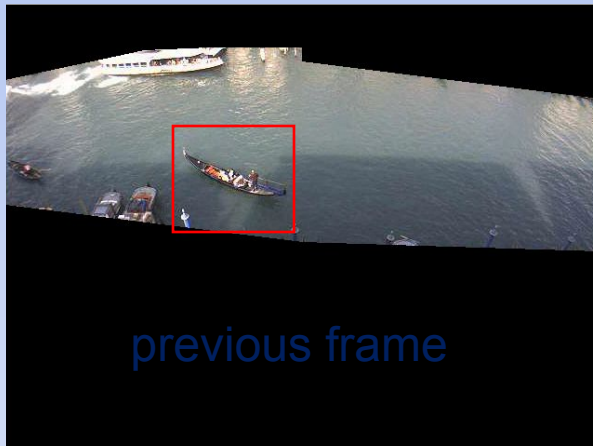
Background Image  
computed from S  
(the image display  
only the higher  
gaussian values)

# Background Subtraction



# Optical Flow Computation

We use a sparse iterative version of Lucas-Kanade optical flow in pyramids ([Bouget00]). It calculates coordinates of the feature points on the current video frame given their coordinates on the previous frame. The function finds the coordinates with sub-pixel accuracy. Every feature point is classified into one of the four principal directions NE, NW, SE, SW.





# Segmentation

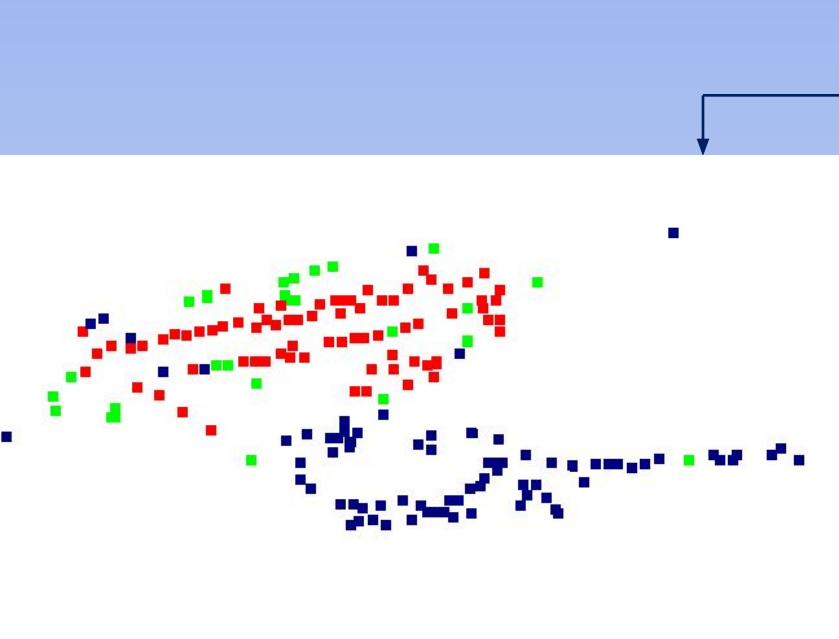
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Exploiting the foreground image and the optical flow image, for every blob we obtain

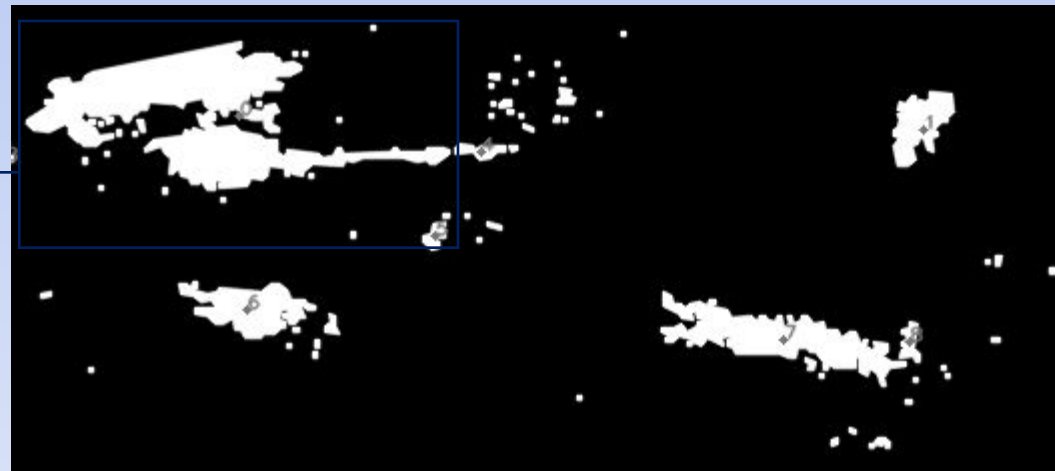
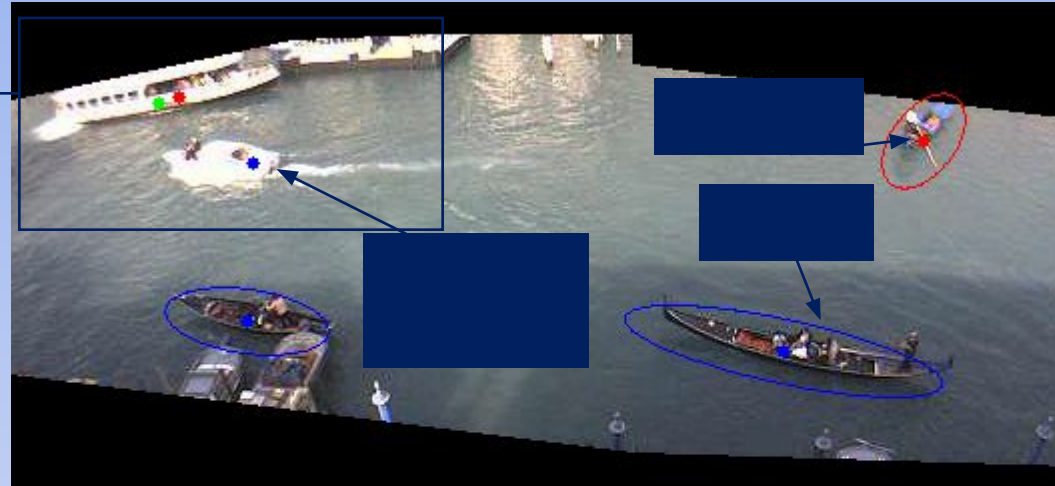
- its centroid (that is  $(x, y)$  position into the current frame)
- its direction (and consequently the probability of under segmentation if the blob is classified into more than one of the principal directions)
- its ellipse approximation (and consequently its dimensions in meters through homography matrices)

- ✓ Blob filtering: If a blob is too small according to the minimal dimension a boat must be in order to navigate the Gran Canal)
- ✓ Under segmentation: If a blob has two or more directions we compute the center of mass and the variance for every of the four predetermined principal direction.

# Segmentation (2)

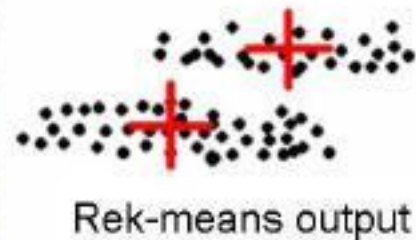
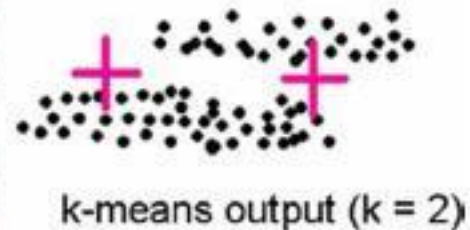
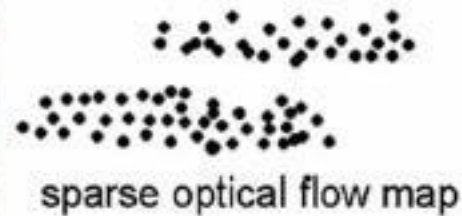


blue → NW direction  
red → NE direction  
green → SE direction

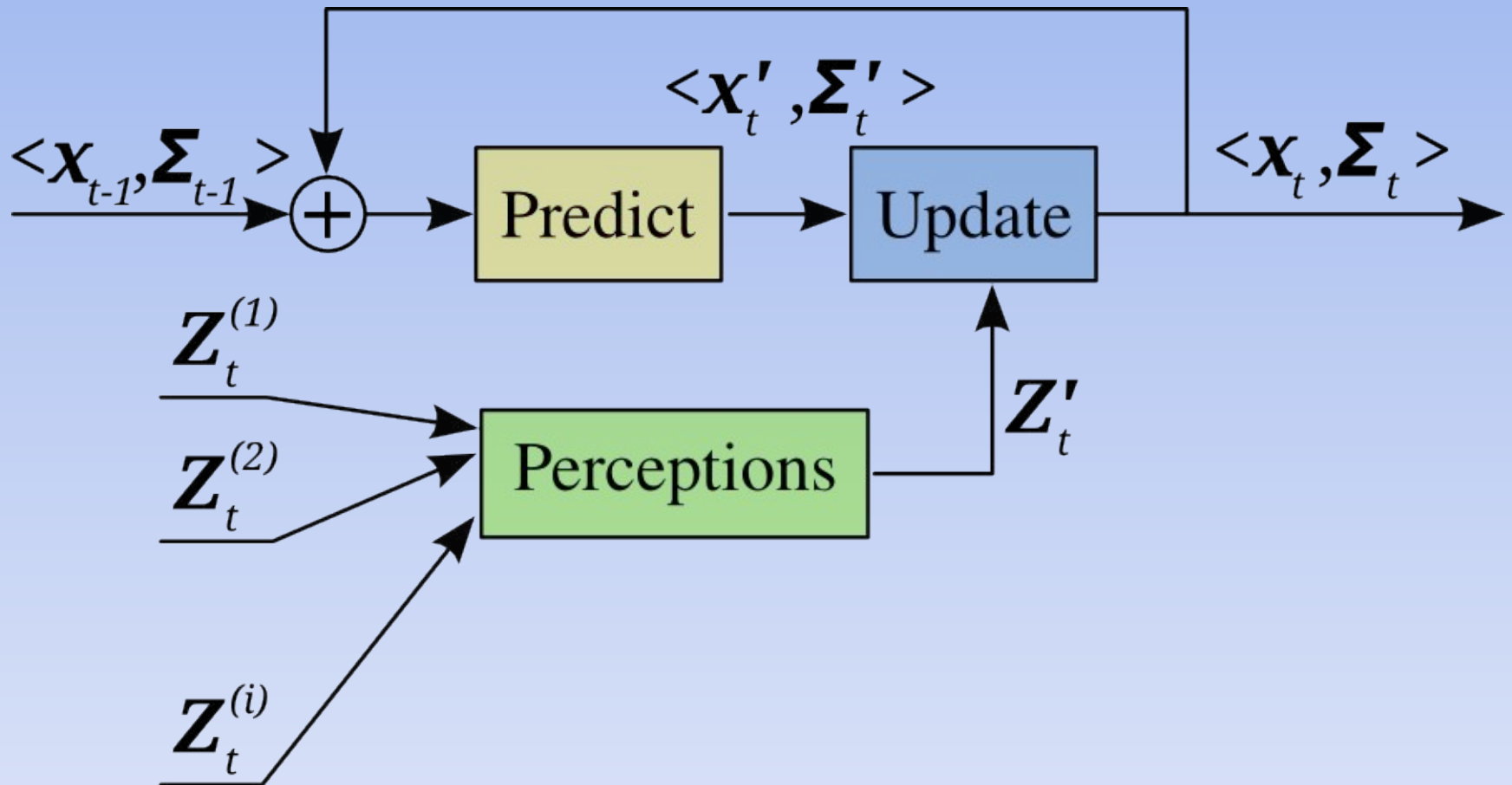


# Segmentation (3)

Unsupervised clustering with Rek-means [Bloisi, Iocchi 2008]



# Tracking module



# Tracking module

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## Single-hypothesis Tracking

We use a set of Kalman Filters (one for each tracked boat).

Data Association: Nearest Neighbor rule

Track formation: unassociated observations

Track deletion: high covariance in the filter

## Multi-hypothesis Tracking

Track splitting: in ambiguous cases (data association has multiple solutions)

Track merging: high correlation between tracks

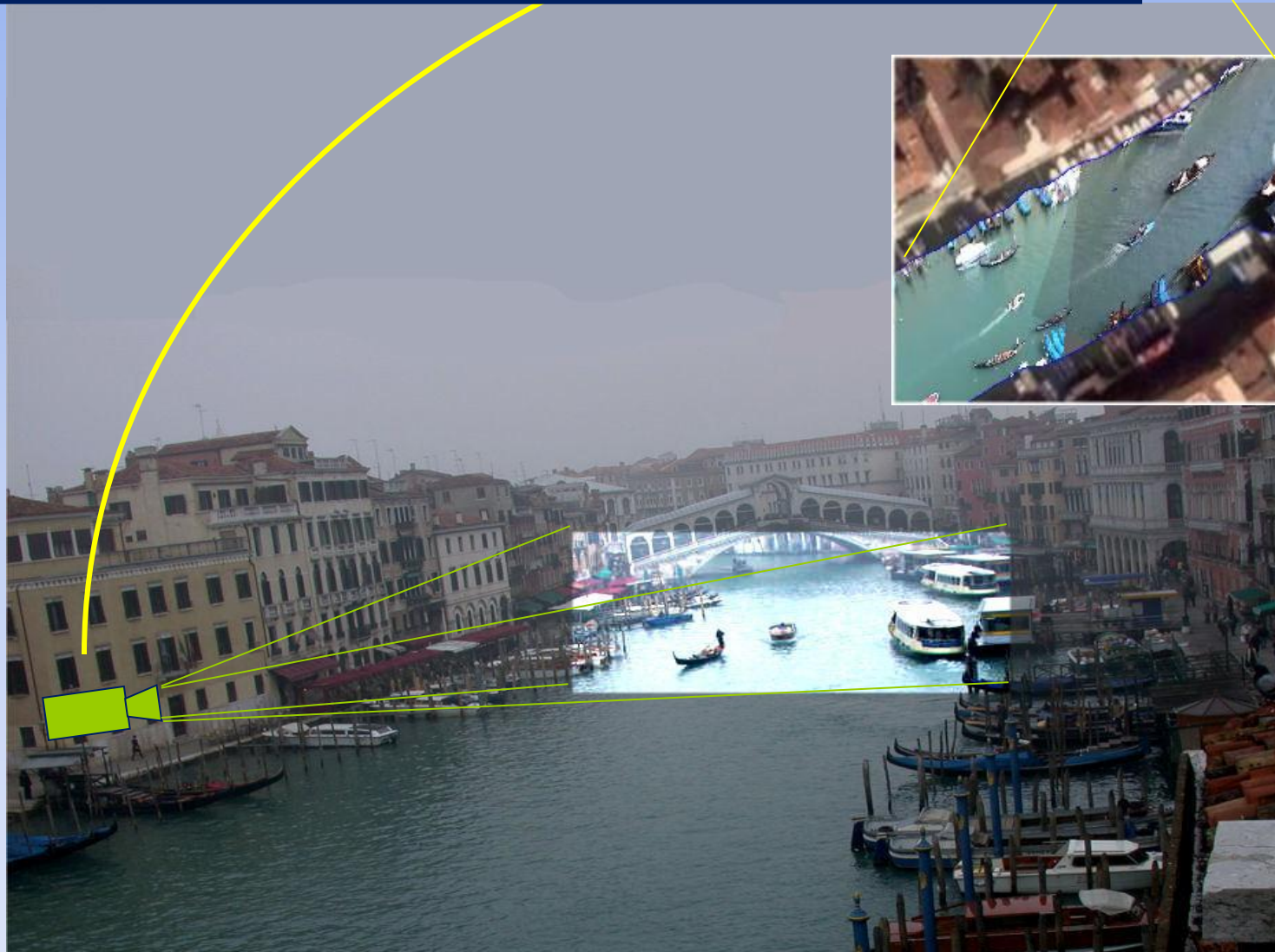


# Multi hypothesis tracking (2)



3 tracks (240, 247, 285)  
only 1 actual observation (285)

# Rectification

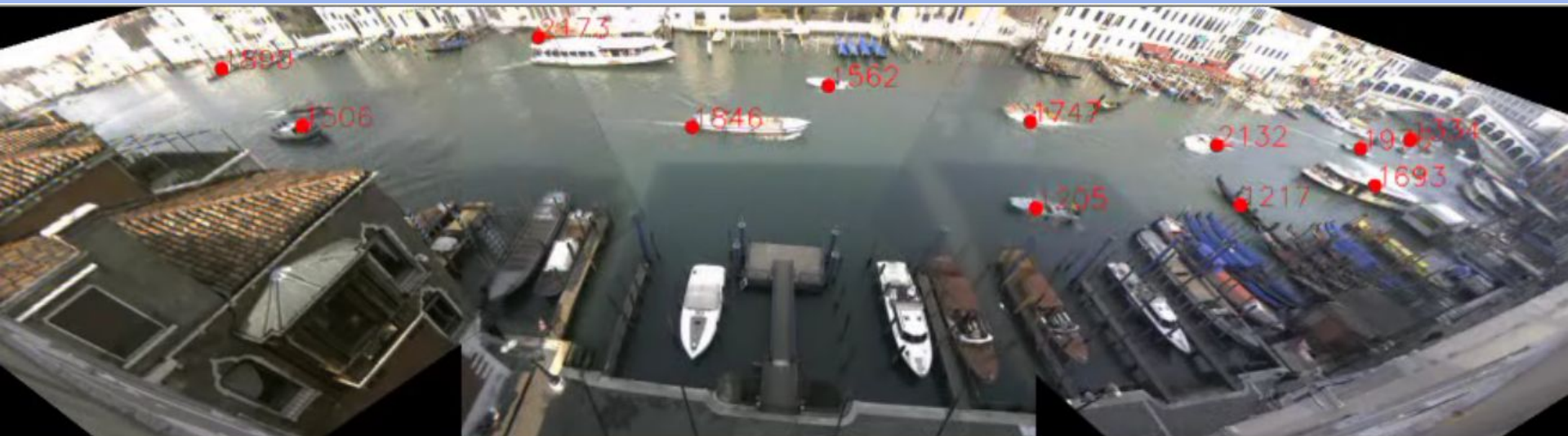




# Unified Views



# Panoramic view



## PTZ Camera





# DENSITA' DI TRAFFICO – TEMPO REALE

DENSITA' MEDIE E MASSIME DEL TRAFFICO				
02/11/2006 ore 11,30				
Numero Totale Imbarcazioni in Canal Grande: 121				
Tratto	Da	A	Densità media	Densità à max
1	Ponte Libertà	Scomensera	5	8
2	Scomensera	Ponte Calatrava	6	12
3	Ponte Calatrava	Ferrovia	8	10
4	Ferrovia	Cannaregio	10	18
5	Cannaregio	Santa Fosca	6	18
6	Santa Fosca	Ca D'oro	4	4
7	Ca D'oro	Rialto	12	16
8	Rialto	San Silvestro	5	8
9	S.Silvestro	San Tomà	14	26
10	San Tomà	Ca' Rezzonico	21	25
11	Ca' Rezzonico	Accademia	8	9
12	Accademia	Salute	14	18
13	Salute	Bacino S.Marco	8	8



# Traffic control



# Multi target tracking





# Count and speed estimation

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# Experimental Results

TRACKING EVALUATION (avg. error per minute)

	Day	Duration (min.)	Meteo	FN	FP-R	FP-W
1	07/01/2008	130	Cloud/Fog	0.062	0.215	0.531
2	08/01/2008	130	Sun/Cloud	0.038	0.192	0.431
3	15/01/2008	130	Sun/Cloud	0.031	0.154	0.323
4	31/01/2008	120	Cloud	0.075	0.158	0.400
5	01/02/2008	120	Cloud/Fog	0.000	0.150	0.392
6	04/02/2008	120	Cloud/Rain	0.000	0.200	0.342
7	05/02/2008	120	Sun/Cloud	0.000	0.225	0.392
8	06/02/2008	120	Sun/Cloud	0.017	0.200	0.333
9	07/02/2008	120	Sun	0.033	0.167	0.442
10	11/02/2008	120	Sun	0.017	0.292	0.375
11	12/02/2008	120	Sun	0.025	0.158	0.383
12	13/02/2008	120	Sun	0.033	0.267	0.367
13	14/02/2008	120	Sun	0.067	0.108	0.300
14	15/02/2008	120	Sun	0.000	0.150	0.250
<b>Avg.</b>	-	-	-	<b>0.028</b>	<b>0.188</b>	<b>0.375</b>

# Experimental Results

## COUNTING EVALUATION (percentage error)

Video	<i>n</i> boats	FN	FP	count accuracy %
20070928_1335_c09	47	0.11	0.04	93.6
20071030_1015_c07	37	0.05	0.03	97.3
20070928_1335_c10	36	0.11	0.06	94.4
20071031_1000_c03	35	0.17	0.03	85.7
20071030_1035_c04	35	0.06	0.06	100.0
20071030_1025_c05	33	0.03	0.00	97.0
20071214_0939_c08	31	0.10	0.00	90.3
20071030_1355_c12	29	0.03	0.03	100.0
20071210_1300_c06	17	0.12	0.00	88.2
20071213_1130_c03	17	0.00	0.06	94.1
20071030_1335_c10	14	0.07	0.07	100.0
20071210_1145_c01	9	0.11	0.00	88.9
<b>Avg.</b>	<b>28.3</b>	<b>0.08</b>	<b>0.03</b>	<b>94.1</b>



# System Performance

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ARGOS (DualCore 2.4 GHz)

3 video streams 640x480 -> 6.5 fps

HYDRA (QuadCore 2.4 GHz)

4 video streams 640x480 -> 6 fps

# Boat classification

ARGOS\_public dataset

20 classes

4774 training images

1686 test images

image size: 118 x 224 x 3

Noisy unbalanced dataset

## ARGOS BOAT CLASSIFICATION CATEGORIES

### PEOPLE TRANSPORT



Lancia fino a 10m



Lancia fino a 10m  
bianca



Lancia fino a 10m  
marrone



Lancia maggiore di  
10m



Lancia maggiore di  
10m bianca



Lancia maggiore di 10m  
marrone



Alilaguna



Vaporetto ACTV



Motoscafo ACTV

### GENERAL TRANSPORT



Motobarca



Mototopo



Raccolta Rifiuti



Motopontone  
rettangolare

### PLEASURE CRAFT



Barchino



Patanella



Sanpiero



Cacciapesca



Topa

### ROWING TRANSP.



Gondola



Sandalo a remi



Caorlina

### PUBLIC UTILITY



Polizia



Ambulanza



Vigili del Fuoco