

Preliminary Program - Papers

Program

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262	A Review of Mobile Phone Usage in Enclosed Areas and RF Safety Guideline	TT-EAH-2
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265	Analysis and Simulation of Speed Control for Two-Mass Resonant System	TT-MS-3
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Preliminary Program

Program tracks

Program papers

			Tsavo	Samburu/Amboseli	Cub	Lioness	Nyama Choma Ranch	Mantu poolside	Tivuli Terrace
Tue 22 Sep	18:30	21:00							Welcome Reception
Wed 23 Sep	08:30	08:45		Welcome KN: Mugo Kibati					
	08:45	09:30							
	09:30	09:45						Break	
	09:45	11:15	TT-CA-1	TT-CSP-1	TT-EES-1	TT-EIR1			
	11:15	11:30						Break	
	11:30	13:00	TT-CA-2	TT-CSP-2	TT-EA-1	TT-EIR-2			
	13:00	14:20					Lunch		
	14:20	15:50	TT-CA-3	TT-CSP-3	TT-EAH-1	TT-MS-1			
	15:50	16:05						Break	
	16:05	17:35	TT-CA-4	TT-CSP-4	TT-EAH-2	TT-MS-2			
Thu 24 Sep	08:30	09:15		KN: Dietmar Dietrich					
	09:15	09:30						Break	
	09:30	11:00	TT-EPS-1	TT-CSP-5	TT-CIS-1	TT-MS-3			
	11:00	11:15						Break	
	11:15	12:45	TT-EPS-2	TT-CSP6	TT-CIS-2	TT-EDC-1			
	12:45	14:05					Lunch		
	14:05	15:35	TT-EPS-3	TT-CSP-7	TT-LEO-1	TT-EDC-2			
	15:35	15:50						Break	
	15:50	17:20	TT-EPS-4	TT-PED-1	TT-EM-1				
	18:30	22:00						Gala Dinner	

Fri 25 Sep	08:30	09:15	KN: Daniel Foty			
	09:15	09:30	Break			
	09:30	11:00	TT-EPS-5	TT-PED-2	TT-CMA-1	TT-MCA-1
	11:00	11:15	Break			
	11:15	12:45	TT-EPS-6	TT-PED-3	TT-CMA-2	TT-MCA-2
	12:45	14:05	Lunch			
	14:05	15:35	TT-CS-1	TT-PED-4	TT-IM-1	TT-MCA-3
	15:35	15:50	Break			
	15:50	16:05	Closing			

Preliminary Program - Tracks

Program

Program papers

Code	Name
TT-CA	Control and Automation
TT-CIS	Computer, Information Systems and Software Engineering
TT-CMA	Computational Methods and Applications
TT-CS	Computational Semiotics
TT-CSP	Communication and Signal Processing
TT-EA	Electromagnetics and Antennas
TT-EAH	Engineering Applications and Health
TT-EDC	Electron Devices and Circuits
TT-EES	Education and Engineering Skills development
TT-EIR	Energy and ICT for rural areas
TT-EM	Engineering Management
TT-EPS	Energy and Power Systems
TT-IM	Instrumentation and Measurement
TT-LEO	Lasers and Electro-Optic Systems
TT-MCA	Mobile Computing and Applications for ICT
TT-MEM	Micro-Electro-Mechanical Systems (MEMS)
TT-MS	Modeling and Simulation
TT-PED	Power Electronics and Drives

Statistical Modeling of Video Object's Behavior for Improved Object Tracking in Visual Surveillance

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Abstract – This paper describes a post processing method for detected video objects to enhance the quality of detection. Starting with a basic set of video parameters (such as video frame and time, label of objects, the objects position in pixel, the width and height of object's bounding box) statistical parameters (such as arithmetic mean and standard deviation) about features are computed and with these parameters different statistical models are built. These models can be used to estimate the “normality” of an object's behavior.

I. INTRODUCTION

There are many papers about video data analysis, object recognition, and object tracking in artificial as well as natural video, based e.g. on foreground-background separation methods. Most of them are pixel-based; some of them are object-based. The range of applied methods includes the definition of description languages [5], kernel density estimation [6] [13], mesh representations [7], and spatiotemporal relationships and trajectories [8]. There are also methods working with several layers of processing, e.g. the author of [14] uses a combination of grouping and segmentation within a higher-order statistical framework. A five-step processing region-based classification is introduced in [15], whereas [16] introduces categories of objects in a hierarchical object representation. However, none of them use statistical post processing for analysis of behavior of objects. This paper opens a new direction in this field.

A. Project Background

This work is part of the SENSE¹ project. The SENSE [1] project (Smart Embedded Network of Sensing Entities) will develop methods, tools and a test platform for the design, implementation and operation of smart adaptive wireless networks of embedded sensing components. The relevant parts of the project here are concerned with video surveillance systems [2] and parameter inference [3]. This paper is about combined video data parameter inference.

SENSE is a European project about security for public spaces. A test platform for a civil security monitoring system will be developed as a test application, composed of video cameras and microphones. The test platform will be installed in an airport, to yield real data and performance goals from a realistic test environment. The SENSE network adapts to its

environment, learns (unsupervised learning) the “normality” in the environment in order to detect unusual behavior (e.g. people “lurking” in an area), situations (e.g. baggage left unattended) and to inform the user [3], [4]. An important section in the project is video data analysis. This paper is about post processing the obtained video objects in order to improve the performance of the overall SENSE system.

B. Video Objects

In the video modality of the SENSE system, objects (O) are detected. This can be e.g. persons, group of persons, luggage, or unclassified objects. Each object is surrounded by a bounding box. The input data (these basic data from other components of the SENSE project) for post processing consists of: frame number (F, from 0 to 14; for each second) and time (T, second), ID of objects (L, from 1 to n; video processing has some tracking mechanisms implemented), the object's position (X, Y) in pixel, and its width (W) and height (H). These will be later called basic input data set. To deal with these data we have to research the characteristics of them. Video frame and time changed linear with time. Each new object gets a new label, but different objects have different durations in the data, with changed time some objects appear in the data, some objects disappear and some objects keep longer. The duration of objects is a random variable, it is nonlinear. More interesting and difficult is each object has its own position (X, Y) and the position changed with time or not (object stays only at a position and does not move for a few seconds or minutes, perhaps moves again later), it is a random variable. The width (W) and high (H) of objects is related with different objects and locations, it is random variable again. In the following, this notation will be used for objects:

$O_{\text{time, Label}} = \{O_{t,L}, O_{t,L+1}, \dots, O_{t,L+n}\}$, t is the timestamp; L is the object's label, $L \geq 0$; n is the number objects at time t , $n \geq 0$; if $L=0$ and $n=0$ at the time t , that means there are no objects in the data at that time, and for the probability depending on the nonlinear parameters

$$P_{t,O(t,L)} = P(X_{t,O(t,L)}, Y_{t,O(t,L)}, W_{t,O(t,L)}, H_{t,O(t,L)}).$$

C. Statistical Parameters

If we observe the multiple objective nonlinear parameters video data, at time point t different objects at different position and with changed time the parameters changed. Each object has its own parameter and it is not related with others, it is much more difficult to learn some useful parameters from each object, but if we give up to search the single object and observe the general behaviors of the parameters, perhaps we

¹ This work is partially funded by the European Commission under contract No. 033279.

will find a new way. That is in a complex situation if we cannot use functions to describe the relationship between parameters, at least we can try to use statistical method to describe the parameters. E.g.: using the mean (μ) and standard deviation (std σ , or variance σ^2) to describe the parameter distribution and with the statistical parameter (μ and σ) we can build statistical models and with the models we can describe the complex situation, such as multiple objective nonlinear parameters video data.

II. STATISTICAL PARAMETERS AND MODELS FOR VIDEO DATA

The video data consists of frames with 640x480 pixels. Each frame is divided into pixel clusters (C) of 16x16 pixels, yielding 40x30 clusters as shown in Fig.1. We call a pixel cluster $C_{i,j}$, where i is the cluster index in x-axis and j is the cluster index in y-axis. Each cluster possesses several statistical models. For each frame the bounding boxes for all objects are created; these will commonly reach over different pixel clusters. The statistical models of a cluster that is covered by an object will incorporate object parameters; these parameters will be modeled utilizing Mixture of Gaussians (MoG) [9]. Hence, over time each cluster collects statistical models of parameters from objects passing it. Because of the frame rate of 15 fps the total amount of video data for one minute sums up to $60 \times 15 = 900$ frames. For a common database this amount of data will soon exceed reasonable limits, therefore a "data window" should be used, which means that data older than a particular timestamp will not be taken into computation; only a constant amount of data is used to represent the entire past. All the frames are segmented into 40x30 clusters, for each cluster the following parameters are modeled:

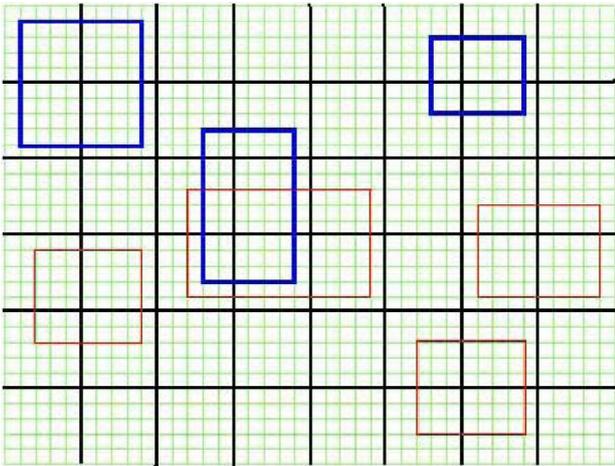


Fig. 1. Depiction of data input. The small squares are pixel, the big grid represents the clusters, and the other rectangles are various objects: the blue thick rectangles represent one object and the red rectangles represent another object in different frame and location.

A. Mean and Std for Scalar Data: Size (S)

From the basic input data set (see section 1.B) we can get the object parameter size (S). We calculate how many objects (O) cover which clusters in a time interval T' (e.g. one minute, equaling 900 frames) and add them up to the object count $C(O)$. In each frame if clusters are covered by objects,

the value of these clusters will add one, if some clusters are not covered by any objects, the value of these cluster will be zero:

$$C(O)_{i,j} = \sum O_{t,(i,j)}, i \in [1, 30], j \in [1, 40], t \in (0, T']; \quad (1)$$

Second, we add all the object's sizes in each cluster together:

$$C(S)_{i,j} = \sum S_{t,(i,j)}, i \in [1, 30], j \in [1, 40]; \quad (2)$$

For the calculation of the distribution of sizes (S) in each cluster we use (2) and (1). For implementation reasons, there can be some clusters with $C(O)_{i,j} = 0$; μ of these cluster will be zero and σ is zero too.

Mean μ of the size (S):

$$C(\mu_s)_{i,j} = C(S)_{i,j} / C(O)_{i,j}, \text{ if } C(O)_{i,j} \neq 0; \quad (3)$$

$$C(\mu_s)_{i,j} = 0, \text{ if } C(O)_{i,j} = 0; \quad (4)$$

Std. dev. σ of the size (S):

$$C(\sigma_s)_{i,j} = \text{std}(S_{t,(i,j)}), \text{ if } C(O)_{i,j} \neq 0; \quad (5)$$

$$C(\sigma_s)_{i,j} = 0, \text{ if } C(O)_{i,j} = 0; \quad (6)$$

After the models are initialized that way, an online learning algorithm is used for updating. This algorithm is described below.

B. Mean and Std for Scalar Data: Angle (A)

From the basic input data set we can get the object parameter Angle (A). For the calculation of the distribution of angles, we could use the same idea as for the size, but it is obvious that a sum of angles – where people can move in any direction at the same place – does not tell us anything about the real behavior of them. E.g. for two main routes of people the average value would be in the middle – which was maybe even never used by a person. To solve this issue, we use mixture of Gaussians (MoG) models to deal with the fact that there will be many different angles at the same cluster. An MoG is a vector of Gaussian models (called components or mixture components) with independent parameters each. To learn a MoG model fully automatically, split-merge criteria have to be introduced before we beginning to search the parameters of the components $C(\mu_A)_{i,j}$ and $C(\sigma_A)_{i,j}$. There are many papers about split and merge algorithms [10], [11], [12], but for this real time system an easy and quickly online algorithm has to be utilized:

(a) Split and merge update algorithm for modeling the distribution of angles

For each cluster in the frame we need to initialize the MoG with random numbers. In the case of angles, the means are in the range of 0 ... 360, std was chosen to be 50 ... 100, the number of initial components is 3. For each new observation A_r , following steps have to be carried out (s ... component index, T ... maximum number of data points, T' ... current data count):

1) Compute and then normalize posteriors

$$P_s(A_r) = P(A_r, s); P_s(A_r) = P_s(A_r) / \sum (P(A_r, s)) \quad (7)$$

2) Compute new means

$$\mu_{A(i,j),s} = (1 - P_s(A_r)) * \mu_{A(i,j),s} + P_s(A_r) * ((T' * \mu_{A(i,j),s} + A_r) / (T' + 1)) \quad (8)$$

3) Compute new variances

$$\sigma_{A(i,j),s} = ((1 - P_s(A_r)) * \text{sqrt}(\sigma_{A(i,j),s}) + P_s(A_r) * \text{sqrt}((T' * \sigma_{A(i,j),s} + (\mu_{A(i,j),s} - A_r)(\mu_{A(i,j),s} - A_r)) / (T' + 1)))^2 \quad (9)$$

4) Compute new priors

$$P(s) = (T' * P(s) + P_s(A_r)) / (T' + 1) \quad (10)$$

5) Flatten learning curve somewhere

$$T' = \min(T' + 1, T) \quad (11)$$

6) If necessary, split components

If $\sigma_{A(i,j),s} > \text{threshold}$ then

Create new component (index S)

$$\mu_{A(i,j),s} + \text{sqrt}(\sigma_{A(i,j),s}) / 2$$

$$\mu_{A(i,j),s} - \text{sqrt}(\sigma_{A(i,j),s}) / 2$$

$$\sigma_{A(i,j),s} = \sigma_{A(i,j),s} / 2$$

$$\sigma_{A(i,j),s} = \sigma_{A(i,j),s} / 2$$

$$P(s) = P(s) / 2$$

$$P(S) = P(s) / 2 \quad (12)$$

7) If necessary, merge components

If $(|\mu_{A(i,j),s'} - \mu_{A(i,j),s''}| < \text{threshold and } |\sigma_{A(i,j),s'} - \sigma_{A(i,j),s''}| < \text{threshold})$ or $P(s') < \text{threshold}$ then merge component s'' into s'

Delete component (index s'')

Renormalize priors

$$P(s) = P(s) / \sum P(s) \quad (13)$$

(b) Get the $C(\mu_A)_{ij}$ and $C(\sigma_A)_{ij}$

What we have done is only in one cluster, if we do the same way in all 1200 clusters, we can get $C(\mu_A)_{ij}$ and $C(\sigma_A)_{ij}$.

C. Mean and Std for Vector Data: Velocity (V)

From the basic input data set we can get the object parameter velocity (V). Velocity is a vector variable, it has a direction and an absolute value. Hence, angle is already modeled as described above. For the absolute value of velocity we use also a MoG, but we take over the priors and number of components from the angle models. In that way we get one speed distribution component per direction.

D. Duration (D) of Stay for Each Object

For a surveillance system it is also important to observe how long persons (video objects) stay in several areas. If an object stays in the picture much longer than the others, perhaps the object is an abnormal object or there is something wrong with it.

Because each object has its own object label, so we can find when $(O_{t,L})$ an object appears in the data and when $(O_{t',L})$, the same object disappears. Using the difference of the two time points we can find the duration of the object stay in the data.

$$D(O_L) = t' (O_L) - t(O_L) \quad (14)$$

E. Appearance of Objects

In the video data there are different objects that we want to find out where and how often the objects appear or disappear (if an object appear or disappear at the edge of the picture, it will not be calculated).

When a new object appears in picture we can get the time “t_app” and its appearance location (i, j), just like when an object disappears from the video data, we can get the “t_disapp” and its disappearance location (I, J).

For an object appearance:

$$O_{t_app, (i,j)}, \text{ with } 1 < i_{\min} \text{ and } i_{\max} < 30, 1 < j_{\min} \text{ and } j_{\max} < 40; \quad (15)$$

For an object disappearance:

$$O_{t_disapp, (I, J)}, \text{ with } 1 < I_{\min} \text{ and } I_{\max} < 30, 1 < J_{\min} \text{ and } J_{\max} < 40; \quad (16)$$

If we sum all the “appearance and disappearance” objects together in time interval T’ we can find out where and how likely this happens. Maybe there is a door or pillar in the scene...

$$O_{app, (i,j)} = \sum O_{t_app, (i,j)} \quad (17)$$

$$O_{disapp, (i,j)} = \sum O_{t_disapp, (i,j)} \quad (18)$$

III. RESULT AND CONCLUSION

For validating the algorithms we used a short sequence of real video data which contains 25 video objects in total.

A. Mean and Std for modeling Size (S)

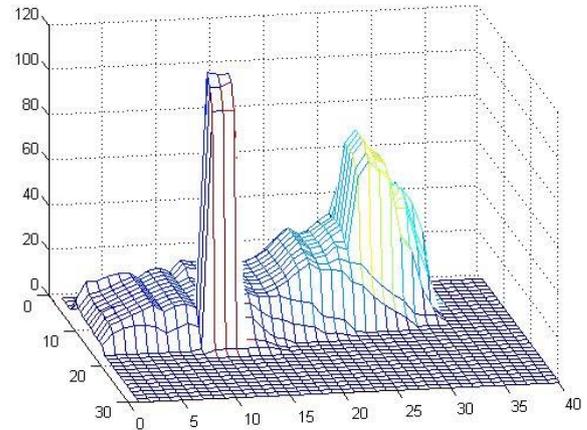


Fig. 2. The number of objects per cluster. The x and y axis represent the cluster index.

Fig. 2 shows how many times objects appeared in clusters $C(O)_{ij}$. From the figure we can see that some clusters have never been covered in this video sequence. The z-axis is the times that clusters are covered by objects.

From equations (3) and (4) we get $C(\mu_s)_{i,j}$. These are depicted in Fig. 3. From the figure we can see that the left top and the right top side of the figure have slightly smaller mean size values than the middle. This is because the objects sizes are smaller when they are farther away from the camera.

Compare the actual objects size with the learned objects size model we can find the anomaly objects size.

Using (5), (6) we get the $C(\sigma_s)_{i,j}$, the std. deviation of the size models. Fig. 4 shows that at the left top edge of the figure there are bigger std values than the other locations. This is because there are only few objects detected and if the object's sizes there changed a little the std value is influenced more.

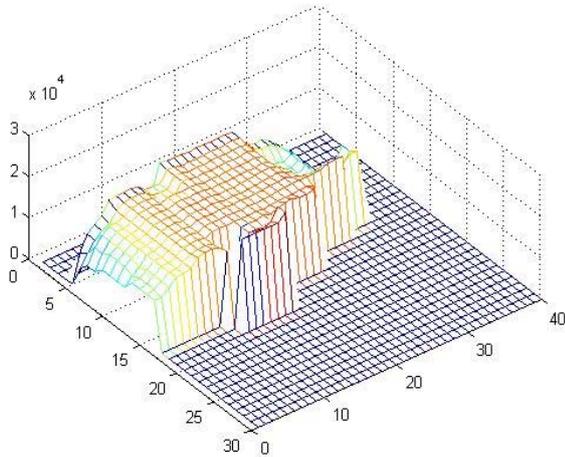


Fig. 3. Mean value of the size in each of the clusters ($C(\mu_s)_{i,j}$)

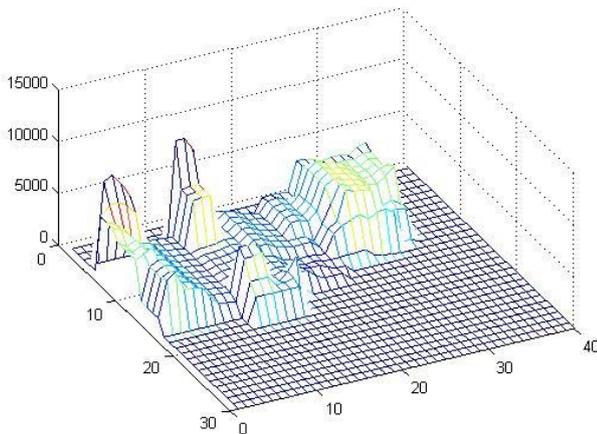


Fig. 4. Std deviation value of the size in each of the clusters ($C(\sigma_s)_{i,j}$)

B. Means and Stds for modeling Angles (A)

The means are shown in Fig. 5. We can see that in most of the clusters there are more than one angle mean value (z-axis is the angle mean value and the different colors are the different cluster columns, the points are the mean angle value in each cluster), this is the result from angle split and merge.

Fig. 6 shows quite small std values for each cluster which proves the use of a the split and merge algorithm ((7) - (13)). The MoG components represent frequent used directions of video objects. If the std value is zero (that means all the angles in one angle sets have the same value) it is not shown in the figure.

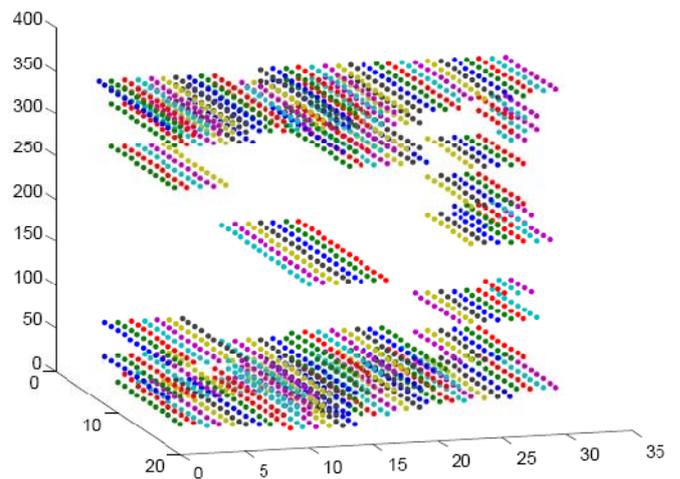


Fig. 5. Mean values of the angle in each of the cluster ($C(\mu_A)_{i,j}$)

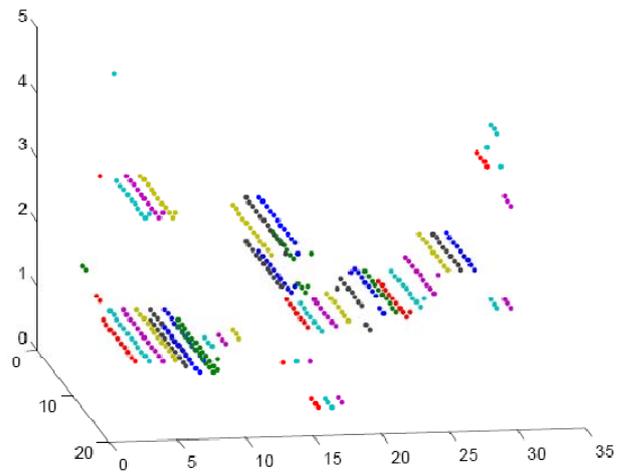


Fig. 6. Std values of the angle in each of the cluster ($C(\sigma_A)_{i,j}$)

C. Means and Stds for modeling Velocity (V)

Fig. 7 shows the velocity mean values of the objects in each of the clusters. From the figure we can observe that most of the objects moved around with nearly the same absolute value which corresponds to walking speed.

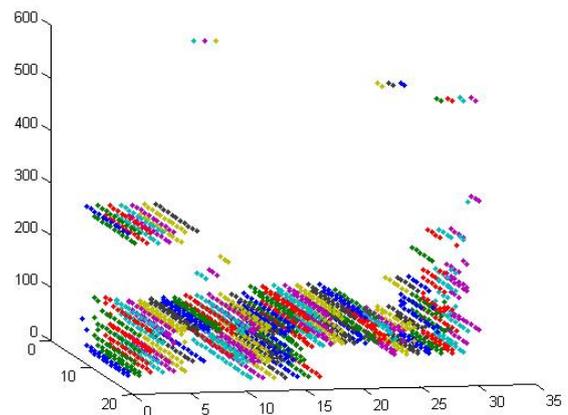


Fig. 7. Mean values of the absolute velocity in each of the clusters ($C(\mu_v)_{i,j}$)

Fig. 8 shows the velocity std values of the objects in each of the clusters. In some location there are bigger std values, since we model velocity according to the movement direction of the objects, so if objects have the same direction but have bigger different in the absolute velocity, there will be a bigger std value.

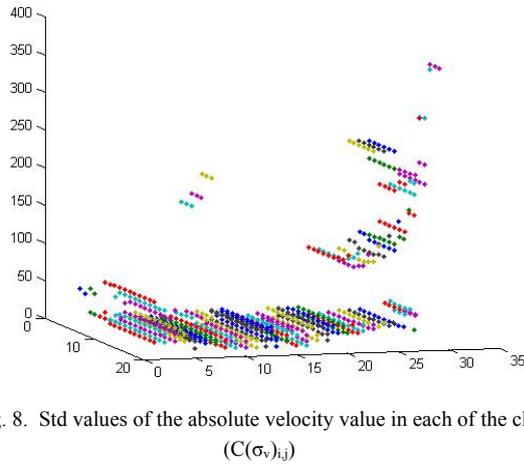


Fig. 8. Std values of the absolute velocity value in each of the clusters $(C(\sigma_v)_{i,j})$

D. Duration of Stay for Each Object

From equation (14) we can get the duration of each object's stays in the pictures. Fig. 9 shows that the objects 5 and 7 stay in the pictures much longer than the others and most of the other objects stay in the pictures less than one second. All the objects with very low duration of stay can be considered visual detection errors.

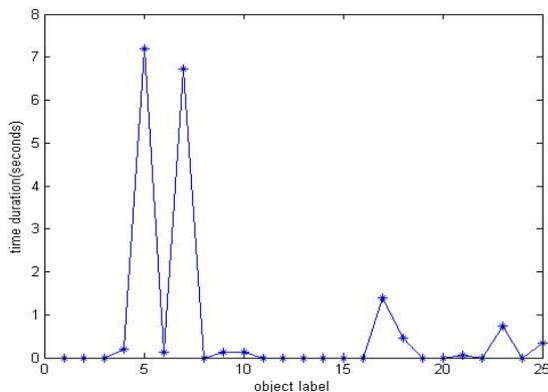


Fig. 9. Duration of stay for each object in the video

E. Appearance of Objects

Fig. 10 shows where and how often objects appear in the picture.

Fig. 11 shows where and how often objects disappear in the picture. It looks very much like Fig. 10 because most of these objects appear and disappear at the same locations – being visual detection errors which show up and vanish instantly.

III. OUTLOOK

This first results presented here show the possible potential for using statistical post processing to enhance the overall

detection quality for video observation systems. However, one possible improvement could be to deal with choosing of the cluster size. The questions is whether the used cluster size is much bigger or smaller than the general size of the objects. It has to be investigated if other cluster sizes have an influence on the error rate.

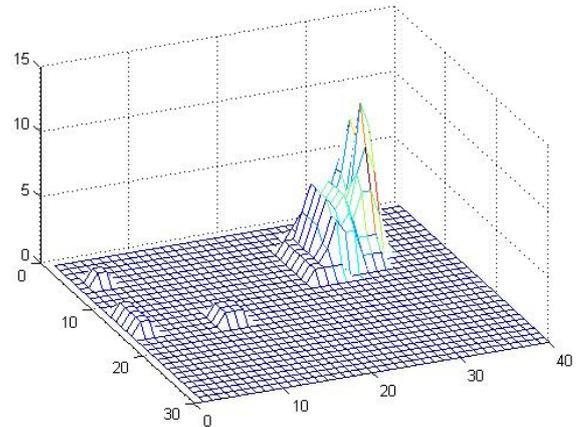


Fig. 10. Where and how often the objects appear in the video

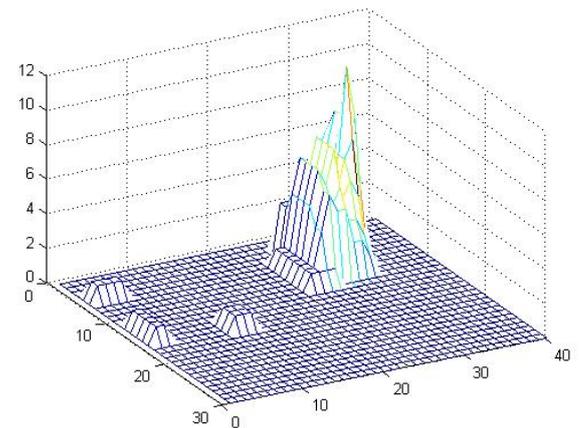


Fig. 11. Where and how often the objects disappear in the video

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