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High Availability Video Analysis for People Behaviour Understanding

D2.1 v2

People Behaviour understanding in single and multiple camera settings

Video Processing and Understanding Lab

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Supported by

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CONTENTS:

1. Introduction

1.1. Motivation

This work package 2 (WP2) aims at developing the required tools, models and control signals in order to enable the development of adaptive and collaborative approaches for video-based understanding of people behaviour. In particular, the goal of this task is to provide the required video analysis tools to fulfil the objectives of the project. It considers both comprehensive related work studies and the development of novel approaches for long-term analysis.

This deliverable describes the work related with the task T.2.1 Analysis Tools for human behaviour understanding. The people behaviour understanding in this project has been already designed as a sequential combination of object segmentation, people detection, object tracking and behaviour recognition. In particular, during this two years of the project there have been a focus on developing different approaches for segmentation, people detection, tracking and behaviour recognition.

1.2. Document structure

This document contains the following chapters:

- Chapter 1: Introduction to this document
- Chapter 2: Object segmentation analysis tools
- Chapter 3: People detection analysis tools
- Chapter 3: Conclusions

2. Object segmentation analysis tools

2.1. Long-Term Stationary Object Detection Based on Spatio-Temporal Change Detection

Stationary Object Detection (SOD) has recently experienced extensive research [1] due to its contribution to prevent terrorist attacks by detecting abandoned objects [2] and illegal parked vehicles [3]. SOD aims to detect the objects in the scene that remain stationary after previous motion. Typically, a Background Subtraction (BS) algorithm extracts the objects and SOD decides whether they are stationary or not [4]. However, current BS algorithms present many shortcomings to label foreground and background regions in real situations [5], thus highly determining the SOD accuracy. In this paper [6] we propose a block-wise approach to detect stationary objects based on spatio-temporal change detection without using BS (see Figure 1).

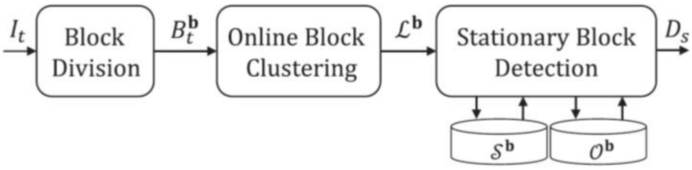


Figure 1. Block diagram of the proposed approach.

Firstly, a Block Division stage decomposes each frame into non-overlapping $N \times N$ blocks $B_t^{\mathbf{b}}$ at each instant t, where $\mathbf{b}$ denotes the block location. Secondly, an Online Block Clustering stage models each location $\mathbf{b}$ over time, updating a cluster partition $\mathcal{L}^{\mathbf{b}}$. This stage handles the temporal adaptation to scene changes, by assigning each incoming block to one cluster of the partition or creating a new one. Only stationary blocks (i.e., without motion with respect to $B_{t-1}^{\mathbf{b}}$) are analyzed at this stage. This clustering provides robustness against illumination changes by considering pixel ratios at block level which groups blocks even if their illumination has changed. Finally, a Stationary Block Detection stage outputs a result image D_s with stationary objects (see Figure 2), where s defines the sampling instant each k frames. Data associated to the last stable cluster $\mathcal{S}^{\mathbf{b}}$, old stable clusters $\mathcal{O}^{\mathbf{b}}$ and the alarm time T is used to respectively detect the spatio-temporal stability changes, discard those changes caused by previously visualized clusters (i.e. empty scene or previous detections) and detect stationarity for changes longer than the alarm time.

Figure 2. Examples of D_s image in different datasets. Detections are marked in red.

The last stage improves the state-of-the-art by reducing false alarms due to intermittent object motion and allowing to detect stationarity for objects not fully visible during T. Figure 3 presents an example of the scene analysis.

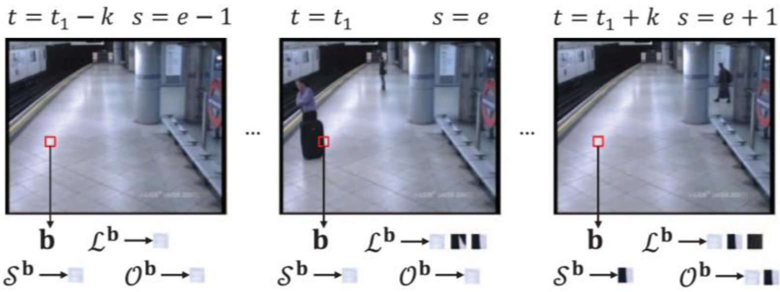


Figure 3. Example of the temporal analysis for a block location where the stability is modified changing from the empty scene to a suitcase.

2.2. Comparative evaluation of Points of Interest techniques for detection and description in images

We have decided to include the keypoint detection and description algorithms in this section. Although they are not exactly object segmentation approaches, their purpose is similar. Local descriptors [33] isolate and describe points of interest and feeds the other system stages: segmentation, object detection, tracking, etc.

One of the main objectives of this project [34] has been to develop a framework for the evaluation of keypoint detection and description algorithms, in order to update the references of the state of the art in this topic. Based on this framework, the other main objective has been to perform a comparative evaluation of the state of the art algorithms in local features field.

To this aim, three main stages have been faced. The first one has been to propose a new dataset, together with an evaluation methodology, based on an analysis of the strengths and weaknesses of previous frameworks in the state of the art. This proposal will set a new evaluation framework for the following stages.

The second one, an exhaustive study of the state of the art allowed to select the main techniques and categorize them according to its properties.

Finally, those selected techniques were tested on the proposed evaluation framework.

Figure 4. Visual example of keypoint detection, description and matching between two images with different point of view.

3. People detection analysis tools

3.1. People density estimation in crowded environments

Currently, the use of artificial vision systems has acquired great relevance due to the advancement of digital image and video processing technologies and the cheapening of capture tools. The crowd density estimation as part of artificial vision systems has an important niche market in video-surveillance. The crowd density estimation is an important tool to detect abnormal situations in public places such as fights, disturbances, violent protests, panic or congestion. Density information could be also helpful for creating a business strategy according to the distribution of people in public places or shopping centers and the distribution of people over time.

So far, a large number of crowd density estimators has been implemented. A significant part of these estimators use background subtraction and extract features from foreground pixels [11] [12]. All of them use foreground-background segmentation getting good results for the studied scenarios. This work [8][22] introduces the use of people-background [13] segmentation for crowd density estimation. With the goal of comparing both types of segmentation, one algorithm of the state of the art for density estimation has been implemented and then, results for both types of segmentation, foreground-background and people-background segmentation, has been compared in several scenarios (see Figure 5 and Figure 6).

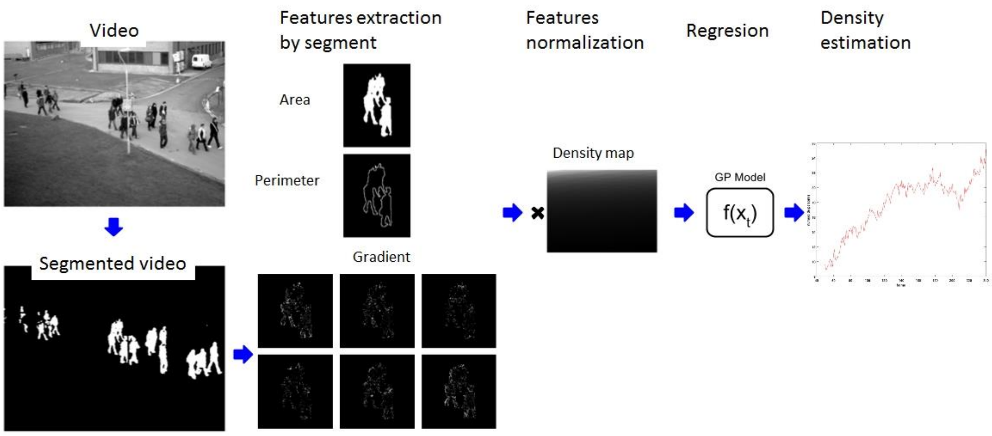


Figure 5. People density estimation system based on foreground-background segmentation.

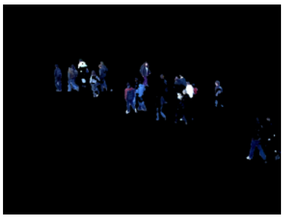
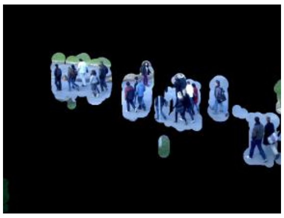
	
Input frame	Region of interest (ROI)
	
Foreground-background segmentation	Filtered foreground
	
People-background segmentation	Filtered foreground

Figure 6. Examples of foreground-background segmentation and people-background segmentation.

3.2. People detection in groups

In video signal processing, people detection is one of the most difficult tasks, even though there are actually some algorithms that give good results. However, when the detection takes part in complex environments the quality of the performance decreases, that is why the aim of this work [9] is the implementation of a people detection in groups algorithm in C++, as well as the integration on the proprietary video analysis platform called Distributed Video Analysis (DiVA). This platform allows us the execution with online and off-line videos, with the objective of verifying the functionality and efficiency in crowded environments.

The algorithm implemented, known as Multi-configuration Part-based Person Detector [14], is an adaptation of the algorithm known as DTDP (Discriminatively Trained Part Based Models) [15] to improve the detection in these types of environments. It is founded in an exhaustive search of person models, which are formed by the mixture of different body parts. Thanks to this search it obtains good results despite of the processing time, therefore the analysis of this algorithm is not possible in real time.

In order to complete our goal, we have developed a user interface so that any user can interact with the algorithm and prove easily the functionality of the algorithm in different environments as well as test the efficiency of the different models defined (see Figure 7 and Figure 8).

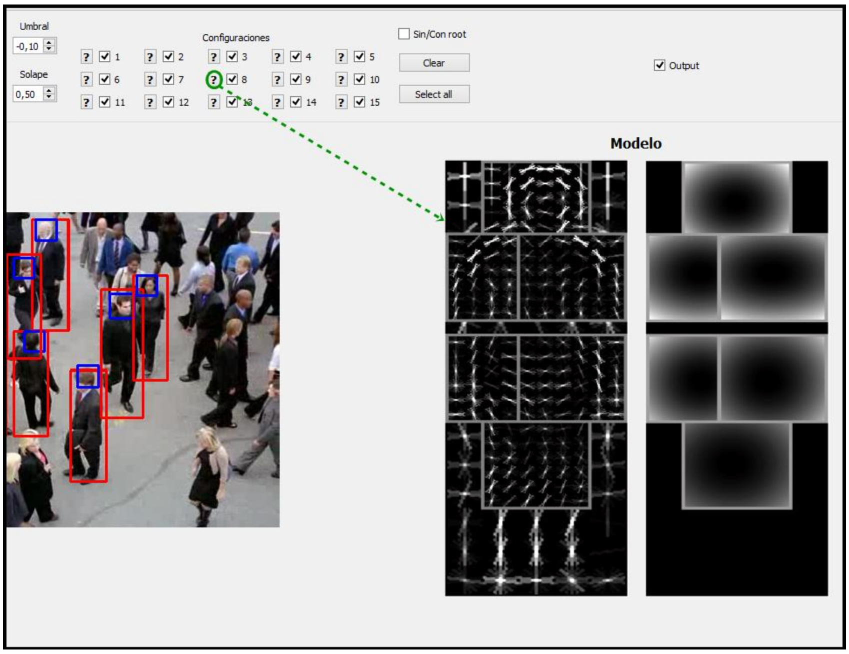


Figure 7. Visual example of the body parts configuration including six body parts, named configuration 8, following [16].

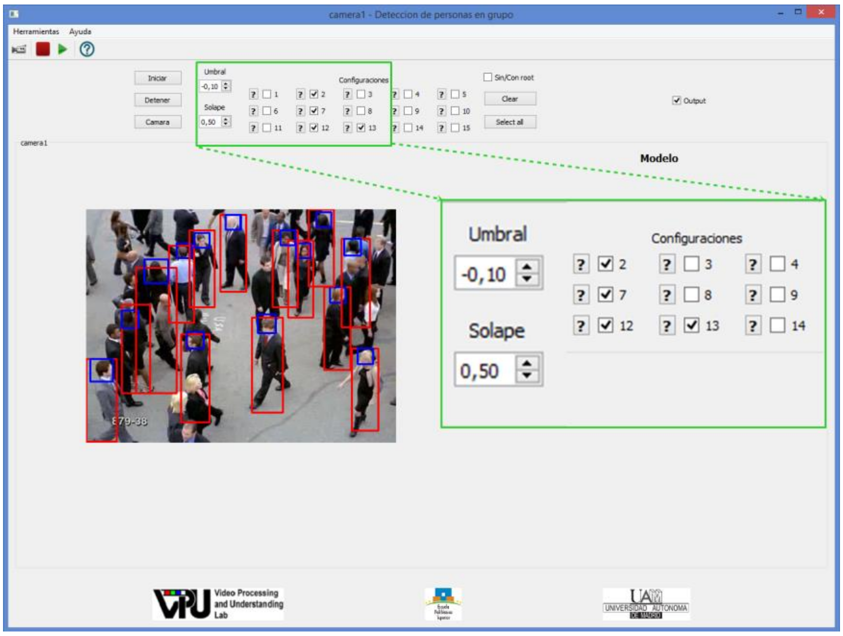


Figure 8. User interface example with selected configurations 2,7,12 and 13, following [16].

3.3. People detection in presence of groups

In this work [9] we address one of the most typical problems of people detection in presence of groups of people: in this kind of scenarios, traditional people detectors have difficulties dealing with several occlusions. In order to deal with this problem, we propose the use of two different hierarchies. The first one consists of a hierarchy of people, i.e., the use of the detections of different people belonging to a group in order to refine the individual’s detections. The second one consists of a hierarchy of parts [14], i.e., the use of different combinations of body parts in order to refine the final detection.

Our main aim is to be robust to different groups configurations, camera point of view, scene constraints, etc. Therefore, we propose to update this hierarchies structures frame by frame, so we can adapt the detection system to specific scene variations.

In order to update both the hierarchy of people and the hierarchy of parts, we study the detection results and determine which have been the most typical or representative configurations over time (scales and body parts configurations). Using only the last most representative configuration, we are able to reduce the computational cost and false positive detection and therefore the global detection results.

3.4. People detection in residential and hospitalary environments

There is a large demand in the area of video-surveillance, especially in detecting people, which has caused a large increase in the number of researches in this field. For elderly people detection, the detector must have into account different positions such as sitting or in a wheelchair. Also is important the cost involved in making these detectors.

Therefore, this work [16] has two main objectives. The first has been to develop a sitting person model with the aim of completing a detector for a nursing home scenario. The second one was based on reducing the amount of resources needed and save the cost of having to record sequences for a detector in this scenario. To achieve this, three synthetic images dataset were created in order to perform three different models, evaluating which model is optimal and finally analyzing its feasibility by comparing it with the people detector in wheelchairs. Figure 9 shows an example of each image dataset.

The result, as expected, is worse than the performance of the trained detector with real images, but a functional detector has been obtained without having to record the real object. This method can be useful in situations where there it is not possible to record a dataset of the desired object type, or in cases in which obtaining it has a high cost. Other examples in which this technique is applicable, considering people detection, could be for people riding horses or people in the supermarket with shopping carts.

Figure 9: Image example of each created dataset.

4. Object tracking analysis tools

4.1. Object tracking based on TILDE points

The aim of this work [17] is the design and development of a video object tracker based on point-of-interest (PoI). Specifically, we focus on the potential benefits of including a recently published PoI detector in the core of the tracking process. The design of the algorithm starts by studying existing tracking algorithm emphasizing in methods using PoI in any stage of their tracking algorithm. In order to provide a flexible framework on which to develop potential improvements, the algorithm's design builds on the basic PoI-based tracking scheme. From the state-of-the-art, we propose to use TILDE (Temporally Invariant Learned Detector [18]) as the PoI detection method. TILDE is a train-based PoI detection method which is claimed to provide stable results to change in illumination and appearance. TILDE-driven correspondences are used to spatially constrain the target position between consecutive frames. Final result is refined by means of a classic cross-correlation method. The tracker is experimentally evaluated in a generic evaluation corpus. From this evaluation we aim to discuss on their benefits and drawbacks. Furthermore, we also compare the tracker against state-of-the-art trackers, in order to quantitatively contextualize its operation. Experimental results (see Figure 10) indicate that the designed tracker performs significantly better than a common references (Normalised-Cross-Correlation ncc [20]) and slightly worse than a deep-learning-based approach (MDnet [19]); hence, results partially validate the design and development of the algorithm and suggest that the use of TILDE may help to generate robust constraining schemes for trackers based on cross-correlation.

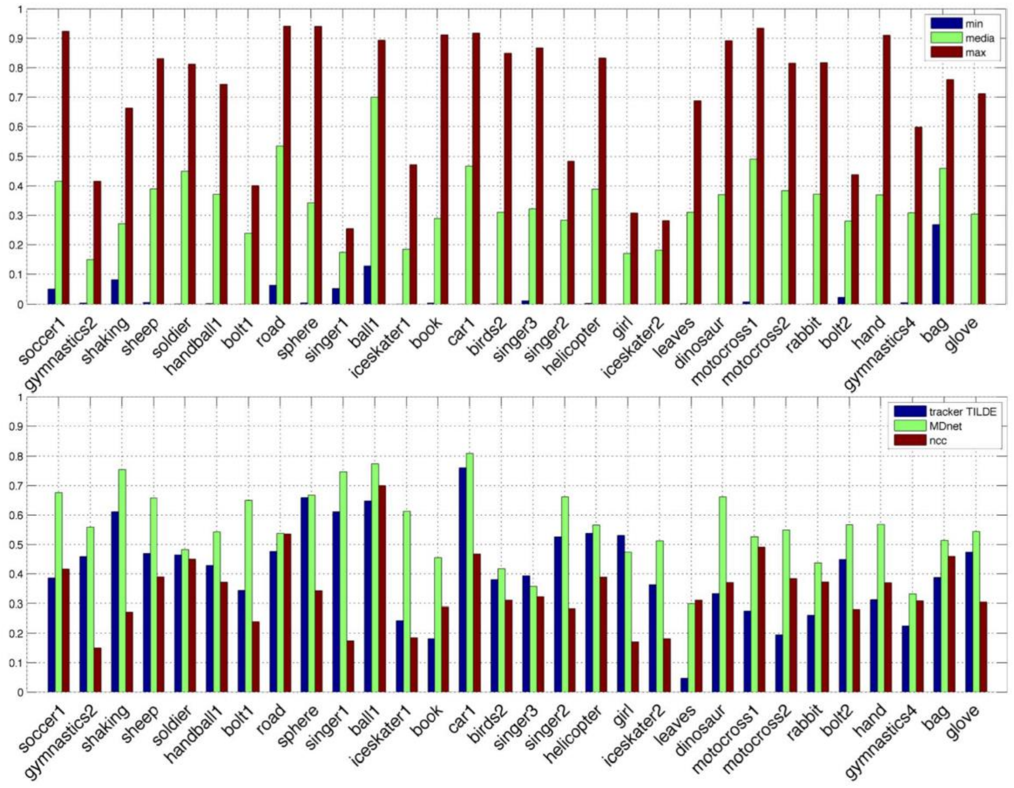


Figure 10: Comparative evaluations in terms of tracking accuracy of the designed tracking approach (tracker TILDE [18]). Top. Operation extrema of the proposed method when analyzing the VOT2016 dataset. Bottom, comparison with a reference method (ncc [20]) and the winner of the competitions, a deep-learning method (MDnet [19]).

4.2. Visual Attention Based on a Joint Perceptual Space of Color and Brightness for Improved Video Tracking

This work [23] proposes a new visual attention model based on a joint perceptual space of both color and brightness, and shows that this model is able to extract more discriminant visual features, especially when dealing with objects that are very similar visually. That joint color and brightness space is based on a biologically inspired theoretical perceptual model originally proposed by Izmailov and Sokolov [24] in the scope of psychophysics. The present paper proposes a computational model that allows the application of Izmailov and Sokolov's theoretical model to digital images, since the original model can only be applied to perceptual data directly drawn from psychophysical experiments. Experimental results with real video sequences show that the proposed visual attention model yields significantly more accurate results in the particular application scope of video tracking than well-known visual attention models that process color and brightness separately.

4.3. Automatization of functions for teacher tracking in lectures broadcasting

The main motivation behind this Project [27] has been to automate the process of tracking a teacher in a classroom so as to be able to broadcast classes via the internet to students who, for various reasons, can't physically attend the class that is being taught.

This project is a continuation of several previous works, as a result of which there is an algorithm that uses images from a video sequence taken by a fixed camera to track, in real time, the position of a teacher in a classroom, and guides in that direction a mobile camera whose video signal is the image the student will see. Furthermore, there is a web application that allows users to view these classes (see **Figure 11**).

The integration of an HOG people detector in the original algorithm is detailed in this project. This detector is useful so as to be able to automate the initialization phase, and it allows a faster recovery of the target once the algorithm determines that it has lost it.

Once the changes that have been made to the tracking algorithm have been explained, two new proposals that improve the mobile camera movements are introduced. With these proposed solutions better movement control and zoom levels are obtained, making seem as if a person is controlling the mobile camera. Of these approximations, one is based on the original rule scheme, while the other attempts to predict the target's future position using a Kalman filter [28].

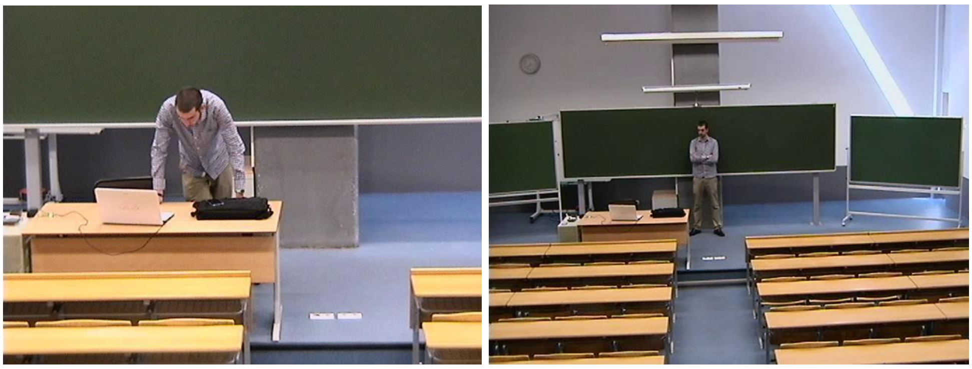


Figure 11: Visual examples of the teacher tracking system.

4.4. Long-term objects tracking in video sequences

In this master thesis [32] an analysis of tracking objects in long-term sequences is proposed. Recently, the development of video tracking algorithms has been focused on short videos. However, the need to operate for long times (e.g. 24/7 video-surveillance) have increased need to study mechanisms to improve and update existing tracking algorithms for their use in long-term sequences.

The main aim of the work is the study, design and evaluation of an algorithm that combines other trackers sequences previously developed both short and long term. For this objective, first it has conducted a study of the state of art related to object tracking, focused on the case of long-term videos. After, this project focuses on the selection and description of the chosen tracking algorithms to evaluate and compare the set of videos of this project. Once these trackers have been studied, a fusion algorithm is implemented which examines the behavior of the combination of algorithm under the long-term framework.

Figure 12 shows one example of different trackers and the proposed combination.

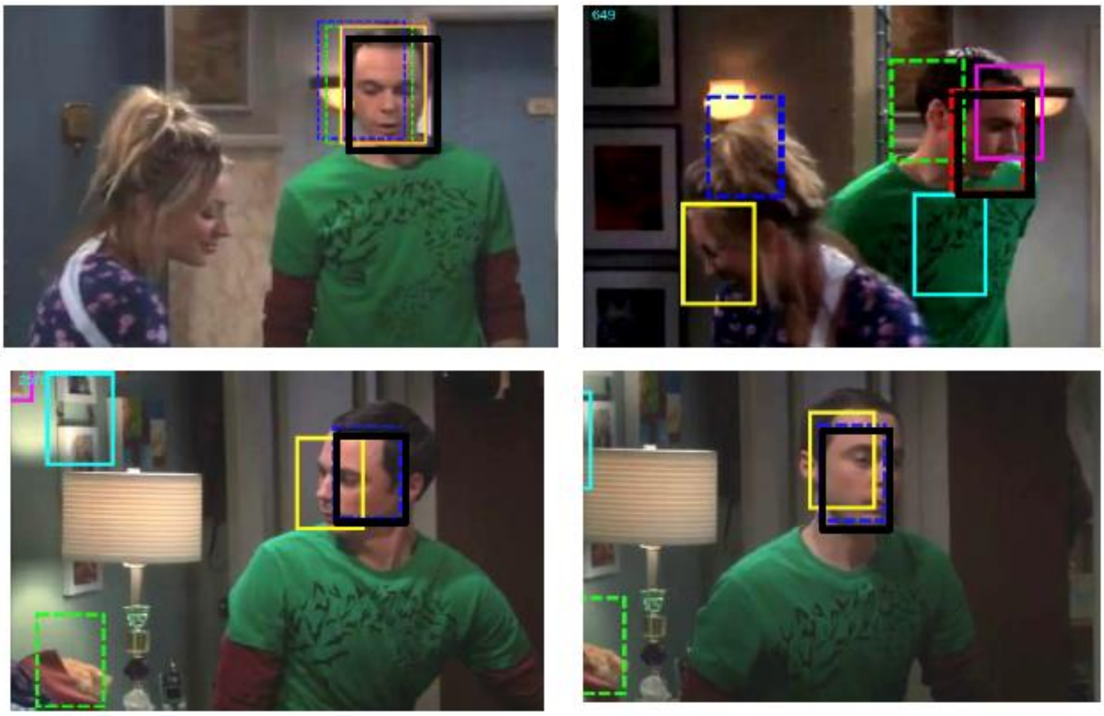


Figure 12: Visual examples of different SoA trackers and the proposed combination (in black color).

5. Behaviour recognition analysis tools

5.1. Integration and evaluation of abandoned-stolen object detection systems in security-video

This final degree project [21] (proyecto final de carrera) proposes a configurable abandoned-stolen object detection system in security-video that integrates the most relevant techniques in each one of its stages. A formalization of the problem is presented, followed by a description of the different analysis stages required for the detection. Firstly, this work analyses the state of the art to know the present date problems about the matter. Secondly, the work focuses on the integration of the most recent and relevant algorithms of the literature in every single phase of the system. It also designs the necessary interfaces for its execution in a sequential order (see Figure 13).

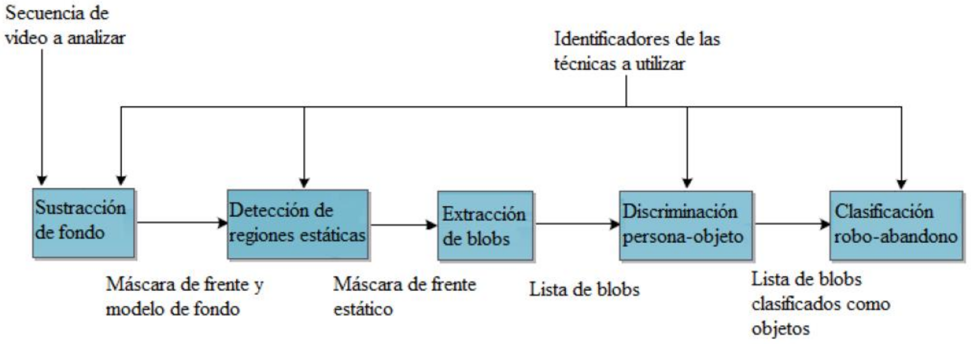


Figure 13: Block diagram of the proposed system for evaluation

To conclude, the different configurations of the system regarding the detection of static regions as well are evaluated and compared, while it is classified as abandoned-stolen about a compound of heterogeneous videos sequences. Abandoned/stolen object event detection depends on the parameters that modulate the absorption of the blobs from the static foreground by the background model. The results of abandoned/stolen detection stage are affected by the propagation of errors in the earlier stages as it is the last stage of video analysis system (see Figure 14).

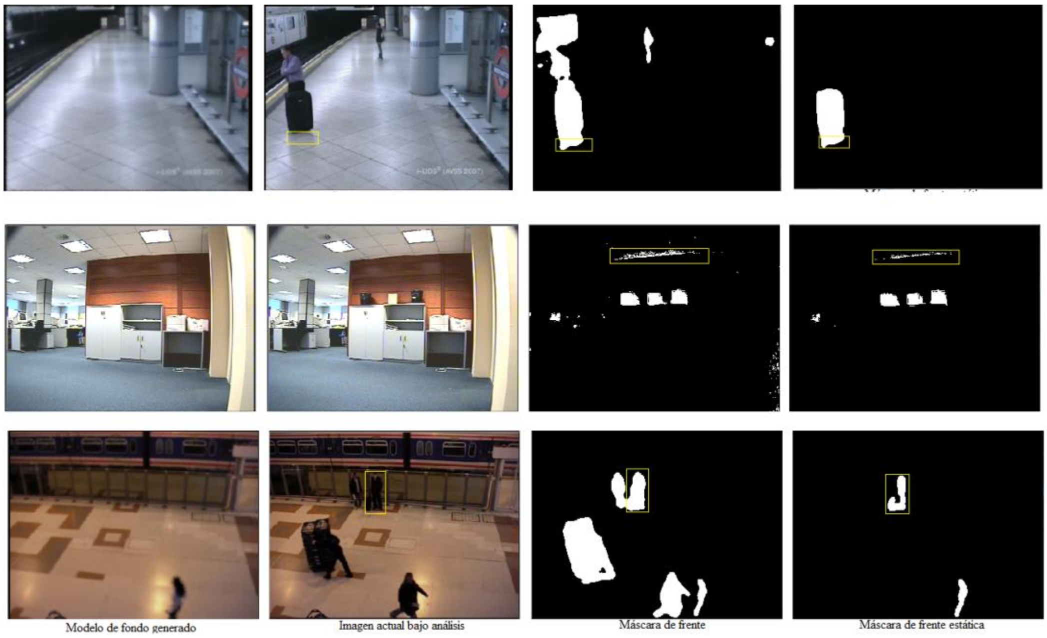


Figure 14: Examples of the output generated by the different configurations of the system.

5.2. Fall detection using video

This Master Thesis Project [25] consists on studying the development of a fall detection video-based system, primarily intended for implementation in home environments to promote independent living for the elderly. Due that falls are one of the main problems of the elderly population, we are in a field with great potential still developing. In the first place, we conducted a comprehensive study of the art of existing methods in the detection of falls in general, as well as exclusive video analysis algorithms. Once detailed the techniques, we chose the one that best fits the needs of our project and provides reasonable results in the detection of falls. Then, we have implemented an algorithm that characterizes the chosen technique. The algorithm is evaluated by a different set of videos with different features and various approaches that allow us to draw conclusions. Figure 15 shows visual examples of the fall detection system.

Figure 15: Visual examples of a normal detection (green blob on the left) and a fall detection (red blob on the right).

5.3. Activity analysis in multicamera sports videos

Sport video-content analysis systems are on the rise both from the commercial view point and the researching viewpoint. In this scope, the video processing group (VPU-Lab) developed a prototype for sport video-content analysis previously to the beginning of this master thesis. This prototype performs the detection and tracking of players in sport videos, and provides statistical information about their behaviour.

This prototype achieved good results in quantitative and qualitative terms, presenting some deficiencies which motivate this mater thesis. These deficiencies were mainly related to aspects as usability, system interaction, results visualization and fine-tuning.

This project [26] has been focused in providing a solution for those problems by working on three main tasks. Firstly, the work focused in compacting the prototype. In origin it was divided in modules which have to be manually linked and which are programmed in different languages. As a result of the project there is a unified prototype fully programmed in C++, full working and portable.

Secondly, efforts were aimed to improve the usability, interactions and results visualization of the prototype. Two applications were developed and adapted to guarantee specific sports support, football and tennis. They allow a non-expert user to fully control the prototype and visually obtain its results, via a Graphical User Interface (GUI) (see Figure 16).

Finally, keeping in mind that these products use to work under supervision in commercial applications, the prototype and the interface have been equipped with tools to allow the online interaction with its results. This improvement allows a supervisor to control the application and correct its results when necessary, obtaining more reliable results than any other automatic system.

Figure 16: Graphical User Interface (GUI) application.

5.4. Activity analysis in basketball videos

The video processing group (VPU-Lab) developed a prototype for sport video-content analysis previously to the beginning of this master thesis [26]. This prototype performs the detection and tracking of players in sport videos, and provides statistical information about their behaviour. The application had been created both for individual and collective sports, but in this last case, it only worked for soccer videos. Due to this, a new line of investigation arose, that consisted in the adaptation of this prototype to another sport such as basketball [31].

Therefore, this Project [31] has worked among the same lines, solving the existing issues and creating a similar prototype on which to continue investigation and further development. Following this, the Graphical User Interface (GUI) has been modified, (see Figure 17), to be able to optimally represent the newly obtained results (basketball), maintaining the full functionality of the previous prototype.

Figure 17: Basketball Graphical User Interface (GUI) application.

Furthermore, an improvement of the obtained results in these new videos was researched, with the system that was being implanted. The goal was to obtain the best possible results in both detection and tracking by adjusting different parameters.

Lastly, due to the interface being the visible part of this project, there have been updates made to improve it, by including a new homography creation module that simplifies the use by the end user even more, (see Figure 18).

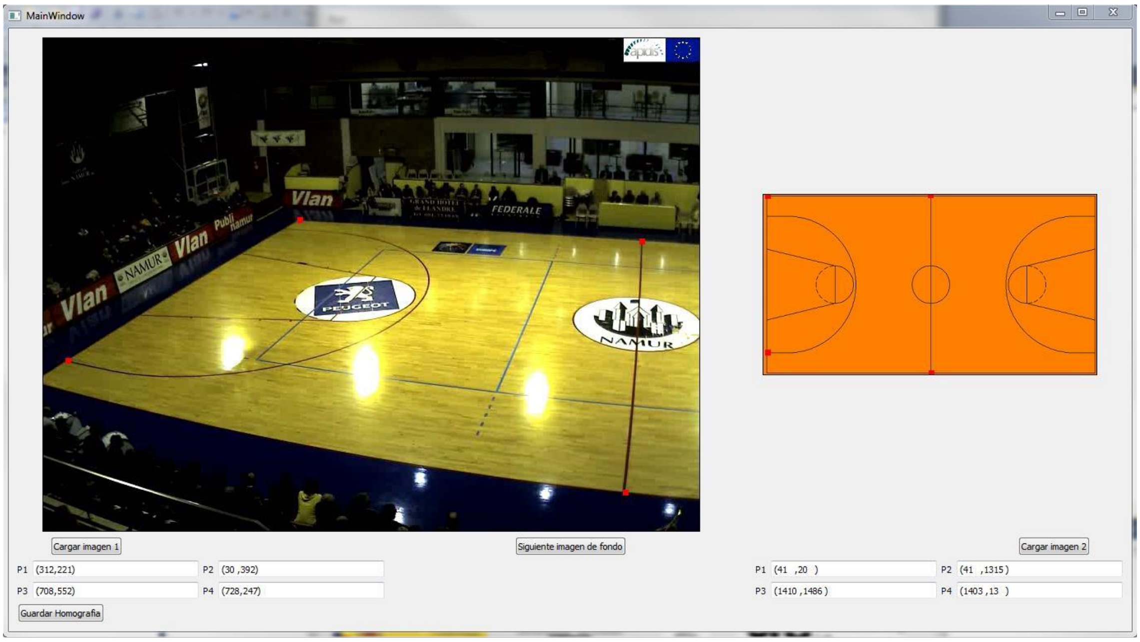


Figure 18: Homography creation module Graphical User Interface (GUI).

6. Conclusions

In relation with segmentation, a long-term stationary object detection based on spatio-temporal change detection has been implemented and evaluated [7], we propose a block-wise approach to detect stationary objects based on spatio-temporal change detection without using background subtraction. In addition, an evaluation framework and a comparative analysis of state of the art local features detection and description algorithms has been developed [34].

In relation with people detection several approaches have been implemented and tested: people density estimation in crowded scenarios [8], people detection in groups [9], [10] and people detection in residential and hospitalary environments [16]. A significant part of people density estimation approaches from the state of the art use background subtraction and extract features from foreground pixels. All of them use foreground-background segmentation getting good results for the studied scenarios. The proposed work [8], introduces the use of people-background segmentation for crowd density estimation. On the other side, [9] and [10] propose two different approaches in order to deal with people detection in crowded scenarios or in presence of groups of people. Finally, [16] propose a sitting person model with the aim of completing a detector for a nursing home scenario and explore the possibility of creating synthetic images datasets reducing the amount of resources needed and save the cost of having to record sequences for a detector in this specific nursing home scenario.

In relation with tracking, a video object tracker based on the point-of-interest TILDE has been implemented and evaluated [17]. TILDE-driven correspondences are used to spatially constrain the target position between consecutive frames. Final result is refined by means of a classic cross-correlation method. Also, a new visual attention model based on a joint perceptual space of both color and brightness for improved video tracking is proposed [23]. In addition, an enhanced version of a teacher tracking system in a classroom has been implemented and tested [27]. And finally, a fusion algorithm [32] has been implemented which examines the behavior of the combination of different tracker from the SoA under a long-term framework.

In relation with behaviour recognition, a configurable abandoned-stolen object detection system in security-video that integrates the most relevant techniques in each one of its stages is proposed [21]. Also, a fall detection video-based system to promote independent living for the elderly is proposed [25]. In addition, a unified prototype Graphical User Interface (GIU) for sport video-content analysis has been implemented (soccer [26] and basketball [31]).

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