Automatic Video Monitoring system for assessment of Alzheimer's Disease symptoms

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Abstract

In order to fully capture the complexity of the behavioural, functioning and cognitive disturbances in Alzheimer Disease (AD) and related disorders information and communication techniques (ICT), could be of interest. This article presents using 3 clinical cases the feasibility results of an automatic video monitoring system aiming to assess subjects involved in a clinical scenario.

Method and population:

The study was conducted in an observation room equipped with everyday objects for use in activities of daily living. The overall aim of the clinical scenario was to enable the participants to undertake a set of daily tasks that could realistically be achieved in the setting of the observation room. The scenario was divided in three steps covering basic to more complex activities: (1) Directed activities, (2) Semi-directed activities, (3) Undirected ("free") activities. The assessment of each participant of the study was done with an automatic video monitoring system composed of a vision component and an event recognition component. The feasibility study involved three participants: two AD patients and one elderly control participant.

Results:

The first result of the study was to demonstrate the feasibility of this new assessment method from both the patient and the technical points of view. During the first step the control participant performed all these activities faster than the two AD participants. During the second step of the scenario AD participants were not able to follow the correct order of the tasks and even omitted some of them. Finally during the last step of the scenario devoted to free activities the control participant chose one of the proposed activities (reading) and undertook this activity for almost the entire duration. In contrast, the two AD participants had more difficulties choosing one of the suggested activities and were not able to undertake any one activity in a sustained manner.

Discussion:

The automatic video monitoring system presented here analyzes human behaviours and looks for changes in activity through the detection of the presence of people and their movements in real time. Once the technique has been standardized, it could significantly enhance the assessment of AD patients in both clinical and clinical trial settings as well as providing further information regarding patient frailty that could enhance their safety and ease caregiver burden.

Alzheimer Disease (AD) and related disorders represents a major challenge for health care systems with aging populations. AD is associated with neurodegenerative changes that compromise cognitive and functional abilities and may result in behavioral and neuropsychiatric symptoms (NPS). Many efforts are currently undertaken to investigate AD pathology and develop appropriate treatment strategies. These strategies focus on preserving cognitive and functional abilities along with reducing NPS and maintaining quality of life in the AD sufferer. Rating scales are essential tools for the diagnosis of AD, the assessment and careful monitoring of symptoms, as well as the evaluation of treatment effects. However these standard rating scales do not fully capture the complexity of a disease. In fact, AD includes deterioration in cognitive, behavioral and functional domains that do not always progress in parallel and may change idiosyncratically according to the individuality of a given patient. For this reason, information and communication technology (ICT), in particular, techniques involving imaging and video processing, could be of interest. Such techniques enable the patients' performances and actions in real time and real life situations to be captured.

Over the last several years, research has focussed on developing and employing various sensors to monitor activities in the elderly as well as in AD patients. These include cameras and microphones for activity recognition [1, 2], embedded sensors [3, 4], or sensors placed on the body [5]. This is a challenging domain for multiple reasons. Firstly, for clinicians it is important to establish the exact type of indicators that are clinically relevant and can provide information that can be used in daily practice. Secondly, for ICT engineers, the challenge is to adapt the technical constraints with the needs of the clinician. For patients and caregivers, participating in an active way and giving an opinion on the feasibility and tolerability of the project is important . With these challenges in mind, the SWEET Home project was devised.

The main impetus of the SWEET Home project comes from the societal objective of assisting and keeping elderly people in their familiar home surroundings, or to enable them to "age in place". More specifically, the overall aim of the project is to develop a technological approach for behavioural assessment and preventative care in early and moderate stage AD. This article will present the following: (1) a clinical scenario of the project, highlighting behavioural indicators; (2) the ICT methodology using an automatic video monitoring system; (3) the results of a feasibility study with two AD patients and one elderly control participant. Such behavioural assessment using video monitoring system has never been done in AD.

Methods

This project was approved by the local ethics committee. Each participant had the capacity to consent to the study and signed an informed consent form.

Participants

Participants were recruited from the Nice Memory Center. Inclusion criteria were: (1) a diagnosis of AD according to NINCDS-ADRDA criteria, and (2) Mini-Mental State Exam (MMSE) [6] score above 20. AD patients with significant motor disturbances as per the Unified Parkinson's Disease Rating Scale were excluded. Controls participants needed to have neither behavioural disturbance nor cognitive disturbances.

*Assessment*s

Global cognitive functioning was assessed using the MMSE [6]. Behavioural assessments included: (1) the Neuropsychiatric Inventory (NPI) [7]; (2) the Apathy Inventory (AI; caregiver, patient and clinician versions[8] the Montgomery Asberg Depression Rating Scale [9]; and the Geriatric Depression Scale (GDS; [10]) The degree of independence in activities of daily living (ADLs) was assessed by interviewing the caregiver(s), as well as the Instrumental Activities of Daily Living scale [11].

Experimental Site

The clinical part of the SWEET Home study was conducted in the Nice Memory centre, located in the geriatric department of Nice's university hospital. An observation room was equipped with everyday objects for use in ADLs and IADLs, e.g. an armchair, a table, a coffee corner, a TV, a PC, and a library. Two fixed monocular video cameras (8 frames/seconds) were installed in order to capture the activity of the participants (figure 1).

Clinical scenario

The overall aim of the clinical scenario was to enable the participants to undertake a set of daily tasks that could realistically be achieved in the setting of the observation room. The scenario was divided in three parts covering basic to more complex goal directed activities. (1) Directed activities (10 minutes' duration): The aim of this part of the assessment was to identify characteristics of gait and walk parameters in activities with limited implication of cognitive capacities. This part was based on the short physical performance battery[12] and required the examiner, who remained in the room, to verbally direct the participant to undertake various daily tasks. The examiner also scored the performance (see Table 1). (2) Semi-directed activities (20 minutes' duration). The aim here was to determine the extent to which the participant could undertake a list of daily activities in a given order, after having been given a set of instructions (see Table 2). Prior to leaving the room, the examiner described each of the activities and the location and use of various objects needed to undertake the task. The examiner left the room only after it was clear that the participant understood the task. The participant was able to keep the instructions and refer to them at any point during the assessment. The participant could leave the room only when they felt that they had completed the required tasks.

(3) Undirected ("free") activities (30 minutes' duration): The aim here was to assess how the participant spontaneously initiated activities and organized their time. Several items were at the participant's disposal, including magazines, newspapers, a book of photos, drinks (coffee, tea, fruit juice), plants, and dominos, playing cards, TV and a telephone. During this period the participant was informed that the telephone might ring 30 minutes after the examiner had left the room and that they would be required to answer it. This was the only instruction given to the participant. They were otherwise free to do as they pleased for the duration of the time. The participant was also told that the examiner would be available for questions on the other side of the door and that they could leave the room at any point should they choose to do so.

Automatic Video monitoring system

The input for the automatic video monitoring system is of two types, video streams and *a priori* knowledge. The system itself has two components (figure 2): (1) the *vision* component and (2) the *event recognition* component. The a priori knowledge represents all the information used by the automatic video monitoring system to infer high semantic representation of the scene. This a priori knowledge is composed of three dimensional (3D) geometric information and event models. 3D geometric information includes, in particular, a decomposition of a 3D projection of the floor plan which has been divided up into a set of "zones of interest" corresponding to the daily-use items (i.e. TV, armchair, table). Event models correspond to the description by human expert of all the knowledge in a natural language used by the system to detect an event occurring in the scene. This language is declarative and intuitive (in natural terms), so that the experts can easily define and modify the event models.

The *vision* component (figure 3) aims to detect and track people moving in the room by means of a set of vision algorithms coming from the scene-understanding platform (SUP) [13]. The event recognition component uses the tracking of mobile objects, the *a priori* knowledge of the scene and predefined event models. It computes (i) all possible events (activities) related to any mobile objects (i.e. persons) present in the observed scene. In particular it recognizes an event by detecting the silhouette and the posture of the observed people (sitting, standing, lying). The most similar extracted 3D silhouette is considered to most accurately correspond to the current posture of the observed person. The recognition is performed in real- time (about eight frames per second), and does not depend on camera position. The event recognition component deals with mis-detection and noise and is able to recognize several events. It computes the likelihood (degree of trust of the recognition of the event) of the recognition of the event in question based on the reliability computation of the event components. The proposed automatic video monitoring system enables the location of the observed person at each time point to be detected and recognizes all the activities done by the person in real time, as well as the amount of time spent on each activity. Using this system of detection, the video monitoring system can automatically compute many indicators. For the directed activities' part, these indicators are: (1) the *speed of execution* of each activity (seconds), which corresponds to the time spent undertaking each activity; (2) the *speed of displacement* of the participant (cm/seconds) computed on the basis of the 3D coordinates of the person over time, and (3) *the step stride length* (centimetres). For the semi-directed activities part, these indicators are: (1) speed of execution (seconds), (2) number of tasks done in the correct order, which corresponds to the correct order of recognized activities in the video monitoring system, (3) number of errors in the order of the tasks undertaken by the participant ,and (4) task omissions, referring to any task that the participant was unable or forgot to undertake.

For the free activities' part these indicators are: (1) *Number of occurrences* of an activity, (2) time spent in each activity chosen by the participant, and (3) proportion of free activity time not recognized by the video monitoring system.

Results

Clinical vignettes

Two AD patients and one-control participant were included in the study. Quantitative clinical characteristics of the participants are shown in table 3. Brief case histories are outlined here below:

- *Participant 1:* Mr M. was a 77-year-old retired engineer who lived at home with his wife. He was diagnosed with AD seven years ago. He had no significant medical comorbidities other than a major depressive disorder associated with AD. At the time of the assessment, he had some depressive symptoms but was not apathetic. He was no longer independent and his wife assisted him with most ADLs. Current medications included galantamine and escitalopram, both of which were well-tolerated. On neuropsychological testing, he demonstrated difficulties in episodic memory and executive function especially in attention, inhibitory control, planning and mental flexibility. MMSE score was 21.

- *Participant 2:* Mrs B was a 76-year-old woman who lived at home with her sister. She was diagnosed with AD 7 years ago, according to NINCDS-ADRDA criteria. She also had a diagnosis of essential hypertension and osteoarthritis of her knees. Medications included galantamine, lisinopril and paracetamol. On neuropsychological testing, her profile was similar to Mr M., but with additional deficits in episodic memory and executive function. MMSE score was 20. She was generally independent with ADLs, but required some assistance from her sister for more complex tasks She had clinically significant apathy as determined by the cut-off on the Apathy Inventory.

Participant 3: Mr D was a, 77-year-old man, with no significant medical history and not on any medication. He was cognitively intact on testing and fully independent in ADLs.

Automatic video monitoring results

The results show that we could differentiate between the three participants using the new technology (table 4). Participant 1 took the longest time (134 seconds) to perform the balance and sitting-to-standing (39 seconds) tasks. Participant 1 walked also slower compared to Participant 2 (54.5 cm/s) and Participant 3 (100 cm/s). There were also important differences among the three participants in the gait parameter of step length. Total duration of the semi-directed activities also differed significantly among different for the three participants: 4:21 minutes for the control participant;, 15:54 minutes for Participant 1; and 12:44 for Participant 2. The speed of execution and data regarding the tasks undertaken is outlined in Table 5. Briefly, this revealed that the control participant was able to undertake the semi-directed activities in the correct order, in contrast to the two AD participants who made several errors and had omissions. Finally, the activities detected for each participant during the undirected or "free" part are presented in table 6. The total duration of this part was 30 minutes, however, whereas the video monitoring system captured 25 minutes of the control participant's (P 3) in only one activity (reading), only 11 minutes and 13 minutes of activity were captured for Participants 1 and 2 respectively. This was due to the AD participants being too close to or behind the camera and therefore not being properly detected by the monitoring system.

Discussion

The phenomenology of AD combines symptoms belonging to different domains, including cognition, behaviour and daily functioning. These domains are usually assessed separately with specific scales or interviews involving the clinician, the patient and the caregiver. In general, these evaluations provide an overview of the patient's ability and, ideally, offer a correct understanding of the level of severity of the disease. In contrast, the objective of the current study was to assess patients in situations closer to real life by using a different assessment approach. In other words, patients were invited to spend some time and to undertake daily activities in a room equipped with an automatic video monitoring system. The first result of the study was to demonstrate the feasibility of this new assessment method from both the patient and the technical points of view.

It was interesting to note that following a full explanation of the automatic video monitoring system, none of the AD patients nor caregivers refused to participate. The assessment was also interesting from the caregiver's point of view in that they were able to observe the AD participant's behaviour by means of a monitor located outside the study room. This is meaningful from a qualitative perspective in understanding the AD patients behavioural disturbances.

The scenario was composed of three distinct steps. The first step was devoted to examiner-directed motor activities such as standing and sitting. The control participant performed all these activities faster than the two AD participants. Results also indicated that the motor parameters obtained with the sensor allow the two AD participants to be differentiated. Participant 1 was faster than Participant 2 during the walking task, whereas the opposite was seen for the balance task. These parameters are interesting to observe considering that recent studies show that ambulatory velocity decreases with the severity of the disease [14, 15].

The second step of the scenario was composed of semi-directed cognitive activities. Here the speed of processing also differed among participants. Furthermore, AD participants were not able to follow the correct order of the tasks and even omitted some of them. These types of disturbances have previously been demonstrated using multitasking[16] in AD. Indeed, multitasking is characteristic of complex situations with few external constraints, and requires a number of executive competencies, such as selecting, organizing, and executing various tasks and impact on daily functioning. The last step of the scenario was devoted to free activities and the data collected are particularly interesting from a qualitative point of view. The control participant chose one of the proposed activities (reading) and undertook this activity for almost the entire duration. In contrast, the two AD participants had more difficulties choosing one of the suggested activities and were not able to undertake any one activity in a sustained manner for the entire duration (30 minutes) of the step. Hence, these results demonstrate that assessments using ICT are not only feasible and well-tolerated, but can also provide useful information concerning motor, cognitive and behavioural dimensions of a disease such as AD.

There are, however, several limitations to this study. From a clinical point of view, this was a pilot study and it is therefore impossible to clearly demonstrate that the technology can differentiate significantly between AD participants and controls on the basis of only three clinical cases. Similarly, concurrent validity of the motor, cognitive and behavioural characteristics need to be compared with existing scales in these areas. In order to do this, a second version of the scenario, which is closer to the existing standardised rating scales, needs to be devised. From a technical point of view, the automatic video monitoring system needs to be improved in order to be able to capture all the activities undertaken within the room. At the moment this is not the case, particularly for the AD participants during the free activities step of the scenario.

In order to avoid this kind of false negative event, the automatic video monitoring system needs to be improved. This can be achieved with further development of the vision algorithms and the predefined event models. Two points may also help to a better recognition. The fact that some activities were not captured by the automatic video monitoring system was not due to the fact that the video event recognition algorithms were not working properly, rather that in this particular experiment, the video cameras did not capture the entire scene. Choosing the best location of the videos cameras to enable them to capture the entire scene should allow all the activities top be detected. Another important point is that all the event models of the activities of interest need to be defined so that they can be recognised by the system. If an event model is not defined and not inputted into for the video event recognition system, the event instance will not be detected. Thus the event-modelling step is essential, which is why the technology team worked closely with the clinical team to elaborate the event model database.

The automatic video monitoring system presented here analyzes human behaviours and looks for changes in activity through the detection of the presence of people and their movements in real time. The system also automatically recognizes events and positions. The vision component (e.g. detection, classification and tracking tasks) enables the person in the scene to be detected and his or her movements to be tracked over time.

In conclusion, despite the limitations outlined above, the results of this study are important since this is the first time automatic video analysis has been used as an objective measure of motor, cognitive and behavioural symptoms in AD. Once the technique has been standardized, it could significantly enhance the assessment of AD patients in both clinical and clinical trial settings as well as providing further information regarding patient frailty that could enhance their safety and ease caregiver burden.

For the time being, such experimentation is most appropriately and accurately undertaken in a hospital setting, even when observing real AD patients. The next stage in the development of this technology is to be able to undertake such experimentation in the home setting

None of the authors has any competing interests to disclose.

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Table

Table 1: description of the directed activities (first step of the clinical scenario)

Balance testing (score ranging from 0 to 4)

a- <u>Side by side stand, one's feet together</u>

- Held of 10 seconds	1 pt
- Held for less than 10 seconds	0 pt
- Unable	0 pt

End of the balance testing if scoring is 0.

b- <u>Semitandem stand, stand with the side of the heel of one foot touching the big toe of the other foot</u>

- Held of 10 seconds	1 pt
- Held for less than 10 seconds	0 pt
- Unable	0 pt

End of the balance testing if scoring is 0.

c- <u>Tandem stand, with the heel of one foot in front of and touching the toes of the other foot</u>

- Held of 10 seconds	1 pt
- Held for less than 10 seconds	0 pt
- Unable	0 pt

Unipodal balance testing (Tinetti)

This test is made of 2 distinct sequences. Participant stands on one foot (right then left foot), eyes open, for 10 seconds or less if he has difficulties.

<u>Right foot :</u>	Held of 10 seconds	Y/N	
	Held for less than 10 seconds:		*sec*
<u>Left foot :</u>	Held of 10 seconds	Y/N	
	Held for less than 10 seconds:		*sec*

Speed of walk testing (score ranging from 0 to 4)

Walk through the room, from the opposite side of the video camera for 4 meters and then go back to the starting point.

First attempt:	Time to walk 4 meters:	sec
Second attempt:	Time to walk 4 meters:	sec

For a 4 meters walk:

More than 8.7 seconds:	1 pt
From 6.21 to 8.7 seconds:	2 pt
From 4.82 to 6.2 seconds:	3 pt
Less than 4.82 seconds:	4 pt

Repeated chair stands testing: From sat to stand position (score ranging from 0 to 4)

The examiner asks the participant to make the first chair stand, from sat to stand position without using his arms. The examiner will then ask the participant to do the same action 5 times in a row.

The participant hasn't completed rises in less than 60 seconds:	0 pt
16.70 seconds or more:	1 pt
From 13.70 to 16.69 seconds:	2 pt
From 11.20 to 13.69 seconds:	3 pt
11.19 seconds or less:	4 pt

Table 2: List of the activities proposed to the patient during the semi directed activities (second step of the clinical scenario)

•1.Walk to the reading table and read something for 2 mn •2.Walk to the coffee corner where the kettle is and make warm some water. •3.Walk to the phone and compose this number: xxxxxx. •4.Take the watering can and water the plant. •5. Walk to the television and turn it on with the remote control. •6. Walk to the reading table, take the playing cards and classify them by color (reds with reds, blacks with blacks). •7. Take the green "ABCD" folder on the desk with the A, B, C, D sheets in it. •8. Match the A, B, C, D sheets from the folder to one's dispersed all over the room; A with A, etc… •9. Put the "ABCD" folder back on the desk. •10. Get out of the room.

Table 3: Clinical characteristics of the 3 subjects participating to the protocol.

	Mr M Participant 1 - AD	Mrs B Participant 2 - AD	Mr D Participant 3 - Control
Sex	M	F	M
Age	77	76	77
Level of Education	High	High	High
MMSE score	21	20	29
NPI total score	17	9	0
NPI domain score	17	9	0
NPI *Delusion*	0	0	0
Hallucination	0	0	0
Agitation	0	0	0
Depression	6	6	0
Anxiety	0	0	0
Euphoria	0	0	0
Apathy	2	4	0
Desinhibition	3	1	0
Irritability	3	0	0
A M B	0	0	0
Sleep disorder	3	0	0
Appetite	0	0	0
MADRS	32	7	0
GDS	14	4	0
AI caregiver	2	6	0
AI patient	0	6	0
AI clinician	2	6	0
IADL-e	29	22	9
UPDRS	0	0	0

A M B = aberrant Motor behaviour. MADRS = Montgomery Asberg depression scale; GDS = Geriatric depression scale; AI = Apathy inventory

Table 4: directed activities step video monitoring results: the speed execution (seconds) of each part of the directed activities (balance, walk, sit-to-stand), the speed of displacement (cm/s) of the participant and the step length (cm).

Activity	**Participant 1 - AD**	**Participant 2 - AD**	**Participant 3 - Control**
Time execution of balance exercise(s)	134	52	62
Time execution of walking exercise(s)	33	34	26
Time execution of sit-to-stand exercise(s)	39	11	8
Speed of walk(cm/s)	18.18	54.5	100
Step-length(cm)	40.8	46.1	88.9

Table 5: semi directed activities video monitoring results. Activities done by each participant in the correct order, the activities done but not in the right order (error of order), the activities that participants have not done or forget to do (omission) and the speed of execution of the activity (minutes: seconds).

Participant 1 (AD)	**Right order**	**Error of order**	**omission**	**Speed**
1. read something for 2 mn	X			2:20
2. make warm some water	X			0:28
3. compose phone number			X	
4. water the plant			X	
5. and turn TV on (remote control)		X		0:31
6. classify playing card by color		X		1:06
7.. Take the “ABCD”			X	
8. Match the A, B, C, D sheets			X	
9. Put the “ABCD” folder back			X	
Participant 2 (AD)	**Right order**	**Error of order**	**omission**	**Speed**
1. read something for 2 mn	X			2:18
2. make warm some water	X			1:16
3. compose phone number		X		1:04
4. water the plant			X	
5. and turn TV on (remote control)			X	
6. classify playing card by color		X		0:57
7.. Take the “ABCD”		X		
8. Match the A, B, C, D sheets		X		3:36
9. Put the “ABCD” folder back		X		
Participant 3 (Control)	**Right order**	**Error of order**	**omission**	**Speed**
1. read something for 2 mn	X			1:46
2. make warm some water	X			0:15
3. compose phone number			X	
4. water the plant	X			0:05
5. and turn TV on (remote control)	X			0:25
6. classify playing card by color	X			0:55
7.. Take the “ABCD”	X			0:02
8. Match the A, B, C, D sheets	X			0:19
9. Put the “ABCD” folder back			X	

Table 6: Activities recognized by the video monitoring system during the free activities part. For each activity: time sent to the activity (in minutes) and the number of different occurrences of this activity.

	Mr M Participant 1 - AD	Mrs B Participant 2 - AD	Mr D Participant 3 - Control
Reading	-	1 mn (1)	24 mn (2)
Making tea / coffee	-	12 mn (3)	-
Watching TV	10 mn (4)	-	-
Looking at the library corner	1 mn (2)	-	1 mn (2)

Figure

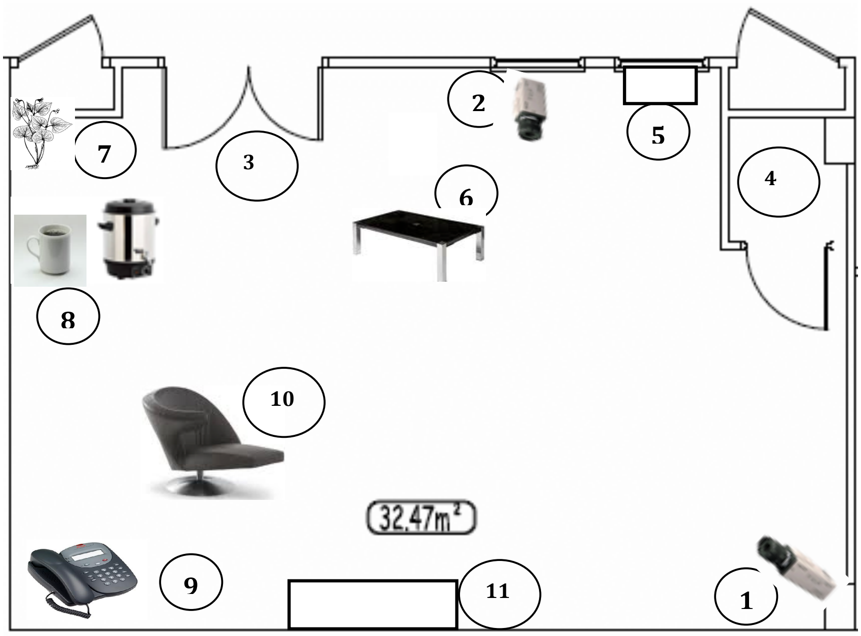

Figure 1: Organisation of the observation room for ecological testing. Two video cameras (1 and 2) are positioned in two opposite places of the room. The room has two doors, the entrance (3) and the access to the bathroom (4) and is equipped with several objects a TV (5), a table for reading (6), a plant (7), a coffee corner (8), a phone (9), an armchair for sit-to-stand exercise (10) and a library (11).

Figure 2: Architecture of the automatic video monitoring system

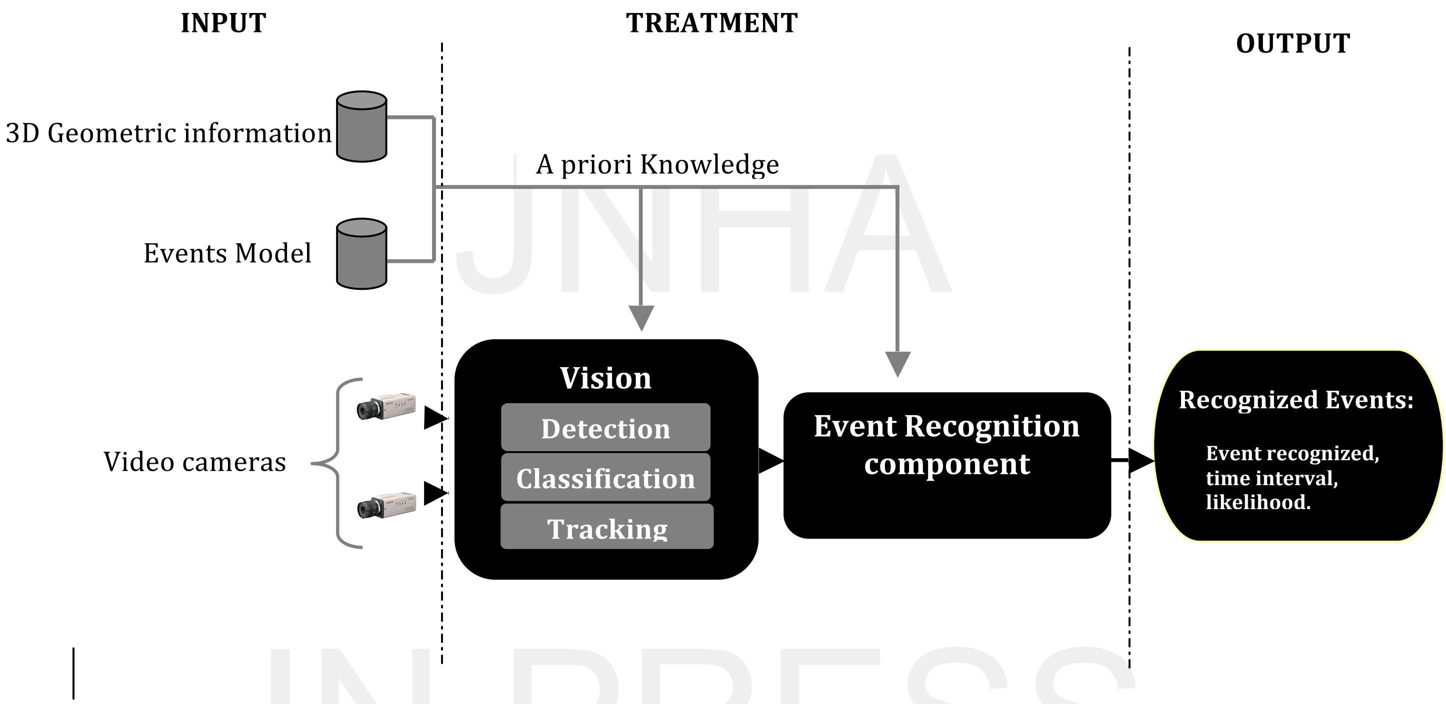

Figure 3: Vision component of the automatic video monitoring system: the vision component consists on detecting for each frame the mobile objects in the scene and classifying them with labels such as PERSON, corresponding to their type based on their 3D size and their shape. The tracking task associates to each new mobile object a unique identifier and maintains it globally throughout the whole video.