A Fuzzy Multi Agent Architecture for Sensor based Automated Scene Surveillance

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ABSTRACT: *Human recognition and movement analysis are important tasks in various applications especially in video surveillance. This paper proposes a multi agent architecture for sensor based automated scene surveillance using Microsoft Kinecet camera. It aims to record videos about each person that appears in the scene and to generate sonorous alarms when an abnormal situation is deduced. This decision making support system had to deal with environment uncertainties through fuzzy expert system which is responsible of person recognition.*

Keywords: Multi Agent System, Video Surveillance, Fuzzy Expert System, Decision Making, Uncertainty

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1. Introduction

The changing world scenario, where the security is a risk for several factors including industrial espionage and terrorism, requires sophisticated surveillance. Depending on its type, surveillance systems can provide information with details such as dates, times, and persons of interest. The demand of automated surveillance system is increasing. Otherwise, research proved that video surveillance systems are mostly used in order to assist security guards in their work. In their basic form, although these systems are numeric, they have functions that are limited to the capture, transmission, storage and display of visual data at the monitoring center. They are typically consisted of several cameras distributed through an area connected to monitors in a central operator room, where highly qualified personnel are in charge of reviewing and analyzing the video stream of each camera to observe suspicious activity or persons. However, human actor could not be very efficient detecting at every moment abnormalities. Most problems are tiredness and human dependence due to the continuous monitoring [1] [2].

The solution is in technology integration (hardware and software) that increases the share of assistance to human operator and reduces the share of intervention of this later. The video surveillance system must evolve from its traditional form to new forms that incorporate additional features of data processing, analysis and decision making.

This work aims, in one hand, to provide a solution to this problem by designing and developing a multi-agent system (MAS) for surveillance based on Microsoft Kinect camera. In fact, our surveillance system uses the Microsoft Kinect to recognize when a human enters the image and it is able to differentiate between known and unknown persons by maintaining a database of known persons' skeleton dimensions. In another hand, our research enhances uncertainty effects by introducing a fuzzy expert system (FES) in alarm generation. These combined capabilities allow delivering an intelligent, autonomous security system capable of detecting an unwanted intruder and alerting the human operator, while minimizing false alarms.

This paper is organized as follows: the first section presents related works with fuzzy MAS for surveillance. Second section is reserved to the proposed approach used in video surveillance. Finally, results are illustrated to focus on importance of the study.

2. Related Works with Fuzzy Surveillance Architecture

2.1 Multi Agent Systems (MAS)

In artificial intelligence research, agent-based systems technology has been hailed as a new paradigm for conceptualizing, designing, and implementing software systems. Agents are sophisticated computer programs that act autonomously on behalf of their users, across open and distributed environments, to solve a growing number of complex problems [13]. Increasingly, however, applications require multiple agents that can work together. A multi-agent system (MAS) is a loosely coupled network of software agents that interact to solve problems that are beyond the individual capacities or knowledge of each problem solver.

MAS has the following advantages over a single agent or centralized approach: An MAS distributes computational resources and capabilities across a network of interconnected agents. Whereas a centralized system may be plagued by resource limitations, performance bottlenecks, or critical failures, an MAS is decentralized and thus does not suffer from the "single point of failure" problem associated with centralized systems. Furthermore, an MAS allows the interconnection and interoperation of multiple existing legacy systems. By building an agent wrapper around such systems, they can be incorporated into an agent society. In another hand, MAS models problems in terms of autonomous interacting component-agents, which is proving to be a more natural way of representing task allocation, team planning, user preferences, open environments, and so on. We notice also that MAS efficiently retrieves, filters, and globally coordinates information from sources that are spatially distributed and it provides solutions in situations where expertise is spatially and temporally distributed. We conclude then that MAS enhances overall system performance, specifically along the dimensions of computational efficiency, reliability, extensibility, robustness, maintainability, responsiveness, flexibility, and reuse.

Nowadays, systems that detects suspicious objects [3], that analyze [4] object movements and that give person gait are very encountered [5] [1]. A network of camera surveillance that communicates is usually used to have maximum information about the global situations. Multi agent systems were proposed in several works of video surveillance because agents are autonomous and communicate and cooperate with each other. Actually, surveillance is, usually, assured by a network of cameras that need to exchange data and information. A tracking system based on agents was proposed by [7]. A framework based on cooperative agents for visual surveillance was proposed by Remagino et al. at Kingston University. The system consists of several cameras distributed through the area of interest where the field of view of the cameras can be overlapped [15]. Also, [6] proposes a multi agent architecture to detect and to analyze collected sensors data.

2.2 Fuzzy Expert System (FES)

To derive reliable decisions, the process of decision making has to deal with data of different qualities. The quality is determined by the degree of uncertainty and the amount of missing values that are propagated and aggregated by the transformations applied to the data [12]. This paper research indicates that uncertainty in video surveillance should be treated to have efficient decisions. Many methods calculate uncertainty using statical and probabilistic theories. Besides, heuristic methods such as markov chain and fuzzy logic revealed interesting results.

The uncertain environment of this recognition application is caused by many factors. In the first side, we notice that sensors measurements are uncertain especially when the distance is important between camera and the object. Fuzzy logic is used in several works to minimize uncertainty effects in several domains especially decision making in camera surveillance [8][9]. In fact, in [8] Fuzzy distances from the multi-view dynemes are used to represent the human body postures in the dyneme space. In an earlier work, we've proposed a generic FES for surveillance that was applied in industrial and medical diagnosis and in person recognition.

2.2 Research Issue

In this research, we are proposing these goals to achieve:

- Conception and development of multi agent architecture for video surveillance using KINECET camera: This system is responsible of: displaying live scene, recording tracking videos about each person in the scene and generating alarms in suspicious situations.

- Conception of generic fuzzy expert system: Person recognition and alarm generation must be robust against uncertainty.

3. Proposed Fuzzy MAS for video surveillance

This section is composed of two parts. Details about Microsoft kinecet camera that is adopted in the surveillance system are exposed. Then, MAS components and collaborations are detailed using AUML methodology.

3.1 Microsoft Kinecet camera

Kinect for Xbox 360 changed the way people play games and experience entertainment. Now, Kinect for Windows is transforming how people interact with computers, kiosks, and other motion-controlled devices. From healthcare and physical therapy to retail, education, and training, Kinect for Windows is making it possible for computers to work for us instead of the other way around. Businesses worldwide are using the Kinect for Windows sensor with the Kinect for Windows software development kit (SDK) and an end-user license agreement to develop and deploy solutions that give us the ability to interact naturally with computers by simply gesturing and speaking. [1] Let's start with a small overview of the sensor itself before actually developing for it! Inside the sensor case, a Kinect for Windows sensor contains [2]:

• An RGB camera that stores three channel data in a 1280×960 resolution. This makes capturing a color image possible.

• An infrared (IR) emitter and an IR depth sensor. The emitter emits infrared light beams and the depth sensor reads the IR beams reflected back to the sensor. The reflected beams are converted into depth information measuring the distance between an object and the sensor. This makes capturing a depth image possible.

• A multi-array microphone, which contains four microphones for capturing sound. Because there are four microphones, it is possible to record audio as well as find the location of the sound source and the direction of the audio wave.

• A 3-axis accelerometer configured for a 2G range, where G is the acceleration due to gravity. It is possible to use the accelerometer to determine the current orientation of the Kinect.

Kinecet camera is a Microsoft product which is, normally, designated to video games. In fact, it used interaction techniques permitting a response to voices and movement in captures. It provides two data streams.

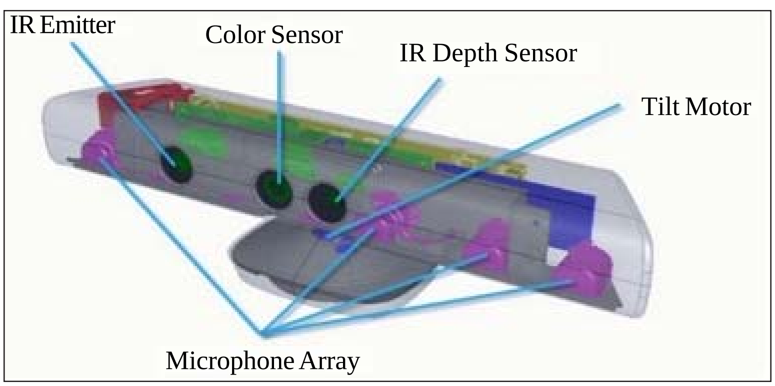

Figure 1. Kinecet Camera

3.1.1 Kinecet Characteristics

It is equipped of sensor that detects colors, depth of objects and sensor to detect movements. Table 1 illustrates sensors information dimensions and types, the field of view and types of data stream.

3.2 MAS Architecture

Proposed multi agent system is composed of seven agents that are summarized in table 2: agent user interface, agent controller, agent normalization, agent tracker, agent knowledge, agent recorder and agent alarm. Each agent had specific tasks and they all communicate through messages to accomplish system functionalities. To represent agents' functionalities and collaborations, we are using AUML methodology.

Kinect	Array Specifications
Viewing angle	43° vertical by 57° horizontal field of view
Vertical tilt range	± 27°
Frame rate (depth and color stream)	30 frames per second (FPS)
Audio format	16-kHz, 24-bit mono pulse code modulation (PCM)
Audio input characteristics	A four-microphone array with 24-bit analog-to-digital converter (ADC) and Kinect-resident signal processing including acoustic echo cancellation and noise suppression
Accelerometer characteristics	A 2G/4G/8G accelerometer configured for the 2G range, with a 1° accuracy upper limit.

Table 1. Kineket carachteristics

Agent	Role	Agent	Role
AGUI (User Interface)	It provides a graphical interface for system users.	AR (Agent Knowledge)	Is responsible of deciding whether the person in the scene is recognized.
ACN (Agent Controller)	It had a global view about the system environment. It controls all other agents.	AR (Agent Recorder)	Is responsible of recording tapes for each person in the detected scene.
AN (Agent Normalization)	It is created by ACN when a Kinecet is connected. It is responsible of generating video and depth data streams.	AA (Agent Alarm)	It generated alarms when an intrusion is detected.
AS (Agent Tracker)	Created when new person enters In the scene. It saves data about new persons.		

Table 2. Agent of surveillance system

General architecture of the system is illustrated by figure 2. It is composed of MAS that communicates with data base containing recorded videos and known person's dimensions. The system disposes also of captures inputs (video and depth data) and one sonorous output for alarms. The global functionalities of all agents are summarized by the following algorithm.

Each agent has different capabilities for specific surveillance tasks. The concept of coalition appears when a group of autonomous agents choose to work together temporarily to achieve a common goal. Next, we give a brief description of the different types of autonomous agents belonging to the multi-agent system: *AGUI* provides a graphical user interface that shows the evolution of the targets that are being tracked, receives commands from the user and acts. It does not have the proactive behavior, packaging the requests and send them to appropriate agents. *AC* has a general vision of the whole scene. It translates user requests received by the interface agent in a series of tasks. It determines, also, the best sources to get the information required to process requests and make decisions among alternatives and it analyzes the environment in order to manage the resources and coordinate the other agents. *AN* is dynamically created by the Control agent whenever a kinect camera is connected to the network. It receives data streams provided by the kinect camera and split them up into depth stream and video stream. *AS* that

```
Start
AGUI starts the interface; AC explores its environment;
Creation of AN ;AN manages data streams provided by
kinect;
Creation of AE ; AGUI displays live video;
if (AN detects a new person by depth data stream) then
        Creation of AS;
        AS records videos sent by AE;
        Creation of AR;
        while ( Person is in the scene) do
                if (Person not identified) then
                  AS sends a research task to AR; AR runs
                                    FES to respond to AS;
                End if
if ( Person doesn't respect its privileges) then
                        AS informs AA;
                        AA generates an alarm;
                        AS notifies AGUI;
End if
        end
        AR is deleted;
        AS informs  AE that recording is finish;
        AS sends  task of saving data in DB to AE;
End if
end
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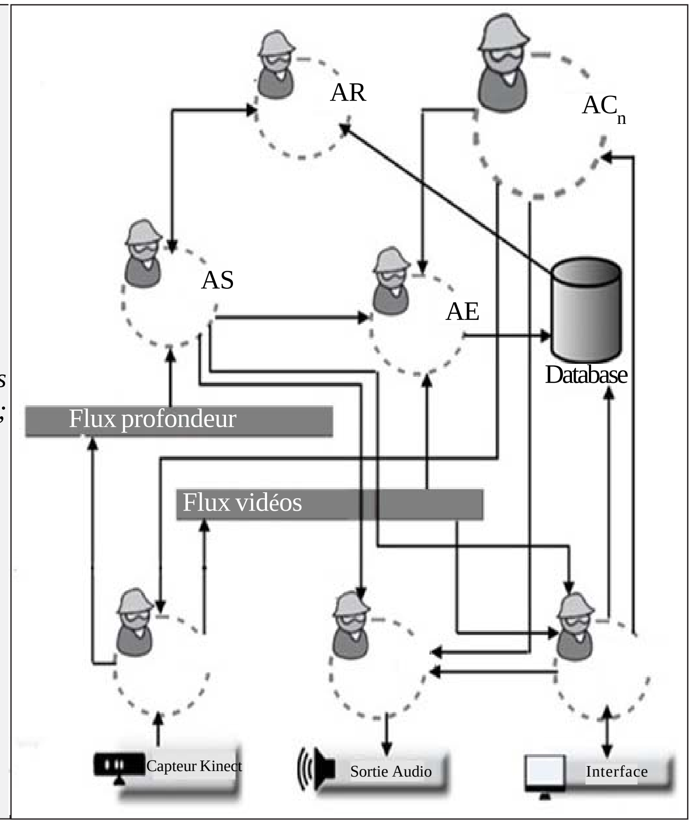

Figure 2. Algorithmof MAS/General architecture of MAS

is created whenever a person is detected by the Kinect coordinated with other agents in order to improve surveillance quality. It has a general vision of the whole scene and makes inferences on the targets and the situation. It is responsible for monitoring the skeleton detected using contextual information and prediction of certain situations requiring a call to the alerting agent. The agent stores information about static objects that could provoke partial occlusions of the tracked targets but it also stores dynamic information about the scene. For each tracking agent correspond a recognition agent (*AR*) that is in charge of identifying the detected person. It makes a search to match the measurements of skeletal received with a known skeleton in the database. *AR* belongs to a specific camera with recording features only. It records videos of detected people using the video stream from the Kinect camera. It adds to the database details received from other agents. And finally, *AA* is in charge of declaring alarms.

In fact, Agents have autonomous activities and goals, this is what differs an agent of an object, therefore UML is insufficient for modeling agents and multi-agent systems and it is for this reason that we have used AUML to model our system. Figure 3 is general use case that explains the task of each agent and system principal functionalities.

AUML sequence diagram presents a set of interactions between agents playing roles in collaborations. To represent the interactions between agents, the definition of the concept called message used in the UML need to be extended to represent elements sending and receiving messages and not only calling methods of other elements.

In this section, we've described the SMA architecture by précising agents and their roles. In another hand, the general structure of the system and the algorithm governing it are detailed. Finally, AUML modeling as adopted in order to precise relationship and collaborations between agents. In this part, main functions are to be explained especially: data acquisition, person recognition and alarm generation. [10] [11].

3.2.1 Data Acquisition (AN)

Data acquisition module is developed through "*#C* ". Information is stocked in *mysql* database which relational model is illustrated in figure 5. Kinecet provides two data streams that must be preceded and saved in the data base. In fact, Microsoft gives with the camera a library with some dedicated functions. These tools permit to give 9 positions corresponding to person

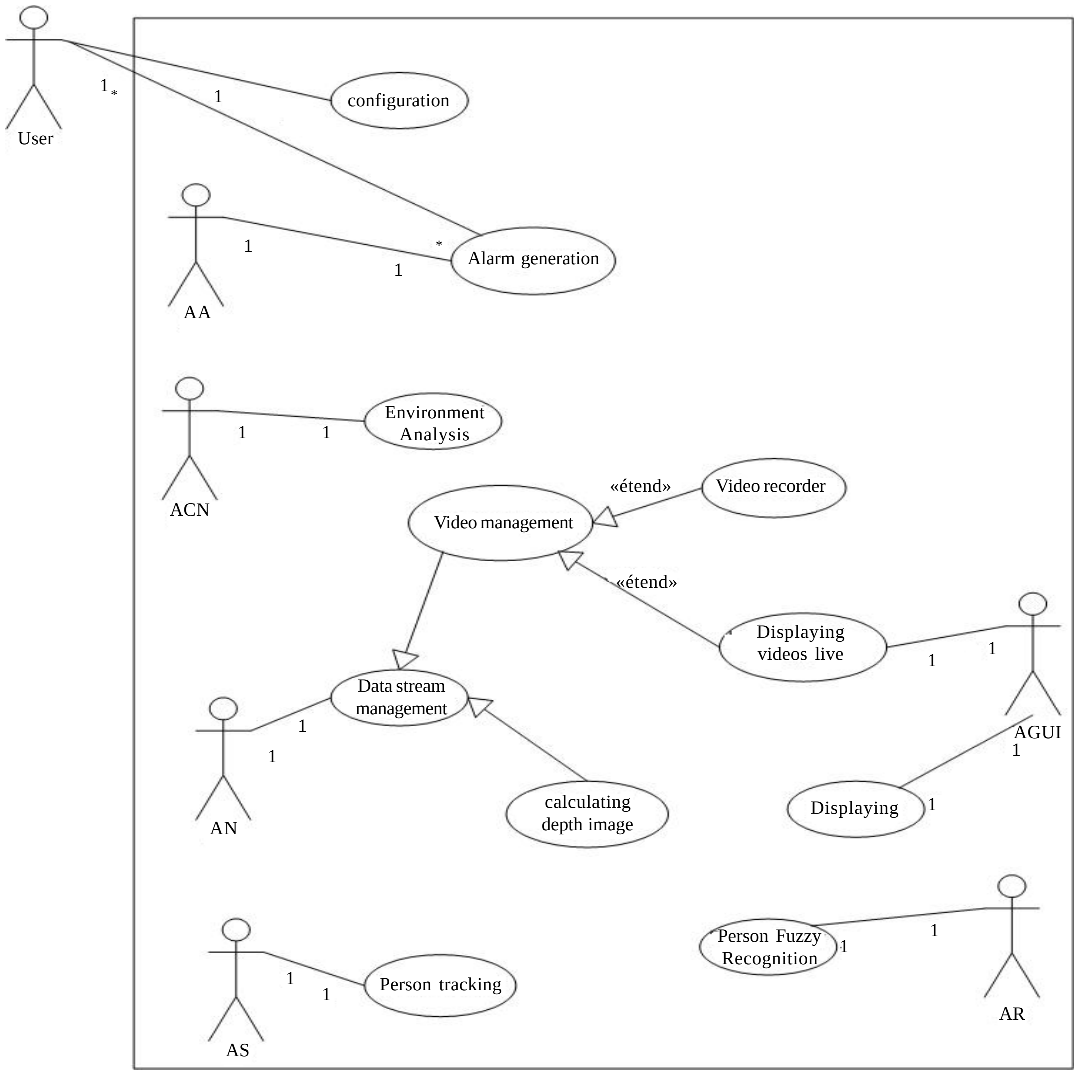

Figure 3. AUML Genral User case

articulations. Furthermore, it takes several shoots in different positions changing the distance between camera and the person.

With every new entry in the camera field of view, several shoots are taken (particularly 10) and the depth stream flow gives 12 positions for each shoot. A simple database that contains three tables is created in *Mysql*. Table "*person*" contains the articulation positions for each new person with ten shoots. Besides, a table 'known' contains nine measurements for persons allowed to be in the field of view.

These nine measurements correspond to person members length which are respectively: right hand up (*rhu*), right hand down (*rhd*), left hand up (*lhu*), left hand down (*lhd*), right leg up (*rlu*), right leg down (*rld*), left leg up (*llu*), left leg down (*lld*) and shoulders (*sh*). Consequently, data acquisition module calculates vector ***d*** for each person for ***n*** view.

$$d = [rhu, rhd, lhu, lhd, rlu, rld, llu, lld, sh]$$

We estimate that we could identify a person with theses information. The uncertain environment of this recognition application is caused by many factors. In the first side, we notice that sensors measurements are uncertain especially when the distance is important between camera and the object. Besides, when object position is not adequate articulations measurements are estimated by the camera and not real. Finally, adopting members' length to recognize an object or a person is not a unique identifier which raises uncertainty effects in decision making in this case.

Figure 5 describes a simple model of three tables that contains: table "*squelette*" where person entering in the scene data are

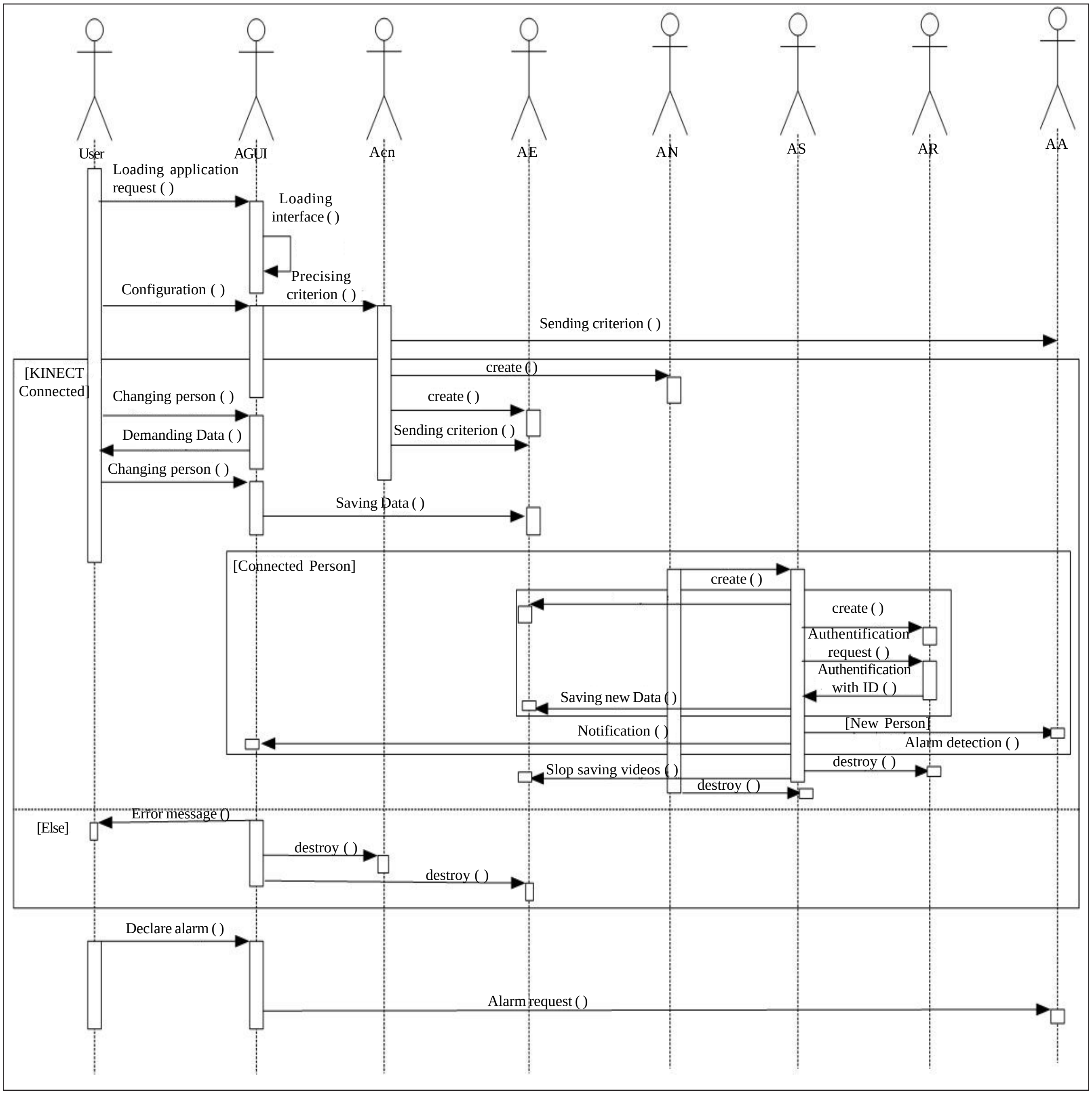

Figure 4. AUML Sequence diagram

saved, table "*person*" where known persons data are saved and finally, table "*videos*" where videos about person in the scene are saved.

3.2.2 Fuzzy Person recognition (AR)

We estimate that we could identify a person with theses information. The uncertain environment of this recognition application is caused by many factors. In the first side, we notice that sensors measurements are uncertain especially when the distance is important between camera and the object. Besides, when object position is not adequate articulations measurements are estimated by the camera and not measured. Finally, adopting members' length to recognize an object or a person is not a uniqueidentifier which raises uncertainty effects in decision making in this case. For these reasons, fuzzy logic is proposed to qualify the distance between a new person member's length and known persons in the data base. A generic fuzzy expert system is developed to guarantee and minimize uncertainty effects.

We consider an approach which is based on residual analysis. Residual is distance between real values and references. Our aim is to have zero distance between them. In this case, we consider member dimensions vectors $\boldsymbol{d_i}$ (i *in* $[1 - n]$ of each view captured of person in camera field of view which is saved in table *squelette*. We consider also $\boldsymbol{d_{ref}}$ which is a vector of member dimensions of known persons saved in table *person*. To identify the new entry we calculate a residual vector:

$$r_i = [(rhu_{ref} - rhu_i), (rhd_{ref} - rhd_i), (lhu_{ref} - lhu_i), (lhd_{ref} - lhd_i), (rlu_{ref} - rlu), (rld_{ref} - rld_i), (llu_{ref} - llu_i), (lld_{ref} - lld_i), (shd_{ref} - shd_i)]$$

with i in $[1 - n]$ *and n is the number of captures fixed at* 5.

$$dr_i = [r_{i+1} - r_i]/t_{i+1} - t_i$$

Fuzzy expert systems are implemented for each variable of d (in this case, 9 FES are used). The proposed fuzzy expert system is having two entries residual r_i end its variations dr_i and one ouput cf which represent the certitude coefficient of an alarm generated on person member. Three parts are to be considerate: fuzzification, inference engine and défuzzification.

3.2.2.1 Fuzzification

Linguistic variables r and dr are variables ranging respectively in sets of symbolic labels $A(r)$ and $B(dr)$. The terms describe qualitative value of magnitude of both residue and its variations (*NB*: Negative Big, *NM*: Negative Moyen, *NS*: Negative Small, *Z*: zero, *PS*: positive small, *PM*: positive Moyen, *PB*: positive Big).

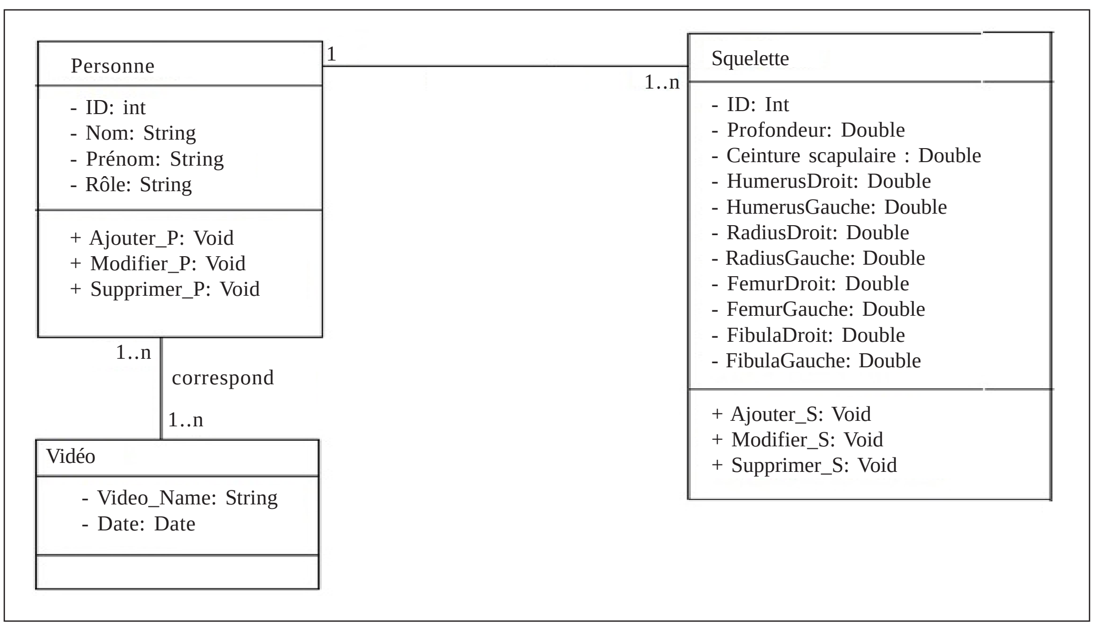

Figure 5. Data base tables

$$A(r) = \{NB, NM, NS, Z, PS, PM, PB\}; B(r)= \{NB, NM, NS, Z, PS, PM, PB\}$$

The linguistic variable cf is output variable ranging in sets of symbolic labels $C(cf) = \{AL0, AL0.2, AL0.4, AL0.6, AL0.85, AL1\}$. Figure 6 illustrates the membership functions types and numbers. In fact, for the two entries trapezoidal membership functions are adopted and for the output triangular functions are adopted.

3.2.2.2 Inference engine

Linguistic model relating variables r and dr to variable cf is written as rule base, relating the terms of $A(r)$ and $B(dr)$ to those of

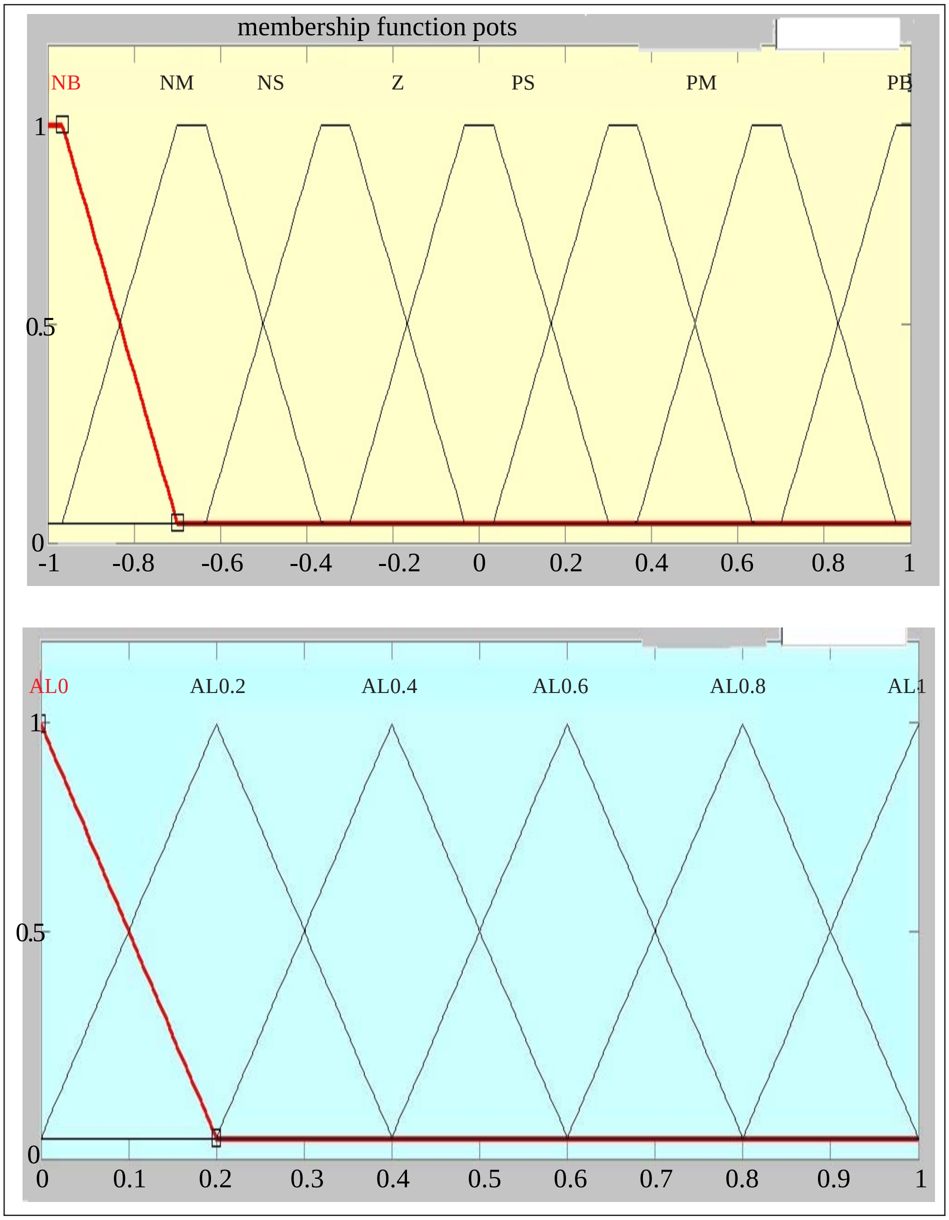

Figure 6. *r*, *dr* and *cf* membership functions

C (*cf*) in 49 rules. Table 3 summarizes the pattern that matches the two inputs *r* and *dr* to the output *cf*.

$$\text{If } r \text{ is } A_k \text{ and } dr \text{ is } B_l \text{ then } cf \text{ is } C_s \qquad (1)$$

3.2.2.3 Deffuzzification

In this system output calculation, a crisp value is required. Thus, the defuzzification operation is requisite. In this approach, the *gravity centre* is the method adopted to get the crisp value traducing the severity of generated alarm, from the output membership function. The 3D representation of cf variation indicates that: with r values around zero, cf is almost minimal. It reaches itsmaximum when *r* and *dr* are important in absolute values. Otherwise, *cf* values are increasing slowly to reach 0,92. Consequently, decision about alarms is no longer binary (0 – 1).

Recognizing a person is then depending of the nine certitude coefficients of each member as follows :

r	dr						
	NB	NM	NS	Z	PS	PM	PB
NB	AL1	AL1	AL1	AL1	AL0.8	AL0.8	AL0.6
NM	AL1	AL1	AL0.8	AL0.6	AL0.6	AL0.4	AL0.4
NS	AL0.8	AL0.6	AL0.4	AL0.4	AL0.2	AL0.2	AL0
Z	AL0.4	AL0.2	AL0	AL0	AL0	AL0.2	AL0.4
PS	AL0	AL0.2	AL0.2	AL0.4	AL0.4	AL0.6	AL0.8
PM	AL0.4	AL0.4	AL0.6	AL0.6	AL0.8	AL1	AL1
PB	AL0.6	AL0.8	AL0.8	AL1	AL1	AL1	AL1

Table 3. Inference Table

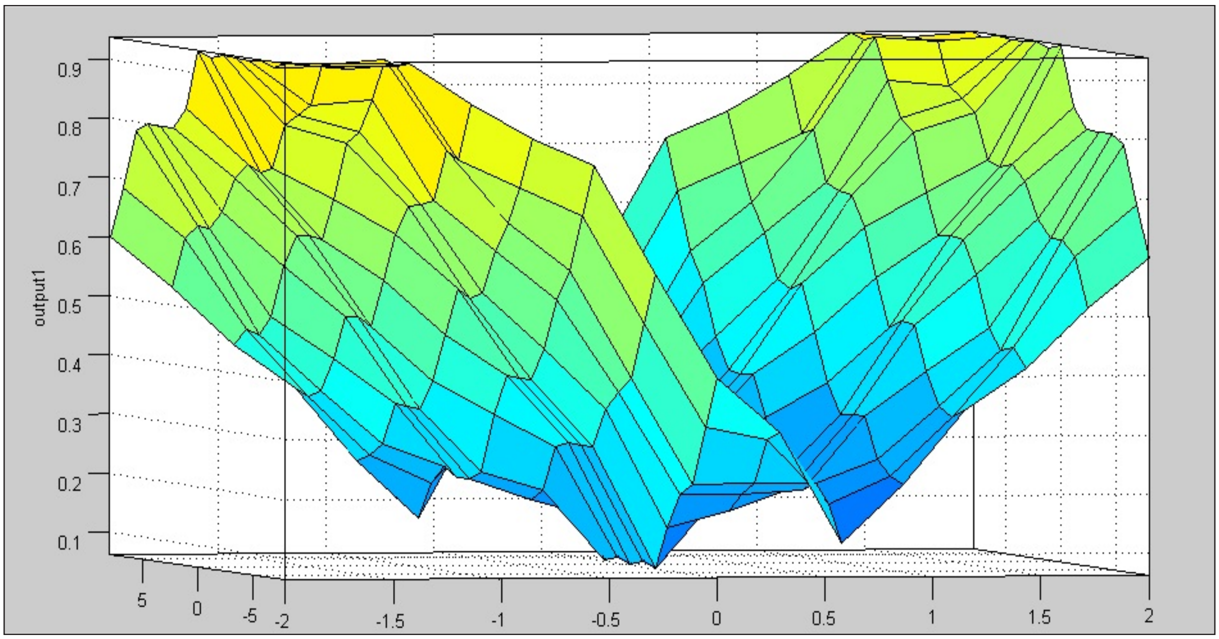

Figure 7. 3*d* variations of *cf*

- *If* (*mean* [*cf* (*rhu*), *cf* (*rhd*), *cf* (*lhu*), *cf* (*lhd*), *cf* (*rlu*), *cf* (*rld*), *cf* (*llu*), *cf* (*lld*), *cf* (*sh*)]) < 0.2) *Then person is recognized*.

- *When the comparison between new person and all known ones is done and it was no recognized then an alarm is generated.*

3.3 Alarm generation (AA)

The declaration of alarms can be summarized by decision rules system of tracker agent that bases its decision on local information. Depending on the role of detected person and its rights of access, if a suspect is detected, an audible alarm sounds. In fact, alarm is generated when an unknown person is in the scene or when known person doesn't respect its role.

4. Realisation and results

To realize this application, we used a specified kit for Kinecet camera "*SDK*" (Software Development Kit) that permits to analyze data coming from sensors. SDK is developed in C# so the MAS was realized using C# which is presented with Visual Studio.NET. The relationship with the data base is assured via JDBC-ODBC or via specific Data Base Management System pilot JDBC. The data base is developed in Mysq l. Finally, FES module is realized using Matlab toolbox.

Figure 8 is an illustration of principal interface of surveillance system. It presents in one hand a live streaming of scene in field of view of connected camera. In another hand, human operator could manage known persons: adds new one, modifies data about existing one or deletes one. Besides, he could consult history of each person that passes in the scene. Videos are saved in the table “*video*”: each video is associated with (person) intruder. Human operator also could generate alarms from notifications of surveillance system or when he realized that there is emergency not detected. Another interesting capture is that of person roles. In fact, each known person has specific role and rights: times associated with its presence in the scene. Figure 9 is an illustration of this functionality that will be interested in alarm generation.

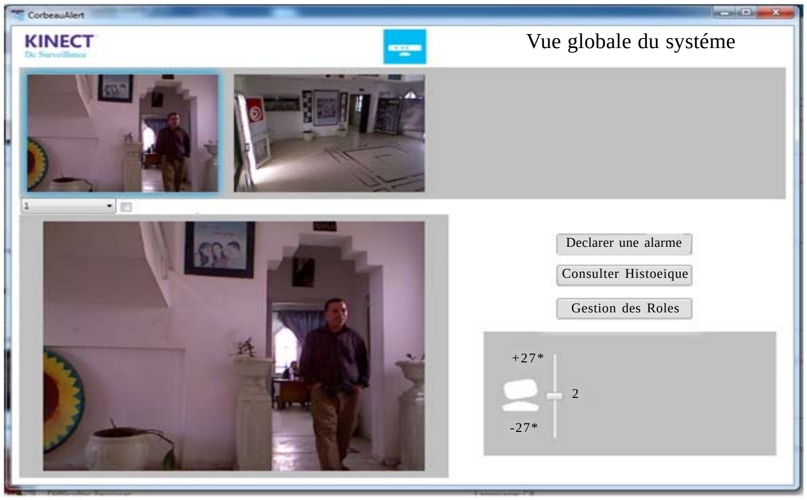

Figure 8. Principal Interface of surveillance system

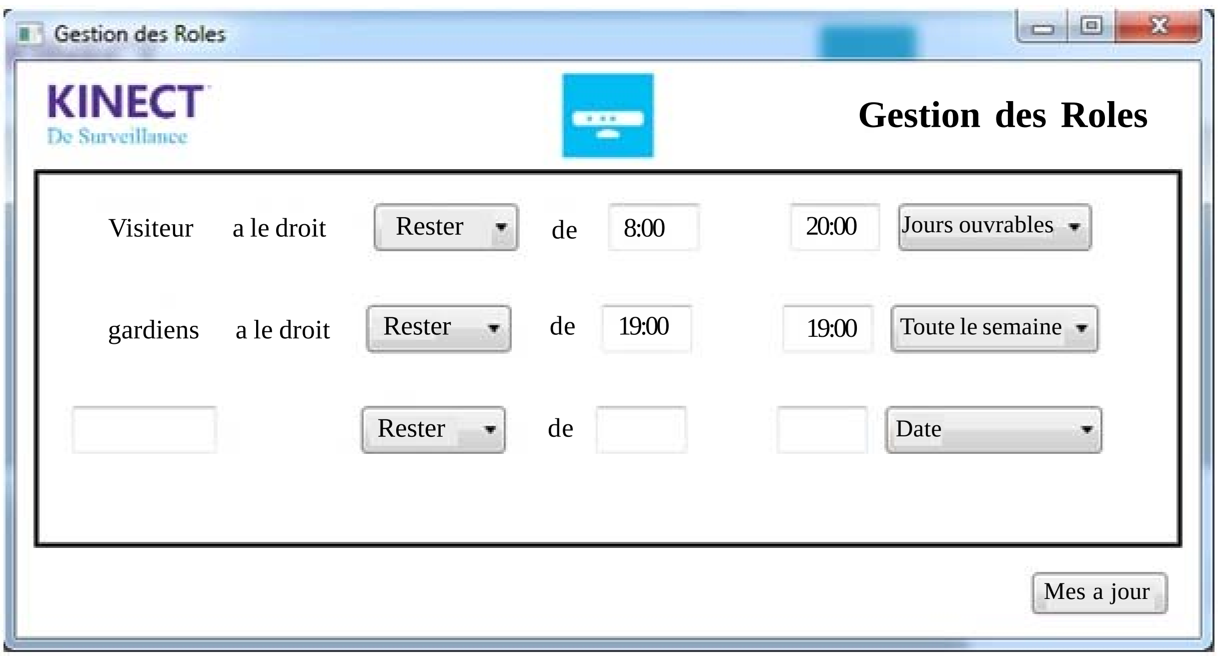

Figure 9. Interface of role management

Finally, we are focusing on fuzzy person recognition. When a new skeleton is detected its member’s lengths are registered in data base at the table “*squelette*”, for five captures. Table 4 presents the comparison between new person lengths and those of known person in the base (residual). Next table illustrates the calculation of cf coefficient for each variable.

Fuzzy expert system calculates for each couple (r, dr) a coefficient of certitude. At every capture, mean of nine members coefficient cf: right hand (up and down), left hand (up and down), right leg (up and down), left leg (up and down) and shoulders.

Minimal value of five captures certitude coefficient is compared to threshold (0.2) to decide whatever the person is recognized.

In the case bellow, the minimal value of all capture is 0.32 which is superior then 0.2 →*toto* and new person are not identical à alarm is generated .Surveillance system indicates this alarm by sonorous and visual effects hich helps operator human beign taking decision.

(cm)	$capture\ 1$ $t = 0\ s$	$capture\ 2$ $t = 2\ s$	$capture\ 3$ $t = 4\ s$	$capture\ 4$ $t = 6\ s$	$capture\ 5$ $t = 8\ s$
$r\,(rhu)$	0.2000	0.1800	0.2100	0.2200	0.2000
$r\,(rhd)$	0.3000	0.3200	0.3500	0.2800	0.3000
$r\,(lhu)$	0.5000	0.5100	0.4800	0.4700	0.4900
$r\,(lhd)$	0.5000	0.4800	0.4500	0.4200	0.4500
$r\,(rlu)$	0.2600	0.2500	0.2300	0.2800	0.2300
$r\,(rld)$	0.0100	0.0900	0.0900	0.1000	0.1200
$r\,(llu)$	0.2000	0.2500	0.2800	0.2800	0.2300
$r\,(lld)$	0.4000	0.5000	0.4200	0.4300	0.2300
$r\,(sh)$	0.0100	0.0200	0.1000	0.0900	0.0900

	$capture\ 1$	$capture\ 2$	$capture\ 3$	$capture\ 4$	$capture\ 5$
$cf\,(rhu)$	0.3144	0.2995	0.3217	0.3291	0.3144
$cf\,(rhd)$	0.4000	0.4000	0.4000	0.3788	0.4000
$cf\,(lhu)$	0.5000	0.5060	0.4879	0.4818	0.4940
$cf\,(lhd)$	0.5000	0.4879	0.4691	0.4483	0.4691
$cf\,(rlu)$	0.3606	0.3523	0.3366	0.3788	0.3366
$cf\,(rld)$	0.0633	0.2107	0.2107	0.2245	0.2477
$cf\,(llu)$	0.3144	0.3523	0.3788	0.3788	0.3366
$cf\,(lld)$	0.4324	0.5186	0.4411	0.4555	0.3297
$cf\,(sh)$	0.0633	0.0633	0.2245	0.2107	0.2107
Mean	**0.3276 >0.2**	0.3545	0.3634	0.3651	0.3487

Table 4. Residual Values and Fes Response for Person Recognition

Figure 10. Alarm generation - intrusion

5. Conclusion

Decision support system in video surveillance domain is a serious need especially in home surveillance. The importance of this application is, especially in Tunisia, not to be denied. In fact, in our country video surveillance is mainly depending on human being presence. Therefore, the conception and the development of muliagent system capable of: managing known persons in database, recording videos about each intruder and generating alarms, must be interesting for home and professional use.

The fact that this application is using MAS architecture makes the migration into a network application of Kinecet easier. To have more global and complete surveillance system, network of cameras permits to track persons in most important field of view. Communication between agents facilitates person tracking.

This work has, also, treated uncertainty in video surveillance using a fuzzy expert system. In fact, data coming from the camera are processed and saved in SQL data base in an acquisition module. The aim of this work is to generate an alarm when an intrusion happens. FES based on error analysis of member lengths of known persons and those of new entries. Fuzzy logic takes into account errors in sensors and in articulations estimations. The minimum certitude coefficient is considered to raise robustness of alarm generation. Also, a threshold is fixed under which reorganization is not possible. This work is to be improved by integrating facial recognition because the actual system is based on members' length comparison.

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