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A Perceptive Model for Virtual Agents in Crowds

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Abstract This paper proposes a multi-perceptive model to stimulate the movement of virtual agents in danger events. The sound source (alarm), visual event and smell event localizations, as well as their attributes, such as sound frequency, event dimension and odor's propagation area, are defined in the virtual environment. In hearing perception, the sound intensity is attenuated according to the distance from the source and collisions with the walls located between the agent and the alarm. Also, the different sensibilities of the human ear are taken in consideration, as well as the natural hearing loss because of the aging. Besides hearing, the model aggregates other perceptions, such as vision and smell, treated by zonal and sensory approaches regarding the distance and the agent view angle to the perceptive area. To provide realism to the model, a pseudo-communication among agents was defined to propagate the individual knowledge acquired by their perceptions. Using this knowledge, the behavior model will define which action is to be taken next in the environment through a decision tree.

1 Introduction

With the growing number of research efforts in behavior animation, the entertainment industry (mostly video games and cinema) has explored extensively the use of virtual humans (or virtual agents). Simulation algorithms, either executed in real-time or not, allow the simulation of complex motions using behavioral animation. In particular, virtual agents having perception abilities such as vision, hearing, smell and communication tend to produce more realistic results. Also, Reynolds [17] suggested that it is wrong to provide an agent with perfect and complete information about its virtual world, since incomplete knowledge is more likely to model reality accurately. Hence, the perception model must present characteristics which resemble a real model, as well the inherent imprecision.

Many authors in the literature have investigated the research area of virtual humans [7, 11, 13, 4, 5], mainly concerned with behavior simulation applications, serious games and training tools, among others. Therefore, the development of virtual humans can provide a valuable tool to games industry. In fact, NPCs (Non-Player Characters) in a simulation could be more perceptive and smarter using, for example, techniques of Artificial Intelligence (AI).

This paper presents a mathematical model to provide virtual hearing, vision, smell, pseudo-communication and a behavioral model for the agents' reaction. The main contribution is to provide virtual humans with artificial perception abilities, such as to hear real sounds (e.g. wave files), to see and to smell dangerous events (e.g. fire and/or smoke events), to interact with other agents for simulating pseudo-communication and, finally, to use an AI technique to allow the agent to make its decision based on its perceptions.

In hearing perception, we considered the sound attenuation as a function of the distance between the agent and the sound source, the sound frequency, the blocking walls and also the agents' individualities, such as age and disabilities. For the pseudo-communication, vision and smell perception, we considered the distance from the agent to the point of interest (e.g. another agent or event), as well as its point of view. Using information obtained as a function of agents' perception, we applied a decision tree to provide the agents' decision of evacuating the environment or not.

Our model is tested by measuring crowd evacuation in a virtual environment, once the agents perceive the danger event through their perception abilities (hearing, vision, smell, pseudo-communication). This work is very useful for simulation in the security area, in which the numerical results could indicate problems of planning in environment architecture. For example, an alarm located at an inappropriate place can result in a large number of people that cannot evacuate the environment because they do not perceive the event. Also, the proposed method can have a wide range of applicability in entertainment projects.

2 Related Works

In order to model the behavior of virtual humans, it is fundamental to provide them with abilities that allow to acquire information from the virtual environment where they are inserted. As the amount and diversity of data available to the agents increase, their decision processes tend to be more accurate. This section presents some related work described in literature.

The inclusion of sounds in virtual environments is a very important aspect that improves the presence sense and immersion [9]. There are many approaches in the literature, related to the synthesis, propagation, reduction and audio perception in virtual environments. Several authors treat specifically the rendering of sounds with multiple audio sources. In particular, sample-based (audio files) rendering of spatial sounds has a special interest, but unfortunately requires complex models of signal processing, even for a small number of resonant sources [15]. This processing can include directional patterns of rendering sources and artificial reverberation [19] and audio positional 3D [3].

Some authors treat the problem of sound propagation geometrically, without considering its wave nature (such as in [21]). Such approach is known as geometric acoustics and, although it is not physically correct, it supplies a reasonably accurate simplification of reality, so the analysis of the simulated environment can be accomplished [8].

Another area related to audio generation and synthesis concerns the verbal communication of autonomous agents that must have the ability to "speak" and "perceive" what others agents "say". Monzani e Thalmann [12] described simple methods for sound propagation during the conversation of autonomous agents. Such approach is made through radial and angular distributions, respectively using the distance and angular variation among agents, where the considered hypothesis determines that sounds intensity should decrease if agents are far from each other or if they do not perceive each other.

Noser [16] treats perceptive autonomous agents using synthesized voices. In such case, the voices are inputs for a sophisticated model of behavioral animation where reactions are initiated. Recently, Conde and Thalmann [6] presented a model of multi-sensorial perception for autonomous agents, including hearing, vision, and touch. The hearing model was implemented through perception cones that filter information and spread the sound through geometric acoustics techniques. The main contribution of Conde's work is to integrate in a single decision process the multisensorial channels of virtual humans.

Another important aspect to improve the realism of simulation is to provide agents endowed with synthetic vision. There are many authors studying this area, and for that reason several vision models have been proposed. Xiaoshan et al. [25] implemented a prototype system which includes a visual sensor using a ray tracing method, so that an agent can analyze the environment. By casting laser rays from the eye position of an agent within a view angle, an agent can compute the intersection of a ray and the near object. A different approach has been proposed by Tu and Terzopoulos [22], where a local temperature sensor and a visual sensor that has access both the geometrical database and the physical simulation are used.

In Reynolds' work [17] concerning flocks of birds and schools of fishes, as well as in Musse's crowds of virtual humans [14], each agent directly knows the position of its neighbors. Shao [20] proposed the improvement of the performance of this technique using perception maps. Such method includes grid maps that represent stationary environmental objects in a local, per region basis, and global grid map that keeps track of mobile objects (usually other pedestrians). These uniform grid maps store information within each of its cells that identifies all objects occupying that cellular area. Each cell of the mobile grid map stores and updates identifiers of all the agents currently within its cellular area. These uniform grid maps store information within each of its cells that identifies all objects occupying that cellular area. Each cell of the mobile grid map stores and updates identifiers of all the agents currently within its cellular area.

The smell perception is different from other perceptions because there is a smaller number of papers in this area, mainly due to its inherent complexity. In one of these papers, Mamlouk [10] used a well-know numerical method to present a robust infrastructure for analyzing and interpreting current and future psychophysical and neurophysiological experiments in terms of "olfactory perception space". Zhang and Wyvill [24] presented a group of butterflies navigating by olfactory sensors. The agents are able to direct their motions according to a scent of the chemicals in the voxel space based on mass transfer theory. Objects in the environment are scanned and converted to the voxel representation to facilitate collision detection.

This paper aims to provide a virtual perceptive model to support hearing, vision, smell and pseudo-communication, where the individualities of the virtual humans are taken into account. Our work provides input information to the virtual agents through audio files for hearing, geometric information for vision and smell perception, and the pseudo-communication happens in execution time, depending on each agent's sensorial field. We focused our applications in crowd simulation during emergency situations, but it could also be applied in others scenarios. In our case, we are interested in evaluating the artificial crowd behavior, since we can specify for virtual humans which abilities they will achieve and measure how it can impact a building evacuation.

3 The Model

This section describes the model presented in our paper to provide artificial perception to agents. In the proposed model, the perception of each agent takes into account individual characteristics of the human hearing system, such as distinct sensibilities in different frequency bands, and the natural losses of hearing due to aging. It is important to characterize that much of the sensibility for hearing loss due to aging is not constant in the audible spectrum. Hence, it is important to analyze the spectral distribution of the emitted sound that can be obtained easily with the Fast of Fourier Transform (FFT). The pseudo-communication vision and smell perception use the zonal and sensory approaches, regarding the distance and the agent view angle to the sensorial area. These perceptions will be discussed in more detail in Sections 3.2 and 3.3. For the behavioral model we adopted a usual AI technique named as decision tree.

3.1 Hearing Model

In the proposed model for artificial hearing, the following factors are used to evaluate the agents' perception, which are related to the emitted sound and the virtual environment, as well as to the agents' individual attributes:

- Emitted sound and virtual environment:
  1. Extraction of the sound properties starting from an audio file:
     Relative sound intensity in each frequency band;
  2. Sound Propagation:
     Loss of energy with respect to the distance from the sound source.
- Agents' individualities:
  1. Curves of normal hearing capacity of people in several age groups;
  2. Auditive loss with respect to different frequency bands;
  3. Auditive loss due to hearing problems.

Initially, an audio file (for example, *wave* file) is supplied to the system, containing the hearing incentive that will be inserted in the environment. Also, the localization and the intensity of the resonant source (in dB)[1] are supplied. Contractions and dilatation of the air volume give us the hearing sensation. As the sound waves fade away, the energy of the wave is dissipated, so that the energy declines as the distance to the source increases. In fact, the reduction of the energy is a function inversely proportional to the square of the distance, so that the resonant intensity at a distance x of the source is given for:

$$I(x) = A_d(x) I_e, \qquad A_d(x) = \frac{1}{x^2}, \tag{1}$$

where $A_d(x)$ represents the distance attenuation and I_e the intensity emitted by the source. A person located at a distance x from a sound source receives as input to his/her auditive system a sound intensity $I(x)$. Actually, this intensity is distributed along the hearing spectrum (approximately between 125Hz and 20kHz), and the sensibility of the human ear is different for each frequency band (some bands are more audible than others). For example, the human voice varies between 60Hz and 1300Hz, and it is easily heard. To take in consideration this variation of sensibility, an attenuation curve $A_f(f)$ was used to increase the sensibility of more audible bands in comparison to less audible bands, according to the pattern IEC 60179 of International Electrotechinical Commission. This attenuation function is given by:

$$A_f(f) = \frac{k_c (2\pi f)^2}{((2\pi f)^2 + 129.4^2)\,((2\pi f)^2 + 76655^2)}, \tag{2}$$

where $k_c \approx 5.91797 * 10^9$ is a constant fixed, and f is the frequency in Hz. The sensibility graphic A_f in function of frequency is illustrated in Fig. 1 (the frequency axis is shown in logarithmic scale, for a better visualization).

Besides frequency sensibility variation, there is also a natural loss of hearing sensibility as we age. This sensibility loss is not uniform for all frequency bands, and it increases progressively with the age. We used an extension of Fowler's Criteria [1], which provides the attenuation in function of the age, in some determined frequencies:

$$A_a = \alpha + \beta(age) + \gamma(age)^2, \tag{3}$$

where the α, β, γ are coefficients given in Table 1, that vary in different frequencies[2].

[1] The sound intensity (in dB) is given by $I_{db} = 10 \log_{10}\left(\frac{I}{I_0}\right)$, where I is the intensity of the emitted sound, and I_0 is the intensity of reference, defined in terms of the hearing threshold of the human ear.

[2] As it can be observed, it does not have references from research which frequencies higher of the one than 8 kHz. Therefore, for these frequencies we used the same coefficients for 8 kHz.

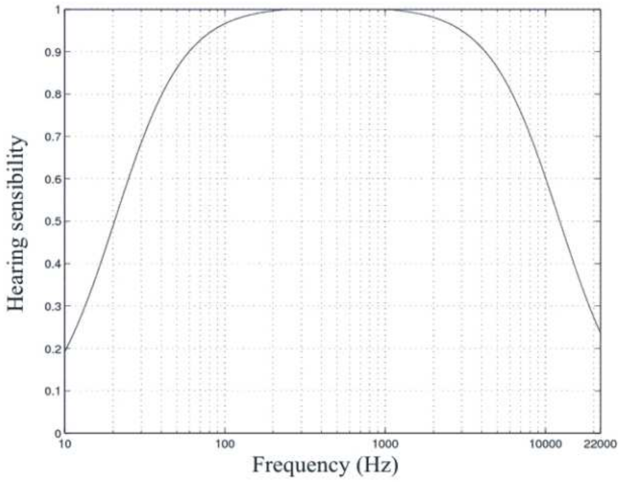


Fig. 1 Sensitivity graphic of the human ear in frequency function.

Frequency (Hz)	Coefficients α	β	γ
125	3,31	-0,262	0,0052
250	7,21	-0,483	0,0078
500	8,85	-0,594	0,0096
1000	12,36	-0,794	0,0120
2000	14,06	-0,925	0,0145
3000	12,16	-0,879	0,0157
4000	9,1	-0,747	0,0153
6000	9,11	-0,794	0,0172
8000	9,62	-0,87	0,0194

Table 1 Values attributed to the coefficients α, β e γ, for different key frequencies.

As Table 1 provides the reduction just for some frequencies, the power spectrum of a sound was divided into frequency bands, as illustrated in Table 2. All the frequencies within each band are decreased according to the reduction coefficient of the band frequency, according to Table 1.

Frequency Band (Hz)
0 - 125
125 - 250
250 - 500
500 - 1000
1000 - 2000
2000 - 4000
4000 - 6000
6000 - 8000
8000 - 20000

Table 2 Frequency Bands.

Also, the additional losses of hearing due to external sources as exaggerated exposure to noisy environment can be considered. Each person can suffer an additional hearing loss according to Table 3. Such table is used by Social Security in Brazil to classify the hearing loss of workers. The refraction with the wall also causes an attenuation in the sound energy. We consider a wooden wall 6mm thick, which causes a decrease of $\approx 50\%$ in the energy in each refraction of sound [2].

Hearing problem	Extent of hearing loss
Normal hearing	until 25 dB
Light loss	between 26 dB - 40 dB
Medium loss	between 41 dB - 60 dB
Severe loss	more than 60 dB

Table 3 Decree number 3048 of Social Security in Brazil - 05/06/1999.

Finally, when the sound arrives at agents' ear, it suffers attenuations due to the distance between the agent and the alarm, the hearing sensibilities variations from human ear, the expected loss due to aging, and the interference caused by walls. If the overall intensity perceived by the agent is larger than a threshold T, the agent reacts to the stimulus. Although the limit of hearing sensibility is around 0 dB, sounds with very low amplitude are usually not perceived by humans, justifying the use of the threshold (in this work, we used $T = 10$ dB).

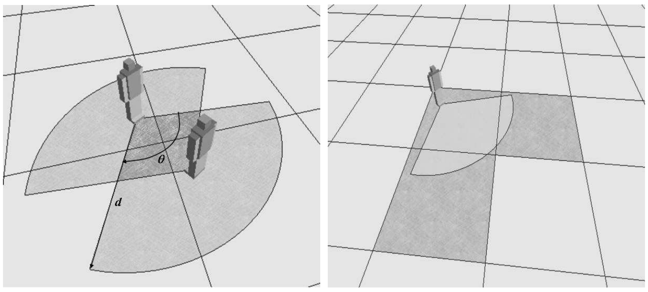
The proposed model for a virtual agents' hearing perception can be summarized in the following steps:

1. Read the alarm position, the audio file, and the sound intensity I_e (in dB).
2. Calculate the FFT of the sound, resulting in a vector $F_0(i)$ with different frequency responses.
3. Based on the distance x between the agent and the alarm, and the hearing losses, multiply the vector $F_0(i)$ by the attenuations and the reductions $A_d(i)$, $A_a(i)$ and $A_f(i)$ (here, i denotes the frequencies in the digital domain). The resulting vector is called $F(i)$.
4. Calculate the loss L (in dB) between the emitted signal and the perceived signal, through the division of energies
$$L = 10 \log_{10} \left(\frac{\sum F_0(i)^2}{\sum F(i)^2} \right)$$
5. Add to L the losses of individualities and the intersections with the walls (Table 3), given the total loss L_T.
6. If $I_e - L_T > T$, the flag of hearing is marked.

3.2 Vision and Pseudo-Communication Model

In a simulation with many virtual agents, it is essential to use a visual perception technique which acquires information from the environment within a reasonable frame rate, since the quicker the agent can detect objects in its environment the faster will be its decision, resulting in a smoother animation.

In this work, we use the zonal approach: it involves surrounding the virtual agent with a perception region. This region is the combination of perception distance d_i and the view angle θ_i, which are fixed values attributed at the beginning of the simulation. The perception of another agent or/and an event is realized when the element entering in the area is sensed by the agent (Figure 2.a).



(a) (b)

Fig. 2 (a) both agents are perceiving each other and interacting and (b) using perception map to improve the performance of zone approach.

Each agent has an individual attribute (named C) which characterize its knowledge acquired by pseudo-communication, associated to the information provided by perception models. Since the perceptive model contains three senses (sight, smell and hearing), the attribute value is a decimal representation of the senses binary codification in the previous cited order. Hence, when there is communication between agents, the value attribute for both agents will be an application of binary operator "or". The pseudo-communication (PC_{ij}) between $i-$agent and $j-$agent is defined as

$$PC_{ij} = C_i \vee C_j \tag{4}$$

After the pseudo-communication, the value attribute C of both agents will be the result of equation 4.

To improve the performance of zone approach, we also represent the virtual floor by map grid (named perception map), adapted of Shao [20]. This map represents stationary objects in a region, such as events or obstacles, as well as dynamic elements, such as virtual agents. In our work, these grid store information inside uniform cells that identifies all the elements (event and agents) occupying that cellular area. Each agent transmits to the floor its new position and, if necessary, the cellular area is updated. Therefore, only the cells which belong to the result of intersection between virtual floor and respective zone approach of an agent are considered to find the neighbors (Figure 2.b).

3.3 Smell Model

There are certain applications where olfactory perception can present relevance in the coherence of acquired results. Particularly in the subject of crowd simulation, agents endowed with ability of detecting odors can result in more realistic simulations, providing accurate diagnostics and behaviors during hazardous events.

However, the accurate implementation of an olfactory perceptive model is not a trivial task. Indeed, olfactory stimulus in the nose produced by odor molecules is transmitted by the receptors neurons to the brain cortex, but it is still unknown how the brain generates a recognition pattern about the odor. The human olfactory perception is capable of detecting smells in concentration from one part per million to one part per billion, depending on the odor in question. Moreover, it is much easier to detect increases than decreases in concentration and the magnitude perceived, and such relation is not linear with changes but closer to a logarithmic relation [26].

Due to the inherent complexity of the human olfactory perception, we present in this work a simplified model in order to implement smell perception for virtual humans in a crowds. The proposed model uses the zone and sensory approach, considering that the agent perceives the odor when there is intersection between the propagation zone of smell and olfactory perception zone of the agent. After the agent has detected the odor, the olfactory perception zone is subdivided in sensors that will contain normalized values, according to equation:

$$v_s = \begin{cases} 1 - \dfrac{d_s}{d_m}, \text{ if } d_s \leq d_m \\ \quad 0, \text{ otherwise,} \end{cases} \tag{5}$$

where d_s is the sensor distance to the focus of the smell event, d_m is the maximum distance of odor propagation and v_s will indicate the sensor proximity to the focus position of smell event. When these sensor values are computed, a search by region (3x3 square kernel to each sensor) containing the biggest sensorial environment is made. After this, the central position of this region is used to give the direction to the agent to locate the event. This orientation by the smell perception is only used when the event is perceived and the agent reaction is "investigated", given by the behavioral model. Figure 3 illustrates the olfactory perception zone for the agents.

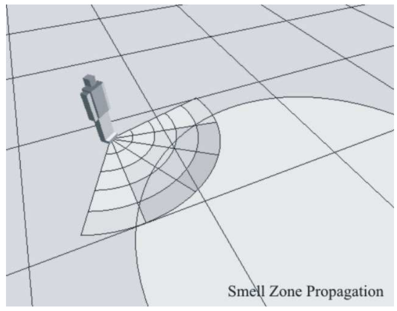


Fig. 3 Olfactory perception zone for the agents.

3.4 Behavioral Model

In order to model the decision of agents in our model, we use a well known AI technique: decision tree. Indeed, it is one of the most traditional concepts of machine learning to implement agents' decisions [18]. Therefore, the agents' behavior is not boolean and they become capable of reacting in different ways using their sensors (sense) which are activated in a given moment.

To build the decision tree, some subjects (around 30) were evaluated in our laboratory and they answered some questions concerning their reactions during hazardous situations, e.g.:

- "What do you do if you SEE a danger event?"
  (1) Nothing
  (2) Escape
  (3) Investigate

The subject answers were saved in a database, and used as input in the software (Weka) [23]. This software was responsible for the automatic generation of the decision tree (J48) with 10-fold cross validation. The generated decision tree built based on subjects' answers was then integrated into our prototype aiming to guide the behavior of virtual agents.

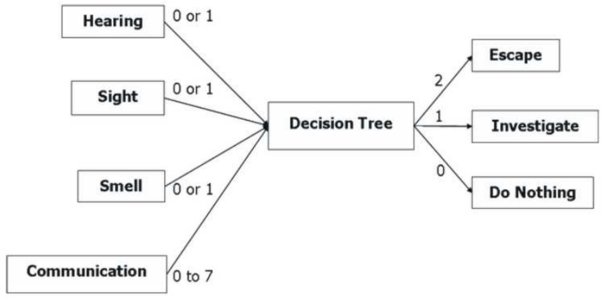


Fig. 4 Behavioral model diagram for the agents.

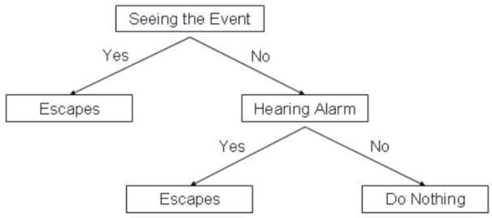


Fig. 5 Example of a decision tree used to model the agent behavior. In this case, the agent is in the work with all perceptions activated.

4 Simulator of Crowds in Emergency Situations

The large concentration of people in public space is an outstanding characteristic of current urban centers. Consequently, big agglomerations in different environments such as stations of public transport, sidewalks, banks and shopping centers are quite common. Moreover, the number of events that simultaneously attract thousands of people has grown year after year. Due to this fact, the modeling and simulation of crowds' behavior becomes an important research subject, especially in order to provide comfort and security to the crowds.

In the simulator, agents are represented by particles and do not have collision avoiding and grouping formation, since we are mainly concerned with behavior selection. For each frame of simulation, their perceptive data are processed, and then the decision tree selects the next objective for each agent ("escape" from the environment, "do nothing" or "investigate" the situation - see Figure 4).

In Figure 5, we can see an illustration of a decision tree. It is important to note that the subject answers in the survey also considered the location of people when the hazardous event is detected (work place, house, park and shopping). Simulations performed in this paper considered populations located only at their work place, since such questions presented richer results in terms of diversity. In addition, Weka did not take into account the least important attribute to build the decision tree. In the case of Figure 5, the smell and communication were pruned.

Following, we see the input data of the simulator. For hearing perception, the following parameters are considered:

- Sound properties (extracted from input data);
- Average age of the agents;
- Hearing loss by agents' disabilities;
- Alarm position.

In combination with hearing parameters, there are vision, smell and communication ones, which are processed in same perception model. They are:

- Radius of the sensorial field;
- Angle of the sensorial field;
- Event
  - Position;
  - Propagation radius of smell;
  - Event dimension (radius).

Finally, to evaluate results of the model, we calculated the number of safe agents in simulation. In other words, the agents that could perceive the hazardous event and evacuate from the environment.

5 Results

The simulations were performed in an environment having $600m^2$ of area subdivided in six rooms of $40m^2$, a bigger room of $240m^2$ and a corridor of $120m^2$ (Figure 6). In the biggest room, there are 50 agents, while in the other rooms there are five agents into each one. The positions of the agents are randomly defined, totalizing 85 agents in the simulation. To validate our model, situations including several perception abilities were simulated. To optimize the computational performance, the visual and smell perceptions are only performed when the agent is located in the same room of the event. The results and analysis considered the percentage of safe agents, i.e., agents which perceive the event and decide to escape from the environment. In this paper, an agent is considered safe when it is about half meter from an escape door (there are two emergency doors in the environment, located at the corridor) and the considered average speed for agents is 0.9m/s.

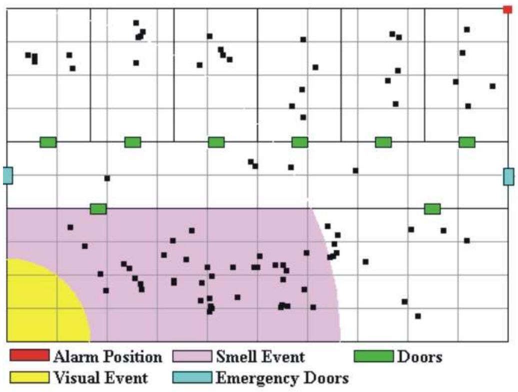


Fig. 6 The simulation environment.

In the hearing perception, we simulated the environment with one alarm, and it was positioned in three different places: bottom left corner, upper right corner and in the center. The sound files contain information of 6kHz and 12kHz. The environment is populated with 9 possible combinations, considering 3 groups according to agents specified age (young population, old, and age mean equal to 55 years - Table 4) and 3 groups according to their hearing condition (normal, mean and sick - Table 5). In all simulations, the alarm volume was adjusted to 100 dB.

Ages (years)	Young	Old	≈ 55 years
25	56%	4%	6%
35	14%	4%	10%
45	10%	6%	20%
55	6%	6%	30%
65	6%	10%	20%
75	4%	14%	10%
85	4%	56%	4%

Table 4 Used populations - ages.

Figure 7 presents the simulation results considering only hearing perception including sound propagation attenuation and without pseudo-communication. It is possible to verify that highest frequencies lead to less agents that perceive the alarm (consequently the number of safe agents decreases). We can also see that sicker and older the population is, the number of safe agents decreases too. Figure 8 shows the same simulations previously presented, but with pseudo-communication activated. It is possible to perceive that this ability minimizes the effect of sickness and age, since an agent that perceives the alarm can inform to a sick neighbor.

Hearing	Normal	Mean	Sick
Normal	70%	25%	10%
Light Loss	10%	25%	10%
Medium Loss	10%	25%	10%
Severe Loss	10%	25%	70%

Table 5 Used populations - hearing loss.

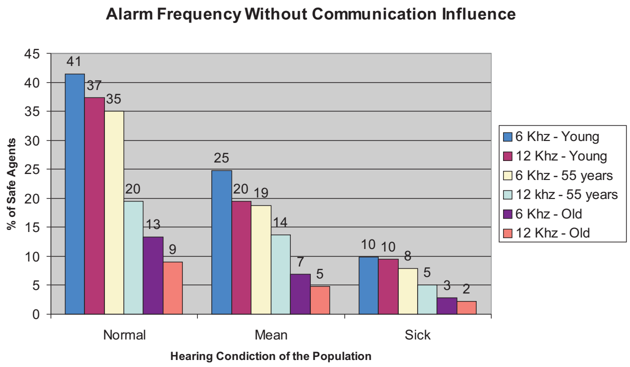


Fig. 7 Hearing without communication.

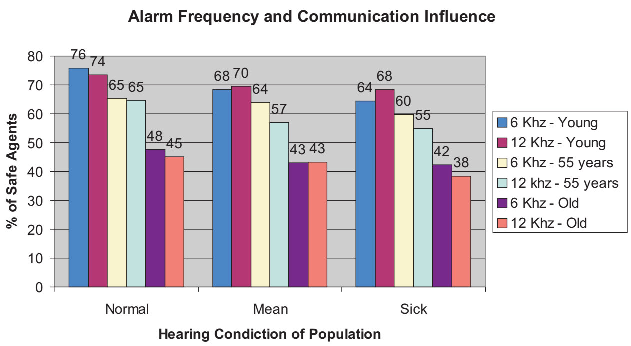


Fig. 8 Hearing with communication.

Figure 9 presents the impact of wall attenuation in young and healthy population. It is possible to observe that the number of safe agents increases when the alarm is located at the center of the room. On the other hand, if we not consider the wall attenuation, almost the totality of agents are saved, due to the fact of the environment area is small to impact significantly the sound intensity.

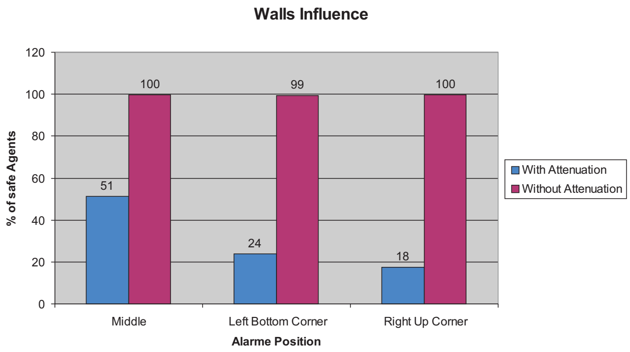


Fig. 9 Walls influence in the hearing model.

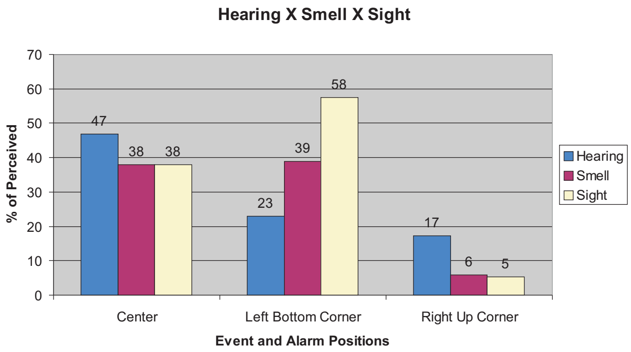


Fig. 11 Hearing *versus* Smell *versus* Sight.

Figure 10 presents an analysis of the number of safe agents considering only the visual and olfactory capacity for different locations of danger event. As expected, the visual perception presented better results if compared with olfactory perception, due to its larger space of perception. As previously observed, when pseudo-communication is activated, results indicate that number of safe people increases. Yet, there is more agents which perceive the harzardous event through their visual perception than olfactory.

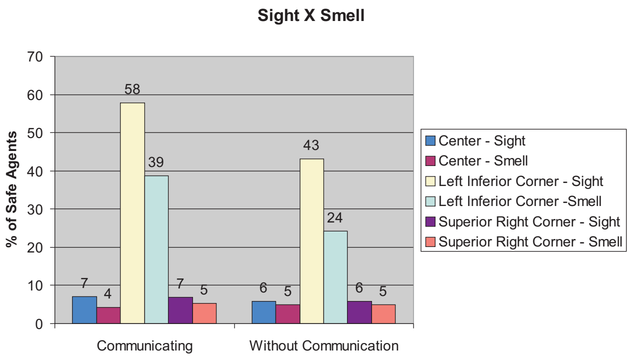


Fig. 10 Sight *versus* Smell.

Finally, Figure 11 presents an analysis considering all perceptions (hearing, sight and smell) without pseudo-communication, for different places of the danger event and alarm (coincident positions). Initially, we can observe that alarm located in the center of the building is the best choice for the virtual environment defined in this paper. Moreover, due to the number of agents concentrated in the biggest room (left bottom corner), a great percentage of agents perceived the danger event in this room using vision and/or smell. It is also possible to verify the significant number of agents who had perceived the danger event, when this occurred in the building center. This situation occurred due to the fact that agents, after they perceive the event in their room and start to evacuate, also "smell/see" the hazardous event in the corridor (where exit doors are located).

6 Conclusion

This paper presented a multi-perceptive model to virtual agents in crowds. The application was the emergency simulation in a virtual environment with agents of different ages, sound frequency perceptions and possible hearing disabilities. Besides the hearing perception, the agents can see and smell the danger event. To complement the simulator, a pseudo-communication method was developed, where agents interact and transfer their knowledge to other agents.

As expected by the authors, when the sound frequency is higher, the agents' perception decreases (due to the hearing sensibilities curves). This fact occurs mainly when simulating older, younger and people with and without hearing disabilities. Beside these factors, the pseudo-communication presented a great influence in order to propagate the knowledge of the danger event, resulting in increasing the number of safe agents.

Other interesting aspect is the fact that smell sensor does not impact results as the visual sensor does. It happens due to the decision tree we used in order to select the next action for the agents, based on the responses of evaluated subjects as described before. The subject answers related with smell ability present more diversity than others asked perceptions. Finally, when all sensors were activated, we verified the increase in the number of safe agents.

The improving on perceptive aspects of virtual humans in this work has extreme importance to crowd simulation in emergency situations. Without the inclusion of sensorial aspects, the result is not realistic or comparable to real life.

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