

Increasing the Efficiency of NPCs using a Focus of Attention based on Emotions and Personality

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Abstract

Several games nowadays try to improve the player immersion by representing human behavior as real as possible, generally using agent technologies to model non-player characters (NPCs). However, agent-based behavioral models representing the existing complexity of, for instance, a decision-making for a real life situation can become a very intensive computing task. For this reason, real-time simulation-based games may benefit from optimizations produced on how NPCs react to changes in the simulated game world. This paper presents an approach for speeding up the decision-making of autonomous agents representing NPCs of a game. The optimization is reached by bounding the agent perception to a subset of all agent surrounding elements, which contains only the most important elements for the agent at current time. In other words, the agent is modeled as having “focus of attention”. The attention focus represented in this work is based on theories of emotions and personality.

Keywords:: Real-time Strategy, Agents, Human behavior emulation, Emotional characters

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1 Introduction

In the last years, the use of models of emotions and personality has been largely explored in games using agent technologies to model game characters. Most of the works on this subject aim to make them more believable [Bevacqua et al. 2010], making them able to exhibit realistic behaviors or human-like emotional expressions. Most of these works have dealt with the concepts of emotions and personality as a way to improve or to better represent the NPC believability and decision-making process, i.e. they have been focused on how an agent can trigger an action (or an expression) based on its current emotional state and/or its personality profile. However, emotions and personality do not only have an impact on how individuals make a decision. They also impact on the whole cognitive system of individuals, starting from their perception mechanism. Emotions and personality make people to get different perceptions from the same situation. Also, emotions also makes an individual to get different perceptions when facing the same situation at different times.

The ability of a NPC to answer differently according to its traits and/or current state is one of the major feature in advanced games. For instance, the FIFA Soccer game has provided this feature since its beginning version. However, the traits modeled in FIFA game impacts specifically on the quality of the NPC's actions (for instance, the quality of a hit to the goal), but not on how they reason. Consider now a game with goal-oriented NPCs, referred hereafter as agents, able to dynamically construct their plans, as the game F.E.A.R does [Orkin 2006], and the need of introducing the ability of different agents to answer differently for a same situation. In this case, agents characteristics would drive not only the quality of their actions but also the planning path used to find them. Depending on

how the latter is modeled, the number of possibilities can quickly explode, compromising the capacity of the game to answer at real-time. The current work tries to optimize this issue without changing the reasoning/planning procedure. It just put a filter before the NPC planning process, where the game elements surrounding the NPC are filtered according to its individual characteristics, i.e. we endow the agent of attention focus.

Thus, the current paper presents a perception-filtering strategy useful for goal-oriented agents and how it can interact within a game environment. Our approach is based on the fact that human perception does not take into consideration all the information that is available in a complex environment. On the contrary, part of it is left aside and forgotten, and the attention is focused on what is considered important. Our hypothesis is that, when the agent attention is focused on only some aspects, the efficiency of its planning process improves. The proposed mechanism uses emotions and personality as parameters for driving the agent attention focus [Damasio 1995]. In addition, it can also make the behavior of the agent, as a game character, more realistic and believable. The proposed agent attention focus is structured as a spatial focus, which is related to the contents the agent is interested in, and as a temporal focus, which is related to how many perceptive elements the agent is able to perceive in order to keep at real-time frame ratings.

This paper is divided into five sections and it is organized as follows. Section 2 describes the research works related to the subject of this paper. The proposed agent architecture is completely described in Section 3. In Section 4, the development methodology and tests procedures are described. Finally, Section 5 presents the final remarks of this paper and the future works.

2 Related Work

2.1 Regarding Attention Focus

The human emotional aspects were integrated in Morgado's work [Morgado 2006] to achieve better results for the reasoning process of agents situated in complex environments like the realtime ones. At this work, physiologic models (where the emotions are connected with internal alterations of an adaptive organism) and appraisal models (where the emotions are extracted from evaluations - appraisals - of events or actions) are connected to implement the proposed architecture. However, humor and personality are disregarded. Morgado's model represents the agent goals and the environment cognitive elements as periodic functions with a fixed frequency. The agent interest level for a cognitive element is determined by the resonance between the cognitive element frequency and the agent objectives ones. As a result, only the elements with a resonance relation higher than a minimum level of interest are perceived. According to Morgado, a depletion barrier is created establishing the agent attention focus. The resonance physic law is used to create the agent focus of attention in Morgado's proposal. The focus description would be a burdensome task for dynamic environments as the ones found in computational games. The definition of a set of frequencies that correctly resonate with a set of objectives of a large game scenario, with groups of different NPCs can not be considered as an easy work.

Another work related to attention focus which can be applied to computer games was proposed by Sarmento [Sarmento 2004]. He

modeled a complex environment based on a forest on fire [Oliveira and Sarmento 2002], where a group of emotional agents have to cooperate in order to extinguish the fire. The agent emotional state is created by a rule based analysis of the agent's cognitive experience. The emotional state is stored in the emotional accumulators that are dynamically updated. Therefore, the agent decision process is influenced by the emotional accumulators. For instance, a wind blast causes an accidental high fire exposure which increases the value of the fear accumulator. As a result, the agent first action is to escape from the fire and then, for a period of time, the agent's action decision process will only choose the most conservative available actions. After this first reaction, based on the updated emotional accumulators, different kinds of reactions will appear. Sarmento's proposal defines a two level reasoning process. The first one deals with the information related to the agent's survival objectives and the second one with the deliberation about the other environment information. In other words, the agent attention focus is settled in an indirect way by the two levels of the split reasoning process, since the first level treats only a portion of available information. For this reason, the attention focus can not be dynamically changed during the simulation time. This is can be a very restrictive limitation for computer games that requires continuous environment changes.

2.2 Regarding emotions, humor and personality

The use of emotion models in the previous works was justified as an attempt to improve the behavior of agents situated in complex and dynamic environments as the real time ones. In other words, it can be considered as a solution problem approach. The next works introduce the use of emotions, personality and humor models to achieve a human like behavior.

The emotion, personality and humor models are used to simulate human behavior in systems like ALMA (A Layred Model of Affect) proposed by Gebhard [Gebhard 2005], BASIC (Believable Adaptable Socially Intelligent Character for Social Presence) proposed by Romano et al [Romano et al. 2005], SIMPLEX (Simulation of Personal Emotion Experience) proposed by Kessler et al [Kessler et al. 2008] and the proposal of Kasap et al [Kasap et al. 2009]. All these proposals use the emotion and personality models relations defined by Mehrabian [Mehrabian 1996][Mehrabian(a) 1996] in a similar way as a manner to create a character capable of emulating a human conversation interaction. This character is capable of showing surprise or fear and a set of other emotions including a mood driven behavior initialized by the agent's personality.

Mehrabian describes a general framework for explaining and measuring individual differences in temperament based in three nearly independent traits: pleasure (P), arousal (A) and Dominance (D), so called PAD. This framework implements a 3-dimensional mood space that is used for modelling the humor for the conversational agent in the above mentioned systems. Mehrabian also describes the relationship between the PAD model and the OCC emotion model [Ortony et al. 1998][Ortony 2003], as well as the relationship between the BigFive personality model [McRae and Costa 1996][da Silva 2009]. This last relationship is also used in the above mentioned proposals in order to model the agent's emotion and personality.

3 Behavioral architecture

The proposed architecture uses a focusing process in the agent's perception of the environment cognitive elements. The focus of attention produces a filtered subset of environment cognitive elements that allows an optimization in the planning and reasoning process.

Real-time game scenarios can be very complex. In this situation, complex is understood as a large quantity of information that is necessary in order to model the environment where the agent is situated. Consider, for instance, a game similar to Total War games series [Assembly 2010] where the units (represented as agents) are not reactive, but goal-driven instead. Despite the fact

that it is possible to design agents with only partial vision on the environment, the quantity of elements perceived by each agent (unit) can be very large. However, agents decision-making are limited by some factors such as time, power and computational capacity. Regarding these limitations, an optimized decision process is hard to be carried out considering all the available information.

The implementation of a perception attention focus reduces the set of available cognitive elements to a subset containing only the most important elements for the context where the agent is situated. This focus defines which significant information is needed to be perceived. In our approach, the information selection is structured as a spatial focus, which is related to the contents the agent is interested in, and as a temporal focus, which is related to how many cognitive elements the agent is able to perceive in a fixed discrete time. The latter can be set according to the processing capacity to keep a real-time frame rate.

At his architecture, the evaluation of the cognitive elements of the environment (actions, events and objects) causes reactions that change the agent emotional state and its level of knowledge (set of facts containing the agents beliefs). The agent's emotional state is responsible for driving the operation of the attention focus where some environmental elements are disregarded. In other words, the agent forgets some elements and ignores others in the environment, like a real person normally does. This feature can also improve the believability of the game characters as they can behave more realistically.

3.1 Architecture Model

The agent architecture is composed by two structures: 1) the Core Agent, that is responsible for the reasoning, action planning and action selection, and; 2) the Agent Behavior, that is responsible for perceiving the environment and executing the action. The behavior is selected according to the actions chosen for execution by the Core Agent. The architecture showed in Figure 1 is fragmented in the following modules:

- Sensing and filtering: module responsible for the perception of environmental cognitive elements which is performed by the sensors set. The perceived elements are filtered by a process that works under the spatial and temporal focus definitions; therefore, a subset of elements is created and sent to the Core Agent;
- Focus: module that defines the spatial and temporal focus;
- Belief Base: module where the agent beliefs about the environment and about itself are stored. These beliefs are consequences of environmental perceptions or conclusions of the agent reasoning process;
- Reasoning and Planning: module responsible for creating and evaluating a full detailed plan. The latter is a hierarchical tree of possible actions and its evaluation process is restricted by the temporal focus. This tree is created using the facts saved in the belief base. The outcome of this process is a set of actions to be performed by the agent, similar to what the F.E.A.R. agent architecture does [Orkin 2006];
- Emotion, humor and personality: module responsible for establishing the agent's emotional state. This component is introduced over the others, since it does not save or process information, but it rather establishes the way in which the other components carry out the whole process [Campos et al. 2009][Campos et al. 2008];
- Action: module responsible for the action execution process.

3.2 Emotion, humor and personality

Models of emotion, humor and personality are used in this proposal in order to achieve a more effective agent's behavior, specially in complex game environments. In the same direction, it is important to notice that time is very significant for the human

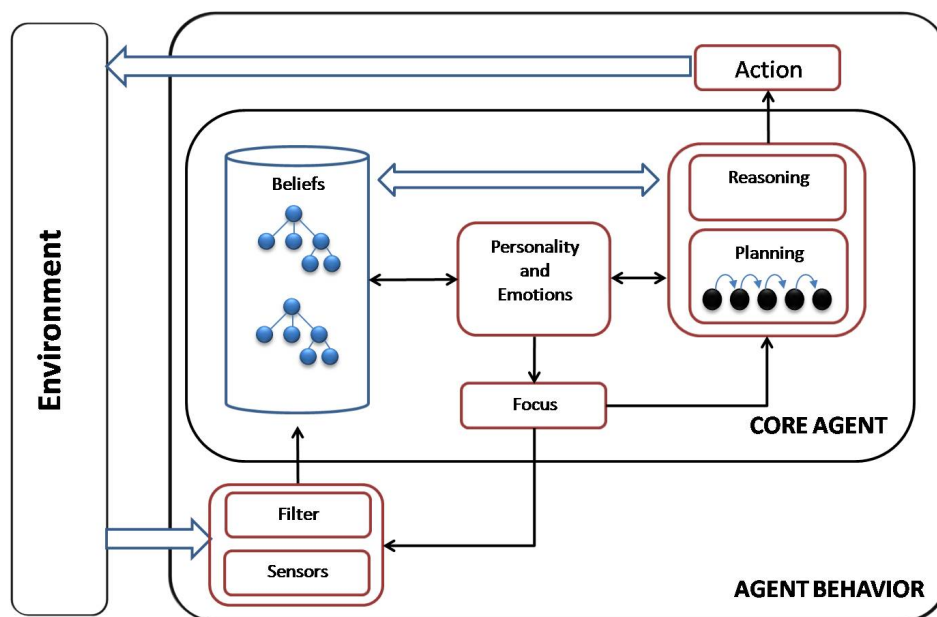


Figure 1: Agent architecture model

temperament emergence, because there is a temporal relationship among emotions, humor and personality. Emotion has a transitory duration, that is, it is a short-term expression. In its turn, humor is a medium-term expression and finally, personality is a long-term expression [Gebhard 2005][Kasap et al. 2009][Kessler et al. 2008]. Thus, our approach model three layers that structure the agent behavior: emotions, humor, and personality. The selection of the models for implementing each level was carried out considering recognized computational implementations already done [Burkitt and Romano 2008][Gebhard 2005][Kasap et al. 2009][Kessler et al. 2008]. As a result, the following models were selected: the OCC appraisal model for emotions [Ortony et al. 1998][Ortony 2003], the PAD model [Mehrabian 1996] for humor and the BigFive model [McRae and Costa 1996] *apud* lcitephd-danielle0 for modeling personality.

The OCC model defines the agent's emotional state as an evaluation of the environment situation considering some aspects as: events, actions (done by other agents) and objects. The relationship between these aspects are described in a hierarchy that classifies 22 emotions types and, for each emotion type, a list of variables affecting intensity is provided. The PAD model explains that the agent's mood can be expressed in terms of three traits Pleasure (P), Arousal (A) and Dominance (D). For Mehrabian [Mehrabian 1996] these three traits (also called dimensions) creates a 3D mood space. The implementation of the PAD mood space uses axes ranges from -1.0 to 1.0 for each dimension and an agent's mood state is defined by a tuple with the values for each dimension ($\langle +P, +A, +D \rangle$). Finally, the Big Five model is a common schema that specifies the personality by five basic traits: openness, conscientiousness, extroversion, agreeableness and neuroticism. The combination of these traits explains the general (affective) agent's behavior.

The Figure 2 shows the relationship between the emotion, humor and personality models. The personality model is responsible for the establishment of the agent's basic humor, and this process is based on the relationship described by Mehrabian [Ortony et al. 1998] who states that individual personality traits define a basic humor state for the agent. The agent basic humor state is the start reference for the PAD model and the state where the agent's humor returns when the appraisal of environmental cognitive elements stops [Gebhard 2005]. The changes in the agent's humor state, which occur in the PAD 3D space, are influenced by the emotions appraisal done through the OCC model and their valence values. The latter means that an appraised emotion has an attached value that indicates if the perception is good or bad and its intensity. In other words, any perception done by the agent about an action

or an event of the environment causes an emotion appraisal that can be positive (good emotion) or negative (bad emotion). The positive emotions cause changes in the agent PAD 3D space toward a position that represents a good mood state and the negative emotions cause changes toward a position that represents a bad mood state. The variation in the PAD space determines the values of some parameters of the agent architecture such as spatial focus, temporal focus, reasoning time and the beliefs base.

Considering the agent reasoning process in the Figure 2, the set of preferences used to assist the decision about available solution options are defined by the agent personality. The preferences make the agent reasoning and planning process more realistic and more flexible [Campos et al. 2009]. The personality is also related to the velocity of emotions intensity decay. In other words, as pointed out by Kasap [Kasap et al. 2009] "for people who are more neurotic, positive emotions disappear more quickly and negative emotions disappear more slowly. The opposite is true for people with more stable personalities".

The elements of the agent architecture are influenced by the humor state variation as seen below (Figure 2).

- **Spatial focus:** the spatial focus can change according to the agent humor state. That is, considering two agents executing the same behavior, the agent in bad mood may prioritize its attention in different environmental elements that the agent in good mood.
- ***l* limiter:** the quantity of environmental elements that an agent can perceive is defined by the temporal focus thorough the *l* limiter. The outcome of the filtering process over the set of perceived elements using the spatial and temporal focus is an ordered list with a size of *l* elements. The *l* limiter is influenced by the agent's humor state, so that an agent in a good mood can perceive more environmental elements than an agent in a bad mood.
- ***k* limiter:** some environmental information that does not belong to the agent spatial focus list can become important in some specific occasions, and in these occasions it has to be considered in the agent reasoning process. For example, an alarm is not important when it is silent, but it brings up a very important information when it goes off and, therefore, it must be considered in the agent reasoning process. The *k* limiter establishes a number of elements inside the list defined by the filtering process to be used by this kind of information. For example, if the *k* limiter is equal 0.8, twenty percent of the filtered list belongs to this kind of information.

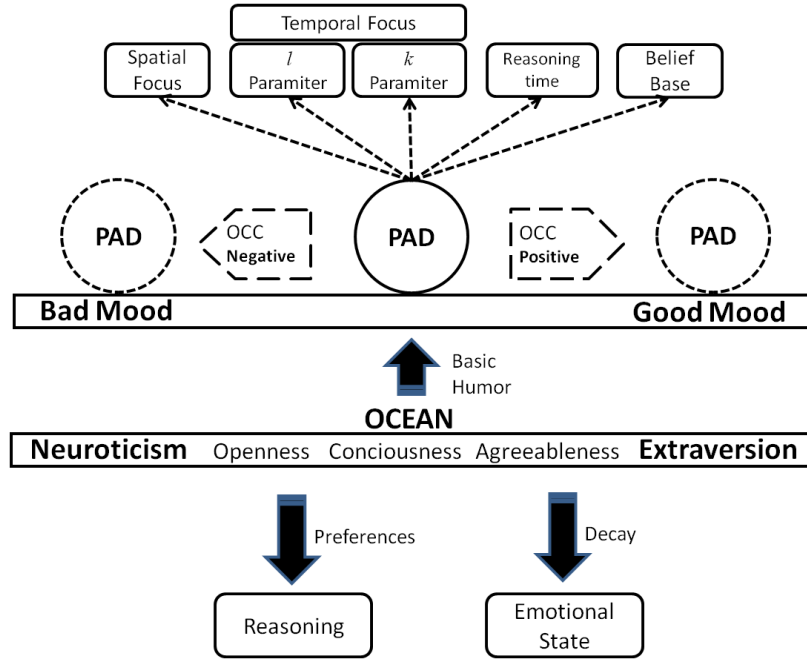


Figure 2: Emotion, humor and personality relationship

3.3 Environmental cognitive elements

The environmental information is collected by the sensing module and converted into a format that can be processed by the agent's internal process. These elements, called perceptive elements, are represented in a $[0, 1] \in \mathbb{R}$ scale. The perceptive elements have some associated tags that are used as meta-information to drive the agent's reasoning process.

In an instant of time t , the sensing module receives a set of perceptive elements $E(t) = \{e1(t), e2(t), \dots, en(t)\}$ from the environment, where each element $ei(t)$ is a tuple $ei(t) = \langle di(t), Ri, \Delta di(t) \rangle$ such that:

- $di(t)$ is the value associated to the information in the instant of time t ;
- Ri is a set of tags associated to the perceptive element $ei(t)$;
- $\Delta di(t)$ is the variation in the value of $di(t)$ in the instant of time t since the last perception.

The set of tags associated to the perceived element is a tuple $Ri = \langle Ai, Vi \rangle$, such that:

- Ai is a set with the names of the agents responsible for the element $ei(t)$;
- Vi is a set of tags informing how to process the variation of $di(t)$.

For each perceptive element $ei(t)$, the value between two consecutive game loop iterations may suffer a positive variation ($\Delta+$, when the value of $di(t)$ has increased) or a negative variation ($\Delta-$, when the value of $di(t)$ has decreased). Each agent may have its own set of thresholds to define if a perceptive element variation is significant to be analyzed. A positive threshold, $\Delta di(t)+$, is used to evaluate the positive variations, and a negative one, $\Delta di(t)-$, is used to evaluate the negative variations. The variation of a perceptive element value is defined as $\Delta di(t) = di(t) - di(t-1)$.

Environmental elements of information can be analyzed according to three different possibilities of variation, such that:

- $Vi = \{+\}$: the perceptive element is important when $\Delta di(t) > 0$ and $|\Delta di(t)| \geq \Delta di(t)+$;
- $Vi = \{-\}$: the perceptive element is important when $\Delta di(t) < 0$ and $|\Delta di(t)| \geq \Delta di(t)-$;

- $Vi = \{+-\}$: the perceptive element is important when $\Delta di(t) < 0$ and $|\Delta di(t)| \geq \Delta di(t)-$ or $\Delta di(t) > 0$ and $|\Delta di(t)| \geq \Delta di(t)+$.

The threshold values can be implemented as a function of the agent's emotional state but, normally, they are static values defined during the agent's design phase.

3.4 Spatial Focus

The spatial focus is responsible for establishing the level of importance for the environmental information collected by the sensing module. The environment is characterized according to a set of attributes called aspects. The interest related to each aspect of the environment is signed by a value in a $[0, 1] \in \mathbb{R}$ scale and it represents the level of interest (*LoI*) of the agent over that aspect. Based on the *LoI*, the agent creates a priority order over the perceptive elements of the list $E(t)$.

The spatial focus is defined as a function $f : S \rightarrow R$, where $S = \{s1, s2, \dots, sn\}$ is the set representing the aspects of the environment the agent is interested in. Considering that the total agent interest as 100%, the sum of the interest over all the aspects considered by the agent achieves the value 1. Each perceptive element belongs to one or more of the aspects of the environment and, for those that belong to a more than one aspect of the environment, the agent has to consider all the *LoIs* to define his interest over that element.

The agent's interest over a set of perceptive element $E(t)$ is defined by the function $I(t) : E(t) \rightarrow R$, that maps each perceptive element $ei(t)$ to a set of values of interest. The latter values are based on the aspects of spatial focus where the element $ei(t)$ belongs.

The priority order over the list $E(t)$ above mentioned is defined considering the relationship between the spatial focus and the perceived elements list. For instance, considering a spatial focus with three aspects of interest, $S = \{s1 = 0.7, s2 = 0.1, s3 = 0.2\}$, the first step splits the $E(t)$ list in three parts, each one with the elements of the original list that belong to the relative aspect, i.e. the first list is related to the aspect $s1$ and contains $l * k * s1$ elements that belong to the aspect $s1$ ordered by the $di(t)$ values and so on. The second step joins the three sub-lists in one single list containing $l * k$ perceptive elements related to the spatial focus that are used by the agent's reasoning process. The remaining elements join the set of perceptive elements that do not belong to any aspects considered in the agent's spatial focus. These elements may

become important in some specific occasions, when they have to be considered in the agent reasoning process. They are ordered by the $di(t)$ values in what we named as exception ordination. The latter is defined as following: considering two perceptive elements $e1(t) = \langle d1(t), R1, \Delta d1(t) \rangle$ and $e2(t) = \langle d2(t), R2, \Delta d2(t) \rangle$, $e1(t) \succeq_E e2(t)$ if only if $Ex(e1(t)) \geq Ex(e2(t))$, where $Ex: E(t) \rightarrow R$ is the function:

$Ex(ei(t)) = \max(Ex_+(ei(t)), Ex_-(ei(t)))$, where:

$$Ex_+(ei(t)) = \begin{cases} \Delta di(t) \text{ se } \Delta + \in Vi \text{ and } Sit_1 \\ 0 \text{ otherwise} \end{cases}$$

$$Ex_-(ei(t)) = \begin{cases} |\Delta di(t)| \text{ se } \Delta - \in Vi \text{ and } Sit_2 \\ 0 \text{ otherwise} \end{cases}$$

where:

$$Sit_1 = \Delta di(t) > 0 \text{ and } |\Delta di(t)| \geq \Delta di(t) +$$

$$Sit_2 = \Delta di(t) < 0 \text{ and } |\Delta di(t)| \geq \Delta di(t) -$$

The exception order allows the agent to perceive the elements of the environment that do not belong to the spatial focus and that had the major value variation since the last perception.

3.5 Temporal Focus

The temporal focus is responsible for defining the quantity of perceptive elements which are used by the agent's reasoning process. This quantity varies according to the time and the agent's emotional state. In other words, the reasoning process uses an ordered list containing a fraction of the total perceptive elements received from the environment by the sensing module.

The set U of perceptive elements used by the reasoning process is formed by joining two sets: M , which is ordered using the interest defined by the spatial focus and N , which is ordered using the exception ordination. The U 's cardinality is defined by the l limiter combined with the k limiter (both explained before). Both limiters define the distribution of perceptive elements between the M and N sets inside U , so that the M 's cardinality is $k\%$ of l and, in consequence, N 's cardinality is $(l - k)\%$ of l . In other words, for $k = 0.8$ and $l = 100$, the cardinalities of M and N are 80 and 20 elements respectively.

The l limiter is a function of the time and the agent's emotional state, and as a result this factor depends of the agent's state of humor and it assumes different values when the agent is in a bad mood or in a good mood. This approach is used by B. G. Silverman [Silverman et al. 2006a][Silverman et al. 2006b] when he describes the relation between the effectiveness of the agent's decisions and the agent's state of stress through an inverted "U" curve.

The assumption used in this work is that the quantity of perceptive elements considered for reasoning is directly related to the effectiveness of the agent's decisions, and the agent's state of humor is directly related to the agent's state of stress. As a result, the l function was empirically defined as a pseudo Gaussian distribution defined as following: $l(x) = e^{-\delta(x-\mu)^2}$. The parameters δ and μ are adjusted during the agent's design phase and the value of x is derived from the agent's state of humor. This derivation is implemented using an average between the distance of the point representing the current agent's state of humor in PAD-3D space, and the positions representing the extreme relaxed mood ($+P - A + D = +1 - 1 + 1$) and the extreme anxious mood ($-P + A - D = -1 + 1 - 1$). These extreme points in the PAD-3D space were selected because of their similarity to the stress level concept used by Silverman [Silverman et al. 2006a][Silverman et al. 2006b].

4 Development methodology and testing procedures

In this work the reasoning efficiency of agents situated in environments with a large amount of perceptive elements is observed. The aim of this proposal is to compare agents with and without perception attention focus in this kind of environment.

An exploratory and experimental research is the methodology used for developing and adapting the architecture of agents based on emotion, humor and personality. Therefore, the classical approach of developing simulating models is used, which results in a cyclical and interactive process. During this process, several prototypes are developed and tested, exploring progressively the possibilities of interaction between the agents and the environment. Finally, the prototypes are adjusted according to the testing results and a new modeling-executing-validating process is started.

4.1 Testing Scenario

Prior to test the proposal in a production game, we choose to test it at a prototype scenario. The prototype scenario is an 2D grid game environment where the size of its cells is defined *a priori*. This environment simulates in a movie theater room with several characters inside and a fire suddenly occurs. Some restrictions were placed on this scenario. Although the individuals, represented by agents, can occupy the same space, other agents are considered obstacles to achieve the main agent's objective, that is to find an emergency exit to guarantee its self safety.

The movie theater room has some emergency exits and audible and visual fire alarms and the suited agents are aware of the elements that are present in the room. During the simulation, one or more fire outbreaks start in the room, all of them with radially expansion from the origin point. The fire that naturally causes an increase in the temperature, also brings the smoke as a consequence, which propagates in the same way as the fire. When the fire starts, all the alarms go off. The agent's death can occur by fire exposure or smoke exposure. The starting time and the quantity of fire outbreaks are parameters defined in the beginning of the simulation. The position of the fire origin points are defined by the system as free cells randomly chosen.

In this testing scenario, we modeled the agent perception through four perception senses: audition, smell, vision, and touch feeling. Thus, agents can perceive surrounding noises (for instance, the fire alarm), smoke (even if the alarm has not yet started, the agent is able to smell fire smoke), see exits, fire and other agents on its direction, as well as to feel the surrounding temperature (if it is hot or not). Regarding the temperature, the agent can only perceive the 8 cells that surround its current position. It is not possible to perceive anything beyond that, although the agent can infer from other perceived elements (fire, for instance) and its belief base.

The path the agent takes to reach the exit is decided in a step by step utility-based reasoning process, where each step consumes a BDI reasoning cycle. The decision takes into account the cost for all the possible steps. The cost calculation considers the elements perceived in the cells, the distance of the elements to the agent, the belief base and the current emotional state.

For this scenario, the agent's spatial focus was created using three aspects of the environment: danger, exits, and agents.

The choice of this scenario was based in some important requirements for gaming goal-oriented agents using emotion as a part of the perception and reasoning process. These requirements are:

- Large number of game objects for planning in real time;
- Characters with multiple goals;
- Multiple agent interaction;
- Real world problem proximity.

These requirements are important to effectively test emotion-cognition interactions, because simple environments do not reveal the need for emotional mechanisms. As Sarmiento points out [Sarmiento 2004]: "Simpler environments or agents with fewer goals will simply not need emotional mechanisms because possible problems may be solved with the help of simpler, more straightforward mechanisms".

A complex environment is also necessary to answer one question before the use of the emotional mechanisms in the proposal

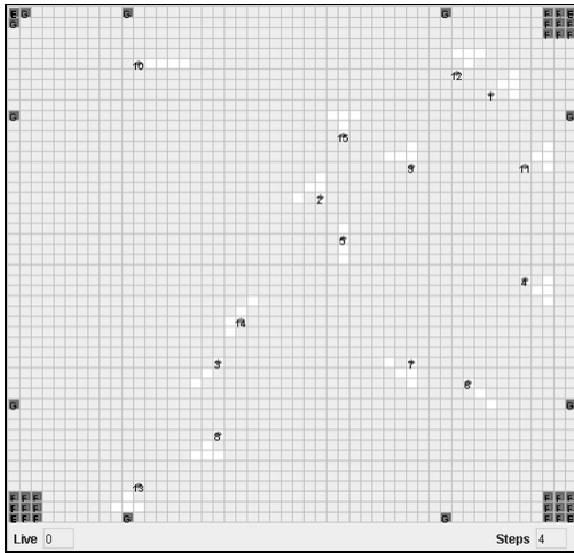


Figure 3: Prototype scenario for testing the architecture.

architecture: is it possible to achieve a more effective decision process using a perception focus of attention? Normally, in this kind of environment it is expected that not all the available information is relevant for a correct and effective decision process. As a result, it is necessary to answer the question about the attention focus and, if the answer is affirmative, to establish the best value of the l parameter for the chosen environment.

In the next section the testing procedures and the results that answers affirmatively the above mentioned question, as well as the definition of the best value for the l parameter are shown. These results also bring a more natural behavior when the agent clearly points out its preferences and seems to forget some environmental elements.

4.2 Comparative analysis

4.2.1 Testing procedures

The tests were divided in two groups, one to define the best parameters for the attention focus in the perception process (perception focus), and another one to evaluate the efficiency of the perception focus regarding the execution time and the quantity of alive agents after the simulation.

In the first group of tests, the experiments were divided into several stages in order to define the best parameters for the perception focus. The first stage found the best values for the agent's interest in each aspect of the spatial focus, that is, the best interest value for the aspects danger, exits and agents. The second stage uses the best values defined in the first stage to establish the best value for the l parameter. Finally, the third stage uses all the best values found before to define the best value for the k parameter.

In the second group of tests, several experiments were conducted with two type of samples. In the first type, all agents were executed without attention focus, i.e. they could use all information the environment give to them for their decision making. In the second type, all agents were executed using the focusing mechanism described in the paper. The decision making mechanisms of both agents are identical. They used a utility-based approach to evaluate the best path to follow in order to reach the exit avoiding fire. Both agents also take into account all the information they receive in order to calculate the best surrounding cell to step in. The difference between them is the existing filter in the focused agent prior to sending data to decision making procedure.

All the experiments were made with fifteen situated agents. The agents were distributed in fifty different ways, composing in this way fifty test scenarios. Each scenario was executed with focused agents and with unfocused agents, and repeated about fifty times for

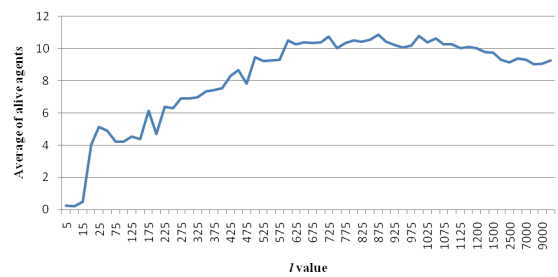


Figure 4: Average of alive agents regarding l parameter

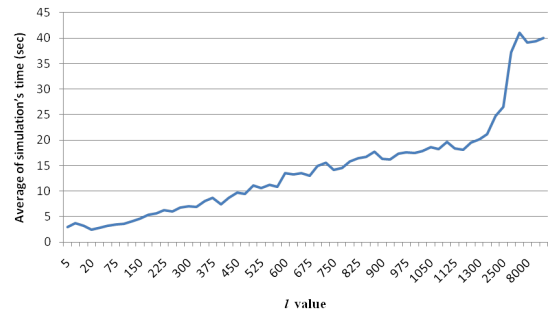


Figure 5: Average of simulation's time regarding the l parameter

each one since environment changes (for instance, fire expansion) followed an indeterministic approach.

4.2.2 Testing results

As previously mentioned, the experiments were conducted through three different stages in order to define the best values for the agent perception mechanism. Firstly, the values of l , k , $\Delta+$, and $\Delta-$ were arbitrarily fixed and the degree of agent interests were checked, i.e. the values for the tags *danger*, *exits*, and *agents*. The values were initially fixed as follow: $l = 2560$ (which is maximum of perception given the testing environment), $k = 0.8$, $\Delta+ = 0.1$ and $\Delta- = 0.1$. The initial results for the agent interests were *danger* = 0.3, *exits* = 0.7, and *agents* = 0. These values represent the best average of alive agents after all the simulations considering the given fixed values.

In the second stage, the best values of agent interest were used to define the best value for the l parameter (which was arbitrarily fixed in the previous stage). The results considering the value of l and the average of alive agents are showed in the figure 4. In that figure, it is possible to see that the interval between 600 and 1500 represents approximately a stabilized value for the average of alive agents and, for values of l under 600, the performance of simulation is very unstable. Observing the figure 5, where the average time of simulation (in seconds) vary in function of l , it is possible to see that the time of simulation grows proportionally to the value of l until the value $l = 1500$. On this value, the agent starts to perceive all the environmental elements and the simulation time increase very rapidly.

Finally, the third stage of experiments define the best value of the k value using the best parameters values defined in the first two stages of experiments. The results are showed in the figure 6, where it is possible to see that the best configuration of the agent's perception focus is achieved using a proportional relation between the l and k parameters. In other words, the best results are achieved when the agent's focus of attention uses elements from spatial focus as well as elements that belong to the exception ordination list. In the testing scenario, the proportion of elements belonging to the exception list can vary from 10% ($k = 0.1$) to approximately 80% ($k = 0.8$).

Considering these three stages of experiments, the best parameters for the agent using the attention focus are: $l = 600$, *danger* = 0.3,

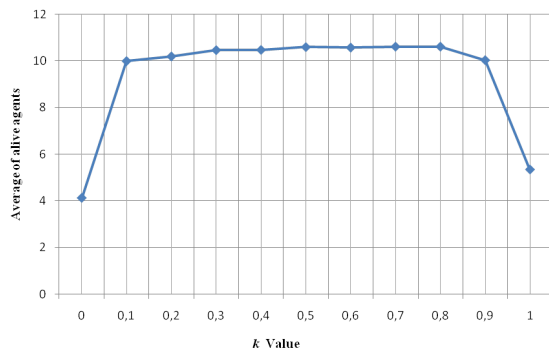


Figure 6: Average of alive agents regarding k parameter

Measurements	Without A.F.	With A.F.
Average	9.500	10.500
ADeviation	5.194	2.843
Steps	42.750	48.167
SDeviation	9.231	3.020
Time	47.651	13.544
TDeviation	17.634	5.018

Table 1: The final comparative results

$exits = 0.7$, $agents = 0.0$ and $k = 0.8$. After these definitions, the tests with the agents without the perception focus were executed.

The final comparative results between agents with and without the attention focus are showed in the table 1 where: the *Average* line represents the average of the amount of alive agents after the simulation, the *ADeviation* line represents the standard deviation of the Average, the *Steps* line represents the average of the simulation's steps in each simulation process, the *SDeviation* line represents the standard deviation of the steps, the *Time* line represents the average of the execution's computational time in seconds and, finally, the *Tdeviation* represents the standard deviation of time.

With the the standard deviation values showed in table 1, it is possible to see that the experiments using agents with the attention focus results in very more stable simulations. Regarding the objective of representing human behavior as real as possible, these results are very important since stability of a behavior is expected to be a fundamental aspect of the agent behavior's plausibility. Also regarding the efficiency, the experiments with the attention focus produced simulations with a major number of steps, but with almost 30% more efficient (considering time response). The latter result is very important considering the approach for speeding up the decision-making of NPCs.

5 Final remarks and Future works

The architecture proposed in this work shows a way of designing goal-oriented agents that are able reduce the amount of time spent to take a decision without losing efficacy. This approach is useful for games to provide better frame rates for game characters designed with goal-oriented architectures. Moreover, it takes into consideration the use of emotional and personality factors, which can improve the characters' believability. Furthermore, the structure of the spatial focus makes it possible to define changes in the agent's attention. It results in a completely different behavior which does not require alterations in the agent's reasoning or planning process. As a consequence, it is expected that a set of completely different agents can be easily designed.

The current work was aimed in defining a new approach for filtering perceptive elements for agents and also to construct a testbed environment where the proposed mechanism could be evaluated. Once evaluated, next steps include a better encapsulation of the overall architecture. This new work aims to facilitate the use of the mechanism in different applications. More specifically, we intent

to reuse the approach in the development of a serious educational game. In the game, the player compete against another human player in a realtime strategy game, and uses slave NPCs as advisers. The NPCs should be able to infer possible consequences from the changing environment in realtime. Thus, a filtering approach is welcomed.

A future work also aims to investigate the use of the proposed filtering mechanism in games by exploring the parallel nature of GPUs. As the filter is a process separated from the agent decision-making, we expect that the perception focus could be implemented using some threads of the GPU. In this possible approach, the GPU calculates the priority of the perceptive elements while the agent process data from a previous environment state.

Beside the test of applying the architecture in a real game engine, other issues we also wish to address include how emotional and personality parameters can really reinforce character believability and how to tune up the speed of a decision-making in order increase believability.

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