Gaia: Intelligent Control of Virtual Environments

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RESUMO:

A indústria dos jogos de computador tem, hoje em dia, receitas na ordem dos milhares de milhão de euros. No entanto, jogos de computador ainda mostram algumas lacunas, nomeadamente na utilização do ambiente de jogo como um elemento da narrativa.

Muitas formas de arte utilizam o ambiente virtual como um dos elementos mais poderosos na narrativa de uma história. Apesar deste facto, jogos de computador ainda apresentam ambientes que mudam pouco ou mesmo nada conforme a história do jogo evolui.

A sensação de presença dos observadores pode ser melhorada fornecendo informação extra sobre a história do jogo através do ambiente. É importante que esta informação seja apresentada aos observadores sob uma forma que lhes seja familiar e que não vá contra aquilo que lhes é familiar ou expectável. De forma a fornecer mais informação aos observadores sob uma forma que lhes fosse familiar, foi procurada inspiração em técnicas utilizadas nos filmes. Mais especificamente, técnicas de representação de valores de tensão baseadas em iluminação.

Nesta dissertação, apresentamos uma framework inspirada no workflow utilizado na indústria cinematográfica. O objectivo desta framework é representar valores de tensão através da iluminação. Esta framework também foi desenvolvida com o objectivo de ser aplicável à maioria dos mundos virtuais em que se conta uma história, incluindo jogos multi-jogador.

Um sistema foi criado para implementar a framework. Este sistema tem dois agentes inteligentes que cooperam para ler a tensão de cada cena e manipular a iluminação para exprimir essa tensão.

Foi efectuado um case study através da aplicação do nosso sistema ao projecto FearNot! (um ambiente virtual de aprendizagem habitado por agentes autónomos). O case study foi, consequentemente, avaliado com resultados positivos.

PALAVRAS-CHAVE: Narrativa, Ambiente, Iluminação, Tensão, Presença
ABSTRACT:

The computer gaming industry is currently a multi-billion euro industry. However, computer games are weak in some aspects, namely in the utilization of the environment as a storytelling element. Many art forms use environments as one of the most powerful elements in telling a story. In spite of this fact, computer games still present environments that change little or not at all. Observer presence can be improved by using the environment to provide observers with more information about what is going on in the story. It is important that this information be delivered to the observers in a form they are familiar with and that does not go against their expectations. For the effect of providing observers with more information in a form they are familiar with, inspiration was taken from motion picture techniques involving illumination based representation of scene tension values.

In this dissertation, we present a framework that was inspired in the motion picture workflow with the objective of achieving illumination based representation of scene tension values. This framework was also developed with the goal of being applicable to most virtual storytelling worlds including multiplayer games.

A system was created to implement the framework. The system has two intelligent agents that cooperate to read scene tension values and manipulate the lighting to express those values. The system was case studied by applying it to project FearNot! (a Virtual Learning Environment inhabited by autonomous agents) and was consequently evaluated with positive results. It was evaluated if the illumination variation was understood by observers as tension variation and if observers understood the story better with the use of our system.

KEY-WORDS: Storytelling, Environment, Lighting, Tension, Presence
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Chapter 1

Introduction

1.1 Motivation

In today’s world, computer games have taken an important role in our economy. In 2007 the computer game industry in United States of America grew 6% and took in about USD $9.5 billion [1], with games such as World of Warcraft [2] having nearly 10 million active users [3], Second Life [4] where more than 15 million accounts have been registered [5] or The Sims [6] having sold 100 million copies worldwide [7] just to mention a few games. However, computer games still lack in some aspects. Art forms such as cinematography, photography, painting or even storytelling use environments as one of the most powerful elements in telling a story [8] [9] [10] [11]. In spite of this fact, computer games present mostly static environments. With static environments we mean that all elements of the virtual world that are not directly involved in the main action remain unchanged throughout the course of the game or change in specific points of the storyline.

Some exceptions have weather pattern variations or changes according to the time of day (changes not employed to tell the story) or a small number of predetermined changes that occur in specific points of the story.

1.2 The Problem

How can we control virtual environments in a way that improves the telling of a story?

We first look at what makes an environment improve the telling of a story. The main objective of every story is to transmit information between a storyteller and an audience in the most entertaining form possible. For that purpose, a rich employment of the environment where the story happens will help make the audience experience the story as though they are a part of it.
When telling a story, if the storyteller describes the environment in which the story is happening the audience can visualize what is happening and the story experience becomes more involving for the audience. We will give an example of a story told with and without resource to a description of the environment:

- **Without description of the environment** - “(...) So little Red Riding-Hood pulled her hood over her curls, and set off down the slope, with her basket in her hand, at a brisk pace. But as she got deeper into the forest, she walked more slowly. Everything was so beautiful; the child began singing as she went, she could not have told why, but I think it was because the beautiful world made her feel glad. (...)”

- **With description of the environment** - “(...) So little Red Riding-Hood pulled her hood over her curls, and set off down the sunny green slope, with her basket in her hand, at a brisk pace. But as she got deeper into the forest, she walked more slowly. Everything was so beautiful; the great trees waved their huge arms over her, the birds were calling to one another from the thorns all white with blossom, and the child began singing as she went, she could not have told why, but I think it was because the beautiful world made her feel glad. (...)” [12]

When the story is told with a description of the environment the audience is drawn into the fictional world.

In order to tell our story with a rich employment of the environment, we have to address several issues:

- **How to control the virtual environment?** Our approach uses an intelligent agent architecture based system that will embody the virtual environment. Because it embodies the environment we shall call it Gaia. Gaia must provide autonomous behavior, analyzing the story and acting upon the environment making the changes it finds necessary.
Autonomy is an important aspect of Gaia because it will maximize the system’s usefulness and interest.

- **How to manipulate the environment?** An environment has an almost infinite number of variables that can be manipulated.

Each object in the environment occupies a space, has a color, a pattern, a shape, a movement. Each object has a set of lines that help to define it. Each of these characteristics vary in time according to a rhythm (whether the characteristic alternates or not, whether it repeats its values or not and the speed at which it changes). The combination of two objects generates new variables. Whether the objects contrast or show affinity in any of the other characteristics. For example, when you have two objects, their shapes can show affinity as in a scene with two circles (Figure 2) or they can show contrast as in a scene with a circle and a rectangle (Figure 3). [9]

![Figure 2 - Shape Affinity between Two Objects](image)

We have other objects that combine the variables of regular objects with special characteristics that influence the way other objects are seen. Examples of such objects are lights. Lights combine the variables of regular objects with the possibility of illuminating other objects. Light can illuminate with different intensities and colors. With all these variables, the possible combinations of environment changes verge on infinite. In order to define what subset of variables to choose from we will look at other forms of art. These have been manipulating environments to tell stories for decades.
How the changes made to the environment affect the audience? Along with defining what set of variables should be manipulated in the environment we must know what effect these changes have on the audience. When telling a story, the way it evolves through time is a very important factor in the interpretation the audience has of that story. When environment variable values change a great deal over time, environment states contrast with the subsequent environment states as illustrated in Figure 4. When environment variable values change slightly or don’t change over time, environment states show affinity to subsequent environment states as illustrated in Figure 5. The more contrast a sequence of shots shows, the more visually intense the scene will be [9]. It is our hypothesis that the more intense a scene is the more tension it provokes on the audience. Tension can be defined as the audience’s stress level in reaction to the intensity of the scene [13].
1.3 Road Map

The way the rest of this document is organized is as follows:
Chapter 2 (Related Work) looks into what makes an environment more involving for an observer and also looks into techniques used to improve the impact of virtual environments are presented and compared.
Chapter 3 (Framework) describes the framework we devised. The objective of our framework is controlling and manipulating the environment in such a way that improves the involvement of the observer in the story. This chapter first looks at the film industry, arguably the most advanced in the use of techniques that improve observer involvement. Then, describes how we take inspiration the processes used in this art and create our framework from them.
Chapter 4 (Implementation) describes the architecture for our agent-based virtual environment control system. The chapter describes how the system works as a whole and then describes its two composing agents.

Chapter 5 (Case Study) looks at how we case studied our system by using the FearNot! project. First, the chapter explains the FearNot! architecture at a high level. Then describes what was necessary to apply our system to FearNot!.

Chapter 6 (Evaluation) describes how we preformed the experiment to evaluate our implementation of the architecture designed to controls virtual environments in the context of the FearNot! case study.

Chapter 7 (Conclusion) gives an overview of what was done, draws some conclusions in the work and lays down future work.
Chapter 2

Related Work

In this chapter, we explore research that is related to intelligent control of virtual environments. As mentioned, we aim at creating a virtual environment control system that improves the understanding and integration of the observer in the main action. In order to achieve our objective we divide our analysis in two areas. Firstly (Section 2.1) we look at what makes an environment more involving for an observer. Secondly (Section 2.2) we present techniques used to improve the impact of virtual environments. Finally (Section 2.3) we compare the different techniques presented.

2.1 Presence

Presence can be defined as the phenomenon of a virtual world being experienced by the audience as a real place [14] [15]. Investigation in text environments (such as books) and desktop virtual reality (such as PC based systems or game consoles) support that these seem capable of producing high-presence experiences. [16]

To understand what makes an environment improve observer involvement we first explore the concept of presence and discuss how immersion relates to presence. In order to deliver a high presence, virtual worlds are usually depicted with a high level of realism. Realism is defined in Encarta® as a “lifelike artistic representation: in artistic and literary works, lifelike representation of people and the world, without any idealization”. We will briefly discuss whether realism is a necessary condition for presence or if, on the other hand, presence can be achieved by creating worlds that function according to what the observer expects and is familiar with. This would mean that, if you have a virtual world that functions in a way that is not lifelike but you familiarize the audience with its rules of functioning, the audience would still maintain high levels of presence even when they are faced with unrealistic events.
2.1.1 Presence and Immersion

*Immersion* is defined as the degree to which a system delivers information about the virtual world (to all the senses) and tracks the audience so that a high degree of fidelity is maintained in relation to their equivalent real-world sensory modalities [15]. Research on the relation between presence and immersion confirms that – the more immersive a virtual environment is, the more presence the audience tends to experience in it [17]. Some theorists (for instance, M. Slater in [18]) argue that the form of the presence experience (that is, the way the information is presented to the audience) is more important than the content (that is, the information itself). The load of information presented to the audience about the environment may be enough to ameliorate any difference due to the form in which the information is delivered, a detailed written account of a scene might, by virtue of the high information load it carries, produce more presence than a photograph [19]. This supports our belief (first stated in section 1.2) that when the environment is used as an extra storytelling element we improve observer involvement which in turn increases the immersion of a virtual world. We will later perform experiments (Chapter 6) to evaluate whether by using the environment to provide the audience with extra information on the story will improve observer involvement in the main action.

2.1.2 Presence through Realism

David Nunez states in his work [19] that many researchers interpret the link between immersion and presence as an indication that realism is an important factor in determining presence – from this point of view, realistic simulations which are realistically depicted will lead to presence. The emphasis on realism can be found in several places in the literature: for example, the Presence Questionnaire [20] treats realism (both in terms of display as well as content of the environment) as a determining factor of presence directly, while El-Nasr, M. [15] argues for presence as the condition when the audience is behaving in such a way as they would in if the virtual environment were real. We believe however, that the notion of observed realism, particularly from a cognitive science perspective is problematic. It implies that information arising from the ‘real world’ has some special property which makes it inherently different or distinguishable from information which arises from other sources [19].

2.1.3 Expectation

When observing a scene or exchange, our perception will include aspects such as what has immediately preceded this particular exchange (context). Also included is our experience with similar exchanges (learning) [21]. Therefore it is more useful to think of presence in terms of expectation, rather than in terms of realism [19]. We will perceive of something as realistic if it is in line with our expectations of what one will find in that particular setting. Research found that fire-fighters and policemen described traumatic situations or situations of extreme danger as though they were watching a movie. This research seems to indicate that even if high fidelity information were supplied
to all the senses this alone would not be enough to guarantee a sense of realism or of presence [19]. When firefighters and policemen were faced with a situation completely outside their expectations it led them to a ‘break in presence’, even though the information their senses was feeding them was of high fidelity [22].

### 2.1.4 Audience Familiarity

Let us first define audience familiarity. We define *Audience Familiarity* as the set of knowledge and past experiences with which a group of people contextualize the story of which they are an audience. Movies often include a musical score. Although this is entirely unrealistic (music does not accompany important events of our life as it does for characters in movies) it can increase the level to which audiences become involved in the story. By using a musical score the presence felt in the virtual world increases. This occurs because the musical score is a standard device the audience has experienced many times in other movies. The audience knows the score is commonly used to reinforce the scene’s action or to convey extra storytelling information (by giving an insight into the character’s feelings for example). If the audience is not familiar with the particular codes or stylistic conventions then the meaning will be lost and the expectations of the audience are not matched [19].

### 2.1.5 Concluding Remarks

Presence is a strong factor when one is conveying stories that are memorable to their audience. If the audience feels like they are inside the virtual environment, their experience is much closer to them than if they are detached. In order to achieve presence, realism is not an important factor, audience expectation on the other hand is. Audiences will not break presence when faced with unrealistic exchanges, so long as the exchanges go in accordance with the audience’s familiarity. Unrealistic techniques that are familiar to the audience such as a musical score or stage lighting manipulation can improve the understanding and involvement in the story and not only, not go against the expectations of the audience but reinforce and support them.

### 2.2 Techniques to Improve the Impact of Scenes

The techniques used in different art forms, from motion pictures, to literature, from photography to painting, have been used to improve the telling the story for many years and are familiar to most audiences. In this section, we look into some motion picture techniques, namely related to lighting, then we explore the static manual lighting used in most computer games nowadays and an improvement over static manual lighting that some games are starting to employ: dynamic lighting. Finally, we present two lighting engines proposed by El-Nasr that take on the role of placing lights across virtual environments and controlling their illumination parameters.
2.2.1 Motion Picture Techniques

As outlined in many film books [9] [10] [11], movies use several color and lighting techniques to create a desired effect based on the director’s style. In this section, several color and lighting patterns will be discussed. These patterns were formulated based on a qualitative study of over thirty movies. According to this study, the techniques used can be divided into shot-based color techniques (color techniques used in one shot) and scene-based color techniques (techniques used on a sequence of shots) [23].

Lighting design theory discusses several other techniques that designers use to balance these effects with other lighting design goals, such as projecting depth, establishing necessary visibility, and providing motivating lighting direction [9] [10] [11]. However these techniques are outside the scope of our work and will not be looked into.

Several movies use contrast between shots to evoke arousal [9] [10] [11]. For instance, filmmakers use warm colors in one shot then cool colors in the other, thus forming a warm/cool color contrast between shots to reflect a decrease in dramatic intensity. Color warmth is calculated by Katra and Wooten described in [24] using linear regression method in RGB color space as follows:

\[
\text{Warmth} = 0.008 \cdot R + 0.006 \cdot G - 0.0105 \cdot B - 0.422
\]

Equation 1 - Color Warmth Calculation

Some designers use saturated colored shots then desaturated colored shots creating a contrast in terms of saturation. Examples of films that used this technique include Equilibrium [25] and The English Patient [26]. Based on these observations, the following patterns were identified in El Nasr’s work [23]:

Pattern I

Subjecting audience to affinity of high saturated colors (where high saturation ranges from 70% to 100%) for some time increases projected tension.

Pattern II

Subjecting audience to contrast in terms of high saturated then low saturated colors (where saturation ranges from 100% to 10%) over a sequence of shots decrease projected tension.

---

1 Including “The Cook, The Thief, His Wife and Her Lover” [45], “Equilibrium” [25], “Shakespeare in Love” [46], “Citizen Kane” [47], and “The Matrix” [48]
**Pattern III**

Subjecting audience to contrast in terms of low saturated then high saturated colors (where saturation ranges from 10% to 100%) over a sequence of shots increase projected tension

**Pattern IV**

Subjecting audience to contrast in terms of high brightness then low brightness (where brightness ranges from 100% to 10%) over a sequence of shots increase projected tension

**Pattern V**

Subjecting audience to contrast in terms of low brightness then high brightness (where brightness ranges from 10% to 100%) over a sequence of shots decrease projected tension

**Pattern VI**

Subjecting audience to contrast in terms of warmth then cool colors (where warmth ranges from 100% to 10%) over a sequence of shots decrease projected tension

**Pattern VII**

Subjecting audience to contrast in terms of cool then warm colors (where warmth ranges from 10% to 100%) over a sequence of shots increase projected tension

**Pattern VIII**

Subjecting audience to increase of brightness contrast subjected in a shot (where brightness contrast is measured in terms of difference between bright and dark spots in an image) over a sequence of shots increases projected tension

**Pattern IX**

Subjecting audience to decrease of brightness contrast subjected in a shot (where brightness contrast is measured in terms of difference between bright and dark spots in an image) over a sequence of shots decrease arousal.

**Pattern X**

Subjecting audience to increase of warmth/cool color contrast subjected in a shot (where contrast is measured in terms of difference between warm and cool spots in an image) over a sequence of shots increases projected tension.
Pattern XI

Subjecting audience to decrease of warmth/cool color contrast subjected in a shot (where contrast is measured in terms of difference between warm and cool spots in an image) over a sequence of shots decreases projected tension.

Although no conclusive proof of the effectiveness of these patterns in projecting increased or decreased arousal is presented, it is assumed that these patterns are effective based on their use in films. The effect of some of these patterns on self reported affective state has been confirmed experimentally [27] [28].

2.2.2 Manual Lighting

Several game titles adopt a manual technique for lighting a game environment, whereby a designer, knowing the level of tension he needs to elicit, manually places lights and adjusts their colors in the environment [23]. An example of a game that uses such an approach is Devil May Cry I [29] a game that sold more than two million copies [30] [31] [32]. In this game, the dramatic tension is broken into discrete segments that are materialized when an appropriate level is loaded. In some cases, the difference between levels is only in texture or lighting colors; for example, the last level of Devil May Cry I is colored in a distinct saturated red color, signifying the climax. While the technique works to supply the necessary tension through the game, it suffers from several problems. From a design perspective, it is very tedious to redesign and relight each level. The technique requires the designer to break the flow of tension into segments and manually adjust the textures or lighting to accommodate the increase and decrease in tension. Furthermore, such an approach results in a static design, which limits lighting movements or variations within a level.

2.2.3 Dynamic Lighting

The recent inclusion of dynamic lights allowed game developers to investigate the inclusion of dynamic lighting effects, e.g. explosions and lightening. Horror films use many lighting patterns to evoke fear and shock, e.g. light flickering at specific situations in a movie to create anticipation and fear, or increasing darkness or contrast in specific parts of a movie for the same purpose. Examples of these patterns can be seen in several games, such as F.E.A.R.: First Encounter Assault Recon [33], Silent Hill [34], and Doom 3 [35]. An example pattern used extensively in Doom 3 is the sudden light flicker and the increase in saturated warm colors in certain areas of the level. These changes parallel the techniques used in Horror movies and use dynamic lights mainly to evoke fear.

The dynamic lighting method still suffers from many problems. These effects are scripted and thus need to be planned. Also, the levels need to be well designed for such dynamic changes in lighting. For example, designers are required to plan textures and the lights used, such that they would be in accordance with the desired shifts in color. Additionally, these changes are often computed with little consideration to the game play or other lighting design goals, which results in frustrating and badly lit
environments. While it is always the artist’s choice to sacrifice one goal for the other, oftentimes a balance can be achieved by simply balancing the lighting in the environment. This is difficult to achieve with a combined static and dynamic lighting approach.

2.2.4 Expressive Lighting Engine

The Expressive Lighting Engine (ELE) is an automatic intelligent lighting control system proposed by El-Nasr in her work [13]. It was then extended by the same author with the Temporal Dynamic Expressive Lighting Engine (TDELE) proposed in his work [23].

ELE is based on cinematic and theatrical lighting design theories. It is designed to automatically select the number of lights, their positions, colors, and angles. To accomplish this task, ELE uses lighting design rules formulated with base on a study of film and theatre lighting. These rules are represented mathematically in an optimization function. The use of optimization is important to balance conflicting lighting-design goals. While adapting the lighting to the interaction, ELE also maintains visual continuity and style.

The Temporal Dynamic Expressive Lighting Engine (TDELE) was proposed in [23] and extends ELE by adding a state that keeps track of ticks (simulation time) as well as the history of lighting color compositions used in the past. This state is represented as a list of light colors for each area as well as contrast value and contrast type; color values are stored in terms of RGB and HSL as well as calculated warmth value (according to Equation 1). Based on this state information, the desired pattern given the patterns discussed in section 2.2.1, and the desired tension level, the system calculates constraint values, including desired saturation level, desired warmth value, desired brightness value, and desired contrast level. These values are then given to ELE to manipulate the current frame. Notice that ELE already balances these values with the required visibility, motivation, etc. Therefore, the resulting lighting setup created presents a balanced lighting design.

There are several advantages to using such a system. First, as discussed in section 2.2.1, the system embeds several patterns that are not currently used by game developers. Second, it presents a system that establishes a well-balanced lighting design. Because it is based in lighting design theory [5] [6] [7] that establishes how to balance these effects with other lighting design goals, such as projecting depth, establishing necessary visibility, and providing motivating lighting direction. Third, it allows designers to quickly compose the scene by just choosing the pattern and tweaking it, rather than re-designing the lighting for every level.

An example was developed for El-Nasr’s work. Using this implementation within Unreal, a first person shooter mod was developed. The lighting compositions varied within the level composed. For example, in the beginning a decrease of brightness contrast was established through the opening scene, shown in Figure 6, where the left image shows a screenshot at an earlier time than the right image. At the end, a warm/cool color contrast as well as brightness contrast was used, as shown in Figure 7.
2.3 Technique Comparison

In this section, we compare the different techniques analyzed. The elements considered most relevant were:

- **Audience Familiarity** – Does the technique provide a representation that audiences recognize?
- **Multiplayer Environment Implementation** – Can we use this technique in a multiplayer environment?
- **Automatic Light Placement** – Does the technique automate the process of light placement?
- **Temporal Light Variation** – Does the technique allow for light parameter variation through time?
- **Non-predetermined Behavior** – Can the technique be applied to a virtual world where the story is not predetermined?
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Table 1 - Comparison between the Different Studied Techniques
Chapter 3
Framework

This chapter describes the design of a system that controls the environment and manipulates it in such a way that improves the involvement of the observer in the story.

Film making is the art that is, arguably, the most advanced in the use of techniques that improve observer involvement. For this reason we took inspiration in the processes used in this art. These processes have evolved over time to create environmental setting that will tell the story of the script in a way that is most involving to the observer.

The film director has the responsibility of making the movie happen. He constructs his own understanding of the script into an idea of a movie commonly referred to as the director’s “vision”. More concretely, we define vision as the information (processed data) deemed relevant to build the story that the film director draws from the script.

Directors work with actors, makeup artists, cinematographers, writers, and film, sound, and lighting technicians. From all these different relations we will focus on the director - cinematographer relation. It is mostly in this relation that the visual style of the movie is built.

Film making is a unilateral process in which there is no observer interaction in the story. Since our goal is to develop a system that employs the processes and techniques involved in film making, and uses them in interactive scenes, the inspiration that can be drawn from film making is limited.

Our system will not work only with predetermined environments. It must continually understand the scene, update the film director’s vision and apply the changes to the environment in order to reflect this updated vision.

3.1 Film Industry Approach

In the film industry, the process used to produce environments that are involving to the observer has been in place for many years. The process starts with the production of a script. After that, the film director reads the script and builds a plan of what story he wants to tell and how he wants to tell it. In the following step the film director transmits to the cinematographer his vision. Based on the film director’s vision the cinematographer manipulates the environment to produce the visual style that fits the film director’s requirements. Finally, while the observer watches the movie, the environment
contributes explicitly or covertly, to the understanding of the story and to the observer’s interest in this story. Figure 8 is a diagram of the described process.

![Diagram of Environment Control in the Film Industry](image)

**Figure 8- Environment Control in the Film Industry**

### 3.1.1 Script

The script is put together by a screenwriter and constitutes the story that serves as a base for the movie. We will not focus too much on the script. Even though our system is applicable to scripted stories our goal was to create a system that would also work in non-predetermined stories.

### 3.1.2 Film Director

The film director has the responsibility of turning a script into a movie. The film director decides what to draw from the script and whether or not he will closely follow the script. The methods used by film directors to produce a vision for a movie vary widely and are mainly the fruit of the director’s creativity rather than the application of a set of rules. Some film directors develop a style that they become associated with, while others experiment with a different style for each of their movies.

### 3.1.3 Vision and Tension

Being cinematography an art, there are many ways in which a cinematographer can represent the director’s vision. Because representing the film director’s vision accurately and completely was not the focus of our work and was not necessary for our approach, we restricted the vision representation to the tension. Some techniques were researched to represent tension. These techniques were discussed in section 2.2.1.

The film director produces a vision for each scene. This vision contains the story information and it can be divided into three parts:

- *Information that is not transmitted to the observers*. Some information about the story is kept from the observers. This is typically done by Film Directors to improve the telling of
the story. Some Directors make whole movies around this information. For example in “The Sixth Sense” where one of the main characters only discovers he is dead in the end or in “Fight Club” where the main character discovers in the end that the character played by Brad Pitt, “Tyler Durden”, is his alter ego;

- Explicitly Transmitted Information (ETI). This type of information is conveyed by means of dialogs between characters or other forms of speech, actions, portraying of objects or text alone in screen. Explicitly transmitted information requires less thought in order to be understood by observers. For this reason it is the most commonly used by directors to guide the observers through the plotline;

- Implicitly Transmitted Information (ITI). The transmission of this type of information is done through the manipulation of the illumination conditions of the scene, the color saturation of the film, presence of objects in the scene that are not required by the action, the music score of the movie, etc… ITI is not mentioned by ETI because its purpose is to give hints on the story to the observers in a non-obvious way. It is typically meant to influence the observers and lead them to make assumption on the ETI in a subconscious manner. Usage of type of information is present in almost all movies. For example, in the movie “Citizen Kane” the camera looks up at Charles Foster Kane and his best friend Jedediah Leland and down at weaker characters like Susan Alexander Kane [36] or in the movie “Pulp Fiction” every time the character Vincent goes to the bathroom something “bad” happens [37].

The assumptions made by observers when presented with ITI are managed by film directors to lead the observers to a state of tension.

We previously defined tension as the audience’s stress level in reaction to the intensity of the scene [13]. If it is apparent to the audience that an important event will happen, the audience’s tension levels will rise. The more eminent the event is and the bigger its relevance is to the observer the bigger the tension caused by it.

Tension can be used by film directors to different effects. We will proceed to describe the four effects in which tension is used that were considered.

---

2 Spoiler Alert: If you have not seen the movies “The Sixth Sense” or “Fight Club” please watch them and then come back to this paragraph.
3.1.3.1 Event Build-Up

In an event build-up, ITI is given to the observers that lead them to believe that important event is going to happen before the event actually happens.

In order to present an example of event build-up let us imagine a terror movie scene. In this scene a group of people are in a house having a conversation on some mundane topic (this constitutes the scene’s ETI) while they are having this conversation the scene’s lighting gradually darkens, through a window, trees start wavering in the wind (these elements constitute ITI) and suddenly the unspeakable monster appears and starts chasing the group while they scream and run. In this example the ITI leads the observer to believe a bad event is going to happen before the event actually happens and without any explicit reason to believe so. This build up is used because by elevating the observers’ levels of tension before the event they sustain higher levels of tension for a longer time.

3.1.3.2 Surprise Event

Surprise events lead to sudden elevations of the tension values. In these scenes, the ETI gives the observers information that could lead them to high tension values, however, by not providing the
corresponding high tension value ITI the film director leads the observers to believe nothing important will happen.

In order to exemplify this type of scene let us imagine a scene from a war movie. In this scene, the observer has been previously informed that the headquarters will be attacked. A character is in the headquarters doing some chores like cleaning his weapon or eating (ETI). The illumination is bright, the film score is calm (ITI). Suddenly a bomb explodes near the character and combat initiates. In this example, even thought the observer has explicit information that the headquarters will be attacked he is lead to believe that nothing important will happen soon because there is no ITI indication so.

3.1.3.3 False Event Build-Up

![False Event Build-Up Graphic](image)

**Figure 11 – False Event Build-Up Graphic**

In a false event build-up the observers are lead to believe an important event is going to happen through the ITI when in fact no important event will occur. Film directors use false build-ups to generate high tension levels in otherwise monotonous scenes. The use of false event build-ups is also important because, has discussed earlier in this section, ITI is supposed to give hints in a non-obvious way. False events build-ups lessen the effects of observers having decoded the use the film director has of ITI.
3.1.3.4 Event Resolution

![Event Resolution Graphic](image)

**Figure 12 - Event Resolution Graphic**

In event resolution ITI is given to the observers that lead them to believe that the important event that occurred has been resolved. Film directors use event resolution to lead observers to relax the high tension brought on by the event.

3.1.4 Cinematographer

Also referred to as “director of photography”, the cinematographer is the person responsible for the filming of the action and lighting of the set, both on the technical as well as the artistic dimension. Film directors have a vision of the film they want to create and after they convey this vision to the cinematographer it is the cinematographer’s task to capture the action in the style the film director intended.

3.1.5 Environment

By configuring the environment in different ways the cinematographer can set the visual style of a whole movie or a scene. Depending on the freedom given by the film director, the cinematographer can be more or less limited. Stricter film directors can limit the cinematographer to the more technical decisions of the lens or film stock used in each scene, while others can free the cinematographer to decide the whole configuration of the environment including lighting, framing of the scenes or even presence of objects in scene.

3.2 The Gaia Approach

The main difficulty in applying the film industry approach in our system is that in an interactive world there is no set script of the story. The film director entity has to construct an understanding of a continually changing story. Then, whenever his vision for the current scene changes he has to update
the cinematographer entity with his new vision for the scene. It is then the cinematographer’s responsibility to continually update the environment to fit the film director’s vision.

We will proceed by textually and visually describing our approach in Figure 13 and following that we will go into depth explaining the concept of each entity.

![Diagram](image)

**Figure 13 – Environment Control with the Gaia System**

The observer is the person or group of people that is targeted by our system. It is the observer that Observer is the person or group of people the system wants to influence by manipulating the environment. The observer can be passive, only drawing information from the virtual world or active, by also interacting with the world. The world contains the environment which we define as everything that is not interactive to the observer or part of the main action. The film director interprets the world, constructs his vision of the events that occur in the world. The cinematographer then receives the director’s vision and manipulates the environment in order to influence the observer in the way the director wants.

### 3.2.1 Observer

Our approach allows the observer to be active and interact with the world or be passive and just be influenced by the world. This does not interfere with the design of our approach because the film director will interpret the world independently of whether there is someone controlling it’s variables of not.

The film director takes information from the world where the action occurs. By *action* we mean all the interactions between characters, character-object and between objects that occur in a world. The characters interact with each other and with the world while playing out the action. Therefore, it makes no difference whether the characters are controlled by the observers or by any other means.

Let’s look at a possible simple application of our approach to a game like World of Warcraft (WoW) in order to better understand how it makes no difference whether the characters are controlled by the observers or by any other means. In the context of WoW, the observer is the person that is playing the game. Our film director could interpret, for instance, how much life the player’s character has left and how much damage he is taking. With this information he could build his vision of how close the
character is to dying. The cinematographer could then manipulate the environment’s torches to burn redder the closer the character is to his death (which is the information the director’s vision is giving him). If instead of a person controlling the character we had some form of artificial intelligence or script, the application of our approach would be the same as long as the action was replicated.

![Figure 14 - World of Warcraft](image)

### 3.2.2 Environment

Our approach defines *environment* as the set of all the elements of a virtual world that are not interactive to the observers, remain unaltered by the action and do not restrict possible action. Taking as example a game of Tetris (Figure 15), we consider as part of the environment the color of the pieces, the lighting of the world, the contrast between the pieces and the background, etc. We don’t consider part of the environment the position of the pieces and the orientation of the pieces because these are observer controlled, we also don’t consider part of the environment the rate of decent of the pieces or the fact that when a full line of pieces is laid that line is removed from play because these are part of the action, in this case, game rules.
3.2.3 Film Director

Taking inspiration from the film industry approach, our system employs a film director entity that has the task of producing a vision for the scene (not a specific scene but the current set of events that are happening).

From the vision, we restricted the production of the film director to the Implicitly Transmitted Information (as described in section 3.1.3). This ITI is a sub-set of information that the director wants to be transmitted implicitly. This simplification was brought on because the control of the environment, as is our objective, is done with the recourse to only the ITI.

Because there is no set script the film director entity needs to be constantly interpreting the world and constantly informing the cinematographer of his renewed Vision for the current scene.

Looking again at the example started earlier in section 3.2.1 the film director takes information from the world where the action occurs. The information drawn from the world constitutes the director’s vision (as defined before in the introduction of this chapter), however, since there are no predefined scripts in games like WoW the information has to be constantly drawn as the action occurs.

The director’s vision could contain information like: what characters should be in scene, what are the names of the character’s enemies that are in scene, etc… but these constitute Explicitly Transmitted Information. ETI is not contemplated in our approach, only Implicitly Transmitted Information like: how close is the character to completing his objectives, how much danger is the character in, how many other characters are helping the character, etc…

The film director draws the ITI from the world by reading the relevant variables and then doing some calculations on them. For a simple example of how the film director could determine how much danger the character is in he could read the number of hostile creatures that are close to the character, multiply it by their respective levels (generally, the higher the creature or character’s level the more skilled he is) and then subtract that number by the number of other characters that are helping the main character multiplied by their level (Equation 2).
Equation 2 - Example of an ITI Equation

\[ \text{dangerLevel} = \left( \text{numHostiles} \times \sum_i \text{level}(i) \right) - \left( \text{numFriendlies} \times \sum_j \text{level}(j) \right) \]

3.2.4 Cinematographer

The cinematographer entity is being continually updated of the film director’s vision. It is the cinematographer’s responsibility to manipulate the environment in such a way that passes to the observer the information present in the film director’s vision that is not transmitted otherwise. The role of the cinematographer was modified in our approach for simplification purposes, camera control was considered outside the scope of the system. Some of the variables not included were the scene framing, focal distance, lens aperture and lens choice.

3.2.5 Requirements

Having defined our approach there are some factors to take into account when using our system.

- The virtual world should have an ongoing main action, be it one main action global to the world or many particular main actions local to each actor in the world. This is fundamental to the role of the Film Director that needs a main action in relation to which he draws his Vision from.
- In the world where our system is going to be used, some elements (variables) that are not directly involved in the main action should be defined. These will be considered part of the environment and are necessary for the Cinematographer to have available tools for the expression of the Film Director’s Vision.

3.3 Concluding Remarks

By taking inspiration in the Film Industry we designed a model based on a process that has been proven to produce involving environments that improve the telling of a story. Building on this concept, we hope we managed to arrive at a design that is usable in a large set of virtual environments. The design concept described is applicable, without any need for adjustments, to virtual environments ranging from simple storytelling environments, through single player games, all the way to online multi-player games.

In the design of our framework we arrived at the conclusion that in order to apply our system, two elements should be present in the virtual world (detailed in section 3.2.5). These can be summed-up in two bullets:

- The virtual world should house a ongoing action;
- The world should have background elements not used in this action.
We believe that this model constitutes an innovative approach to virtual environment control that will improve the immersion factor (section 2.1.1) of the virtual environments it is applied to, fruit of its simple but robust concept.
Chapter 4

Implementation

In this chapter, we describe how we designed the architecture for the virtual environment control system. In accordance with the model we described in the previous chapter, two entities are needed to be implemented: the Film Director entity and the Cinematographer entity.

The Film Director needs to be continuously aware of aspects of the virtual world and based on these aspects transmit to the Cinematographer a Vision of the story he wants to tell. The Cinematographer needs to manipulate variables of the environment in order to project to the observers the Vision the Film Director wants to project.

4.1 System Design

In order to implement our concept we turned to an intelligent agent architecture. This architecture is composed of two agents and a module external to the agents. The two agents have different valences and they cooperate to achieve the desired effect. By using this approach we manage a very direct translation from the concept space to the implementation space. The first agent will interpret the role of the Film Director, and the second will interpret the role of the Cinematographer. The external module ITI Adjustment allows the application making use of our system to have some control over the tension representation.

We will proceed to describe our architecture’s design (Figure 16). The film director agent has a number of sensors, each sensor monitors a variable of the virtual world. The sensors then feed their values to the Vision Production module. In turn, the vision production module takes the variable values and calculates the vision information. The film director’s vision information is then fed to cinematographer agent, more specifically, to his vision representation module. As the name indicates, the task of the vision representation module is to take the vision information and translate it into a representation with the virtual world’s environment variables.

It is here that the ITI Adjustment module comes into play. If the vision representation module receives vision information from the ITI adjustment module, that information will override information coming from the film director agent.
After the vision information is translated into environment variables, the vision representation feeds the actuators with the updated environment variable values. The actuators will carry out the task of matching the environment variables with the value the vision representation defined for them.

**Figure 16 - System Architecture**

### 4.2 Film Director

Following the conceptual definition of the Film Director role (section 3.2.3) the main objective of the Film Director agent is to produce a Vision of the current events of the world. We proceed to describe how we implemented the Vision production aspect of our system and the sensors that allow the Film Director to monitor the events of the world.

#### 4.2.1 Vision Production

As we defined before (in the introduction of Chapter 3), the vision is the information a Director draws from the script that he finds relevant to the story. However, when working in an interactive environment there is no script so we needed to dynamically create the vision from the events that take place in the world.
We solved this problem by giving the Director knowledge of the objectives of the characters. By measuring the level of accomplishment of those objectives we construct the Director’s vision of the story, in a world that is not pre-determined by a script.

![Character's Objectives](image)

**Figure 17 - Definition of a Story**

### 4.2.2 Character Objectives

The Film Director needs to have knowledge of the level of accomplishment of the characters’ objectives in order to process his understanding of the story. He then needs to evaluate all events occurring in the virtual world, keep a history of these events and assess how close the character is to completing his objective.

The implementation of the process we just described in any kind of dynamic and autonomous fashion would be an enormous undertaking. Because this type of assessment was not the main focus of our system we designed a solution to circumvent it.

The character’s objectives must be concretely defined in order for a virtual world to be able to employ our system. Concrete indicators of the level of accomplishment of these objectives must be defined. In order to define the indicators, three types of values can be used:

- **World variables** - The health of the main character, the availability of “power-ups” in the virtual world, the speed and direction of the main character, are examples of world variables;
- The result of the indicator in the previous calculation;
- The way the values are evolving through time - By applying an Emotivector [39] to either one of the other two value types, we can use an expectation of how the value should evolve.

The Emotivector gives us an expectation of the value evolution and the relationship between that expectation and the actual value (Figure 18).
The Emotivector defines nine relationships between the expectation and the actual value in a model named by the Martinho, C. in his work [39]. The ‘Nine-sensation model: In the figure, R stands for reward and P for punishment. The first line shows possible outcomes when the Emotivector is expecting reward: ‘significantly better than expected’, ‘better, as expected’, and ‘significantly worse than expected’. The use of an error margin allowed five new sensations (represented by darker cells) to be introduced. From top to bottom, and left to right, they are: ‘reward is as good as expected’, ‘unexpected reward’, ‘no significant reward nor punishment, as expected’, ‘unexpected punishment’, and ‘punishment is as bad as expected’. [39]

Some examples of indicators level of accomplishment of the characters’ objectives:

- How close is the main character to defeating the other characters – For example, in a game where characters compete to beat each other in a race, this indicator would be higher the farther ahead the main character was from the other characters.
- How well defended is the main character’s base – For example, in a real time strategy game, this indicator would be higher the more units the main character had around his base compared to the number of units a hostile character had near the main character’s base.
- How well are the characters’ needs fulfilled – For example, in a life simulation game (like The Sims [6], this indicator would be higher the better the house characters’ basic needs like food, sleep, etc were fulfilled.

As seen in the previous examples, the film director can construct his vision focusing on a character as the main character. This means that, in a multiplayer world, the environment fits each observer’s context. The environment can be different to each observer in the same world because the level of accomplishment of each observer’s focus character is different. For example, two observers playing some real time strategy game against each other, one can see a very bright, colorful environment while the other sees the same environment as very dark and grey.

Our system was built to take another advantage of the fact that the film director can construct his vision focusing on a character as the main character. It is possible to seamlessly and dynamically change the character in focus. An observer can see the same interaction “through the eyes” of
different characters. For example, in a storytelling environment telling the story of Little Red Riding Hood [40], when the wolf is eating Little Red Riding Hood’s grandmother the environment can show a lot of tension if the film director is focusing on Little Red Riding Hood. But the same event can show very little tension if the film director is focusing on the Big Bad Wolf.

4.2.3 Sensors

The film director has a set of sensors. Each sensor has to be assigned to a world variable relevant to the vision production’s defined indicators. Its task is to constantly access the world and update the vision production module with the variable’s value most recent value.

4.3 Cinematographer

As defined before in section 3.2.4, the objective of the Cinematographer agent is to produce a representation of the Film Director agent’s Vision by using variables available in the environment. We proceed to describe how we implemented the Vision representation aspect of our system and the actuators that allow the Cinematographer to manipulate the environment.

4.3.1 Tension

From the indicator values, received from the Film Director, a tension value is calculated. The tension calculation can vary widely from world to world and from indicator to indicator. Being close to some objectives can mean high tension while being close to other objectives can mean low tension. We proceed to present two examples:

- In a world where characters compete to acquire the most resources in a time frame, a character holding the most resources near the end of the time frame (being close to his objectives) leads to low tension values.
- A world in which the characters battle enemies to reach the end of a level (typically the case in First-Person Shooter games), a character that is nearing the end of the stage (close to his objectives) leads to high tension values (Enemies in FPS games typically get harder as the end of the stage draws near).

From this tension value the environment is manipulated. This manipulation is done according to a mapping defined previously as a requirement for the use of our system. The mapping consists of a set of functions that define how each of the environmental variables changes with tension values (those that do change).

4.3.2 Implicitly Transmitted Information (ITI) Adjustment

In section 3.1.3 we explained that film directors use ITI to produce tension in four different event types. Two of these event types are directly invoked through the use of the Implicitly Transmitted Information drawn from the world (Event Build-Up explained in section 3.1.3.1 and Event Resolution
explained in section 3.1.3.4). However, The Surprise Events (detailed in section 3.1.3.2) and the False Build-Up Events (detailed in section 3.1.3.3) require the Film Director to give ITI that goes against the events occurring in the world. Because of this need for knowledge beyond that stemming from the world, we developed an extra module.

The ITI Adjustment module allows for the application making use of our system to introduce ITI values directly into the cinematographer agent. These values will take priority over those coming from the film director agent. This mechanism allows the application to induce the cinematographer to represent tension values independently of what the film director agent draws from the world.

4.3.3 Actuators

The cinematographer has a set of actuators. Each actuator has to be assigned to an environmental variable relevant to the cinematographer’s defined depiction of tension values. The actuator’s task is to constantly keep the environmental variables updated to the values the tension representation module defines. For example in a

4.4 Concluding Remarks

With the architecture we designed, we believe the objective of improving the way stories are told in potentially any virtual world was achieved.

By filling out a small number of requisites our system can be immediately applied to practically any virtual environment. The requirements are the following:

- Definition of the character objective indicators;
- Enumeration of the world variables used for the calculation of the indicators;
- Definition of how the tension value is calculated from the indicators;
- Enumeration of the environment variables used to represent the tension and how they vary in relation to the tension value.

By implementing a framework based in the processes used in the film industry we were able to employ some of the industry’s commonly used techniques. Our framework was based in film industry processes where the environment is predetermined by a script. Despite this fact, we built a system that can be applied to interactive and/or multiplayer environments in the same way it can be applied to predetermined environments. Our system adds to these already interesting characteristics two excellent qualities:

- Possibility of having different points of view in the same virtual environment. Implicitly Transmitted Information is generated in a character oriented manner. Therefore we can seamlessly switch between character’s points of view.
- Possibility of using the four different event types used in the film industry. In addition to two event types autonomously employed by our system we included a mechanism that allows the application our system is integrated in to invoke Surprise Events and False Build-Up Events when required
Chapter 5
Case Study

To make a case study for our system, we applied it to an existing project. “FearNot!” [41] is currently being developed by GAIPS – Instituto Superior Técnico (Intelligent Agents and Synthetic Characters Group). FearNot! is a Virtual Learning Environment inhabited by autonomous agents that create an emergent narrative. The contents of that narrative are a story that aims to teach the children about the problems of bullying.[42]

Figure 19 - Project FearNot World

Two factors made project FearNot an adequate context to case study our system. Firstly our system aims at improving the telling of a story by increasing the involvement of the observers in that story. The increase of the involvement of observers in FearNot could possibly improve the effectiveness of teaching the effects of bullying. Secondly, this system aims at being usable in many different virtual
world contexts. By applying our system to an already existing system, instead of constructing an example tailored for the purpose, we have a stronger case at proving our concept works.

One of the advantages of having used the FearNot project as a base for our system was its sturdiness and large array of tools that helped focus our efforts in the development of our system. We will superficially describe the FearNot project architecture in that which is relevant to our system and proceed to describe the underlying architecture for our system.

5.1 FearNot! Project Architecture

In this section we will describe the FearNot! project architecture at a high-level. In an architecture depicted in Figure 20 FearNot! employs a Stage Manager that sets up the world in the beginning of each scene.

The Stage Manager loads the setting of the virtual world, places all objects and characters in their starting positions, creates the illumination and gives an introduction to the scene. After this setting up of the world, the Event Manager takes over and all further changes in the world must be done through the Event Manager. The Event Manager also provides an interface with which you can register to be informed of the occurrence of events.

The Mind Manager maintains the state of all characters’ Mental State including their emotions, moods and relationships with other characters. If a character’s Mental State requires that he performs an action, the Mind Manager has the task of informing the Event Manager of that request. The Mind Manager will later be informed of whether his task failed or succeeded by the Event Manager and will update the Mental State of the actor accordingly.

![Figure 20 - FearNot Simplified Architecture Diagram](image-url)
5.2 Requisites for Employment

To apply our system to project FearNot! we had to check if both framework requisites as well as implementation requisites were fulfilled.

5.2.1 Framework Requisites

The framework requisites are focused on the eligibility of the virtual world for our system. There are two requisites, the first one asks: “[Does] the virtual world (…) have an ongoing main action, be it one main action global to the world or many particular main actions local to each character in the world [?]” (section 3.2.5). In FearNot!'s virtual world the characters are controlled by autonomous agents that interact to create an emergent narrative [42]. This emergent narrative (or story) constitutes the main action that our system requires.

The second requisite asks: “[Does] the world [contain] elements that are not directly involved in the main action [?]” (section 3.2.5). In inspection of the virtual world one can determine that there are in fact elements not used for the narrative, such as the illumination, the world’s bounding box, the trees and other elements. We can therefore say that we can apply our system to FearNot!.

Figure 21 - Project FearNot's Virtual World
5.2.2 Character Objectives Indicators

In this section we will define the character objective indicators. FearNot! aims at reducing the effects of bullying in school children. In light of this objective we defined the main objective for the character as “being as happy as possible”. This objective has different sub-objectives depending on the type of actor. A “bullying victim” actor has the sub-objective of “not being bullied”, where a “bully” actor has the sub-objective of “bullying”.

With these objectives defined, we set the indicator for the fulfillment of the objective expressed in Equation 3.

$$objectiveIndicator(c) = \frac{1}{100} \cdot \frac{\sum_{j} [mood(j) \cdot like(x,j)]}{N}$$

Equation 3 - Objective Indicator in FearNot!

We will now explain the “what and why” of this equation. Beginning with the “what”:

- $mood(x)$ - is a value that varies between minus ten (-10) and ten [10] and refers to the mood of the actor “x”, the higher the value the better the mood;
- $like(x,y)$ - is a value that varies between minus ten (-10) and ten [10] and refers to how much actor x likes actor y. The like value of a character for itself is 10;
- "mainCharacter" - is a character, it is in he that the Equation focuses;
- $N$ - refers to the number of characters;

Secondly the “why”, the objective of the character is to be as happy as possible. In FearNot! the happiness of the character is defined by its mood. So, the indicator was done as an average of the mood of each character multiplied by how much the main character likes him.

The average is lowered if a character that you do not like is in a good mood. It means that he is not being bullied or that he is bullying (depending on whether you are a bully or a victim). The average is raised if a character you do not like is in a bad mood. It means that you have succeeded in bullying or that you succeeded in not being bullied.

5.2.3 World Variables used for Indicator Calculation

Having defined the indicator for the character objectives we can draw what world variables are used to calculate it. The variables used are the following:

- The mood of the main character;
- The list of moods of all the other characters;
- The list of "like" relationships between the main character and every other character.
5.2.4 Tension Calculation from Objective Indicator

The objective indicator generates a value relating how close the character is to his objective. In this case the closer the character is to his objective the smaller the tension value is. The range of the indicator varies between minus one and one. Therefore the tension calculation from indicator was expressed by an equation presented here as Equation 4.

\[
\text{tension} = \frac{1 - \text{objectiveIndicator}}{2}
\]

Equation 4 - Tension from Indicator in FearNot!

5.2.5 Environment Variables used for Tension Representation

The environment variable used for tension representation was the lighting in the world. The illumination was set to vary in inverse proportionality to the tension value. The darker the environment became, the more tension it generated. This definition was based on research done on cinematic techniques presented in section 2.2.1, namely patterns IV and V.

5.3 Concluding Remarks

In this chapter we described how we case studied the application of our system to a virtual world. This application was relatively simple. FearNot! provides an Event Manager (described in section 5.1) with which the sensors and the actuators can register with, this greatly simplified the invocation of these modules. The fact that we could register the sensors with the Event Manager also optimized the number of times the sensors had to check for value changes, checking values only when an action was performed. This optimization reduced the performance impact of the application of our system. Finally, we can say that (though experimental evaluation is required) our system could possibly improve the effectiveness of the bullying reduction effect of FearNot!. By providing more information on the characters’ internal states observers feel more immerse in the action and therefore more likely to interiorize the lessons to be learnt from FearNot!.
Chapter 6

Evaluation

In this chapter we will describe the experiment we performed to evaluate our implementation of an architecture designed to control virtual environments in the context of the FearNot! case study. We will firstly enumerate the questions we tried to answer with this experiment. Then we will describe how we did the experiment. Finally we will express how we drew our analysis of the data and what conclusions we took from that analysis.

6.1 Research Questions

This experiment was done to test the plausibility of our implementation of an architecture designed to control virtual environments in the context of the FearNot! case study. Three questions were pivotal to our implementation:

- Can we influence perceived tension through the use of just illumination variation? (Does the increase in brightness lessen perceived tension? Does the decrease in brightness heighten perceived tension?)
- Can we improve observer understanding of a story by conveying Implicitly Transmitted Information?
- Can we influence perceived tension through the use of Implicitly Transmitted Information when there is non-neutral Explicitly Transmitted Information present?

6.2 Methodology

6.2.1 Participants

There were thirty participants with ages ranging between nineteen and twenty-eight years old. All the participants had basic understanding of English and seventy per cent (70%) were college degree students.
6.2.2 Setting

All experiments were done in similar environments, the movies were watched in the same laptop and subjects were asked to fill a questionnaire. The experiment was divided into two parts. We will proceed to describe the two parts of the experiment and then present the questions posed to the test subjects.

6.2.3 Procedure

The experiment was divided into two parts with two sets of objectives. The objective behind the first part was to determine if the variation in illumination had any relationship with two things: the evaluation of the positive/negative nature of the characters and the tension associated with the characters. The objectives behind the second part were to test if the manipulation of the environment done by our system gave the observers a better insight into the underlying Implicitly Transmitted Information and if the observers’ experienced tension is influenced in anyway by our system.

6.2.3.1 First Part

The first part of our experiment consisted of the presentation of four short movies (10 seconds long). In these movies two characters introduced themselves. At the end of each movie the subjects were asked what they thought the character was feeling during the movie. The Geneva Emotion Wheel (mentioned in section 2.3) was used to register the subjects’ response. The four movies were randomly selected from five possible movies each with different illumination combinations. The factors that varied between the movies were:

- The illumination at the beginning of the scene;
- The illumination when the first character appears in scene;
- The illumination when the second character appears in scene.

6.2.3.2 Second Part

In the second part of our experiment, the subjects were shown a movie (about 1 minute long). In this movie an interaction between three characters occurs. After the movie is shown the subjects were asked what amount of tension they would say the scene had and how much tension they would say existed between the three characters. Finally, it was asked to describe the emotional state of each one of the three characters using the Geneva Emotion Wheel [43]. The movie shown to the subjects was randomly selected from three possible movies keeping the number of times each movie was shown equal. The movies were equivalent except for the use of our system. The three versions were:

Without the use of our system;
With the use of our system;
With the use of our system but using inverse values for tension.

### 6.2.4 Questionnaire

In order to register the test subject’s answers we designed a questionnaire that we include in this document as Appendix A. The questionnaire was done in Portuguese with Portuguese subjects, however the Geneva Emotion Wheel was in English. In order not to skew our test results because the subjects did not fully understand the questionnaire, we rejected subjects that could not understand all the emotions.

### 6.2.5 Problems and Reiteration

After having concluded the experiments, we analyzed the data and discovered that the data retrieved from the answers given in the form of the Geneva Emotion Wheel was too sparse. The various statistical analyses we wished to perform were not compatible with the type of data we retrieved from the subjects.

In conversation with some of the subjects two problems in our questionnaire were identified. One of the problems was that in the first part of the test, the movies were very short and this led to confusion. In case of confusion most subjects refrained from answering.

The other problem identified was that the Geneva Emotion Wheel gave too many answer options for the simpler nature of the FearNot! scenes which led the subjects to disperse their answers. This factor, combined with the relatively small number of participants, made the data too scant to draw conclusions from.

We proceeded to do some alterations to the questionnaire. We removed the Geneva Emotion Wheel, replaced the emotions defined by the wheel with the emotions that the characters’ minds registered in the scenes and made individual question for each emotion, where all of them had to be answered.

From these alterations a new questionnaire emerged. We include the new questionnaire in this document as Appendix B.

In order to address the problem of the movies being too short, we made the movies longer by expanding the passing of time in them.

### 6.3 Results

In this section we will delve into the results that we had from the experiments. Three types of questions were done. We will proceed to report the results obtained on each type of questions.

#### 6.3.1 Valence and Tension Evaluation in a Neutral Scene

During the first part of the experiment, test subjects were asked how positive each one of the two characters was. The movies shown in the first part were neutral in all aspects of the Explicitly
Transmitted Information. In fact the only element that varied in them was the illumination, this being part of the Implicitly Transmitted Information as explained in section 3.1.3.

We included this part of the experiment to determine if the variation in illumination had any relationship with two things: the evaluation of the positive/negative nature of the characters and the tension associated with the characters.

The results we drew from this part of the experiment were that there is an inverse correlation between the illumination variation and the observer tension evaluation of the characters (as seen in Table 2). When the characters appear on scene if the illumination increases the tension will be reported as lower, if the illumination decreases the tension will be reported as higher. When the illumination doesn’t vary the observer tension evaluation values have no correlation with the illumination.

### Correlations

<table>
<thead>
<tr>
<th></th>
<th>Illumination Variation Values</th>
<th>Tension Values (When Illum. Varies)</th>
<th>Tension Values (When Illum. Doesn’t Vary)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spearman’s rho</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.000</td>
<td>-.803&lt;sup&gt;**&lt;/sup&gt;</td>
<td>.069</td>
</tr>
<tr>
<td></td>
<td>-.803&lt;sup&gt;**&lt;/sup&gt;</td>
<td>1.000</td>
<td>.059</td>
</tr>
<tr>
<td></td>
<td>.069</td>
<td>.059</td>
<td>1.000</td>
</tr>
</tbody>
</table>

<sup>**</sup> Correlation is significant at the 0.01 level (2-tailed).

**Table 2 - Correlation between Illumination Variation and Observer Tension Evaluation**
6.3.2 Emotion Evaluation in Non-Neutral Scene

We aimed at studying if the manipulation of the environment done by our system gave the observers a better insight into the underlying Implicitly Transmitted Information. With this purpose in mind we did an analysis of the Minkowski distances [44] between the responses to each OCC emotion of each character and maximum value experienced by the characters during the scene.

\[ minkowskiDist = \left( \sum_{i=1}^{n} |x_i - y_i|^p \right)^{\frac{1}{p}} \]

Equation 5 - Minkowski Distance

The results were that in a great number of comparisons, the distance between the emotion responses while watching the movie in which our system was used was smaller than with the other movies. An excerpt of those results for John is represented in Table 3. After calculating the Minkowski distances between each emotion and the subjects’ evaluations, an average was done grouping the results by emotions and by movies. The lower the result of the distance, the more accurate the result is. In this case it can be read from the table that the distances between the subjects’ evaluations and the emotion values were smaller when the subjects were watching the movie that was employing our system.

<table>
<thead>
<tr>
<th></th>
<th>Anger</th>
<th>Distress</th>
<th>Reproach</th>
<th>Admiration</th>
<th>Gratitude</th>
</tr>
</thead>
<tbody>
<tr>
<td>Without System</td>
<td>1.417</td>
<td>1.236</td>
<td>1.218</td>
<td>2.104</td>
<td>1.441</td>
</tr>
<tr>
<td>With System</td>
<td>0.97</td>
<td>0.416</td>
<td>0.608</td>
<td>1.334</td>
<td>0.708</td>
</tr>
<tr>
<td>Inverse System</td>
<td>2.084</td>
<td>1.401</td>
<td>1.328</td>
<td>2.032</td>
<td>1.218</td>
</tr>
</tbody>
</table>

Table 3 - Excerpt of the Average Minkowski Distances for Character John

6.3.3 Tension Evaluation in Non-Neutral Scene

We proceeded to evaluate whether the tension values expressed by our system were being correctly evaluated by the subjects. In order to evaluate this, we did two statistical analyses. First, we did a mean and standard deviation analysis of the results. Then we did a correlation analysis between the tension variation as calculated by our system and the tension responses given by our test subjects. Only two event types were represented by our system in the movie shown to the observers, Build-up events and Event Resolution events.

From the mean and standard deviation analysis (presented in Table 4) we drew that with the system in place there was a much larger convergence of reported tension values (lower standard deviation values). This brought us to believe that the use of our system leads to a more convergent observer understanding of tension values.
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Mean</td>
<td>Std. Dev.</td>
</tr>
<tr>
<td>Without System</td>
<td>3.50</td>
<td>1.18</td>
<td>2.30</td>
<td>1.06</td>
</tr>
<tr>
<td>With System</td>
<td>4.25</td>
<td>0.63</td>
<td>2.45</td>
<td>0.60</td>
</tr>
<tr>
<td>Inverse System</td>
<td>3.60</td>
<td>1.35</td>
<td>2.30</td>
<td>1.42</td>
</tr>
</tbody>
</table>

Table 4 - Tension Results Mean and Standard Deviation Analysis

For the correlation analysis (presented in Table 5), our approach was to use Spearman’s rank correlation coefficient, more commonly known as Spearman’s rho. Spearman’s rho is a non-parametric method of correlation.

From this analysis we concluded that, with the use of our system the correlation between the tension values calculated by our system and the tension reported by the test subjects is much higher (0.439 without our system vs. 0.668 Spearman’s rho value).

We also noted that a high statistical significance was also found between the not using our system and the calculated tension values (however less correlated). When there is no illumination variation the information about scene tension is drawn from the interaction. This result led us to believe that the tension drawn from the interaction is moderately correlated in a statistically significant way to the tension value calculated by our system.
### Correlations

<table>
<thead>
<tr>
<th></th>
<th>Value</th>
<th>Without System</th>
<th>With System</th>
<th>Inverse System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spearman's Value</td>
<td>1.000</td>
<td>.439**</td>
<td>.668**</td>
<td>.413**</td>
</tr>
<tr>
<td>rho</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.005</td>
<td>.000</td>
<td>.008</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Without System</td>
<td>.439**</td>
<td>1.000</td>
<td>.625**</td>
<td>.419**</td>
</tr>
<tr>
<td>Correlation Coefficient</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.005</td>
<td>.000</td>
<td>.007</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>With System</td>
<td>.668**</td>
<td>.625**</td>
<td>1.000</td>
<td>.660**</td>
</tr>
<tr>
<td>Correlation Coefficient</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.000</td>
<td>.000</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
<tr>
<td>Inverse System</td>
<td>.413**</td>
<td>.419**</td>
<td>.660**</td>
<td>1.000</td>
</tr>
<tr>
<td>Correlation Coefficient</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td>.008</td>
<td>.007</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>40</td>
<td>40</td>
<td>40</td>
<td>40</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed).

Table 5 - Correlation between Calculated Tension and Reported Tension

### 6.4 Concluding Remarks

In this chapter, we described the experiment we performed in order to evaluate our implementation of an architecture designed to control virtual environments in the context of the FearNot! case study. A questionnaire was developed to provide us with data with which we were able to answer the fundamental questions that our implementation was based on. After the analysis of our data our results suggest that the use of our implementation has plausibility.

To the question: "Can we influence perceived tension through the use of just illumination variation?" the statistical analysis of our data led us to believe that there is an inverse correlation between the illumination variation and the tension evaluation of the characters. This is to say that when the
characters appear on scene if the illumination brightness increases the tension will be reported as lower, while if the illumination brightness decreases the tension will be reported as higher.

To the question: “Can we improve observer understanding of a story by conveying Implicitly Transmitted Information?” our analysis of the results pointed out that there is a closer relationship between the perceived emotional states of the characters and their actual values within the FearNot! system when our implementation is in use. Meaning that, observers have a better understanding of the information that is not explicitly represented (such as the character’s emotions) when our system is in place representing that information implicitly.

Finally we asked: “Can we influence perceived tension through the use of Implicitly Transmitted Information when there is non-neutral Explicitly Transmitted Information present?” To this question, statistical analysis of our data answers that with the use of our system the correlation between the tension values calculated by our system and the tension reported by the test subjects is much higher in the two event types that were represented in the movie, Build-up events and Event Resolution events. Meaning that observers that watch a scene where our system is in place, experience tension in a proportional way to the tension our system represents in these two event types.
Chapter 7

Conclusion

This dissertation aims at improving the way virtual environments are used to the benefit of telling a story in a virtual world. For many years the film industry has used the involving environment of a story as a powerful tool to improve the immersion of observers in that story.

By taking inspiration in the Film Industry we designed a model based on a process that has been proven to produce involving environments that improve the telling of a story. Building on this process we managed to arrive at a design that may be usable in a large set of virtual environments. We hope the framework we described is applicable, without any need for adjustments, to virtual environments ranging from simple storytelling environments, through single player games, all the way to online multi-player games. We believe that this framework constitutes an innovative view on virtual environment control that will lead to improved immersion factor of the virtual environments it is applied to, fruit of its simple but robust concept.

From this framework, an architecture was designed. With this architecture, we believe the objective of improving the way stories are told in potentially any virtual world was achieved.

By filling out a small number of requisites our system can be immediately applied to practically any virtual environment. The requirements are the following:

- Definition of the character objective indicators;
- Enumeration of the world variables used for the calculation of the indicators;
- Definition of how the tension value is calculated from the indicators;
- Enumeration of the environment variables used to represent the tension and how they vary in relation to the tension value.

By implementing a framework based in the processes used in the film industry we were able to employ some of the industry's commonly used techniques. Our framework was based in film industry processes where the environment is predetermined by a script. Despite this fact, we built a system that can be applied to interactive and/or multiplayer environments in the same way it can be applied to predetermined environments. Our system adds to these already interesting characteristics two excellent qualities:
Possibility of having different points of view in the same virtual environment. Implicitly Transmitted Information is generated in a character oriented manner. Therefore we can seamlessly switch between character’s points of view.

Possibility of using the four different event types used in the film industry. In addition to two event types autonomously employed by our system we included a mechanism that allows the application our system is integrated in to invoke Surprise Events and False Build-Up Events when required.

In order to case study our implementation we applied our system to the FearNot! virtual world. Our system has the potential to significantly improve the effectiveness of the bullying reduction effect of FearNot!. By providing more information on the characters’ internal states observers feel more immerse in the action and therefore more likely to interiorize the lessons to be learnt from FearNot!.

Finally, an implementation evaluation was done in the scope of this work. This evaluation left grounds for a good deal of optimism in what relates to the effectiveness of our implementation in fulfilling its objectives.

### 7.1 Future Work

In conclusion of this dissertation, we present some proposals of work that could be done in the future in the context of the framework we have suggested.

Having achieved interesting results, work could be done to build on these results, specifically in the cinematographer agent. Advanced Lighting design theory discusses several techniques that designers use to balance the effects of the techniques the cinematographer currently employs with other lighting design goals, such as projecting depth, establishing necessary visibility, and providing motivating lighting direction these could be incorporated into the vision representation to add levels of complexity to the current vision representation.

Further work could be done developing the cinematographer agent to incorporate more elements into the vision representation. Besides the illumination, the cinematographer agent could control position of environment objects, framing the scenes or even introduce objects into the environment.

Work has been done in the field to automatically place lights throughout the virtual world, namely in [23]. This is not currently incorporated in our system and could be an interesting addition.

During this dissertation our system was only case studied with one application. It would be interesting to apply our system to other applications, namely Netrix [38], World of Warcraft [2] or The Sims [6] just to mention a few examples.

Finally, in the definition of our framework (Chapter 3) four event types are described: Event Build-Up, Surprise Event, False Event Build-Up and Event Resolution. However, only two of these event types were evaluated (Event Build-Up and Event Resolution). It would be interesting to evaluate the other two events in order to determine if they would present the similar results.
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Appendix A

Primeiro Filme

1. O que sentiu em relação ao primeiro personagem?
2. O que sentiu em relação ao segundo personagem?
Segundo Filme

3. O que sentiu em relação ao primeiro personagem?

4. O que sentiu em relação ao segundo personagem?
Terceiro Filme

5. O que sentiu em relação ao primeiro personagem?

6. O que sentiu em relação ao segundo personagem?
Quarto Filme

7. O que sentiu em relação ao primeiro personagem?

8. O que sentiu em relação ao segundo personagem?
9. Que tensão diria que tem a cena?

Tensão Muito Baixa               Tensão Muito Alta

10. Que tensão diria que há entre as personagens John e Ollie?

Tensão Muito Baixa               Tensão Muito Alta

11. Que tensão diria que há entre as personagens John e Luke?

Tensão Muito Baixa               Tensão Muito Alta

12. Que tensão diria que há entre as personagens Ollie e Luke?

Tensão Muito Baixa               Tensão Muito Alta

13. O que sentiu em relação a John?

14. O que sentiu em relação a Ollie?
15. O que sentiu em relação a Luke?
Appendix B

Primeiro Filme

1. Quão positiva é a primeira personagem?

<table>
<thead>
<tr>
<th>Pouco Postiva</th>
<th>Muito Positiva</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. Quanta tensão associa à primeira personagem?

<table>
<thead>
<tr>
<th>Tensão Muito Baixa</th>
<th>Tensão Muito Alta</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

3. Quão positiva é a segunda personagem?

<table>
<thead>
<tr>
<th>Pouco Postiva</th>
<th>Muito Positiva</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Quanta tensão associa à segunda personagem?

<table>
<thead>
<tr>
<th>Tensão Muito Baixa</th>
<th>Tensão Muito Alta</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Segundo Filme
5. Quão positiva é a primeira personagem?

6. Quanta tensão associa à primeira personagem?

7. Quão positiva é a segunda personagem?

8. Quanta tensão associa à segunda personagem?

Terceiro Filme
9. Quão positiva é a primeira personagem?

10. Quanta tensão associa à primeira personagem?

11. Quão positiva é a segunda personagem?
12. Quanta tensão associa à segunda personagem?

Tensão Muito Baixa  Tensão Muito Alta

13. Quão positiva é a primeira personagem?

Pouco Postiva  Muito Positiva

14. Quanta tensão associa à primeira personagem?

Tensão Muito Baixa  Tensão Muito Alta

15. Quão positiva é a segunda personagem?

Pouco Postiva  Muito Positiva

16. Quanta tensão associa à segunda personagem?

Tensão Muito Baixa  Tensão Muito Alta
Segunda Parte

17. Que tensão diria que tem a cena?

18. Que tensão diria que há entre as personagens John e Ollie?

19. Que tensão diria que há entre as personagens John e Luke?

20. Que tensão diria que há entre as personagens Ollie e Luke?
21. O que diria que o John sentiu durante o filme?

- Pouca Esperança
- Pouco Amor
- Pouco Ódio
- Pouca Fúria
- Pouca Angústia
- Pouca Reprovação
- Pouca Pena
- Pouco
- Pouca Adminação
- Pouca Gratitude
- Pouca Alegria
- Pouca Satisfação
- Muita Esperança
- Muito Amor
- Muito Ódio
- Muita Fúria
- Muita Angústia
- Muita Reprovação
- Muita Pena
- Muito
- Muita Adminação
- Muita Gratitude
- Muita Alegria
- Muita Satisfação
22. O que sentiu em relação a Ollie?

<table>
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<tr>
<th>Pouca Esperança</th>
<th>Muita Esperança</th>
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<tr>
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<td>Pouca Satisfação</td>
<td>Muita Satisfação</td>
</tr>
</tbody>
</table>
23. O que sentiu em relação a Luke?

- Pouca Esperança
- Pouco Amor
- Pouco Ódio
- Pouca Fúria
- Pouca Angústia
- Pouca Reprovação
- Pouca Pena
- Pouco
- Pouca Adminação
- Pouca Gratitude
- Pouca Alegria
- Pouca Satisfação
- Muita Esperança
- Muito Amor
- Muito Ódio
- Muita Fúria
- Muita Angústia
- Muita Reprovação
- Muita Pena
- Muito
- Muita Adminação
- Muita Gratitude
- Muita Alegria
- Muita Satisfação