An Interactive Narrative Architecture based on Filmmaking Theory

Magy Seif El-Nasr
Northwestern University
Computer Science Department
1890 Maple Avenue
magy@northwestern.edu

ABSTRACT

Designing and developing an interactive narrative experience includes development of story content as well as a visual composition plan for visually realizing the story content. Theatre directors, filmmakers, and animators have emphasized the importance of visual design. Choices of character placements, lighting configuration, and camera movements, have been documented by designers to have direct impact on communicating the narrative, evoking emotions and moods, and engaging viewers. Many research projects focused on adapting the narrative content to the interaction, yet little attention was given to adapting the visual presentation. In this paper, I present a new approach to interactive narrative – an approach based on filmmaking theory. I propose an interactive narrative architecture, that in addition to dynamically selecting narrative events that suit the continuously changing situation, it automatically, and in real-time, reconfigures the visual design integrating camera movements, lighting modulation, and character movements. The architecture utilizes rules extracted from filmmaking, cinematography, and visual arts theories. I argue that such adaptation will lead to increased engagement and enriched interactive narrative experience.

Keywords
Interactive Narrative, Visual Storytelling, Virtual Storytelling, Interactive Stories, Filmmaking

INTRODUCTION

Developing an interactive narrative experience is an exhaustive and complicated process requiring careful design and layout of the story content and its visual presentation. Due the unpredictability of users' behaviors, adapting the narrative to accommodate the interaction is a very important and difficult problem. Many researchers adopted AI-based techniques including planning, problem-solving, machine learning, and user modeling to generate adaptable narratives (Bates et al. 1992, Reilly 1996, Loyall 1997, Mateas and Stern 2000, Young 2000, Cavazza et al. 2002). Most of the research projects in this area focus on tuning the narrative content accommodating the interaction with little attention to narrative presentation. On the other hand theatre directors and filmmakers have emphasized the importance of visual design. Choices of character placements, lighting configuration, and camera movements, are documented by designers to have direct impact on communicating the narrative, evoking emotions and moods, and engaging viewers.

Film and theatre, as well as animation, artists spend many hours, days, or even months creating a visual design for a production. A visual design is considered the heart of a performance; it deepens and enriches the dramatic experience through manipulation of camera position/angle, character staging, character postures and movement, and lighting color/angle/position (Calahan 1996, Foss 1992, Mascelli 1965, Cheshire and Knopf 1979, Buckland 1998). These elements have many psychological and aesthetic effects that influence viewers' perception of a scene. Manipulation of light colors[1], for example, can create a high contrast scene conveying a very dramatic and intense mood; examples of such effects can be seen in many film noir productions. In addition to portraying visual tension, light colors and contrast can also establish visual focus.

Additionally, character blocking (or staging) can effectively convey character relationships. A picture of a character sitting in the middle of two standing characters is used by filmmakers and directors to emphasize weakness/strength relationship and convey conflict (Mascelli 1965).

In addition to establishing visual tension, visual focus, and portraying character relationships, Foss (Foss 1992) identified several visual design functions, including portraying mood and conveying depth. There are numerous examples of such effects sited in the film and theatre literature (Arijon 1976, Alton 1995, Calahan 1996, Foss 1992, Mascelli 1965, Cheshire and Knopf 1979). Neuroscience and psychology literature have also confirmed these effects (Niebur et al. 1999, Parkhurst et al. 2002).

Even though film and theatre designers have identified the importance of manipulating the visual composition to support and accommodate the narrative (Alton 1995, Calahan 1996, Foss 1992, Mascelli 1965), such effects are often ignored in interactive narrative leading to less fulfilling interactive narrative experiences. In a typical interactive narrative, variations in user's actions cause unpredictable changes in the physical characteristics of a scene, such as camera and characters' positions, as well as dramatic characteristics, such as dramatic intensity and character relationships. To accommodate these variations current techniques rely on scripted visual designs (Carson 2000, Maattaa 2002), which have several disadvantages. They are labor and time intensive to construct. In addition, designers often need to predict user's behaviors and construct several visual patterns to adapt to the variations in users' behaviors. Constructing visual patterns that accommodate interaction is a hard and daunting problem, because (1) it is hard to develop correct predictions of users' behaviors and (2) visual design is an integrative process involving careful scheduling and planning of behaviors among several visual composition elements including cameras and lighting.

Some researchers addressed the role of camera and devised systems to automatically position and move the camera appropriately in an interactive scene (He et al. 1996 and Tomlinson 1999). However, these systems addressed the role of camera in isolation. Filmmakers, animators, and visual artists view visual elements as a coherent unit composed of several parts (camera, characters, and lighting) cooperating together to achieve a unified visual design (Foss 1992, Cheshire and Knopf 1979, Block 2000).

In this paper, I present a new interactive narrative architecture based on filmmaking theory. The architecture is composed of several

[1] Color is used here to mean intensity as well as chroma

subsystems that automatically reconfigure the visual composition of a scene to accommodate the narrative and the evolving dramatic and physical characteristics of a scene achieving several visual goals, including establishing visual focus, providing visual tension, emphasizing mood, and conveying character relationship. To guide this decision-making process, the system employs several rules developed based on filmmaking and theatre visual design theories.

The architecture is composed of several subsystems controlling the initial setup and variations in camera, character, and lighting behaviors. To evaluate the architecture and the utility of visual composition in enhancing the user's experience, I have realized an initial prototype of the architecture in an interactive story called *Mirage*. In this paper, I will discuss the initial prototype showing results. Following this discussion, I will address the prototype's limitations and discuss the next steps and future work.

RELATED RESEARCH

Many research attempts focused on developing interactive narrative architectures that adapt to interaction. Examples of such attempts include character-centric interactive narrative architectures where the narrative emerges as a product of user's interaction with an environment populated with synthetic intelligent characters, e.g. *The Sims*, *Creatures*, *Catz*, *Dogz*, and *The Living Letters* (a product by Zoesis). Researchers working on that type of narrative focus on character development (Bates et al. 1992, Reilly 1996, Loyall 1997). Mateas and Stern (Mateas and Stern 2000) proposed a plot centric interactive narrative architecture, where story events are selected dynamically based on the history of events that occurred, character relationships, authorial goals, and the users' actions (Mateas and Stern 2000). In addition, Young and Cavazza proposed different interactive narrative architectures based on planning techniques (Young 2000, Cavazza et al. 2002).

Most current visual presentation techniques used to realize interactive narratives rely on scripting. For example, a game may have the following rule 'when a particular narrative event *x* (e.g. character *y* enters in scene 11) is triggered a specific camera movement (e.g. crane shot showing the two characters) is fired'. While the camera movement trajectory can be adjusted to run-time characters' positions and actions variations, such motion predisposes a specific function in the narrative which may not be necessary true or may conflict with other visual design patterns that are being fired by the lighting or character action engines.

To establish dynamic visual design while accommodating these factors, the scripting technique needs to be exhaustive. Considering the variability in users' behaviors and narrative structure, such exhaustive scripting technique can be time consuming and labor intensive. For more generative interactive narrative architectures (e.g. architectures that use planning or a character-centric approach) scripting is often impossible.

Few research projects focused on developing an automatic technique for manipulating the visual composition of a scene to suit the situation. Tomlinson developed a system that changes light colors and camera movements to present the user with an interpretation of the world based on characters' emotions (Tomlinson 1999). The system selects camera movements and light colors to show traits or feelings of each character in the scene. For example, it uses a low camera angle to show that a character is powerful or harsh red light to make a character look demonic. In his work, the function of the camera and lighting was restricted to portraying the emotional states of characters in a scene.

He et al. and Christianson et al. used film-based cinematography techniques to guide an authored interactive narrative (He et al. 1996, Christianson et al. 1996). He et al. developed a system that, given a story state, selects a series of shots utilizing some documented film patterns, such as conversational shot patterns (e.g. master shot of the scene followed by a medium shot of the conversation followed by an over-the-shoulder shot of a character talking, then an over-the-shoulder shot of the other character taking).

In contrast to previous work, the architecture described here recognizes the visual design process to be a complete and integrated process which includes coordination between several visual elements, including the camera, characters, and lighting working as a unit to achieve several visual design goals abiding by changes in scenes' physical and dramatic characteristics.

INTERACTIVE NARRATIVE ARCHITECTURE

Figure 1 shows the interactive narrative architecture. At a very high-level, the architecture distinguishes between narrative events and their presentation. It includes a story engine, which is responsible for selecting story events depending on the current situation, and a director agent, who is responsible for automatically integrating a visual design that adheres to the narrative and the dramatic situation. The director agent interacts with the camera, lighting, and character systems to establish and accomplish the visual design. It, thus, acts as a mediator facilitating interaction and cooperation between camera, lighting, and character systems.

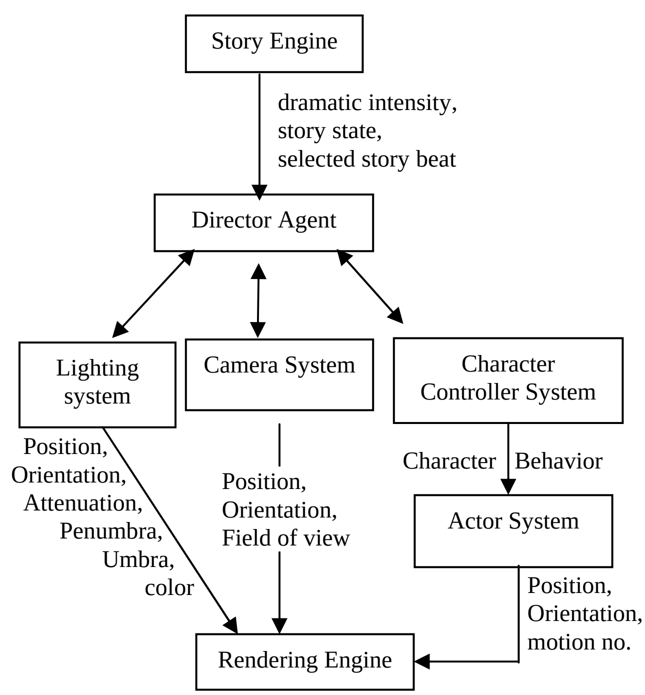

Figure 1 Interactive Narrative Architecture

Story Engine

The story engine is designed to allow writers to construct an interactive narrative as a collection of story beats. The term *beat* was first introduced by Stanislavski; it refers to the smallest unit of action that has its own complete shape, with a central conflict and a mini-crisis (Benedetti 1994). According to Benedetti's description, a beat is a dramatic action that occurs in a scene to achieve a narrative goal. I define a beat as the smallest story unit that achieves an authorial narrative goal.

Beat System – Story Content Planning

Similar to the architecture proposed by Mateas and Stern (Mateas and Stern 2000), the story engine keeps track of its current state including history of user actions, history of selected story beats, and character relationship values. In addition, given user's actions, the story engine models the user's personality as a point in a 4-dimentional space, describing four stereotypes: heroism, violence, self-interestedness, and cowardice. Given a number of authored story beats, the user's modeled personality, and the story state, the story engine selects a story beat for execution using a reactive planning technique (Firby 1989).

A beat is represented as follows:

- *Trigger goal*: goal that the beat solves.
- *Preconditions*: list of predicates that need to be true for the beat to be selected
- *Postconditions*: list of predicates that will be true as a consequence of firing the beat
- *Subgoals*: list of subgoals with *timing constraints* that need to be resolved if the beat is selected

A simple beat is composed of the following:

- *Trigger goal*: goal that the beat solves.
- *Preconditions*: list of predicates that need to be true for the beat to be selected
- *Postconditions*: list of predicates that will be true as a consequence of firing the beat
- *Presentation Goals*: list of visual and audio design goals with *timing constraints* that need to be accomplished to achieve the beat

The algorithm selects beats to solve the narrative goals, and then iteratively loops selecting beats that solve the sub-goals of the selected beat forming an AND-OR tree (Forbus and Kleer 1992) until a plan of simple beats is chosen. Subsequently, presentation goals (or visual and audio goals) associated with the simple beats selected are given to the director agent to construct a visual and audio plan. In this paper, I focus on the visual plan.

Ensuring Dramatic Tension

Building a plot as a collection of beats with timing constraints is often not enough to provide drama and engagement. Thus, I augmented the architecture with a language that writers can use to author rules specifying the development of dramatic tension through a sequence of story beats. These rules are of the following form:

if beat#2 is followed by beat #5
and Electra is using the threatening tactic on the user
then increase dramatic intensity by 10 increments.

The beat selection process is then augmented with a process of examining the beat's influence on the dramatic structure of the narrative experience given these rules. If a crisis peak has not yet been reached, the system will choose the beat that results in gradual increase in tension, otherwise it will choose a beat that results in gradual decrease in tension. This addition to the story content planning system will result in enhancing the dramatic experience by representing and incorporating dramatic tension in the process of selecting beats and actions.

Director Agent

Given the presentation goals, story state, dramatic intensity, and the chosen story beat, the director agent creates a visual design to present the story beat. Visual design is concerned with the perception and intent, which involves grasping attention, supplying visibility, evoking moods, and using body and space to convey action and character relationship.

The director agent constructs a visual plan by interacting with the camera, character, and lighting systems. These systems are designed based on cinematic conventions to select a visual composition that accommodates the situation and the story beat's authorial goal. This composition is constructed from several visual patterns that include changes in visual parameters and associated timing constraints. For example, the lighting system may choose to change several colors of lights in the scene gradually to bring out a character or an object.

The director agent is responsible for integrating the visual patterns proposed by the individual visual systems (e.g. camera, character, etc.). The visual systems send the director agent some proposed behaviors along with the timing constraints and the visual goals they achieve. To integrate these visual plans into a unified plan, the director agent does the following: (1) identifies conflicts and resolves them, (2) merges and synchronizes the plans, and (3) adds behaviors, if needed to maintain visual continuity.

It identifies and resolves conflicts by examining the plans to see if timing clashes will occur. Given the behaviors and the associated visual goals that they satisfy, the director agent rejects plans that solve the same visual goals. The director agent adds behaviors and synchronizes the plans using several rules that include preserving visual continuity; for example, the camera cannot suggest a stationary shot while the lighting system suggests very drastic changes. The director agent resolves these issues by negotiating with the camera system to add camera cuts to hide lighting changes that need to occur and can be distracting, because it is known that viewers don't notice changes between camera cuts (Henderson and Hollingworth in press).

The director agent then forms a visual presentation plan by scheduling behaviors including interjected camera cuts depending on the timing constraints established by the individual visual systems.

Consider the following example. The camera recognizes that a character, *x*, is going to issue a talk action, and hence it issues a close-up on character *x* action to bring character *x* to focus. Recognizing that an increase in the dramatic tension will occur given the dramatic tension rules and the beat selected, the lighting system issues a change in colors and angles of some lights in the scene to establish visual tension. The character system issues a presentation plan which includes gestures and lip sync for character *x*. The character system also issues an audio command for playing the dialogue. The director agent receives these presentation plans from the camera, character, and lighting systems. Cinematic conventions dictates that a character *y* can't begin talking until the camera is in position, and a lighting change cannot occur while the area affected is in view, if the lighting effect is distracting. Thus, the agent selects an order for the presentation plans that satisfies these rules/constraints. If, considering the plans, no specific constraints exist then the director agent assumes parallel execution.

The director agent, therefore, constructs a unified presentation plan, consisting of camera, lighting, and character behaviors (as directed by the camera, lighting, and character systems) with timing constraints. For example, (sequence (close-up Electra) (concurrent (say Electra line1) (Wave-sword-at Electra user)) is a presentation plan that specifies a sequential execution of a cut to a closeup on Electra, and a parallel execution of Electra saying line1 while waving her sword at the user.

Lighting System (ELE)

ELE automatically selects angles, positions, and colors for each light in a scene to satisfy several authorial goals, including: paralleling the dramatic tension, establishing visual focus, establishing visibility for the characters and objects, providing mood, and conveying a sense of realism by conforming to the general direction of light projected from the objects that emit light, such as windows or torches. Since these goals conflict, ELE uses a non-linear optimization algorithm to select the best possible angles, positions, and colors. ELE mathematically represents rules used by film and theatre lighting design theory as multi-objective cost functions weighed by the importance the visual goals, which are modulated by the author or automatically computed by ELE depending on the dramatic situation (Seif El-Nasr 2003).

ELE relays these configuration changes, timing constraints (if gradual changes are needed), and a vector of weights associated with the visual goals describing the goals that these changes will emphasize to the director agent. Given the final presentation plan by the director, ELE then monitors the plan's execution and relays its changes to the rendering engine when appropriate.

Camera System

I have developed a simple camera system that selects several camera shots satisfying the dramatic situation described by the story state and the selected story beat (given by the director agent).

The camera system can establish two kinds of shots: cut or movement. A cut completes in one time step. However, a movement may require more than one time step to complete. The camera system keeps track of its state. It also keeps track of the remaining time it needs to complete the execution of a given shot. It has several built-in shot types borrowed from cinematography theory (Vineyard 2000, Cheshire and A. Knopf 1979), such as close-ups, long shots, birds-eye views, medium shots, pans, tilts, and over the shoulder shots.

The camera system utilizes many simple rules for selecting a camera shot or a plan of shots given the current action. He et al. have identified several rules for conversation shots (He et al. 1996). I augmented these rules with others that take into consideration character relationship values. For example, if character is powerful or threatening then the camera is positioned at a low angle. These rules are discussed and documented in many film books including Mascelli (1965) and Cheshire and Knopf (1979).

Using these rules the camera system suggests a presentation plan synchronized with timing constraints and a vector of weights associated with the visual design goals that it satisfies to the director agent. The director agent then forms an integrated presentation plan and distributes it to the camera, character, and lighting systems.

Given a presentation plan to execute, the camera system monitors the plan's execution. For its own actions, it calculates field of view angle, orientation, and position based the characters' height, width, position, and orientation. It then relays this information to the rendering engine.

Character System

The character controller system selects several character behaviors that suit the story state and selected story beat. The character system uses reactive planning (Loyall 1997), similar to the technique used by the interactive narrative system discussed above. The character system chooses a high-level behavior that achieves the presentation goals; it then breaks down the character behavior into simple behaviors. Simple behaviors are represented by an action, an adverb, and an actor; for example (Walk Electra slowly) is a behavior where the action is walk, the actor is Electra, and the manner in which an action is performed is slowly. Therefore, an action can be animated in different manners defined by the adverb. For example, 'take the sword' is an action that is defined as three animations 'take sword eagerly', 'take sword hesitantly', and 'take sword regretfully'.

The character controller system controls several actors. When the character system receives a behavior from the director agent, it relays the behavior to the appropriate actor as defined in the presentation plan. Each actor has many actions that it can do. These actions are preset to animations with specific attitudes or character traits that pertain to the specific character executing them. Thus, for example, a female character named Electra will walk differently than the male characters Archemedis or Aegisthus. In addition, since Electra has a distinguished personality, she will walk differently than other female characters, such as Clytaemnestra. The actor will issue the appropriate animation of the behavior given by the Director Agent.

PROTOTYPE

A prototype of the proposed architecture has been implemented and tested in an interactive story called *Mirage*, an interactive drama based on the Greek Tragedy *Electra*. The system automatically selects story beats and visual behaviors that dynamically adapt to the users' behaviors. The system is currently running on a Pentium III running Windows 2000.

I used Wildtangent as the rendering engine to render the camera, character, and lighting behaviors. The architecture has been implemented in two languages. Lisp was used to represent the reactive planning architecture used by the story and character engines. The language I designed for designers to author rules controlling beat decomposition, dramatic tension representation, and character behaviors was constructed on top of Lisp. Therefore, designers were asked to represent their rules using lisp notation but utilizing the language constructs designed. For the implementation of the rest of the architecture, including character actions, collision detection, lighting, and camera movements, I used Java.

The interactive narrative system selects beats and passes them to the director agent who passes them to the lighting, camera, and character systems. The lighting system uses optimization algorithms discussed in (Seif El-Nasr 2003) to compute lights configuration, angles (vertical and horizontal), colors, and timing constraints for the changes induced. The camera system uses a rule-based system to compute camera shot given visual goals, story state, character relationship, and dramatic intensity. It then computes the motion trajectory, angles, positions, field of view, and timing constraints. The character system uses reactive planning. Given the authored behavioral rules, it computes character actions given story state, visual goals, and character relationships. These behaviors and timing constraints are then relayed to the director agent. The director agent then filters these behaviors and passes a unified presentation plan to the character, lighting, and camera systems. These systems then compute low-level properties, e.g. light positions, range, attenuation, angles, and camera positions and relays them to the rendering engine (in our case, Wildtangent).

The prototype has several limitations. Wildtangent was chosen as the rendering engine, and thus the choice of the underlying rendering algorithms used by Wildtangent had a direct effect on the pictures rendered. To ensure real-time rendering speed, wildtangent does not accommodate inter-reflections of light, which render images less realistic.

RESULTS

I argued for manipulating the visual design to accommodate interaction and dramatic development. Figure 2 and 3 compare two renderings of the same scene in terms of lighting; one uses statically allocated lights and the other uses the architecture described in this paper, where lighting is automatically manipulated in real-time and synchronized with camera behaviors to enhance and deepen the interaction. As shown in Figure 2 using statically positioned lights may result in unlit or partially lit characters caused by unpredictable changes in camera view and character orientation. In addition, as Figure 3 shows, a dynamically modulated lighting system can result in a more dramatic display of light colors that enhances the overall experience by accommodating the increasing dramatic intensity.

Figure 4 shows some screenshots from scene 8 of *Mirage*. It shows the architecture in action where the scene's visual design is dynamically manipulated as the scene progresses to accommodate changes in the plot, character relationship values, dramatic intensity, and authorial goals. As shown in the figure, the lighting changes dynamically through the scene to emphasize dramatic tension, mood, visual focus, while maintaining visibility and visual continuity. This lighting behavior was integrated with camera movements and cuts as well as character actions. While it is hard to see the character actions in a still picture, it can be seen that the character uses several gestures to convey behavioral goals, and the camera movements and shots work together with the lighting and character actions to emphasize visibility and character actions.

I found several advantages for distinguishing between story beats and their visual presentation. This abstraction has enhanced scalability and promoted reuse by enabling the reuse of the same visual presentation or plan with different story beats. In addition, the methods utilized to detect and handle failure at the visual level are different from those used at the story level. At the visual level, continuous checking of the user's action is important to ensure that the message is being delivered. For example, if a character is threatening the user, and the user starts playing with the objects around him/her then the message is not correctly visually portrayed visually, and different methods for portraying the message should be selected.

The system was shown to few visual artists and lighting designers, including Mary Poole (Theatre professor), Dan Strickland (Lighting Designer in Film, worked on *Candyman*), Annette Barbier, among others. They showed great interest in the system; especially in its use as a rapid prototyping tool for writers.

An earlier prototype of the system was used by a group of students attending an interactive narrative course taught at Northwestern University. The students used the architecture to quickly visualize the scenes they authored. They spent four and a half weeks learning the system and the authoring language. After this period, they started experimenting with their narrative design and manipulating the visual designs by designing rules that override system's decisions. This led to more visually stimulating interactive narrative experiences.

The system has shown great utility as an authoring tool for interactive narrative. However, the language can be further enhanced by augmenting it with a visual programming tool, which will allow art students to quickly learn the utility of the language as an art tool for creating interactive drama/stories.

FUTURE WORK

This early prototype showed great potential, but many elements need further investigation. Earlier in the paper, I discussed the role of character blocking in portraying character relationships and authorial goals/intentions. The character controller system can be augmented with a rule-based system that achieves this purpose. In the future, I would like to undergo a series of experiments exploring different character blocking techniques that convey visual goals.

The rules developed in the camera system were a result of direct implementation of ideas explored in film books and others described in He et al. (He et al. 1996). I would like to further explore the impact of camera movements in portraying and evoking several emotional states, including urgency, excitement, sadness, and tension, and their effect on interaction.

The architecture described above employs very simple visual presentation techniques. It is often the case, however, that authors employ symbols, metaphors, and visual patterns to trigger certain responses or to show an authorial goal. I would like to explore the idea of visual patterns and their existence in today's media; and further extend the architecture to handle such representations.

CONLUSIONS

In this paper I proposed a new architecture for interactive narrative based on filmmaking theory. The significance of the proposed architecture is in its utility to automatically, and in real-time, adjust the narrative events, as well as, their visual presentation to accommodate changes in a scene's physical and dramatic characteristics; and thus, forming an architecture that deepens and enriches the interactive narrative experience.

REFERENCES

Alton, J. (1995). *Painting with Light.* University of California Press: CA, Berkely.

Arijon, D. (1976*). Grammar of the Film Language.* Focal Press: New York.

Bates, J., Loyall, B., and Reilly, S.. (1992). An Architecture for Action, Emotion, and Social Behavior. School of Computer Science, Pittsburgh, PA: Carnegie Mellon University, Technical Rep. CMU-CS-92-144.

Benedetti, R. *The Actor at Work.* (6^{th} Ed.). Englewood Cliffs, New Jersy: Prentice Hill, 1994.

Birn, J. (2000). *[Digital] Lighting & Rendering.* New Riders: IN.

Block, B. (2001). *The Visual Story: Seeing the Structure of Film, TV, and New Media.* Focal Press: USA.

Brown, B. (1996). *Motion Picture and Video Lighting.* Focal Press: Boston.

Buckland, W. (1998). *Film Studies.* Hodder & Stoughton, teach yourself books: Chicago, IL.

Calahan, S. (1996). Storytelling through lighting: a computer graphics perspective. *SIGGRAPH course notes.*

Campbell, D.(1999). *Technical Theatre for Non-technical People.* Allworth Press.

Carson, D. (2000). *Environmental* Storytelling: Creating Immersive 3D Worlds Using Lessons Learned from the Theme Park Industry. *Gamasutra.* March 01.

Cavazza, M., Charles, F., Steven, J. (2002). Planning characters' behavior in interactive storytelling. Journal of Visualization and Computer Animation 13(2): 121-131.

Cheshire, D. and Knopf, A.. (1979). *The Book of Movie Photography.* Alfred Knopf, Inc: London.

Christianson, D., Anderson, S., He, L., Salesin, D., Weld, D., and Cohen, M. (1996). Declarative Camera Control for Automatic Cinematography. In the Proceedings of the AAAI-96:Proceedings of the Thirteenth National Conference on Artificial Intelligence.

Firby, J. (1989). Adaptive Execution in Complex Dynamic Worlds. Department of Computer Science, Yale University, PhD Thesis.

Foss, B. (1992). *Filmmaking: Narrative & Structural Techniques.* Silman-James Press: LA, CA.

He, L., Cohen, M., Salesin, D. (1996). The Virtual Cinematographer: A Paradigm for Automatic Real-Time Camera Control and Directing. *Siggraph 96.*

Henderson, J. and Hollingworth, A. (in press). Global transsaccadic change blindness during scene perception. *Psychological Science.*

Katra, E. and Wooten, W. (1995). *Unpublished*. Perceived lightness/darkness and warmth/coolness in chromatic experience.

Katz, S. (1991). *Film Directing Shot by Shot visualizing from concept to screen.* Michael Wiese Productions: CA.

Kawin, B. (1992). *How Movies Work.* University of California Press: LA, CA.

Kawai, J., Painter, J., and Cohen, M. (1993). Radioptimization – Goal Based Rendering. *Proceedings of SIGGRAPH 1993*.

Kerlow, I. (2000). *The Art of 3-D Computer Animation and Imaging.* (2nd Edition). John Wiley & Sons, Inc: NY.

Lowell, R. (1992). *Matters of Light and Depth.* Lowel-light Manufacturing, Inc.: NYC, NY.

Loyall, B. (1997). Believable Agents. Ph.D. Thesis, Tech. Report CMU-CS-97-123, Carnegie Mellon University.

Maattaa, A. (2002). GDC 2002: Realistic Level Design for Max Payne. *Gamasutra*. May 8.

Mascelli, J. (1965). *The Five C's of Cinematography*. Silman-James Press: LA.

Mateas, M. and Stern, A. (2000). Towards Integrating Plot and Character for Interactive Drama. In *Proceeding of Socially Intelligent Agents: The Human in the Loop AAAI Fall Symposium 2000*.

Möller, T. and Haines, E. (1999). *Real-time Rendering.* MA: USA, A K Peters, Ltd.

Millerson, G. (1991). *The Technique of Lighting for Television and Film*. (3rd. Edition). Oxford, England: Focal Press.

Niebur, E., Koch, C., Itti, L., Steinmetx, P., Roy, A., Fitzgerald, P., Johnson, K., and Hsiao, S.. (1999). Modeling Selective Attention. *From Molecular Neurobiology to Clinical Neuroscience, Proceedings of the 1st Cottingen Conference of German Neuroscience Society*, Elsner and Eysel (eds.), 151.

Parkhurst and Niebur. (2002). Modeling the role of salience in the allocation of overt visual attention. *Visual Research*, Vol. 42, No. 1, pp. 107-123.

Pellacini, F., Tole, P., and Greenberg, D. (2002). A User Interface for Interactive Cinematic Shadow Design. *Proceedings of SIGGRAPH 2002*.

Reid, F. (1995). *Lighting the Stage.* Boston, MA: Focal Press.

Rouse, R. (2000). *Game Design Theory and Practice.* Wordware Publishing Inc.

Schoeneman, C., Dorsey, J., Smits, B., Arvo, J., and Greenburg, D. (1993). Painting with Light. Proceed*ings of the 20th annual conference on Computer graphics and interactive techniques.*

Seif El-Nasr, M. (2003). Automatic Expressive Lighting for Interactive Scenes. PhD. Thesis. Computer science Department. Northwestern University.

Tole, P., Pellacini, F., Walter, B., and Greenberg,D. (2002). Interactive Global Illumination in Dynamic Scene. *Proceedings of SIGGRAPH 2002*.

Tomlinson, W. (1999). Interactivity and Emotion through Cinematography. Master's Thesis. MIT Media Lab, MIT.

Viera, D. (1993). *Lighting for Film and Electronic Cinematography.* Wadsworth Publishing Company: Belmont, CA.

Vineyard, J. (2000). *Setting up your shots: Great Camera Moves Every Filmmaker Should Know*. Michael Wiese Productions, Inc.: Studio City, CA.

Ward, G. (1995). Making Global Illumination User-Friendly. *Proceedings of Eurographics Workshop on Rendering.*

Young, M. (2000). Notes on the use of plan structures in the creation of interactive plot. *Working Notes of the AAAI Fall Symposium on Narrative Intelligence*, Cape Cod, MA, pages 164-167, November.

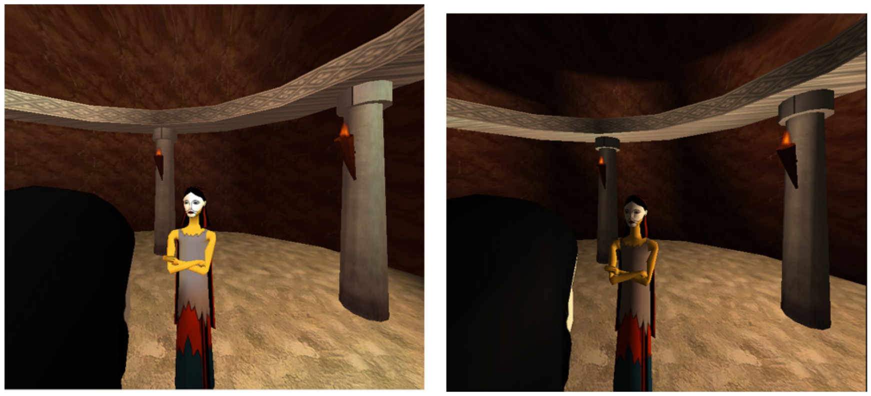

Figure 2. Shows two screenshots at the beginning of the scene;
the image on the left shows scene illuminated by ELE
the image on the right uses a static lighting design where designer configured the lighting

Figure 3. Shows two screenshots from the end of scene 8 in *Mirage*;
the image on the left shows scene illuminated by ELE;
the image on the right is rendered using static lighting

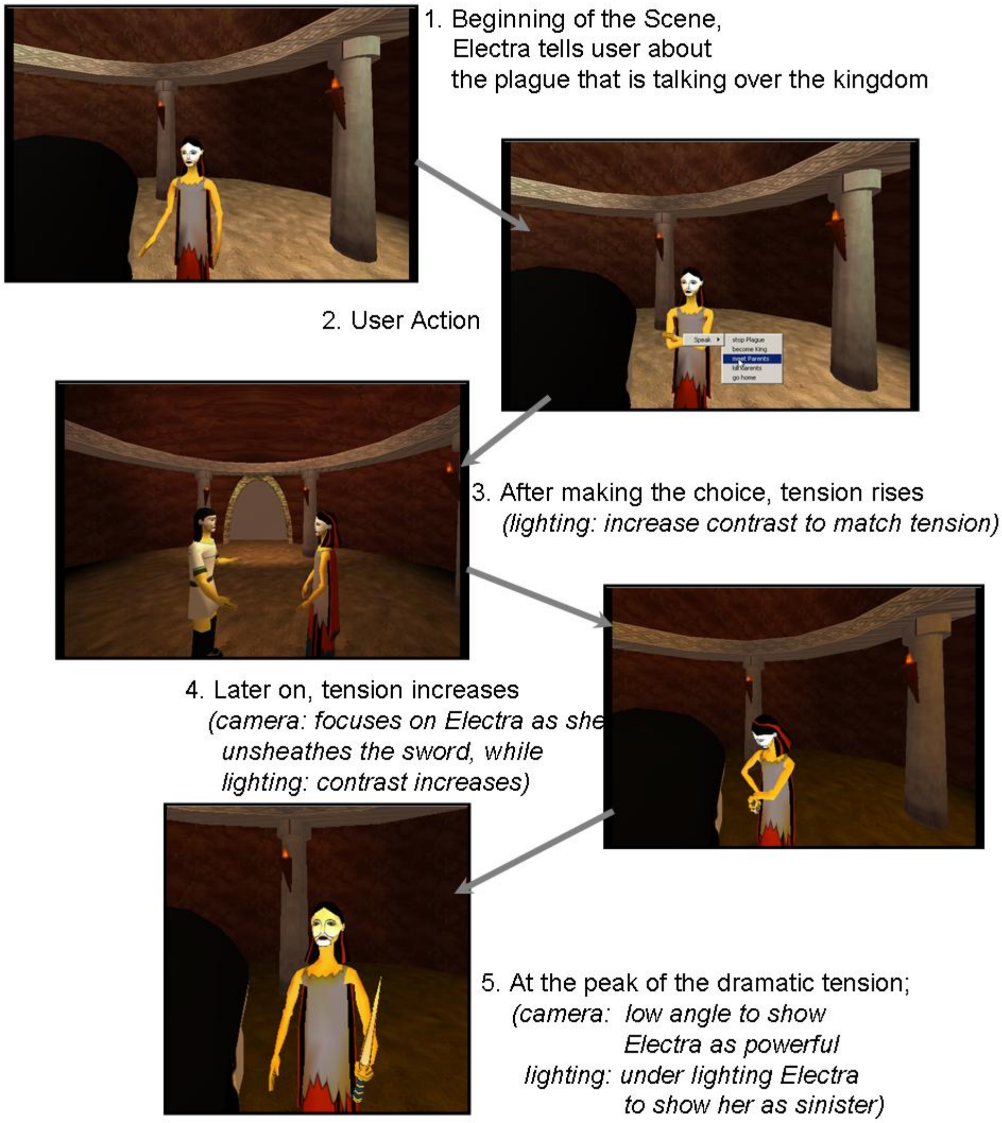

Figure 4. Screenshots from scene 8 of *Mirage*