2
Interactive Storytelling

Interactive storytelling is a form of digital entertainment based on the combination of interactivity and storytelling. Interactive storytelling systems aim to create dramatic and engaging narrative experiences for users, while allowing them to intervene with ongoing plots and change the way that the story unfolds. One of the key challenges in the development of such systems is how to balance a good level of interactivity with the consistency of the generated stories.

Although at first glance interactive storytelling may seem similar to digital games, there is a clear difference between them. In games, stories are essentially used to create challenges for the players, whereas in interactive storytelling stories are created to surprise and to entertain spectators. In both forms of media, users are able to intervene with the ongoing stories in some way. Usually, in interactive storytelling the interaction occurs only at specific points of the story and does not require much effort and attention from users. Although digital games and interactive storytelling are two different forms of media, the field of research in interactive storytelling may offer the opportunity for the development of new forms of digital games. The recent commercial success of the game Heavy Rain (2010) reveals that integrating interactive stories into the gameplay creates a successful experience for players.

Since the advent of the first interactive storytelling systems, a number of techniques and applications have been proposed in an effort to create engaging narrative experiences for users. Particularly, two models, character-based and plot-based, have been widely used in most current interactive storytelling systems. In the character-based approach (Meehan 1977; Cavazza et al. 2002; Aylett et al. 2005; Lima et al. 2014A), a simulation of a virtual world is created and the stories result from the real-time interaction among virtual autonomous agents that inhabit the virtual world and incorporate a deliberative behavior. The main advantage of a character-based model is the ability of anytime user intervention. As a result of such strong intervention, there is no way to estimate what decisions or actions will be made by the virtual actors, which is likely to lead the plot to unexpected situations that can violate the coherence of the story. The second model corresponds to the plot-based approach (Grasbon and Braun 2001; Paiva et al. 2001; Spierling et al. 2002; Magerko and Laird 2003; Magerko 2005), where characters incorporate a reactive behavior, which follows rigid rules specified by a plot. The plot is usually built in a stage that comes before dramatization. This approach ensures that actors can follow a predefined script of actions that are known beforehand. The plot may be automatically generated through planning algorithms or manually built by the author of the story. However, a plot-based approach restrains the user's freedom of interaction. Usually, the user has to wait until the storyline reaches some predefined points to be able to intervene. There are also some hybrid systems (Mateas 2002; Ciarlini et al. 2005; Cai et al. 2007; Si et al. 2008) that combine characteristics of both character-based and plot-based approaches using authoring goals and modeling the behavior of the virtual character in an attempt to reduce the shortcomings of both approaches.

A narrative is generally defined as a series of events that tells a story, either fictional or non-fictional. Interactive narratives can be entirely created manually by an author or automatically generated by planning techniques and simulations. The first case represents the more simple form of interactive stories. Usually, a hand-crafted structure of nodes, often in the form of a graph, defines the possible storylines. Each node of the graph includes a finely-crafted description of the plot event and the connections between nodes represent the possible paths that the story can follow. The user is given the ability to navigate through the graph, and the resulting sequence of nodes constitutes the experience of the narrative. Every possible storyline is manually authored, which ensures the author's vision is precisely preserved. However, the amount of narrative content that must be authored can grow exponentially with the number of user choices and the authoring process of large graphs quickly becomes intractable.

Figure 2.1 shows an example of a complex graph that defines every possible narrative trajectory of the Choose Your Own Adventure book *The Mystery of Chimney Rock* (Packard 1979), which contains 36 possible endings. Choose Your Own Adventure books were originally created by Edward Packard in the 1970s. These books contain a finite number of plot lines and narrative paths. At critical moments in the story, the reader is prompted to play the role of the characters and make a choice between several possible actions, which will direct him/her to another page of the book. Examples of manually authored interactive narratives also include some adventure games and some recent interactive experiences in TV and Cinema.

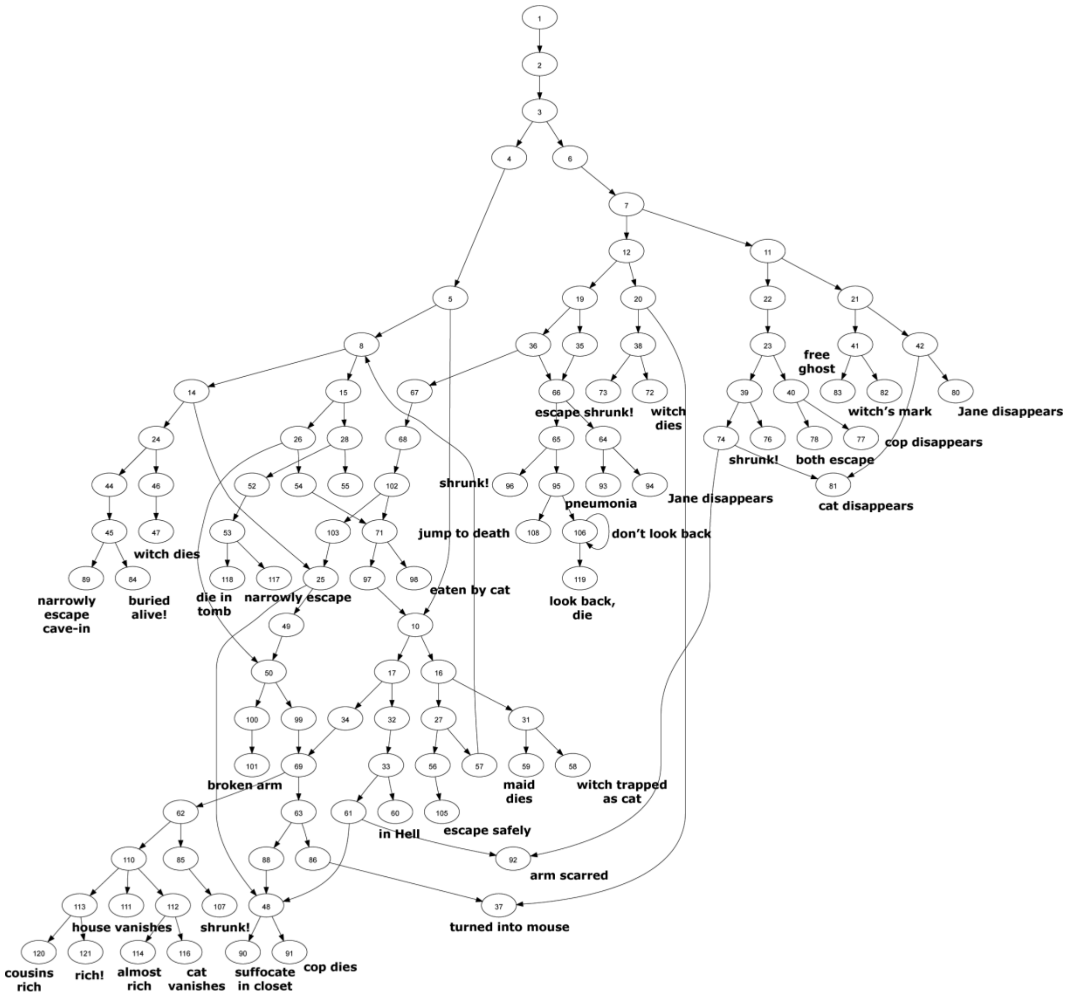


Figure 2.1: Story graph of The Mystery of Chimney Rock (Packard 1979).

Interactive narratives that have plots entirely or partially generated by planning techniques or simulations are the most robust forms of interactive storytelling. In a plot-based approach, the author usually defines only the story characters, a set of narrative events with preconditions and effects, and an initial state of the world. Then, a planning algorithm is responsible for finding coherent sequences of narrative events that will form the story. The advantage of this approach is that the planning algorithms can guarantee the story coherence and avoid the author from having to handle complex graph structures. A drawback is the exponential complexity of the planning algorithms, which require optimization techniques to allow the generation of plots in real-time. In a character-based approach, the author has to encode the behavior, personality traits and intents of virtual autonomous characters in a virtual environment. Then, a simulation process occurs and the storylines result from the interaction between characters and users. The advantage of this approach is the large number of stories that can emerge from the characters interactions, but there is no easy way to guarantee that all of these stories will be complex enough to create an interesting drama. Character-based approaches can also incorporate planning techniques in the simulation of the virtual world to define the behavior of the autonomous characters, as in Cavazza et al. (2002), where each character consults pre-compiled plans encoded as a Hierarchical Task Network (HTN) in order to decide the actions to be performed.

The field of research on interactive storytelling can be divided into three lines of research: story generation, user interaction, and story dramatization. Story generation aims at creating methods for the generation and management of coherent and diversified stories. User interaction aims at designing interaction mechanisms and interfaces that allow users to intervene with ongoing plots and change the way that the story unfolds. Story dramatization aims at generating attractive and engaging visual representations for the narratives.

The origins of the research topic about story generation date back to the 1970s (Meehan, 1977) and several techniques to accomplish this task have been proposed throughout the years. Usually, the process of generating stories involves narrative theories and planning algorithms. The narrative theory gives the formalism on how the story is structured and the planning algorithms are responsible for generating coherent sequences of events to compose the story plot. The formalism proposed by Propp (1968) is an example of narrative theory adopted by several interactive storytelling systems (Prada et al. 2000; Grasbon and Braun 2001; Ciarlini et al. 2005; Szilas 2007]. Propp examined 100 Russian fairy tales, and showed that they could all be described by 31 typical narrative functions, such as villainy, hero’s departure, reward, etc. Propp also showed that these functions have a chronological order that defines the basic structure of a fairy tale. This formalism is commonly used by story generator systems to produce the basic structure of the narratives. The planning techniques commonly used in interactive storytelling systems include Hierarchical Task Networks (HTN) (Cavazza et al. 2002), Heuristic Search Planners (HSP) (Pizzi and Cavazza 2007; Lima et al. 2013), and first order logic planners based on the STRIPS formalism (Szilas 1999; Ciarlini et al. 2005).

The research topic about user interaction investigates new ways for users to intervene with interactive narratives. Several approaches to handle user interactions have been proposed through the years. The forms of interaction vary from traditional GUI interfaces (Grasbon and Braun 2001; Ciarlini et al. 2005) to more complex interaction mechanisms, such as speech recognition (Cavazza et al. 2002; Cavazza et al. 2009), body gestures combined with speech (Cavazza et al. 2004; Cavazza et al. 2007; Lima et al. 2011B), hand-drawn sketches (Kuka et al. 2009; Lima et al. 2011A), physiological inputs (Gilroy et al. 2012), and interaction through social networks (Lima et al. 2012B). One of the key challenges in the development of a user interface for interactive storytelling is how to balance a simple and transparent interface that does not distract users from the dramatic content of the narrative with the need of a robust interaction mechanism that does not restrict the user creativity.

The research topic about story dramatization investigates new forms to visually represent interactive narratives. Text was the most common form of dramatization used by the first interactive storytelling systems like Tale-Spin (Meehan 1977; Meehan 1981), Universe (Lebowitz 1984; Lebowitz 1985) and Ministrel (Turner 1992). Usually, the process of representing stories through text consists of translating the story events into written natural language. The second generation of interactive storytelling systems that emerged in early 2000s was based on 2D or 3D computer graphics (Bates 1994; Mateas 2002; Cavazza et al. 2002; Aylett et al. 2005; Magerko 2006; Mott and Lester 2006; Pizzi and Cavazza 2007; El-Nasr 2007). In this form of dramatization, the story events are represented through animations of 3D models or 2D images. Other forms of dramatization include videos (Mateas et al. 2000; Ursu et al. 2008; Porteous et al. 2010; Lima et al. 2012A), augmented reality (Dow et al. 2006; Zhou et al. 2008; Lima et al. 2011A), and comics (Lima et al. 2013).

2.1. Story Dramatization

The following sections present a bibliographic review of the methods employed by the most relevant interactive storytelling systems to visually represent interactive stories.

2.1.1. Text-Based Dramatization

Tale-Spin (Meehan 1977; Meehan 1981) was one of the first computer programs created to automatically generate stories. The system is based on a character-based approach and it generates narratives by simulating a virtual world where characters try to reach their goals. Stories are created by a planning algorithm that is responsible for generating a plan that will be used by the characters. Once generated, this plan is translated into written natural language and then presented to the user. An example of story generated by Tale-Spin is shown in Figure 2.2.

Once upon a time George ant lived near a patch of ground. There was a nest in an ash tree. Wilma bird lived in the nest. There was some water in a river. Wilma knew that the water was in the river. George knew that the water was in the river. One day Wilma was very thirsty. Wilma wanted to get near some water. Wilma flew from her nest across the meadow through a valley to the river. Wilma drank the water. Wilma wasn't thirsty anymore.

George was very thirsty. George wanted to get near some water. George walked from his patch of ground across the meadow through the valley to a river. George fell into the water. George wanted to get near the valley. George couldn't get near the valley. George wanted to get near the meadow. George couldn't get near the meadow. Wilma wanted to get near George. Wilma grabbed George with her claw. Wilma took George from the river through the valley to the meadow. George was devoted to Wilma. George owed everything to Wilma. Wilma let go of George. George fell to the meadow. The end.

Figure 2.2: Example of story generated by Tale-Spin (Meehan 1981).

In Tale-Spin the process of translating the story events into natural language consists of putting the actor, action and object in the correct position of the sentence (Lee 1994). For each verb used by the program, there is a lexical entry which details the corresponding conjugations of the verb for singular and plural in the past, present and future tenses. The process is entirely ad hoc and is not based on any recognized linguistic theory (Meehan 1981). Therefore, the range of sentences which can be generated is limited.

Even though Tale-Spin is able to generate some interesting stories, most of them are not dramatically interesting. Despite the characters being coherent, stories have no structure and can turn out to be too short (Lee 1994). The translation of the story events into natural language generates very simple sentences that do not attract the reader's attention and are somewhat difficult to read.

Universe (Lebowitz 1984; Lebowitz 1985) is another interactive storytelling system that follows the same idea of Tale-Spin. However, instead of using characters' goals, the planning process is based on authorial goals. This is done by using plot fragments that contains a list of roles to be filled up by the characters, a set of restrictions and consequences, and an ordered list of sub-goals that must be achieved to satisfy the plot fragment. The characters of the stories are defined by personality traits, stereotypes, relations to other characters, and are responsible for assuming roles in the plot fragments. A large number of characters ensures that most situations will have a suitable character. As happens in Tale-Spin, once a plan for the story is generated it is translated into written natural language and then shown to the user. An example of story generated by Universe is shown in Figure 2.3.

Universe does not deal with the problem of natural language generation. The process of translating the story events into text is based on the use of pre-defined phrases and templates to generate the story output. This approach produces good results because the phrases and templates are prepared and written by humans. However, for every new story context, new templates have to be created.

Minstrel (Turner 1992) is another story generation system based on planning. However, different from Tale-Spin and Universe, it uses a planning technique called Case-Based Reasoning (Aamodt and Plaza 1994), where pieces of previously known or pre-generated stories are used in the generation of new ones. The process is based on four types of authorial goals: thematic, dramatic, consistency and presentation goals. Thematic goals are concerned with the selection and development of the theme and purpose of the story. Dramatic goals are concerned with keeping the story interesting by generating suspense, tragedy, presages, etc. Story consistency concerns the credibility of the actions performed by the characters. Finally, presentation goals are concerned with how the story is presented in natural language. An example of story generated by Minstrel is shown in Figure 2.4.

Liz was married to Tony. Neither loved the other, and, indeed, Liz was in love with Neil. However, unknown to either Tony or Neil, Stephana, Tony's father, who wanted Liz to produce a grandson for him, threatened Liz that if she left Tony, he would kill Neil. Convinced that he was serious by a bomb that exploded near Neil, Liz told Neil that she did not love him, that she was still in love with Tony, and that he should forget about her. Eventually, Neil was convinced and he married Marie. Later, when Liz was finally free from Tony (because Stephana had died). Neil was not free to many her and their troubles went on.

Figure 2.3: Example of story generated by Universe (Lebowitz 1985).

Minstrel uses a phrasal parser (Arens 1986; Reeves 1989) to generate written natural language from the story events. The parser integrates syntactic and semantic information into a lexicon of phrases that pair concepts and words. To translate the story events into natural language, the concepts from the story are matched with the lexical entries, and when a match is found, the corresponding words are outputted.

Tale-Spin, Universe and Minstrel are the most relevant text-based interactive storytelling systems found in the literature; however, there are others interesting systems such as Brutus (Bringsjord and Ferrucci 1999), which writes short stories about pre-defined themes, and Mexica (Pérez y Pérez 1999; Pérez y Pérez and Sharples 2001), which produces short stories based cycles of engagement and reflection.

It was the spring of 1089, and Lancelot returned to Camelot from elsewhere. Lancelot was hot tempered. Once, Lancelot had lost a joust. Because he was hot tempered wanted to destroy his sword. Lancelot stuck his sword. His sword was destroyed.

One day a lady of the court named Andrea wanted to have some berries.

Andrea went to the woods. Andrea had some berries because Andrea picked some berries. Lancelot's horse moved Lancelot to the woods. This unexpectedly caused him to be near Andrea. Because Lancelot was near Andrea Lancelot saw Andrea. Lancelot loved Andrea.

Some time later. Lancelot's horse moved Lancelot to the woods unintentionally, again causing him to be near Andrea. Lancelot knew that Andrea kissed a knight called Frederick because Lancelot saw that Andrea kissed with Frederick Lancelot believed that Andrea loved Frederick. Lancelot loved Andrea. Because Lancelot loved Andrea, Lancelot wanted to be the love of Andrea. But he could not because Andrea loved Frederick. Lancelot hated Frederick. Because Lancelot was hot tempered, Lancelot wanted to kill Frederick. Lancelot went to Frederick. Lancelot fought with Frederick. Frederick was dead.

Andrea went to Frederick. Andrea told Lancelot that Andrea was siblings with Frederick. Lancelot wanted to take back that he wanted to kill Frederick. But he could not because Frederick was dead. Lancelot hated himself. Lancelot became a hermit. Frederick was buried in the woods. Andrea became a nun.

Figure 2.4: Example of story generated by Ministrel (Turner 1992).

2.1.2. 2D/3D Dramatization

The second generation of interactive storytelling systems that emerged in early 2000s was based on 2D or 3D computer graphics. In this form of dramatization the story events are represented through animations of 3D models or 2D images. However, this process is not an easy task; representing a narrative graphically involves several challenges. The characters must be believable and attract the attention of the audience, the environment must be rich and coherent with the story, and the camera must be intelligent to correctly show the scenes and improve the dramatic content of the narrative.

The game industry deals with interactive computer graphics since the advent of the first video games. However, interactive narratives are different from traditional games. Usually in a game every little detail is planned by the game designer and created by the artists and programmers to be always attractive and works as expected. In real emergent interactive narratives all the possible storylines that can be generated based on the user choices are not easily predictable. Different from traditional games, interactive narratives demand a high degree of adaptability and intelligent methods to produce attractive and engaging visual representations for the narratives.

The first graphical interactive storytelling system was developed in the Oz Project,[1] as part of their experiments on agent-based storytelling (Loyall 1997). The Edge of Intention (Bates 1992) (Figure 2.5 - *a*) is a virtual world that contains three autonomous animated creatures, called Woggles. Each Woggle has goals, emotions, and personality, and expresses these through movement and facial expression. They also engage in simple social games, exhibit aggression, play, sleep, and perform several other behaviors.

One of the main components of the Edge of Intention is a agent language called HAP (Loyall and Bates 1991). The language directly supports goal-directed action producing behaviors and continuously chooses the agent's next action based on perceptions, current goals, emotional state and aspects of an internal state. The HAP architecture also allows the parallel execution of multiple actions and the early production of next action to allow smooth animations and more believable and engaging dramatizations (Loyall and Bates, 1993).

Based on the ideas of the Oz Project, Mateas (2002) developed another interactive storytelling system called Façade. The main goal of Façade was to provide a complete real-time dramatic experience with a highly interactive story. The story generation in Façade is based on small plot units called *beats*. Each beat consists of a set of pre-conditions, a pre-scripted sequence of events, and a set of effects. The beats are sequenced in such a way as to be responsive to user interactions while providing story structure (Mateas 2002). The stories are represented in a 3D environment through a first-person perspective. An example of scene from Façade is shown in Figure 2.5 - *b*.

[1] OZ Project - https://www.cs.cmu.edu/afs/cs/project/oz/web/

Façade's real-time rendered 3D story world is implemented in C++ with OpenGL (Mateas and Stern 2003). The animation of character's body and face is done through a mixture of procedural animation and layered keyframe animation data. Each of the characters contains a library of behaviors. The pre-scripted beats control the animation of a character's body by issuing commands (e.g. "play this animation script" or "assume this facial expression").

Façade is known as the most successful attempt to create a real interactive drama (Crawford 2004). However, its architecture requires great authorial effort to create new interactive narratives. The authors spent 2 years to create the narrative that has only one scene, two characters and takes about 20 minutes to complete (Mateas and Stern 2003).

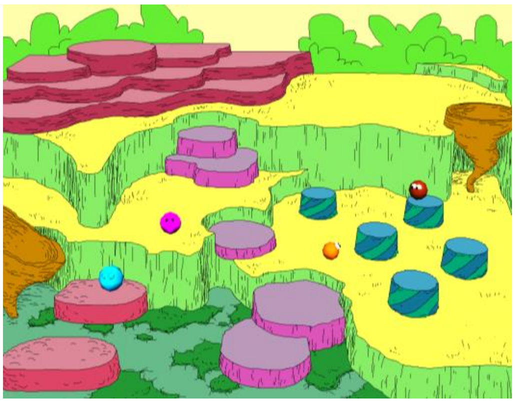
Following a different approach, Cavazza et al. (2002) formalize the concepts of character-based interactive storytelling and presented a system where each character uses a Hierarchical Task Network (HTN) in order to decide the actions to be performed. The HTN consists of a tree-like structure that describes the actions a character can perform in order to achieve his goals. Users can interact with the characters and navigate through their environment or they can verbally interact with them using a speech recognition system. The stories are represented in a 3D environment, but different from Façade, the user assumes a third-person perspective. An example of scene from Cavazza et al.'s system is shown in Figure 2.5 - *c*.

The system was developed using the Unreal Tournament game engine[2] and the story events are represented through animation and subtitles corresponding to the characters' dialogue or important events (Cavazza et al. 2002; Charles and Cavazza 2004). The system incorporates an intelligent camera control to decide which event should be shown to the user when different events occur at different locations at the same time (Charles et al. 2002). This decision is based on the type of event, participating characters, and emotional information.

In a more recent work, Pizzi and Cavazza (2007) present another version of their interactive storytelling system based on a different planning approach. They aim at reconciling narrative actions with the psychological state of characters. The best actions to be applied for a given character are provided by a function of

[2] Unreal Engine - http://www.unrealengine.com/

his/her current feelings, its beliefs, and the world's state of affairs. A multithreaded heuristic search planner is used for controlling each character independently and 3D animations are generated from the grounded actions produced by the planner. During story visualization, the system accepts Natural Language input, which is analyzed to update characters' beliefs and emotional state, thus altering the evolution of the narrative. The Unreal Tournament game engine is used to generate the real-time 3D graphics. An example of scene from Pizzi and Cavazza interactive storytelling system is shown in Figure 2.5 - *d*.



(*a*) Edge of Intention (1992)

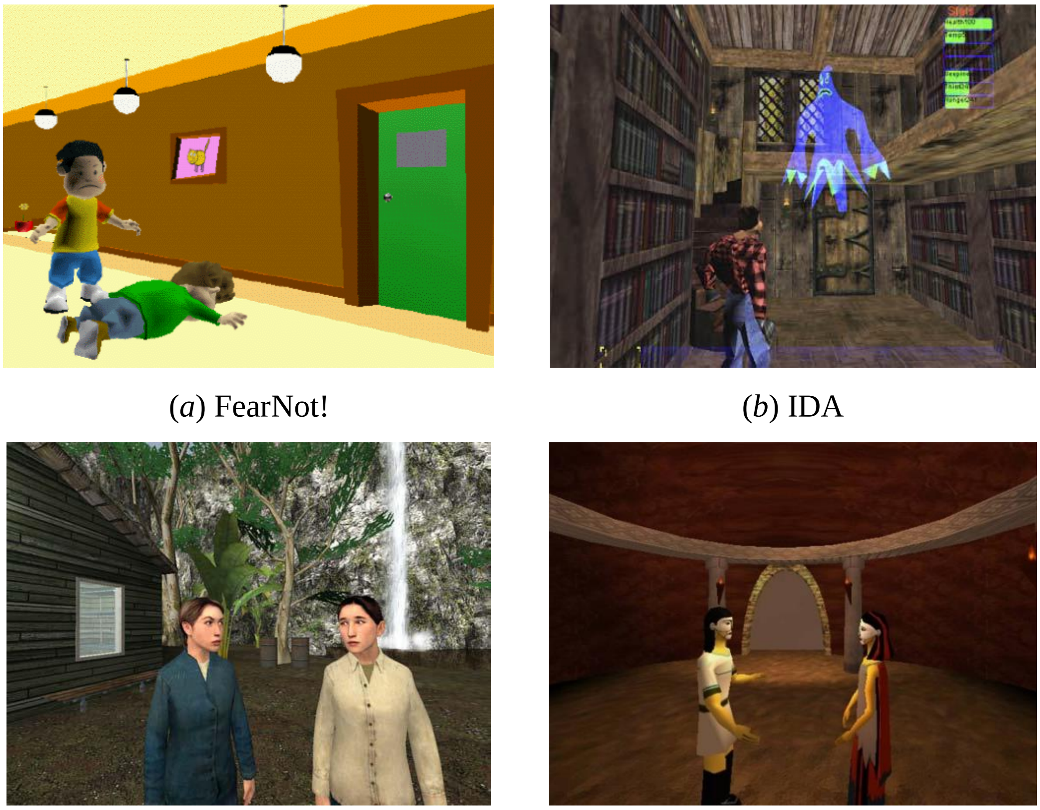
(*b*) Façade (2002)

(*c*) Cavazza et al. System (2002)

(*d*) Pizzi and Cavazza System (2007)

Figure 2.5: Graphical interactive storytelling systems. Image (*a*) shows a scene from the Edge of Intention; image (*b*) shows a scene from Façade; image (*c*) shows a scene from Cavazza's interactive storytelling system; and image (*d*) shows a scene from Pizzi and Cavazza interactive storytelling system.

The story worlds created by Mateas (2002) and Cavazza et al. (2002) are the most relevant graphical interactive storytelling systems present in the literature, however there are other important systems like FearNot! (Aylett et al. 2005), which follows a pure character-based approach using a cognitive and emotional model of human behavior. The narratives presented by FearNot! consist of educational stories about bullying, in which users are able to interact with the victims, giving them advices and observing the results in a 3D environment (Figure 2.6 - *a*). Another example is IDA (Interactive Drama Architecture) (Magerko 2006), which is based on an author-centric approach and uses a story director agent to maintain the progression of the stories. A similar approach is adopted in U-Director (Mott and Lester 2006), where a utility-based director agent monitors the stories according to narrative objectives, user states and story world states. In both systems the stories are represent through a 3D game engine (Figure 2.6 - *b* and Figure 2.6 - *c*). Another example of 3D system is called Mirage (El-Nasr 2007), which uses an architecture based on a set of dramatic techniques for story dramatization (Figure 2.6 - *d*).



(*a*) FearNot! (*b*) IDA

(*c*) U-Director (*d*) Mirage

Figure 2.6: Other graphical interactive storytelling systems. Image (*a*) shows a scene from FearNot! system; image (*b*) shows a scene from IDA system; image (*c*) shows a scene from U-Director system; and image (*d*) shows a scene from Mirage system.

The Logtell system (Pozzer 2005; Ciarlini et al. 2005), which is the base for the development of this thesis, is also an important example of interactive storytelling system that has a 3D dramatization system that represents the stories through a third person perspective. More details on Logtell system will be presented in Section 2.2.

Other examples of graphical interactive storytelling systems includes Mimesis (Young 2001), Dramachina (Donikian 2003), IDTension (Szilas 2003), Gadin (Barber and Kudenko 2007), ISRST (Nakasone and Ishizuka 2007), and PaSSAGE (Thue at al. 2007).

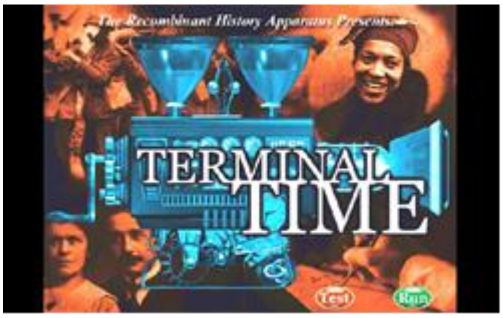
2.1.3. Video-Based Dramatization

The idea of using videos as a form of visual representation of interactive narratives is not entirely new. The first attempts to use prerecorded video segments to represent some form of dynamic narrative appeared with the first experiences for interactive cinema (Činčera et al. 1967; Bejan 1992), and the academic research works on this topic date back to the 1990s (Chua and Ruan 1995; Davenport and Murtaugh 1995; Ahanger and Little 1997).

Terminal Time (Mateas et al. 2000) (Figure 2.7 - *a*) is an example of narrative system that uses videos to produce historical documentaries based on the audience's appreciation of ideological themes. It focuses on the automatic generation of narrative video sequences through a combination of knowledge-based reasoning, planning, natural language generation, and an indexed multimedia database. In this system, video clips are subsequently selected from the multimedia database according to keywords associated with the documentary events and annotated video clips.

Following a different approach, Ursu et al. (2008) explore the idea of a generic framework for the production of interactive narratives. The authors present the ShapeShifting Media, a system designed for the production and delivery of interactive screen-media narratives based on prerecorded video segments. However, the system does not incorporate any mechanism for automatic story generation. Essentially, their approach is to empower the human-centered authoring of interactive narratives rather than attempting to build systems that generate narratives themselves. The variations of the narrative content are achieved by the automatic selection and rearrangement of atomic elements of content into individual narrations.

The applications developed with the ShapeShifting Media system include *My News & Sports My Way* (Figure 2.7 - *b*), in which the content of a continuous presentation of news is combined in accordance with users' interest, and the romantic comedy *Accidental Lovers* (Figure 2.7 - *c*), in which users can watch and influence a couple's relationship. In *Accidental Lovers*, viewers are able to influence the ongoing story by sending mobile text messages to the broadcast channel. Changes in the emotional state of the characters and their relationships depend on the existence of some specific keywords found in the viewer's messages. *Accidental Lovers* was broadcasted several times on Finnish television in late December 2006 and early January 2007 (Williams et al. 2006).



(*a*) Terminal Time

(*b*) My News & Sports My Way

(*c*) Accidental Lovers

(*d*) Last Call

Figure 2.7: Video-based interactive storytelling systems. Image (*a*) shows a scene from the Terminal Time system; image (*b*) shows a scene from My News & Sports My Way; image (*c*) shows a scene from Accidental Lovers; and image (*d*) shows a scene from Last Call.

There are also some examples of video-based interactive narratives developed for TV, Cinema and Web. Last Call (Jung von Matt 2010), for example, is an interactive advert for the 13th Street TV Channel exhibited experimentally in movie theaters. In Last Call, the audience interacts with the actress talking to her via cell phone (Figure 2.7 - *d*). Based on the audience voice commands, the system selects the sequence of videos to be presented according to a fixed tree of pre-recorded video segments.

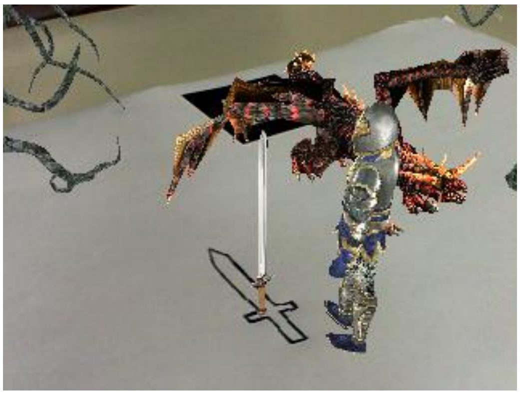
A more complete and detailed review of the previous works on video-based interactive storytelling is presented in Section 4.1.

2.1.4. Other Forms of Dramatization

The current advances in virtual and augmented reality have motivated the development of other forms of story dramatization. Cavazza et al. (2007) present an interactive storytelling system where the narrative unfolds as a real-time stereoscopic 3D animation in an immersive CAVE-like system, where characters express themselves using speech synthesis as well as body animations (including elementary facial animations with lip synchronization) and the user can interact with them naturally, using speech and attitudes, as if acting on stage (Figure 2.8 - *a*). The system follows a character-based approach and the character's actions are driven by their feelings. The immersive narrative, as perceived by the user, is composed of a succession of real-time animations showing the characters moving around on stage, performing actions and expressing themselves through utterances, body attitudes and gestures. All these animations are generated by elementary actions associated to planning operators.

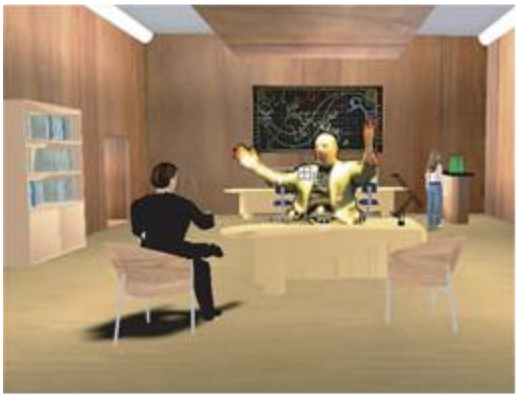
Lima et al. (2014) explore the use of an augmented reality visualization interface combined with a sketch-based interaction interface and presents an interactive storytelling system able to dramatize interactive narratives in augmented reality over conventional sheets of paper. Users can freely interact with the virtual characters by sketching objects on the paper, which are recognized by the system and converted into objects in the 3D story world (Figure 2.8 - *b*). In the system, stories are graphically represented in augmented reality over the paper, which creates the illusion that the sheet of paper is a virtual world populated by virtual characters. The entire world may comprise several sheets of paper, each one representing a different location in the virtual world. Users can switch between places by changing the paper shown to the camera or by pointing the camera to other sheets of paper. They also have the freedom to move the camera and watch the scenes from different angles. Moreover, like film directors, they have the freedom to change the perspective of the stories simply by choosing to focus on a different virtual place, which generates different storylines.

(*a*) Madame Bovary on the Holodeck



(*b*) Paper and Pencil

(*c*) AR Façade



(*d*) Cavazza et al. System

Figure 2.8: Interactive storytelling systems that explore other forms of story dramatization. Image (*a*) shows a scene from Madame Bovary on the Holodeck system; image (*b*) shows a scene from Paper and Pencil interactive storytelling system; image (*c*) shows a scene from AR Façade system; and image (*d*) shows a scene from Cavazza et al. system.

Other examples of immersive systems include the interactive storytelling application presented by Cavazza et al. (2004), which uses a camera to capture the user image to then insert him/her into a virtual world populated by virtual actors. Users are able to interact with virtual actors using body gestures and natural speech (Figure 2.8 - *d*). Other example is the augmented reality version of the desktop based interactive drama Façade (Mateas 2002) presented by Dow et al. (2006), where players can move through a physical apartment and interact with two autonomous characters using gestures and speech (Figure 2.8 – *c*).

2.2. Logtell

The present thesis is part of the Logtell Project,[3] which is a research project that aims at the development of integrated tools for managing both the generation and representation of dynamic interactive stories. The Logtell interactive storytelling system was used as basis for developing the video-based dramatization model proposed in this thesis.

Logtell is an interactive storytelling system based on temporal modal logic (Ciarlini et al. 2005) and planning under nondeterminism (Silva et al. 2010). It uses a hybrid planner that combines partial-order planning and task decomposition to efficiently deal with nondeterministic events, i.e. events that can have more than one outcome. Logtell conciliates plot-based and character-based approaches by logically modeling how goals can be brought about by previous situations and events.

In Logtell, stories are generated in chapters. In each chapter, goals to be achieved are specified either by rules or by user interventions, and the planner tries to achieve them. Situations generated by the planned events and user interventions that occur while the chapter is being dramatized influence the next chapter and so on. The chapters are represented as contingency trees, where the nodes are nondeterministic events and the edges correspond to conditions that enable the execution of the next event. A nondeterministic event e_i is executed by a nondeterministic automaton (NDA) (Doria et al. 2008) composed of actions a_i (Figure 2.9). The automaton contains information about possible sequences of actions and is open to audience's interventions.

[3] Logtell Project - http://www.icad.puc-rio.br/~logtell/

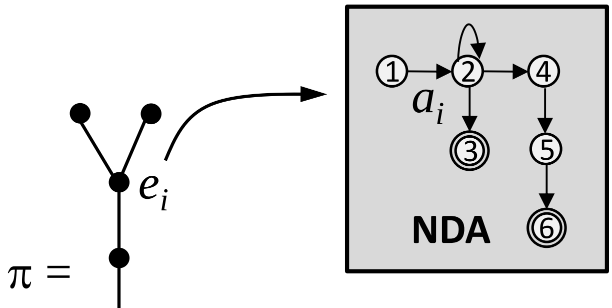


Figure 2.9: Overview of the story generation process. Plot π, events e_i, and nondeterministic automata with actions a_i. Double circles mean final states.

The Logtell system has a client/server architecture (Camanho et al. 2009) that supports multiple users sharing and interacting in the same or different stories. The client-side is responsible for user interaction and dramatization of stories. At the application server side there is a pool of servers sharing the responsibility of creating and controlling multiple stories, which are presented in different clients. The audience can interact with the story by suggesting events to the planning algorithm (to be incorporated in the next chapter) and/or interfering in the nondeterministic automata in a direct or indirect way.

The Logtell system comprises a number of distinct modules to provide support for generation, interaction and visualization of interactive plots (Figure 2.10). In the Logtell architecture, story contexts are stored in a database of contexts (Context Database), where each context contains a description of the genre according to which stories are to be generated, and also the intended initial state specifying characters and the environment at the beginning of the story. The Simulation Controller is responsible for: (1) informing the Drama Manager, at the client side, the next events to be dramatized; (2) receiving interaction requests and incorporating them in the story; (3) selecting viable and hopefully interesting suggestions for users who are intent on performing strong interactions; and (4) controlling a number of instances of the Nondeterministic Interactive Plot Generator (NDet-IPG), which is responsible for the generation of the plan to be used as input to the dramatization process. The Chapter Controller is responsible for generating the plot, chapter by chapter, including the treatment of nondeterminism and the parallel processing of multiple valid alternatives at any given moment. The Interface Controller controls the user interventions and centralizes the suggestions made by the users. On the client side, the user interacts with the system via the User Interface, which informs the desired interactions to the Interface Controller placed at the server side. The Drama Manager requests the next event to be dramatized from the Simulation Controller, and controls actor instances for each character in a 3D environment running on the Graphical Engine.

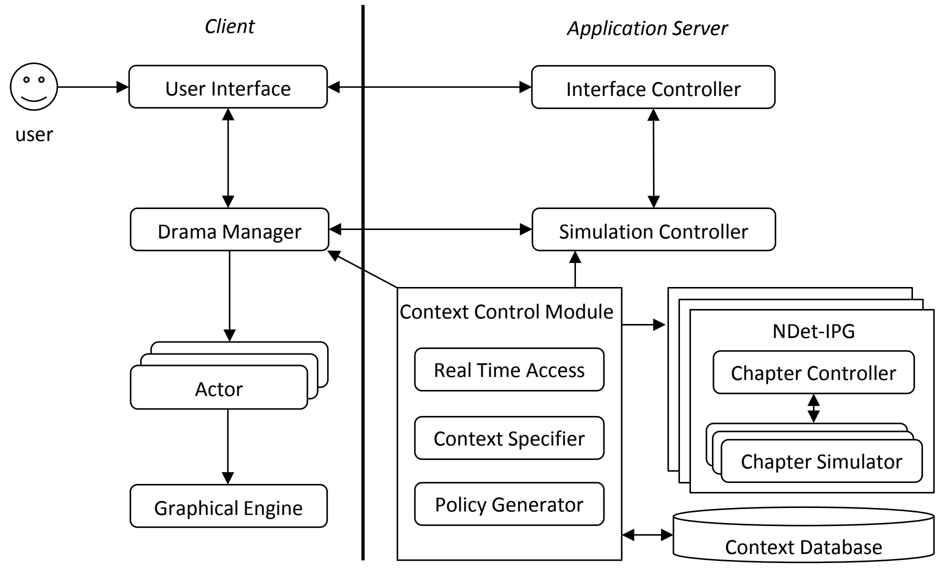


Figure 2.10: Logtell architecture. Source: adapted from (Silva 2009).

2.2.1. Story Generation

The idea behind the story generation in Logtell is to capture the logics of a genre through a temporal logic model and then verify what kind of stories can be generated by simulation combined with user intervention. In this way, the Logtell focuses not simply on different ways of telling stories but on the dynamic creation of plots. The temporal logic model is composed of typical events and goal-inference rules. Inspired by Propp's ideas on the typical functions of a narrative (Propp 1968), Logtell extensively uses planning to generate alternative stories in real-time. The logical specification defines the events that can occur and rules establishing goals to be pursued by characters when certain situations occur. Plots are generated by multiple cycles of goal-inference, planning and user intervention.

The planning process is divided into two phases. In the first phase, a partial-order planner (Ciarlini and Furtado 2002) generates a sketch of the plot by inferring new goals through the goal-inference rules or by incorporating user interventions. This sketch serves as an initial HTN for the second phase, in which a nondeterministic HTN-planner decomposes complex events into basic ones in order to obtain an executable plan. This process creates a contingency tree in which the nodes are basic events and the edges contain conditions to be tested after the event to choose the branch to be followed during dramatization.

Each basic event is modeled as a nondeterministic automaton (Doria et al. 2008), where situations observed in the world are associated to states, and actions that virtual actors can perform are associated to the transitions. In general, there is always a set of states that can be reached after the execution of an action; the selection of which transition must occur could be a user choice or randomly chosen according to weights associated to the transitions. Figure 2.11 shows an example of automaton created to represent the possibilities for the dramatization of an event where a villain kidnaps a victim.

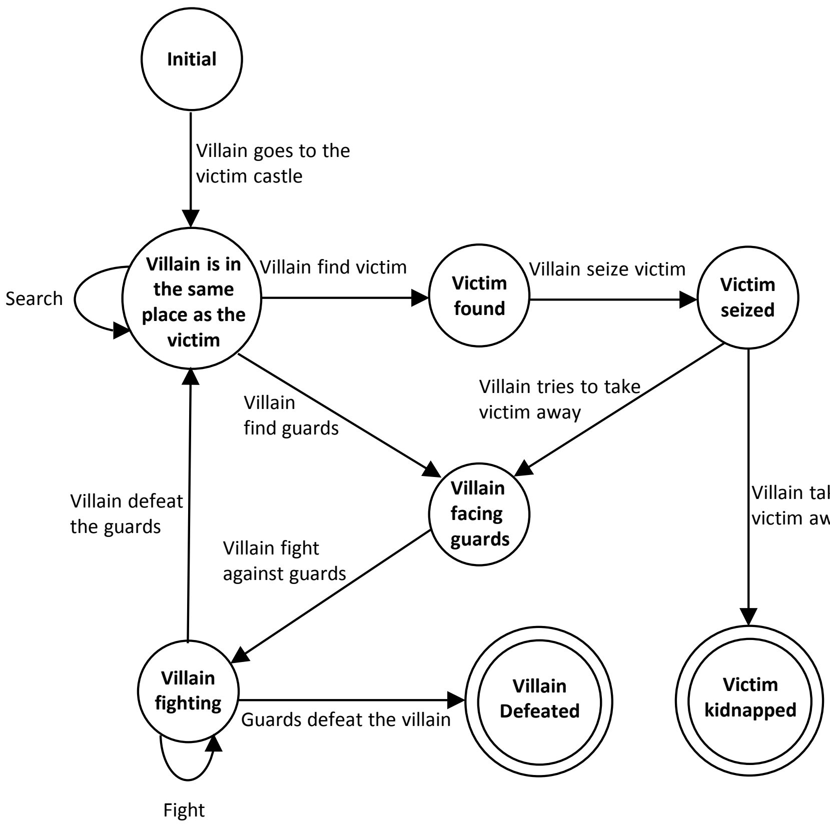


Figure 2.11: Example of automaton representing the possibilities for the dramatization of a kidnap event. Source: adapted from (Doria et al. 2008).

During the dramatization of the nondeterministic automata, the system is also able to automatically select policies that can either accelerate or extend the presentation time. The generated policies can be weak, strong with cycles or strong. In weak policies, there is at least one path from the initial state to a goal state, but states from which it is not possible to reach the goal according to the policy can be reached. When a policy is strong with cycles, the goal state is always reachable but cycles can occur, so that the time to reach the goal might be virtually infinite. Strong policies guarantee that, from any state in the policy, the goal state is reached at some moment. The use of policies allows the system to coordinate plot generation and dramatization in parallel.

More details about the story generation model of the Logtell system can be found elsewhere (Ciarlini and Furtado 2002; Ciarlini et al. 2005; Doria et al. 2008; Silva et al. 2010).

2.2.2. User Interaction

The Logtell system offers two forms of user interaction: (1) weak interventions, where users can select alternatives that are automatically generated by the planning algorithms; and (2) strong interventions, where users can try to force the occurrence of events or specific situations in the story. Figure 2.12 shows the user interface of the Logtell system. The interaction window occupies a small part of the screen and appears in parallel with the main window, where the story is dramatized.

Weak interventions occur by means of the commands “rewind” and “another” (Camanho et al. 2009). The rewind command allows users to “return” to the start of the selected chapter. The chapter is presented again and the user has the opportunity to interact with the system again and select alternatives for the next chapters. When the command is executed, the system retrieves a logical snapshot of the selected chapter and resumes the simulation from this point, discarding the snapshots of the next states, which will be generated again in accordance with the user’s interactions. The “another” command is used to ask the system to provide an alternative for the selected chapter. In response to the command, the planning system generates another solution for the goals that were reached. In this way, a different combination of events can be generated for the chapter, wherefrom a completely different continuation of the story can be developed.

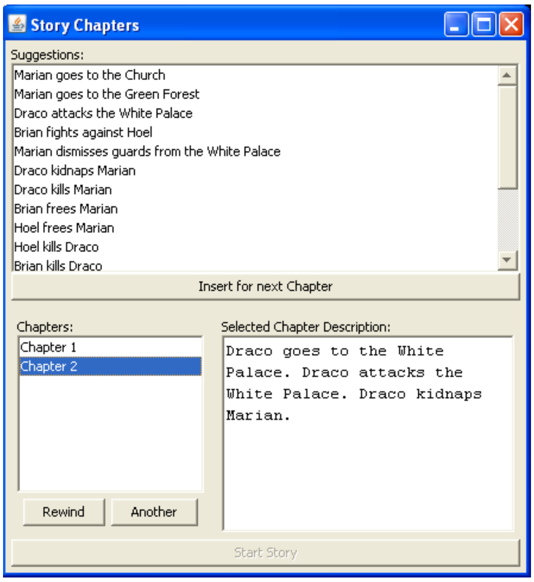


Figure 2.12: User interface for continuous interaction. Source: (Camanho et al. 2009).

Strong interventions enable users to indicate events and situations that should occur in the next chapters. The suggested situations are considered as goals to be achieved at a certain time, and events can have unfulfilled pre-conditions that might demand the insertion of more events. In such cases, the system has to plan a chapter with additional events and constraints that make the user intervention consistent with the plot and the rules of the genre. If this is not possible, the user intervention is simply rejected. The system also includes a mechanism in which viable strong interventions are automatically suggested to users, so that they can simply select the one that better suits their tastes. The list of suggestions is updated whenever the presentation of a new chapter starts.

More details about the user interaction mechanisms of the Logtell system can be found elsewhere (Pozzer 2005; Ciarlini et al. 2005; Camanho et al. 2009).

2.2.3. Dramatization

Logtell represents the stories generated by the planning system in a 3D environment (Figure 2.13), where characters are represented through 3D models and their actions through animations (Pozzer 2005; Lima 2009). The virtual world is represented by a hand-built 3D environment that is consistent with the logical definition of the story context, which means that it contains all the locations where the story events can happen. Similarly, all characters described in the story context are associated with a 3D actor in the dramatization system.

Figure 2.13: Scenes from the 3D dramatization module of the Logtell system.

The system provides a set of parameterized actions that can be used to visually represent the generated stories. These actions correspond to the basic actions described in the nondeterministic automata and are represented by the virtual 3D actors trough animations controlled by the dramatization system. The behavior of the actors is determined by the sequence of actions that must be dramatized in order to represent the story events.

The dramatization system has the goal of emphasizing the dramatic content of the scenes and presenting them in a more attractive and engaging way to the viewers. Its architecture is composed of a set of cinematography-inspired autonomous agents that controls the dramatization, actors, cameras, lights and music. The dramatization system is capable of automatically placing the cameras in the virtual environment, selecting the best camera angle to show the action, and selecting the best visual effects and sound tracks to the scenes of the narrative.

More details about the dramatization process of the Logtell system can be found elsewhere (Pozzer 2005; Ciarlini et al. 2005; Lima 2009; Lima et al. 2009; Lima et al. 2010).

2.3. Conclusion

This chapter introduced the main concepts of interactive storytelling and presented a brief review of the main interactive storytelling systems, emphasizing the methods used by these systems to visually represent interactive stories. Table 2.1 summarizes the results of this study by showing a list of the main interactive storytelling systems and their respective story generation models and dramatization methods. We can observe a variety of dramatization methods that vary from simple textual stories to complex virtual environments. While early interactive storytelling systems were mainly based on textual descriptions of stories, more recent system have been exploring new forms of dramatization, such as immersive mixed reality environments and video-based representations.

System	**Story Generation Model**	**Dramatization Method**
Kinoautomat (1967)	Branching Points	Video
Tale-Spin (1977)	Planning	Text
Universe (1984)	Planning	Text
The Edge of Intention (1991)	Agent-Based Planning	2D
Minstrel (1992)	Planning	Text
I'm Your Man (1992)	Branching Points	Video
Façade (2002)	Agent-Based Planning	3D
Cavazza et al. (2002)	HTN Planning	3D
Pizzi and Cavazza (2007)	Emotional Planning	3D
FearNot! (2005)	Agent-Based Planning	3D
Logtell (2005)	Nondeterministic Planning	3D
Terminal Time (2000)	Planning	Video
Accidental Lovers (2007)	Branching Points	Video
Last Call (2010)	Branching Points	Video
Cavazza et al. (2007)	Emotional Planning	Immersive System
Paper and Pencil (2011)	Agent-Based Planning	Augmented Reality

Table 2.1: List of the main interactive storytelling systems and their respective story generation models and dramatization methods.

Based on this study, we can observe that the most robust interactive storytelling systems adopt a story generation model based on planning, while most of the previous works on video-based interactive storytelling are still based on branching narrative structures. In addition, previous works are entirely based on immutable pre-recorded segments of video, which reduces interactivity, restricts story diversity, and increases the productions costs.