An Interaction Framework for Scenario-Based Three Dimensional Environments

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ABSTRACT

Although popular and engaging, three dimensional environments are rarely deployed to depict strong narratives involving complex characters engaged in reasoning. The design of three dimensional environments rich in narrative and character depth can be facilitated with a detailed representation of interactions between characters. However, the representation of interaction in current 3D development environments such as game engines is quite basic. This work advances a scheme for representing interactions that integrates a representation of semantics from linguistics called FrameNet with conceptualizations of drama and narrative by Georges Polti and Joseph Campbell. The resulting interaction frame facilitates the design of 3D environments by providing designers rich, yet standard elements that include spatial and temporal data, with which to represent complex interactions in 3D environments.This has application for the authoring of dynamically generated interactive narrative environments.

Categories and Subject Descriptors

H.5.1 [**Information Interfaces and Presentation**]: Multimedia Information Systems—*Animations, Artificial, augmented, and virtual realities*; I.2.0 [**Artificial Intelligence**]: General—*Cognitive simulation*; I.2.1 [**Artificial Intelligence**]: Applications and Expert Systems—*Games*

General Terms

Interaction, 3D, narrative, scenario-based learning, emotion

1. INTRODUCTION

Three dimensional environments are popular, engaging and offer enticing graphical and auditory effects. However most three dimensional environments are deployed for specialized military simulations or first person perspective games and relatively few applications have been developed with a strong storyline, complex characters or sophisticated reasoning. The interactive learning environment developed by [7], represents an exception that demonstrates a far broader potential for these environments than is currently exercised.

Designing 3D environments that include a clear interactive narrative, sophisticated characters, knowledge and reasoning is difficult. Typically, as in other forms of media, a narrative emerges through interactions between characters mediated through an environment. Green and Lo [5] have noted that 3D environments are limited by primitive and basic interactions. The lack of a critical or unified vocabulary too, has been identified by [5] as hindering progress toward developing better 3D interaction techniques and applications that use them. Another problem identified by [8] is that there is no formal or established method to identify and develop interactions for 3D environments and current practice relies on common wisdom and guesses.

This paper advances a new technique to design interaction in 3D environments. The approach facilitates the dynamic generation of scenes into a narrative or story that is driven by user involvement in the application environment. The interaction framework identifies and describes interactions for 3D environments from both structured and narrative perspectives and has general application to modeling and describing sophisticated interaction in 3D environments. The interaction framework advanced, integrates a linguistic semantic representation of natural language concepts with a theoretical perspective of drama.

The interaction framework is a tool for existing development environments to facilitate the representation of complex interactions. Further development of Interaction Frames will provide routines that can interface with an existing environment and assist the design of interactive narrative through the selection of interaction frames. Frames provide discrete units that can be linked to a knowledge base and be computationally managed by an inference engine. Frames contain data that relates to the depiction and visualization of scenarios as well as providing spatial and temporal information that can be made explicit or left implicit, depending on the sequence chosen by the 3D designer. This enables the designer to translate a narrative concept or a brief narrative treatment into a series of scenes, each depicting a sequence of complex interactions between the player character and the environment, and between characters.

In the next section the interaction framework advanced is described in some detail. Following that, two sample de-

sign exercises that translate narrative elements to a detailed scene sequence is presented to illustrate the framework in action. Firstly an example translation of interactions from a linear narrative, the Odysseus battle with the Cyclops [6] is presented. This is followed by an analysis of interactions for translation into 3D representations, from an interactive scenario-based application for nurse training in an Intensive Care Unit [12]. Concluding remarks illustrate the state of research with the framework and future plans.

2. INTERACTION FRAMEWORK

The interaction frames described in this paper are data structures that contain definitions of interactions that can be represented in the 3D environment on call. No formal sequence of interaction frames is necessary, but the method is equally useful for formal or linear storytelling. The interaction frames are built from two constructs;
1. Linguistic frame semantics using the Berkeley FrameNet Project [10].
2. Drama. Monomythic narrative template elements described by Campbell [3], and the dramatic situations defined by Georges Polti [11].
These constructs are next discussed.

2.1 FrameNet

The Berkeley FrameNet Project [10], is an online lexical resource based on frame semantics. Its aim is to document the range of semantic and syntactic combinatory possibilities of English words in each of their senses. The major product of the project is a database of lexical units (a word and its meaning) and semantic frames. Although a linguistic resource, the semantic frames incorporate elements or descriptions of a word that encapsulates the flow of an interaction that can be computationally mapped into a sequence to represent narrative elements for interactive story telling.

Currently the English FrameNet project lists over 790 frames. For example, in the *Motion frame*, an entity (Theme) starts out in one place (Source) and ends up in some other place (Goal), having covered some space between the two (Path). Alternatively, the Area or Direction in which the Theme moves or the Distance of the movement may be mentioned.

FrameNet frames describe an interaction or scenario with representational elements. The actors, environment, physical descriptions and actions are defined. The circumstances, stimuli, spatiotemporal information and the event depicted are also identified. Emotions are referenced; these are important for plot deepening and fostering user involvement with the characters. Emotion intensifies the breadth and depth of user experiences in three-dimensional environments, thus making them more engrossing and effective medium [4].

The FrameNet lexical units however, do not include the dramatic template elements necessary for the effective translation of narrative for 3D environments. In this paper we describe the classic dramatic structure [3] [7] [2] as the overarching narrative template. This is illustrated by the top level row in Figure 1.

The dramatic situations described by Georges Polti [11] further provide a narrative perspective for interaction frames combined where appropriate, with the FrameNet lexical description. This results in a tightly constructed Interaction Frame that encapsulates, describes and guides the design, representation and translation of interactions for scenarios and scenario sequences in 3D environments.

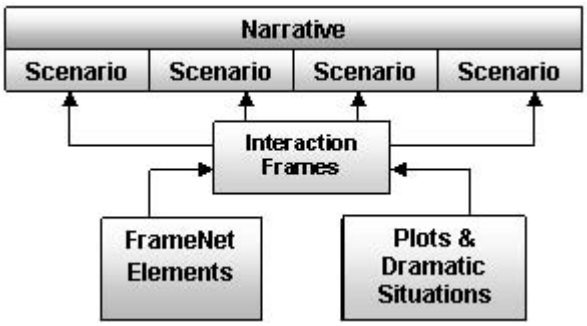

Figure 1: Interaction Frames overview.

2.2 Drama

The idea of a dramatic or narrative structure can be traced back at least as far as Aristotle's [1] division of drama into beginning, middle and end, including plot elements such as reversal of fortune, unexpected revelations and catastrophe.

In recent years, there has been consensus that plots, dramatic situations and stories can be reduced to sets of variables that conform to narrative templates. Murray [9] identifies the Homeric journey story, also called the "monomyth", as an archetype recognized across cultures that has found its way into 3D games.

Using the monomyth, Campbell [3] advances twelve stages of a Hero's Journey based on the idea that all story-telling, consciously or not can be understood in terms of this journey. Booker [2] concludes that there are a small number of narrative plots that are so fundamental to story telling that it is virtually impossible for any storyteller to entirely break away from them.

The Polti [11] dramatic situations were inspired by the eighteenth century Italian dramatist Carlo Gozzi. Polti claimed there are but thirty-six human emotions in life, and linking these to Gozzi's thirty-six dramatic situations gives valuable insight into human actions and interactions.

In the linear narrative of Odysseus' epic encounter with the Cyclops described in the next section, the dramatic situations described by Georges Polti are used to link FrameNet units to narrative units. The thirty-six dramatic situations have been chosen here, because they are concise yet provide rich examples that paint a dramatic structure for the interaction frames and the scenes played out; further, they tightly link to the lexical units.

Polti's situations however have limited use in the Intensive Care Unit (ICU) nurse training example also described in the next section. Stages of Campbell's journey are adapted in this example to provide a cohesive structure for the direction and sequence of the resulting narrative generated from user decisions. The two examples chosen are very different. The Odysseus narrative is, inherently, the hero's journey,

where drama is depicted at every turn. The purpose of the ICU sample narrative however is to demonstrate a possible outcome in a 3D learning environment for a trainee nurse to practice correct procedures in an ICU situation where someone may die. Although there is potential for strong emotions, ICU interactions in the main, relate to caring for the patient, checking life support equipment and responding to alerts. So that a narrative generated in this context makes sense and engages the user, the structure adapted from Campbell has been chosen.

Figure 1 illustrates the flow from lexical and narrative states to Interaction Frames, then to a sequence of scenarios structured by the journey story. In the next section, four Interaction Frame examples are presented to illustrate interactions in two examples.

3. INTERACTION FRAME EXAMPLES

This section demonstrates the representation of dramatic interaction for 3D environments using interaction frames drawn from FrameNet [10] and a narrative structure. Firstly, selected frames for the Homeric [6] story of Odysseus' capture and escape from Polyphemus the Cyclops are presented. This is followed by a sample interaction frame for the Intensive Care Unit nurse training application [12].

3.1 Odysseus and the Cyclops

The narrative is first presented as a textual description followed by a sequence of interaction frames.

> Odysseus and his crew are captives in the Cyclops' cave. Each morning the Cyclops takes his sheep to graze in nearby pastures, blocking the cave entrance with a large stone behind him. Each evening the Cyclops devours some of Odysseus' crew. They must escape to save their lives.
> If they kill the Cyclops they will be trapped in the cave, so Odysseus hatches a clever plan. That evening, when the Cyclops returned, Odysseus plied him with wine. When the Cyclops eventually fell into a drunken sleep. Odysseus and his crew quickly thrust a burning battering ram into the Cyclops' one terrible eye.
> The Cyclops raged and searched for Odysseus and his crew. Eventually he let out his sheep, determined to catch Odysseus and his crew attempting to escape. But Odysseus had tied himself and his crew under the sheep. They safely passed though the cave entrance making a clever escape.

The interactions from the treatment are divided into seven broad sample frames sourced from FrameNet. (a) **Abduct**, (b) **Devour**, (c) **Hatch**, (d) **Manipulate**, (e) **Attack**, (f) **Enrage** and (g) **Escape**. The three frames **Abduct**, **Hatch** and **Enrage** are discussed in detail in Tables 1, 2 and 3.

In this narrative, a user takes the role of Odysseus. Since this is a linear narrative, scenes are authored in linear sequence. Interactivity occurs within the context of each scenario. For example, in the "Hatch" scenario, the user as Odysseus, may need to pick up the wine and select a battering ram before the next scenario where the attack on the Cyclops is presented.

In Table 1 the left column contains the FrameNet frame element descriptors for the lexical unit *Abduct*. The right column depicts the frame elements interpreted for the sample scenario. The last two rows show Polti's tenth dramatic situation *Abduction*.

FrameNet	**Abduct**
Co-abductees	Odysseus' crew
Manner	Forcibly
Perpetrator	The Cyclops
Place	The cave of the Cyclops
Purpose	To taunt and devour Odysseus and his crew
Source	The ship of Odysseus
Victim	Odysseus
Polti	**[10] - Abduction**
Elements	The abductor, the abducted, the guardian

Table 1: Abduct Interaction Frame.

1. The **Co-abductees** are additional subjects taken with the Victim.
2. **Manner** is the manner in which the abduction takes place.
3. The **Perpetrator** is the person (or other agent) who carries off and holds the Victim against his or her will.
4. **Purpose** is what the Perpetrator hopes to accomplish by the abduction.
5. The **Source** is the initial location of the Victim before the abduction.
6. The **Victim** is the person who is carried off and held against his/her will.

The Abduction dramatic situation dictates that a victim, co-victims and perpetrator must be represented. Polti defines them as the abductor, the abducted and the guardian and discusses of the types of scenarios that typically represent a dramatic abduction. FrameNet further enriches the data by defining the manner and purpose of the abduction, and includes spatial data such as the original and destination locations.

In Table 2, the interaction frame *Hatch* is depicted.

1. The **Cognizer** is the person who comes up with or conceptualizes the Invention.
2. **Depictive** is the state of the focal participant during the time the Invention takes place.
3. The **Invention** is the intellectual creation of the Cognizer.
4. The **Means** is the act performed by the Cognizer that

FrameNet	Hatch
Cognizer	Odysseus
Depictive	Odysseus is thinking and planning
Invention	A clever plan
Means	Thought
Place	Inside the Cyclops' cave
Purpose	To safely escape
Result	A cunning plan
Polti	**[8] - Revolt**
Elements	A Tyrant and Conspirator.

Table 2: Hatch Interaction Frame.

contributes to the creation of the Invention.
5. The **Place** is the location where the Cognizer creates the Invention.
6. The **Purpose** is that which the Invention is intended.
7. The **Result** is the outcome.

Since the location of the scenarios has been made explicit in the first interaction frame, it can be left implicit until the location changes.

FrameNet	Enrage
Experiencer	The Cyclops
Circumstance	Blinded and wounded by Odysseus and his crew
Event	The Cyclops rages in pain and anger
Degree	Extreme
Expresser	The Cyclops stumbles blindly around waving his arms and roaring in pain
State	Anger and fear
Stimulus	Injuries suffered
Topic	Pain and blindness
Reason	The Cyclops has been tricked
Polti	**[6] Disaster**
Elements	A vanquished power, a victorious enemy or a messenger

Table 3: Enrage Interaction Frame.

Table 3 depicts the Interaction Frame *Enrage*.

1. The **Circumstance** is the condition(s) under which the Stimulus evokes its response.
2. The **Degree** is the degree to which the Experiencer is enraged.
3. The **Event** is the occasion that the Experiencer participates in a certain emotional State.
4. The **Experiencer** is the person or sentient entity that experiences or feels enraged.
5. The **Expresser** indicates a body part, gesture or other expression of the Experiencer that reflects his or her emotional State.
6. **State** describes a more lasting experience by the Experiencer.
7. **Stimulus** is the person, event, or state of affairs that evokes the emotional response in the Experiencer.
8. The **Topic** is the general subject about which the enragement occurs.
9. The **Reason** is the explanation for why the Stimulus evokes the emotional response.

3.2 Intensive Care Unit

Dramatic interactions for a 3D environment using interaction frames drawn from FrameNet and structured by the monomythic journey story are next presented. Example analyses of interactions from a scenario-based application for nurse training in an Intensive Care Unit [12] are described.

The user in this application takes the role of a novice or trainee nurse who receives explanations and prompts within the 3D interface as the scenarios unfold. The system responses are omitted because the intention of this analysis is to illustrate how interactions are identified, visualized and described in scenarios for a 3D implementation where the user drives the unfolding narrative.

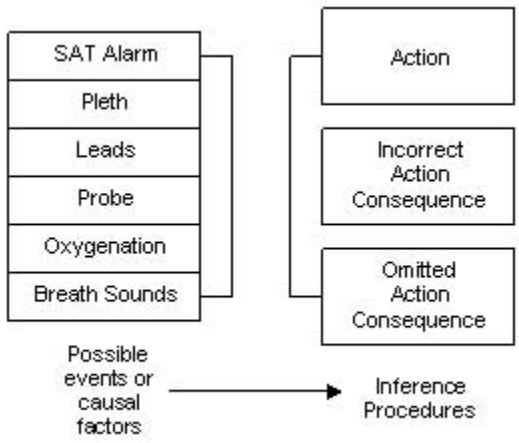

Figure 2: Adaptation of a partial ICU argument tree.

So that complex decision making that must be made under pressure in an ICU can be more easily understood and supported, narrative is integrated with reasoning. Figure 2 shows a data structure called an argument tree. Nodes on the left describe a set of possible events in an ICU setting. For example, a state can be depicted as one where the following events have occurred: the SAT alarm is sounding, the pleth wave is noisy, the leads are functional and the finger probe, blood gas oxygenation and breath sounds are un-

known. Three concepts are inferred from each state: *Action* in Figure 2 is the next action a nurse should take, *Incorrect Action Consequence* and *Omitted Action Consequence* in Figure 2 represents the consequence for the patient if the previous action performed by the nurse was incorrect. The three concepts are woven together to form narrative feedback for the trainee nurse. Further details can be found in [12].

A possible narrative is next presented to describe a sequence of decisions a trainee nurse may make, followed by a sample interaction frame.

> Rave a nurse, is caring for Jim, a 60 year old man admitted to the intensive care unit with acute respiratory failure, when the SAT alarm begins sounding. Rave checks the pleth wave and notices it is noisy. Rave immediately checks the breath sounds and hears a wheeze. However, this is not the best thing for her to do because it has diverted her attention from the real problem that she doesn't know the true oxygen level. As it happens Jim has taken a turn and has a very low oxygen level. Rave checks the endrotracheal tube but has not increased the oxygen intake to 100 percent. Jim has entered seizure due to the low oxygen and dies soon after.
> *Based on an original description by [12]*

The sample interactions resulting from the narrative can broadly be identified as (a) **Alert**, (b) **Inspect**, (c) **Distract**, and (d) **Injure**. **Alert** could be defined as the first Campbell template journey stage, *the call to adventure*, and **Inspect** as *crossing the threshold*. **Distract** and **Injure** can represent types of obstacles or challenges where, in the case of this example, the user was not victorious.

Frame	Alert
Perceiver	Rave
Figure	Change in patient's state
Circumstances	The SAT machine sounds an alarm indicating a change in the saturation and oxygenation of Jim's blood
Degree	Rave is increasingly attentive
Expressor	Rave is flustered by the alarm
Manner	Ineffectual

Table 4: Alert Interaction Frame.

In Table 4 the left column contains FrameNet element descriptors for the **Alert** frame. The right column depicts the frame elements instantiated for the sample scenario.

1. The **Perceiver** is Rave, who responds to the alarm.
2. The **Figure** is the patient Jim, who is the focus of the alert.
3. The **Circumstance** is the situation to which Rave is alerted.
4. The **Degree** is the level of Rave's alertness.
5. The **Expressor** is Rave's visible response to the alarm.
6. The **Manner** describes how Rave's response to the alarm is perceived.

Interaction frames facilitate the work of a designer by providing ready made templates to map a high level story or narrative into structures that are closer in abstraction to 3D development environments. In a linear narrative, a designer begins the task of transforming a narrative or scenario by identifying a sequence of frames from a library that capture the essence. In a narrative generated by a user's decisions, all possible user interactions in response to events in the environment must be predefined for potential inclusion.

A designer extracts those elements from interaction frames that are most relevant to capture the interactions at hand. For example, the FrameNet **Abduct** frame has many more elements than those depicted in Table 1. The designer modifies elements in each frame to accommodate the story. For example, the name of the Victim slot in the **Abduct** frame is instantiated to Odysseus. The Circumstance element in the **Alert** frame is set by default to the SAT machine alarm, so the designer checks that this is the appropriate circumstance for the Alert.

The storyline in the Cyclops story is fixed and linear in that the actions each actor takes is specified fully in advance by the author. In the ICU example, the nurse, at each state may select any available action such as listening to the breath sounds or increasing the oxygen. This leads to a large number of possible story lines. The way the possible storylines and the interaction frames are represented is discussed in the next section.

4. STORYLINES

As illustrated in Figure 1, a scenario is a fragment of a narrative comprised of a sequence of interaction frames. In a linear narrative each character's actions are fully defined in the story so the sequence of interaction frames can be fully specified in advance by the designer *author*. In an interactive narrative, the game player exercises a degree of control over one or more characters actions so the story unfolds differently as the game player selects different actions. In the ICU application, the trainee nurse is the game player and plays the role of the nurse in the game. At any point in time he or she can elect to perform one of twelve different actions such as obtaining a sputum specimen though only one is the correct action given the state of the patient and equipment. After an action is selected, the patient's state may change, the state of equipment may change and again the game player elects to perform any one of the actions though only one is correct.

The states and possible actions at each state have been represented using a decision tree [7]. A decision tree is a di-

rected graph where nodes represent decision points and arcs represent alternate decision choices. The representation of narrative using sequences of interaction frames is readily represented as a decision tree. The nodes of the tree describe states of the world summarized with a descriptor. The interaction frames available to the game player from a state are represented on the arcs emanating from the node. The root of the decision tree that represents a branching ICU story using interaction frames is the establishing scene depicting the patient, nurse and equipment. At that node there is only interaction frame possible, the **Alert** frame. The system is pre-set to assign the **Circumstance** slot in the frame to sounding a SAT Alarm. The node that represents the state of the world after this frame has been traversed is labelled the *Initial alarm state*. Arcs this node represent are the actions open to the game player, captured as interaction. The option of checking the pleth wave to find it accurate is represented with an instance of the **Inspect** frame on one arc. The option of checking the wave to find it inaccurate is on another arc. Each option leads to a different state descriptor.

The explicit representation of possible paths through an interactive narrative using a decision tree can be lead to very large trees. Large trees represent a combinatorial explosion of the problem space and associated difficulties in finding a solution if a problem is represented as a state space graph. However, the tree used here, best described as a state-interaction decision tree, though inevitably large does not pose a problem for a real time search algorithm because the tree is not required to be traversed at runtime. Rather, the tree provides a game designer a systematic way to ensure that all states arising from all possible interactions at each state have been accommodated.

Issues to do with the impact of the interaction frame on the creative process, the role of emotion, the sequencing of interaction frames to form scenes and the possible impact on 3D development environments such as game engines are discussed in the next section

5. DISCUSSION

For a tool to be helpful to designers it must not stifle creativity. Designing is an inherently creative exercise, so rigid constraints on the creative process are not useful. The interaction framework described is expected to enhance the creative process involved in transforming a narrative treatment into a 3D environment or game. Rather than constrain the creative process, the provision of an extensive library of interaction frames has the potential to provide a rich palette for the designer to select from and express design choices succinctly. Further, the inclusion of a dramatic situation entices a designer to consider the drama as it unfolds through each interaction. For instance, if a designer experiences difficulty in assigning a Polti dramatic situation to an interaction frame then there is every likelihood that the interaction is not advancing the narrative drama. Ultimately, the extent to which the interaction frame enhances or stifles creativity is an empirical question. Currently, research is in progress to design a study that will answer this question.

Three dimensional environments have not been applied extensively as interactive learning systems. The branching storyline game described by [7] is a notable exception where a US army officer in training to lead a group of soldiers in Afghanistan assumes the role of the Player Character (PC). The decisions the PC makes, changes the direction of the narrative resulting in a rich and dynamic learning environment. The interactive learning environment approach advanced by [12] provides feedback about the actions an intensive care unit nurse PC makes in responding to an alarm and generates a "Story so far" narrative. This is done with the use of a knowledge based system that draws inferences from a model of expert level nursing. Currently, research is in progress to use the interaction frame to describe interactions the PC can make in a manner that links directly into the knowledge base. This research is expected to demonstrate that the framework can facilitate the deployment of 3D environments for interactive learning.

Ultimately it is conceivable that 3D development environments such as game engines can be designed to automatically implement frame elements. For example, an emotion or affective engine just as sophisticated as current physics engines can conceivably read the emotional state of characters directly from the frame describing an interaction. All facial and body movements corresponding to the emotion nominated by the designer can be automatically created by the affective engine. A similar notion can be applied to more abstract elements. For instance, the element **Manner** in the **Abduct** frame describes the manner in which the **Perpetrator** abducts the **Victim**; violently, forcibly, perhaps respectfully. It is not inconceivable that routines that implement each of these are hard coded into a game engine so that the designer need only specify the degree of force in the abduction.

The representation of emotion in the interaction frame is very important as emotion is central to drama and the human experience. In FrameNet an entire hierarchy of frames exist to describe situations that incite emotion in one way or another. For example, the **Enrage** frame illustrated in Table 3 is a subclass frame of the **Emotion** frame. The element **State** in the **Enrage** frame is inherited from the parent **Emotion** frame to describe the emotional state associated with the **Experiencer**. Its value is set to **Anger or fear** for the **Enrage** frame though its value would be set differently for other frames that inherent from the **Emotion** frame. Accordingly there is no FrameNet element to depict emotion in the **Hatch** frame. Technically this is understandable because arguably the hatching of a plan is a relatively emotionless exercise. However the case for the introduction of an emotion element to all frames in the interaction frame advanced here is strong given the centrality of emotion to the realism of a 3D environment depicting narrative. After all, even an exercise as dry as planning may be hatched with excitement, desperation or even joy.

Authoring a 3D narrative using the interaction frames involves the steps described above; decomposing a narrative treatment into interaction frames, fine tuning and instantiating each frame to convey the essence of the treatment. Scenes are comprised of a group of one or more interaction frames though a frame may be left implicit. For instance the sequencing of the Odysseus frames in the example above

is set chronologically in story time as: **Abduct**, **Devour**, **Hatch**, **Manipulate**, **Attack**, **Enrage** and **Escape**. However, a designer may decide to resequence or to omit a frame from the 3D product, perhaps to speed the tempo or to enhance visual action. The inclusion of the frame in the design is important even if it is not included in the final work because the frame indicates the dramatic situation that would need to be conveyed by other frames. The Odysseus story could well start with the **Devour** frame leaving the **Abduct** frame implicit. Perhaps the **Hatch** frame can be omitted from the 3D product. However, the inclusion of all frames in the design adds to narrative completeness.

6. CONCLUSION

A scheme for representing the interactions between characters in a narrative has been advanced. The framework integrates FrameNet linguistic frames with dramatic situations advanced by Polti and references the monomythic narrative template. The Interaction framework can facilitate the application of 3D environments for narrative and interactive learning environments. Current research involves refining the framework, empirically evaluating the impact in the design process and its application in an interactive learning environment for intensive care unit nurses. Future research involves the development of game engine extensions to implement elements within the frames such as emotional states.

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