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Semantic Framework Promotes Interactive Puppetry Animation Production to Assist Storytelling Training

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The benefit of using virtual puppetry to assist narration in has been proved in current digital storytelling systems. When performing, these systems can provide players with multimode feedback and meaningful immersive learning experiences.

However, despite many years of research and effort, combining with complicated HCI and systematic integration procedure, the production of interactive virtual puppetry animation still remains one of the most labour-intensive and tedious tasks. Due to its inherent functional features, a lot of complex technical problems are involved in generation and various aspects of requirements have to be handled, from the HCI technologies to the efficient management of animation data assets. In this paper, a semantic framework is constructed to provide a clear understanding of VR based interactive animation production and promote its generation, which uses ontological methods for modelling the construction of animation generation at an abstract and semantic level. To facilitate animation generation process and improve its reusability and modularity, two domain-specific ontologies are further defined as the ontological implementation of the framework. And finally, a novel digital puppetry storytelling system is designed to assist young children's storytelling, in which hand-gesture-based interactive control and ontology-based intelligent animation data management is used as case study of the proposed semantic framework.

Keywords: semantic framework, ontology, digital storytelling, virtual puppet, interactive animation

1. INTRODUCTION

With the development of Human Computer Interaction (HCI) techniques, novel VR based interactive devices, such as touch screen, haptic device, head mounted device, motion sensor and tracking device, are involved in the system development, which provides us with more natural and intuitive interactions in virtual environments and new possibilities to explore the training aspects of storytelling by creating new ways of interaction. However, the generation of this kind of interactive digital storytelling system based on virtual avatar interaction is not easy. Despite advanced theories and techniques are developed to help promote generating animations, interactive animation production in this system is still a tedious work and can also be labor-intensive. Its inherent system complexity - having to handle various aspects of functional integration (*e.g.*, graphics, physics, artificial intelligence, engineering, multimodal inputs and outputs) – throw out challenges pushing current research to think: how to arrange the possible combinations of multiple function

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supporting discussed above?

Besides the difficulty of integrating various hardware and software, effective management of animation data used as assets in production process is another focal concern, which is expected to meet the different request of data access and reuse in an efficient and user-friendly way. With the phenomenal increase of multimode data (*e.g.* 2D picture, 3D model, motion file, audio and video clip) generated during animation production, efficient management, including structured data presentation and searching for particular information, becomes an arduous and frustrating work.

Semantic is used to describe things that deal with the meanings of words and sentences. As a branch of philosophy and also one core conception of semantic, ontology deals with the nature of existence, which is an explicit formal specification of a conceptualization [1]. Ontology can be used as an effective tool to represent and process system information and descripts entities at semantic level as well as their properties, relationships and constraints [2]. By providing a clear overall view and understanding, the leveraging of semantic and ontology in complex systematic analysis is becoming one appealing solution, which can capture. Using structured terminology, semantic and ontological analysis is competent to capture a problem's complexity with natural language descriptions [3, 4].

In this paper, a semantic framework is proposed to provide semantic architecture representation at a common abstract level for the purpose of promoting interactive animation production. Two domain-specific ontologies are developed based on the deliberated framework as the further ontological implementation: one labels Human Computer Interaction (HCI) design and another defines animation data assets management. Finally, based on the semantic framework and ontologies, a prototype of an intuitive hand-gesture-based interactive storytelling system is generated to assist children's ability of narration, which also provides guidance in virtual interactive animation generation, as shown in Fig. 1.

Fig. 1. Semantic reasoning and hand-gesture-based virtual interaction.

2. RELATEDWORK

There has been a significant growth of VR technologies over the past decade. To provide users with better immersive experience in virtual 3D environment, interaction interfaces such as head tracking, haptic device, motion detection and more immersive or intuitive technologies have been developed and utilized in various Virtual Reality (VR) application areas, such as pedagogical practices, simulation and training, virtual experiments, and game development [5].

Taken as one of the most powerful and instructive educational approaches, VR technologies are wildly used to provide a synthetic, highly interactive 3D environment, which allow students to experience virtual learning environments in a natural way [6, 7]. Taking

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advantages of these novel technologies, as a modern form of traditional storytelling, digital storytelling systems is becoming a popular and powerful teaching and learning tool, such as FaTe2 [8] and MyStoryMaker [9], in which 3D virtual environments are developed to enhance education.

However, to generate a coherent immersive user experience, the generation of interactive animation has to fulfil various aspects of functional demands from the HCI technologies (involving graphics, multimodal input/output, hardware/software *etc.*) [10]. And also, based on CG technologies, various kind of data assets are generated during digital animation production, which exist in wide variety of forms, such as text files, audio files, video files, texture files, graphic files, 3D model files, motion files, scene files, and many other types. Different from the conventional hand-drawn based animation, the efficient digital animation data management and data reusability has become a focal attention in the process of digitalized animation creation. For the creation process of the digital assets is slow and laborious, once generated, this data is imperative to be archived and retrieved in an intelligent manner for the purpose of being easily retrieved and reused [11].

Both the combination of the multimode functional features and the efficient animation data assets management are been a hot research area of interactive animation generation for several years.

To solve complex problems, the concepts of semantic and ontological analysis are proposed using standardized and structured terminology. These concepts can be utilized to define the core logic of complex systems through high-class descriptions, and could concisely map requirements, and facilitate system design [12].

Ontology, as a significant means and practical application for settling matters in the field of information science and technology, offers a glossary of defined terms and constraints required for different applications [13]. Semantic and ontological analysis supplies a method to deconstruct complex system architectures for analysis and system design.

In recent years, the concept of ontology as a high-level conceptual specification has turn into increasingly significant in the field of computer animation, such as semantic 3D content representation [14-16] and ontology-based 3D model retrieval [17, 18].

In the devise and exploit transversion of multifarious VR applications, there are some semantic-based or ontology-based study work. In Wiebusch's work, the foundation for modeling the semantic requirements of intelligent real-time interactive systems is the ontology [19]. Pellens *et al.* have exploited BehaviorOntology that can accelerate integration and strengthen the interoperability of VR applications, a modeling concept that defines the behavior of targets in virtual circumstances [20]. In a research by Irawatiet [21], a framework for 3D election and operation that supplies some fundamental election and operation techniques for interactive assignments in virtual circumstances is pictured. In order to settle the ambiguity caused by user orders, an Aspartial ontology that can picture the spatial relationship between objects is developed NiMMiT (Representation for Multimodal Interaction Technology) is a graph that uses semantic symbols to describe the concept of multimodal interaction [22].

3. SEMANTIC FRAMEWORK FOR INTERACTIVE ANIMATION GENERATION

As a formal semantic foundation for describing VR-based interactive animation gene-

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ration, a three-layer semantic framework using ontology knowledge is proposed as shown in Fig. 2. This semantic framework specifies the construction of interactive game/animation synthesis and promote system integration in a systematic and standardized way. The framework is flexible enough to recover and to improve on the previously introduced interactive animation synthesis and animation assets management.

The Interactive Animation Generation Semantic Framework (IAGSF) is an integrated system stack using semantic technologies for knowledge management. It has a layered architecture that combines abstract knowledge with application components developed specifically to provide a clear and overview systematic framework. IAGSF is a platform-independent semantic framework for exposing interactive animation generation procedure and accessing structured animation data, semi-structured animation data, and unstructured animation data using ontologies to reconcile semantic heterogeneities within the VR-based animation production.

The architecture of IAGSF is built around a central layer of domain knowledge, designed to enable most constituent modules within the stack to be substituted without major adverse impacts on the entire stack. A central organizing perspective of IAGSF is that of the domain knowledge. This domain layer contains two or more domain ontologies, which is the instance of the given IAGSF to define the structural relationships amongst the abstract layer and the generation layer. The OWL 2 ontology language is used to describe domain-specific ontologies defined by formalizing the multimodal interaction and animation data repository management as the ontological implementation.

Designed of interactive animation at a higher level of abstraction IAGSF delegates functional and natural description for the analysis with larger granularity. In the case of interactive puppetry animation based digital storytelling system, this integration is tighter and supports connectors and modules, which mainly focus on two key components: HCI and Data Repository instead of including all the involved techniques, *e.g.* the game plot/story, application developing or system integration.

HCI and animated data asset repositories are the most significant sides of production,

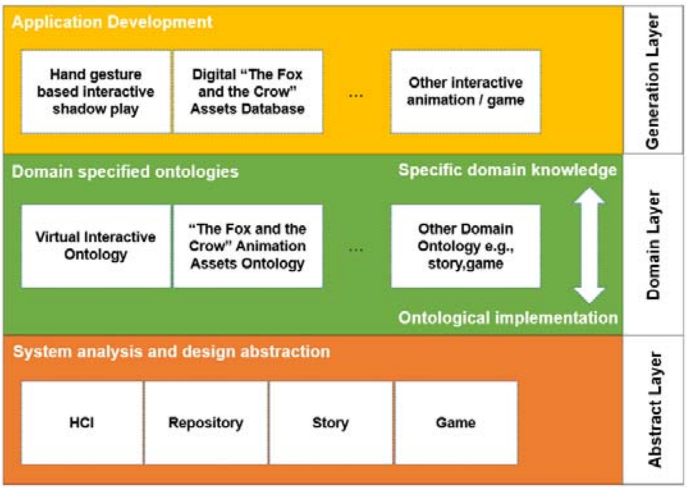

Fig. 2. Architecture of semantic framework for interactive animation generation.

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as are the two components of abstract concepts generated by interactive animation. Conceptual design for interactive animation generation in multifarious application areas will also benefit from these two components. A higher semantic frame is characteristic of this framework. The semantic framework is constructed at a high level of abstraction and can be simply applied to various VR applications for different purposes.

Here is a discussion of the details of the Abstract Layer. At the domain layer, as the ontological implementation of the semantic framework, the domain-specific ontologies will be further defined and provide certain domain knowledge for the following application development. And then, using the predefined ontologies as guidance, animation product or game could be finally developed as described at the generation layer.

In Section 4, we will discuss its implementation based on the development of two domain-specific ontology (mapped to the domain layer), and in Section 5 we will discuss how to use this architecture to generate interactive digital puppetry storytelling animation (mapped to the Generation Layer).

4. DOMAIN-SPECIFIC ONTOLOGIES

Domain ontology (or domain-specific ontology) represents concepts which belong to a part of the world. In this section, as the ontological implementation of the Abstract Layer proposed above, two domain-specific ontologies are developed targeting to the Domain Layer of the proposed semantic framework. Each domain ontology typically models domain-specific definitions of terms: Virtual Interactive Ontology (VIO) mapped to the HCI Component of the Abstract Layer, and Digital Puppetry Storytelling Assets Ontology (DPSAO) mapped to the Repository Component. These two ontologies are realized using the Web Ontology Language (OWL) together with the ontology editor and knowledge framework-Protégé.

4.1 Virtual Interactive Ontology (VIO)

Since domain ontologies are written by different people, they represent concepts in very specific and unique ways. In this research, as interactive animation systems that relies on domain ontologies expand, it needs to customized domain ontologies by hand-tuning each entity.

Fig. 3 (a) shows part of VIO. Below the root "owl: Thing" of each OWL ontology, it consists of three non-intersect classes: "Human", "Device" and "Method". In Fig. 3 (a), each class includes different subclasses as ancestors; as descendants, each of these subclasses contains individuals who are assigned concepts (classes and attributes) assigned to features in the ontology. The design purpose of the object attributes will be introduced in detail in Section 5.1. The purpose is to provide the basic relationship function of the ontology by interconnecting the classes in the individual. As shown in Fig. 3 (b), as an example of use, the gesture-based interaction concept is described as a three-level hierarchy. The lower layer displays motion tracking data including frame information, a list of consisted of hands and fingers. This data is accessed from the Leap Motion sensor controller. At the intermediate level, simple gestures are defined by calculating the speed of movement of the hand, the angle of movement, and the orientation angle acquired from the movement data. At the top level, we can exploit more sophisticated gestures consisted of simple hand gestures.

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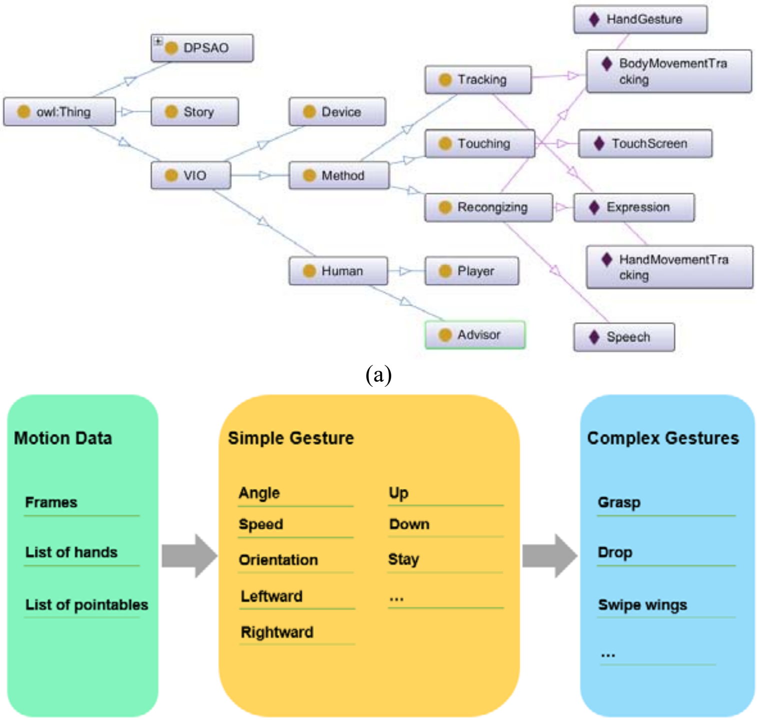

(b)

Fig. 3. Virtual interactive ontology.

4.2 Digital Puppetry Storytelling Assets Ontology (DPSAO)

The top half of Fig. 4 shows the class hierarchy of the Digital Puppetry Storytelling Assets Ontology (DPSAO) defined to map to the Repository Component, which consists of five classes: "Music", "Role", "Other_Character", "Prop" and "Scene". As is the case in VIO, each of these five classes has its subclasses and subclass has its superclass, instances and properties as well.

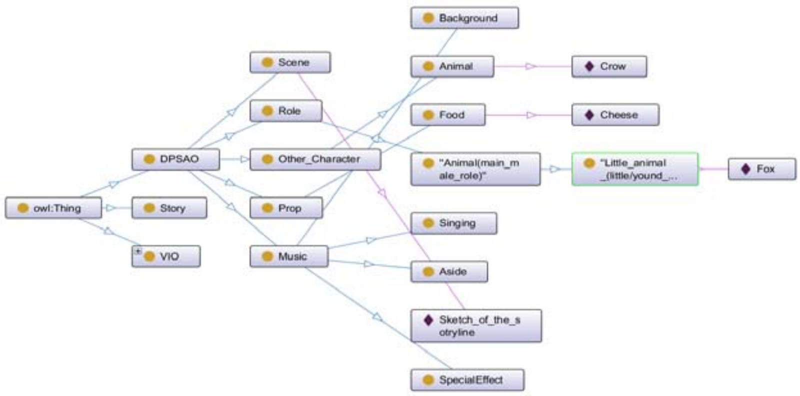

Fig. 4. Digital puppetry storytelling assets ontology (DPSAO).

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5. GENERATION OF INTERACTIVE DIGITAL PUPPETRY STORYTELLING SYSTEM

As the implementation of the Generation Layer in the framework, in section, a prototype of a digital puppetry storytelling system based on intuitive hand gesture interaction is designed and demonstrates how the proposed semantic framework and developed ontologies can be employed to fertilize the design of interactive animation generation. The Generation Layer represents the major HCI workflow requirements and animation data assets management.

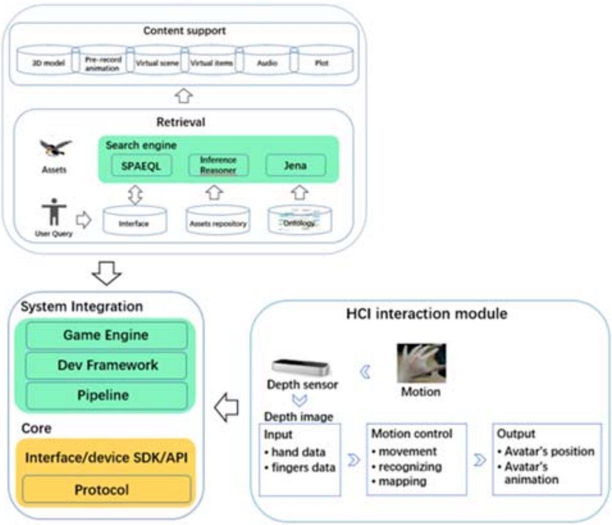

Fig. 5. Prototype architecture.

Fig. 5 gives an overview of the prototype backbone. As mentioned previously, in this paper, we mainly focus on two modules: HCI and Animation Data Assets Support.

Assets Repository is a mixed-type animation database developed for digital puppetry storytelling system based on domain specified knowledge. Fig. 6 shows a usage example of the Assets Repository. As introduced previously, "*Fox*" is a famous character Aesop's story named "Master Reynard", who is an instance of "*Little animal*" (a subclass of "*Animal*"). Through the object property "*has Prop of*", "*Fox*" and his desired food, "*Cheese*"- the instance of subclass "*Food*" which is the subclass of "*Prop*", are connected. Similarly, other animation contents belong to various classes are connected with each other as well by object properties among them. For example, a particular instance "*Sketch of the storyline*" of the class "*Scene*" is assigned to "*Fox*" and "*Crow*", as they are two significant roles in the classic Aesop's story "*the Fox and the Crow*".

Leap Motion sensor device can use infrared depth sensor to provide high fidelity tracking. We use it to track hand movements / gestures [23]. Hands and fingers motion data can be accessed by using the Leap Motion SDK. Through motion tracking and recognition, map the player's relative hand position and gestures to the movement of a digital shadow play in a virtual environment.

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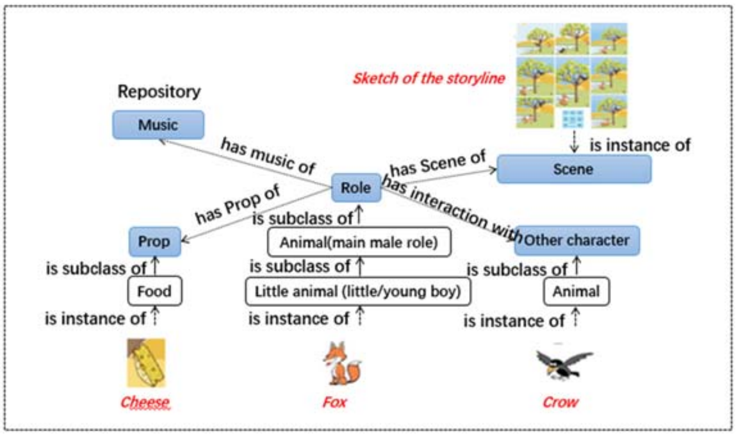

Fig. 6. Usage example of the defined DPSAO.

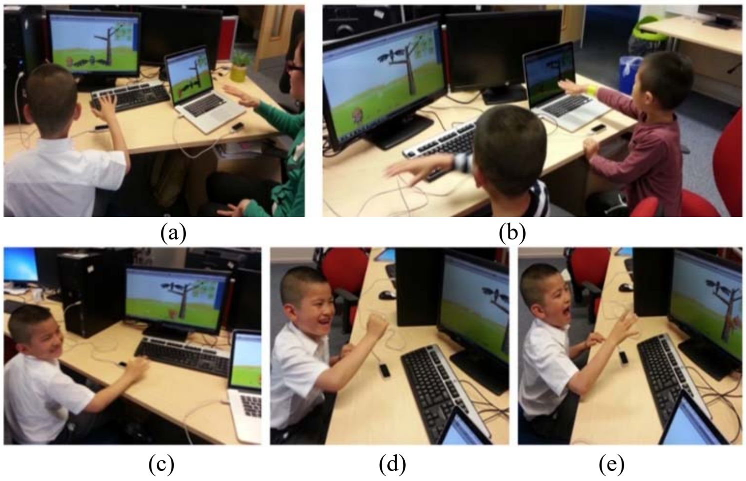
Fig. 7. Scenario of digital puppetry storytelling performed by an 8-year old boy.

Considering the popularity of among young children and its positive pedagogical meaning, we chose Aesop's story "the Fox and the Crow" to implement and to provide children an exciting and educational interactive storytelling experience with our proposed framework. As shown in Fig. 7 (a), one young boy was controlling the puppetry fox, and on the right, an adult was manipulating the puppetry crow to assist the narration as a tutor. A scenario performed by two children corporately is shown in Fig. 7 (b). Figs. 7 (c)-(e) indicates how excited the young player was when performing storytelling through this novel interaction.

The performance of each story point involves a set of hand gestures, which can only be successfully performed by specific hand movement and touch off puppets' related actions. Then the pre-defined animations associated with puppets' particular actions can be successfully triggered.

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6. CONCLUSION

We have created a semantic framework to answer the challenges exist in interactive animation generation using semantic and oncological analysis. We have demonstrated the utility of this framework constructed on an abstract high-level in specific examples of hand-gesture-based interactive animation production. To provide a systematic and standardized semantic description, two domain specified ontologies have been developed as the implementation of the framework, which formalize the multimodal interaction method and the construction of the animation data assets repository. Finally, we propose further developments of this work. A novel intuitive HCI based interactive animation is created in the context of digital puppetry storytelling to assist children's narration, which combines several complex functional features like hand gesture motion control and ontological digital assets management.

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