HyperReal: A Hypermedia Model for Mixed Reality

Luis Romero, Nuno Correia
Interactive Multimedia Group
Computer Science Department, New University of Lisbon
Quinta da Torre, 2825 Monte da Caparica, Portugal
+351 212948536

{lmcr, nmc}@di.fct.unl.pt

ABSTRACT

This paper describes a generic hypermedia model that is used as a framework for building context aware and mixed reality applications. It can handle different media elements, and it defines a presentation scheme that abstracts several relevant navigation concepts, including link awareness. The model specifies a base structure for the relation between spaces, either real or virtual, and supports contextual mechanisms. Additionally, it establishes a way to correlate real/virtual world objects with information present in the hypermedia graph. It also includes store/replay mechanisms that can be used to repurpose the content in new ways, including storytelling applications. The proposed model is being tested in a gaming and storytelling environment that integrates the real world, media elements and virtual 3D worlds. The paper presents the overall framework, the current implementation and evaluates its usage in the prototype application.

Categories and Subject Descriptors

H.5.4 [**Information Interfaces and Presentation**]: Hypertext/Hypermedia – *architectures, navigation, theory;* H.5.4 [**Information Interfaces and Presentation**]: Multimedia Information Systems– *artificial, augmented, and virtual realities, hypertext navigation and maps, video*.

General Terms

Design, Experimentation, Human Factors, Languages, Theory.

Keywords

Hypermedia model; Hypermedia Interfaces; History; Mixed and Augmented Reality; Mobile Gaming and Storytelling.

1. INTRODUCTION

Interactive experiences, where the real world is augmented with computing devices are becoming more common, given the recent trends towards mobility and the new computing and networking paradigms. Hypermedia mechanisms play a central role in most of the existing interactive systems. Even if there is not an explicit model, some mechanisms are always present, in systems that range from technical manuals to recent approaches for delivering multimedia information to mobile terminals. As computing integrates seamlessly into everyday lives, new models and paradigms are required. The introduction of new devices and media types and the integration of the physical space in the application design, taking location and user preferences into account, leads to the need of new ways to structure information. New approaches should take advantage of the tools that were developed previously while integrating the new paradigms. Hypermedia provides powerful mechanisms for structuring and navigating large quantities of information. As this information is presented in different physical and virtual locations, using multiple media, hypermedia models should take this into account. An additional advantage of hypermedia is the fact that it provides an appropriate mechanism for storing the users actions using history/path mechanisms. We are interested in later repurposing these materials for storytelling applications. This allows saving the user experiences, along with the media that was navigated and later replaying it or integrating it in other applications. This mechanism is more relevant when navigating large amounts of heterogeneous information in the real world. Storing this interaction and later replay enables virtual explorations of physical spaces. The work described in this paper is a hypermedia model, implemented as a set of classes, that provide building blocks for mixed reality applications. The proposed model integrates previous work in this area, starting with the well-established Dexter Reference Model. Additional proposals for integrating time-based media, adaptive and spatial hypermedia were also considered and described in more detail in Section 4. The main features that distinguish our model from past approaches are the following:

- Integration in the same framework of virtual documents, 3D environments and the physical world for building mixed reality applications
- Real world entities (e.g., a building or a art piece in a gallery) can be represented as a node in the hypermedia network, allowing hypermedia navigation and history/path mechanisms to be applied also to the real world.
- Space and time representation are integrated in the model. The representation of virtual and physical spaces is also integrated in the model, allowing to model relations between different media elements that are placed in space.
- The mechanisms for replay allow reuse and repurpose of the existing materials, allowing to create new applications, e.g. storytelling, that combine media elements, the user

experience and additional elements that are added at a later time

- Link awareness mechanisms provide a way to represent navigational information. In mixed reality environments, it is particularly important to have these mechanisms at the model level, given the dynamic nature of link representation.

The paper is structured as follows: next section presents related approaches, both in the hypermedia domain and in the mobile, augmented, and virtual domains. Section 3 includes a description of the underlying information model, which is used to structure information in the different environments that are considered. Next, the session and instantiation mechanisms are described. The adopted presentation scheme is discussed along with its application to link representation. The process for delivering contextual information is also described. The following section describes applications that apply the proposed model. The last section presents some preliminary conclusions and directions for further work.

2. RELATED WORK

Many hypermedia systems have been developed during the past years. Early systems include Intermedia [24], HAM [9], and NoteCards [18], to mention a few. In 1990 a group of researchers and developers agreed on a common reference model for hypermedia systems, the "Dexter model" [19]. The Dexter model describes an architecture that is more powerful in some areas than any hypermedia system that exists today. Still some newer proposals for models like the "Tower model" [13] and OOHDM [28] were proposed, and further developments were made based on the Dexter model such as DHM [16] and AHM [20]. "However, the Dexter model remains by far the most widely used reference model, which is still suited for modeling most kinds of hypermedia applications" [12].

The browsing capabilities of hypertext and hypermedia systems created a number of relevant topics in aiding the users navigation and perception of media content. Fluid links techniques [34], path mechanisms [33], construction and perception of context [10], and user orientation using adaptive techniques [7,12], are issues that emerged from those concerns and influenced the work described in this paper.

The past decade has seen a steady increase in research efforts in the area of context-aware applications, and in the special case of location-aware applications [14]. The CYBERGUIDE system was one of the first systems that used location aware information to help tourists [23]. In REAL [3] a hybrid navigation system is developed that relies on different technologies to determine the user's location and that adapts the presentation of route directions to the limited technical resources of the output device and the cognitive resources of the user. The GUIDE-system is a location aware multimedia tourist guide for the City of Lancaster [11] that tailors context and personal preferences. HIPS [25] incorporate more powerful mobile devices (sub-notebooks), which allow for the playback of much better animations and sound files at the cost of additional weight. A survey of context-aware applications is given in [22].

From the moment time-based media data is manipulated the need to control and synchronize the different media over time must be addressed. Early research in this field was done based on the Dexter model with the AHM [20] model. Very interesting aesthetic and narrative properties were presented in HyperCafe [27]. A brief discussion of combining temporal aspects of multimedia presentations with hypertext links can be found in [21].

Augmented reality is a topic that has been an important research issue for the past decade. The rapid development of computing systems allowed more sophisticated interfaces to be deployed, particularly the combination of aligned real and virtual objects in a real environment that runs interactively. An extended survey on this topic can be found in [1], and recent advances in [2]. The combination of real and virtual environments resulted in a new concept commonly known as mixed reality. A few approaches can be found in [30]. Seamless transition between reality and virtual worlds [5] is a very recent topic.

Analysis of spatial hypermedia towards collaborative work [17], and overlay of different information layers over real worlds [31], to mention a few, have been researched recently to provide for multi contextual information in space. Transformation relations of different space representations are under research in the Equator project [29].

Games are a great motivating force [8], in work and education environments. The "Pirates!" [6] main goal was to transform the real world into a multiplayer game board. This objective was achieved by marking the real world with proximity sensors that were able to detect game components and interactions between players. The "ARQuake" [32] is one of the first games to be played in an augmented reality environment where space was previously modeled for registration purposes. The "Equator project" [15] has also done some outdoor and collaborative gamming experiences in mixed reality settings.

3. INFORMATION MODEL

This section presents structuring mechanisms to model information items and the relations among them. It provides a flexible access mechanism to combine entities present in physical/virtual spaces with related information in a hypermedia graph. The model features context-aware mechanisms, which implies a spatial structure definition with position capabilities, not only for location purposes but also to offer navigational possibilities. It also deals with different types of temporal and non-temporal media data.

3.1 Dexter Hypertext Reference Model

To represent the information associated with the entities (e.g. buildings, spaces, paintings or other pieces of art), an object-oriented framework based on the Dexter Hypertext Reference Model [19] is used. In accordance with the original proposal the model consists of three layers: Runtime, Storage, and Within Component, as shown in Figure 1.

The Runtime layer manages data representation to a client. The Storage layer defines a structure to deal with relations between media data. The Within Component layer contains the media data and applications to manipulate it. The Storage layer represents the database organization associated with the hypermedia system. The basic object class provided in the Storage layer is the *Component* which includes three main subclasses; *Atomic*, *Link*, and *Composite*. The *Atomic* component represents a basic data object, either a media type or an abstraction of an entity (e.g. a space or object). The *Composite* component provides a hierarchical structuring mechanism, by including other components on it. The *Link* component, which establishes relations between components, includes a list of specifiers, each including a component and anchor identifiers, and a direction. Anchors provide an interface between the Storage layer and the Within-Component layer, and have identifiers internal to the component, and values to reference data media portions.

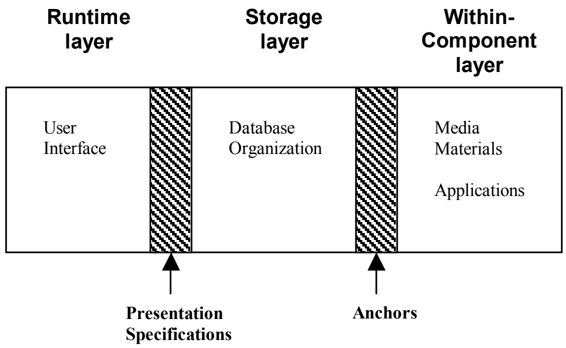

Figure 1. Hypermedia model layers

3.2 HyperReal Data Model

In the proposed model the information data is mainly represented by *Atomic* components. For each media type a subclass of *Atomic* component is defined to cope with specific properties and behavior fields. These include the classes *Text*, *Image*, *Audio*, *Video*, *3D*, and *Map*. The first four classes hold the basic data types, associated with different anchoring mechanisms (see next paragraph). The *3D* class contains 3D descriptions of objects and the *Map* class represents spaces, either as 2D or 3D models. For each class, there are specific fields not only to distinguish the different representation of each data type (e.g., images can have different formats such as jpeg, gif, or tiff) but also to include characteristics directly associated with a data type (length of Text or resolution of Image and Video).

Every component has a general-purpose anchor specification that references global component content. Besides this anchor type, each data type class has its own anchoring mechanisms that behave in accordance to the manipulated data type and are derived from the general-purpose anchor class. For instance, a Text anchor is a one-dimensional subset of characters, an Image anchor defines a spatial area, an Audio anchor is a time interval, and so forth.

It is impossible to specify every existing data type. This yields the need to define a class to embrace the representation of any kind of data type. Although not directly manipulated, its presentation in an interface is possible through a third party application. For such purpose the *Application* class, an *Atomic* subclass, represents media data of any kind that can only be presented (or manipulated) by a specific application.

For semantic purposes, all components have a list of pair's attribute/value that define characteristics or user preferences. This enables features like context searching and user adaptive filtering described in Section 4.3.

3.3 Space and Location

In a location aware application, the space representation has a considerable importance. Space determines the location process, hold the points of interest, and the representation of space in itself can contain semantic information. Spaces can be considered in several perspectives [29], either to represent physical dimensions or to represent semantic content. The first involves the relations between dimensions, say, an outdoor view, with surrounding streets and buildings, and an indoor view, of a particular building, where focus shifts to rooms, halls, corridors and floors, and a relation exists between the two (the indoor is contained in the outdoor). The other is related to semantic information contained in the space. For example, a 2D blueprint is an adequate form to display street information and may have some semantic representation attached to it (e.g., Library buildings in the Campus). On the other hand, a 3D model is a more suitable format to display architectural information and can still have some kind of highlight to enhance aesthetic characteristics. In both situations spaces can contain points of interest (objects or buildings), which strongly depend, not only on the physical space, but also on the semantics coupled with the space representation.

The model represents spaces of any kind in *Map* components. To deal with the different relations, described above, the model considers an underlying structure in representing spaces. Spaces are assumed to have levels (space sub-representation) and themes (contextual representation). To represent both, a *Link* subclass *SpaceRelation* defines the relations by using the directional characteristics of links. Children/parent directionality denotes space sub-representation (e.g., the library blueprint of the campus). Bi-directionality denotes level equality or themes with different representations (1st floor and 2nd floor blueprint, or 2D and 3D representation). *SpaceRelation* links are directly associated with *Map* components, where the geographical data is represented. The use of links, instaed of *Composite* components, to represent space relations allows an easy navigation between different levels and/or representations. To assure correspondence between relations, *Map* and *SpaceRelation* components have fields to define the represented area in space.

Themes define types of geographical data used in particular contexts, where semantic assumptions must be taken into consideration. This semantics accounts for several contextual space representations. For instance, a physical space can be represented in several ways, that is, as a 2D blueprint or as a 3D model. Here the themes correspond to different space representations with relations between them.

Points of interest (e.g., art objects in a gallery) are positioned within spaces through the *Link* subclass *Position*. It uses anchors to reference its location in a *Map* component, and follows the same mechanisms used in the other *Atomic* components, either 2D or 3D. It also contains a Universal Reference to allow correspondence between spaces. The Universal Reference must be viewed as a way to spatially correlate different levels of space and may involve geometrical transformations. Although virtual spaces do not have physical positions in the real world, a way to establish correlation must exist in order to relate with derived entities or define different themes of the same space.

3.4 Context Representation

Although space is a main concern in location aware application, which by itself defines a context, several other user concerns prevail when retrieving information. Users are interested in buildings or other objects and can have preferences that are used to filter and structure the information accordingly. These points of interest define which parts of the information system should be accessed and are directly related with the system knowledge about the environment. When the system detects objects that capture the users attention, it uses this knowledge to access the relevant (and filtered) data. The system containing the information needs to reflect the described nature of a location aware application. This is accomplished through the notion of access portals through which the information is retrieved. Each location or object is associated to a particular access portal that contains the necessary links to the related information.

The objects can be either physical or virtual, where they are just an abstraction of presence. Going further, the access portal actually represents any kind of entity that leads to contextual access to the information to be retrieved.

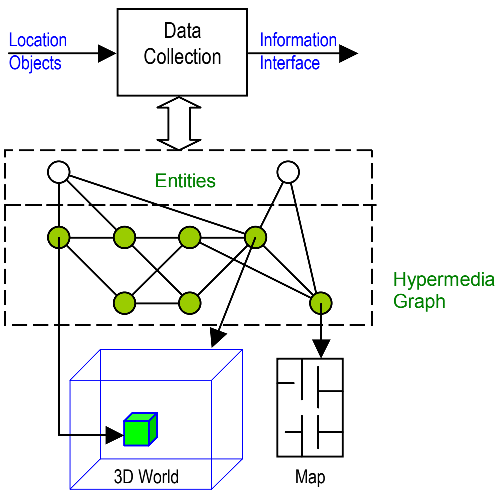

Figure 2. Context representation

The access portals are defined in the model by *Entity* components, an *Atomic* component subclass, that contains the relevant links to access information. The *Entity* component establishes the relation between the real/virtual spaces, with the virtual or real entities within it, and the informational system. For instance in a gallery that exhibits art pieces, the *Entity* components provides access portals to abstract elements such as the gallery space, each art piece, the thematic room, and others.

The *Entity* components have relations among them as the entity space relates with other entities contained within it. In the gallery example, the thematic room entity has art pieces in exhibition, which are entities on their own. Each of the art pieces entities may have a related 3D world, which consequently have other entities within, related or not to the art pieces, and so forth.

This feature defines a first level adaptive process in a location aware application. It consists mainly in adapting the system to possible user interests within a space.

4. SESSIONS AND INSTANTIATIONS

The Runtime layer is responsible for handling links, anchors, and components at run-time. Object classes in the runtime layer include (1) *sessions*, to manage the interface with the hypermedia graph, operation modes, described later in the paper (Section 4.3), and user preferences; and (2) *instantiations*, to manage presentation and interaction with components. The interface between the Storage layer and the Runtime layer includes *Presentation Specifications*, which determine how components are presented at runtime [19], [16].

The following sections focus on three main aspects of the runtime layer, namely: the Presentation Scheme, the Contextual Process, and the History mechanism specification. In a mixed reality environment the presentation scheme is a key to accomplish a variety of possible interfaces. The contextual process is supported by the information described in Section 3.4 and enables selection of the content based on semantic criteria. The history features a playback mechanism and a flexible method to allow different histories to be mixed for repurposing and building new content.

4.1 Presentation Scheme

Many different approaches are adopted in presenting media and navigation to users. From static arrangements of data with simple navigational aids to a more dynamic and fluid interface based on film aesthetics [27], the possibilities are innumerous. An augmented reality environment extends those concepts by introducing the real world as a user interface element. This yields the need for the interface to adapt its content and opportunities to the user's real experience, bringing new considerations into the interface aesthetic dynamics.

The aim is to allow dynamic characteristics, common in augmented reality interfaces, into the interface construction and presentation and permit a structured mechanism in its conception. The presentation space must be managed dynamically through a flexible scheme that allows the position and dimension of spatial containers to change over time. Each container has its own behavior defined by spatial and temporal attributes. A container can include other containers or content to be presented, each having its own independent behavior but relative to the parent container. The container has attributes for screen layout features (such as background color or transparency), specifies position and dimension relative to its parent container, and time behavior specifications for both. This model leads to a tree structure where leaves represent content and intermediate nodes form the interface container hierarchy.

In the hypermedia system, the tree-structured interfaces are specified by *Composite* components. The implicit definition of *Composite* components offers the perfect platform to represent this design concept, by allowing any *Composite* to contain one or more components. The *Composite* component's *Presentation Specification* provides the platform to simulate necessary spatial dynamic behavior. The content is represented by *Atomic* components, as described in the Data Model (Section 3.2). The same content can occur in several interface containers, represented by *Composites*, so it is not viable to use their *Presentation Specification* attributes to model the spatial behavior. Instead, the contents are linked to its parent containers, and the link itself defines the spatial behavior of the content within the *Composite*. This kind of linking is accomplished with the *Content* component, a *Link* subclass. It references the media data and it specifies the spatial behavior within the container. The *Atomic* component *Presentation Specification* attributes are only used to calculate the needed transformation for the content to be presented according to the *Presentation Specification* defined in the *Content* link.

Presentation Specification attributes play an important role in this scheme. In both *Composite* and *Content* components it establishes the timed region to be used relative respectively to its parent and its origin. Three main sets of attributes define the *Presentation Specification* for any component: spatial transformation; temporal pattern; and animation. Spatial transformation specifies the static (or starting) position, dimension and orientation within a container. The time pattern specifies actions on media content, using a list of pairs of action/duration values. The action defines the operation to be performed on a object that is presented, and duration stipulates how long that action will hold before the next one on the list is performed. The animation accounts for motion characteristics of objects. It uses a list of time keys, each with a spatial transformation associated. The animation is accomplished through well-established interpolation methods that are common in computer graphics animation.

4.2 Link Awareness

The navigational link have special requirements to represent concepts of link awareness, following, prediction, and opportunity. Awareness involves the link representation in such a way that the user notices its existence. The following property indicates if the link is about to be followed, e.g., using animation or audio cues. Prediction gives users an idea to what the links stands for. Opportunity defines temporal behavior of the link and temporal existence of the same link. These features are represented with exactly the same mechanisms as the ones used for presenting content, within containers.

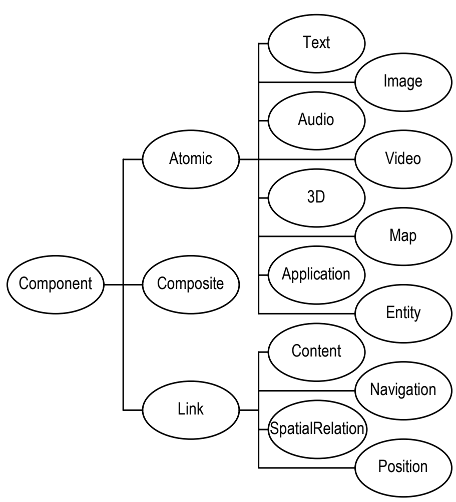

Figure 3. Class structure

To handle the above requirements, navigational links are represented in the hypermedia model by a special Link subclass, the *Navigation* component. Its *Presentation Specification* only defines the regions susceptible of navigational selections. These regions have the same behaviors of the content regions but are not visually represented. The link representation is obtained by linking its content, using *Content* links, to the *Navigation* link itself, with exactly the same possibilities as in the presentation scheme. To allow different representations to be associated with the link, it has at least two special anchor IDs to represent possible link states, such as selected or unselected. To each anchor ID is associated a *Content* link that defines the link representation for both states. Because the *Navigation* link uses *Content* links to represent its existence and state in an interface, it inherits all the associated dynamic characteristics of content representation.

4.3 Contextual Modes

Context aware applications deal with system adaptation to events happening in the surrounding environment [11]. Whether the user moves or a state is changed the system adapts itself and responds accordingly. Knowing the user preferences or experience helps the system to have an adaptive response [12] to the surrounding events. If a user has already obtained information about a particular entity, perhaps she does not want to repeat the process. Knowing the user interests leads the system to filter irrelevant information and present only data that is relevant. For instance, in an outdoor environment, if a user wants to know which museums are near, the system should retrieve only the information about that theme. These concepts are the basic requirements for an application based in an augmented reality environment. The system needs not only to respond to detected objects or entities, but also to make the presented information dependent on the user past experiences and preferences.

It is clear that a context aware application is an event driven process. The events result from the detection process, as the user acts in space. Each event may lead to a new context or destroy an existing one, depending on its meaning. In a museum, when a user enters the American Art (AA) room, an event is created (AA room entered) that leads to a context, the American Art context. But when the user leaves the same room another event is created (AA room left) a context is destroyed as it disappears from the user's point of view.

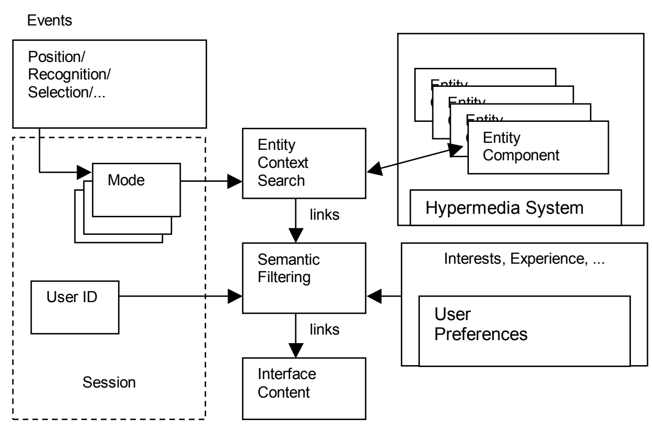

Figure 4. Contextual process

As described, the *Entity* components present in the hypermedia system aim to establish a relation between the world and the information system. To cope with contextual behavior, the session object includes the concept of *context modes*. Each mode defines a context to access the hypermedia data adaptively. These modes are triggered (or destroyed) by events, such as enter a room, recognize an object, or responses to user selections. Each mode references an *Entity* component in the hypermedia system. Each *Entity* component has a set of *Navigation* links, coupled with semantic attributes, to access relevant information to the activated context mode. Only one mode is activated at a given moment even if a given location can create more than one event and consequently several modes. This scheme forms the base for the contextual adaptation of the model.

Although the proposed hypermedia model does not intend to provide adaptive methods [7,12], it offers mechanisms where such a sub-system could be plugged in. As described, every component has a list of semantic attributes (defined as Attribute/Value pairs). These semantic attributes together with definitions of user experience and preferences, allows adaptive methods to be implemented for additional contextual filtering. Since every component in the hypermedia graph has semantic values, it is possible to perform a semantic search in the overall hypermedia system, extending the range of an eventual adaptive process.

Figure 4 illustrates the overall process. The events trigger context modes, which in turn access the correspondent *Entity* component present in the hypermedia graph, retrieving a first set of links. The next module applies semantic filtering over the previously obtained links using user attributes that define his/her experience and preferences. The list of links that are obtained is used to build the interface content.

4.4 History

Most people store photos or videos about past experiences, people or places. The replay of past experiences is a much-appreciated social activity, and involves a large community of users. People gather collections of experiences (photos, videos), later used not only to remember the events but also to create new pieces by arranging them together. In a mixed reality environment, where users are involved in live activities, the replay and arrangement of such experiences is definitely a requirement.

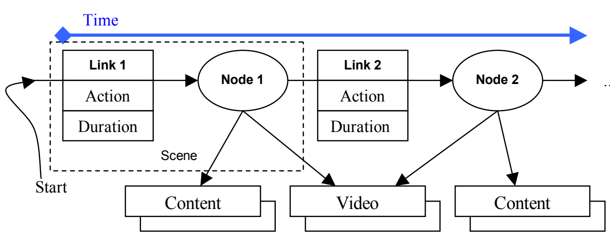

Figure 5. History structure

In a context aware application, one can split an experience into several scenes, each of which triggered by a particular action (as events create context modes). Each of such scenes has two main elements: the content of the interface, and the action that triggered the interface. Associated with the action is also its life period. Each scene is presented before another action is processed that leads to another interface content. For instance, in an augmented reality environment, the real video is needed to replay the experience, as well as the augmented information. The action is the command (or event) that caused the augmented content to be displayed. The experience history is build up of several scenes.

The hypermedia system models scenes with the *Navigation* and *Entity* components. Each scene is a *Navigation* link that points to an *Entity* component. The *Navigation* link contains the action and duration attributes. The *Entity* component is associated to a set of links that specify the data elements needed to replay the scene. The result of navigating in the system, a history instance, is a linked list of *Navigation*/*Entity* component pairs. The *Entity* components are linked together by *Navigation* components, forming a path of links and nodes. Figure 4 illustrates this structure.

This method of specifying history through a sequence of scenes yields to obvious possibilities of arranging it in a different order or introducing new media elements. This is a generic mechanism for repurposing these types of materials and building new applications (e.g., storytelling).

5. APPLICATIONS

There are numerous applications that use hypermedia data and models in fields like museum support, games, guided tours, medical assistance, and many others. From these, museums offer an excellent test bed for hypermedia systems in delivering context aware multimedia information and entertainment activities [4]. For such reasons, we are developing two categories of mixed reality applications in order to test the described hypermedia model, namely: a gallery information assistant and a game that takes place in the gallery environment.

The gallery experimental space consists of a room with two subdivisions to create a navigational need. The physical entities consist of two paintings, Nighthawks and Drugstore, by Edward Hopper, and each painting is positioned in a different part of the room. Virtual 3D models related to these paintings have been created and used to enrich the information setting, augment the user interface and allow navigation within those worlds in search for new experiences and knowledge.

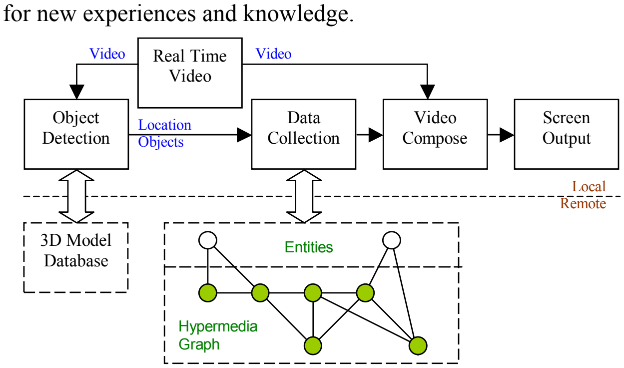

Figure 6. System architecture

The system consists of two main parts, namely the local set up and remote services. The local set up has applications and devices for video capture, object recognition, remote access, and screen output. The remote services provide information that can be classified in two categories: one aids the object location module in the local set up [26]; the other is responsible for gathering objects related data by accessing a hypermedia graph through the correspondent *Entity* components. Figure 6 illustrates the overall system architecture.

The local set up consists of a portable PC, with a wireless LAN card, and a camera to capture the real world video. There are two alternative user set-ups: in the first the visualization and interaction is done directly on the PC; and the other uses a Head Mounted Display, and a 2-3 button device for interaction purposes. We are currently using the Cy-Visor DH-4400VP video see through display. The main recognition process is accomplished through the camera device. There are markers associated with each painting that are optically recognized through an augment reality toolkit (ARToolkit [5]) developed at the University of Washington. The system uses this recognition process to know the user position and orientation. Once objects are recognized, media data is added to the real world video capture [1], by accessing the remote hypermedia graph. When manipulating 3D data, such as the worlds that represent the paintings, a 3D behavior toolkit is used to superimpose the models over the real world video and navigate in them. Figure 7 depicts the augmented reality interface. There is one ARToolkit marker located near the painting. When this marker is recognized the system presents information about the painting and an iconic simplified 3D representation. If the user selects this model it will enter a complex and detailed virtual world representing the painting (Figure 8) where navigation is possible and the game described next takes place.

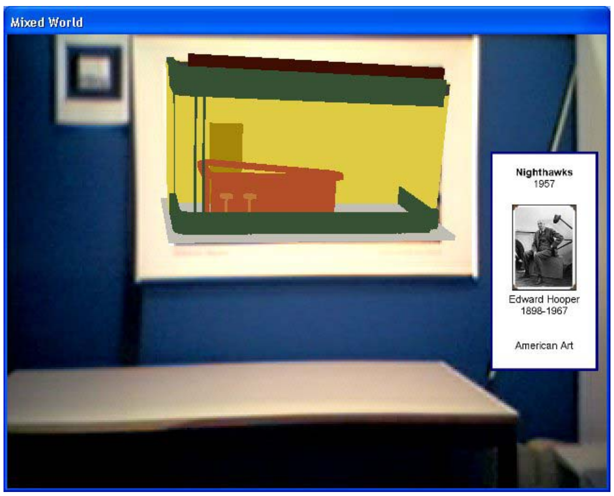

Figure 7. Mixed reality interface

Adding to the gallery information setting, a mystery game was also developed. The story consists in solving a robbery that took place in the gallery. The user has to gather clues and interact with virtual characters to find the stolen item. To do so, the player has to move around the physical and virtual spaces.

Figure 8. Nighthawks 3D virtual world

The game features several objects to be accessed or navigated during playtime, namely worlds, characters and clues. Each of these is represented in the hypermedia model by *Entity* components with semantic attributes for classification purposes. All have 3D representations to be linked to, which is one of the relations referenced by those *Entity* components. Some objects (characters, clues) are represented by 3D components and others (worlds) are represented by *Map* components. The first ones have additional *Position* links into the real/virtual maps, and the others are related to physical objects (paintings), represented by *Entity* components as well. The *Map* component knows all the objects that it contains by following the *Position* links origins.

The game starts with a user selection that triggers an event, which activates a mode that accesses the hypermedia information through a game *Entity* component. This component has all the necessary links to access all the game objects and the user preferences, such as skills and solved clues, are defined through session attributes (User ID).

This application will further test issues like the relation between physical and virtual spaces, object representation, and replaying user experience, to mention a few.

6. CONCLUSIONS AND FUTURE WORK

The paper presents an approach for integrating in the same computational environment the physical world and virtual documents and worlds. The main component of this approach is the hypermedia model, which abstracts the details of each information item, providing a generic interface for navigation and information structuring in mixed reality. The application that we describe, a information system, gaming and storytelling environment, provides a test bed for our ideas but it is just one of the many possible applications, in domains such as education, tourism, information services, and art. The different access modes that are considered in the application (current access on site with AR equipment, with a laptop or desktop computer, or future access using a PDA) promote the usage of computational artifacts in everyday life and move beyond the traditional desktop model. The model is an approach to integrate some of the concepts that were present in past models (e.g., the issues that deal with time) while handling the needs created by the new computing paradigms. These include all the location and space management along with link awareness and contextual mechanisms, that are more relevant when dealing with mixed environments, including the real world. The hypermedia model, modeled and implemented in an object-oriented paradigm, provides a set of services or building blocks for mixed reality applications. Hypermedia plays a central role in this type of application as a way to integrate the different media types and to structure the information items that are manipulated by the applications. It is also a natural way to store associations between different materials in a real world exploration. Future work includes improving the prototype and deploying it in a real location (gallery), for which preliminary contacts have been made. From the experience that we obtained, while developing the application, we have specified an authoring process for this type of environments. As such, we are starting to build a tool that will support authoring based on our model. Replay mechanisms are also a subject for future work. The current history mechanism was designed to allow reuse and repurpose of the materials that are captured during a session with a system supported by the model. This allows saving the entire user experience (including parts of the real time video that is being captured) and play it at a future time, even with a different device. Capturing and saving metadata along with this information and adding new content at a later time enables the creation of new story lines and interactive experiences.

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