Research on Social Simulation Technology for Digital Libraries

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Abstract

The non-document resources of digital libraries include users, user-generated information, and user actions, which are metadata objects for social networks, social media, and virtual worlds. Based on virtual world systems (including registration systems, map systems, dynamic messaging systems, snapshot systems, inventory systems, etc.), digital libraries can develop virtual research environments, virtual campuses, and virtual knowledge-based societies through user modeling and information system modules.

Full Text

Research on Social Simulation Technologies for Digital Libraries

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Abstract: The non-document resources of digital libraries include users, user-generated information, and user actions, which serve as metadata objects for social networks, social media, and virtual worlds. Building upon virtual world systems (including registration systems, map systems, live feed systems, snapshot systems, and inventory systems), this study discusses how digital libraries can develop virtual research environments, virtual campuses, and virtual knowledge societies through user modeling and information system modules.

Keywords: Multi-User Virtual Environment; Moodle plug-in; Metaverse; Avatars; Linden language; Second Life

1. Introduction: Digital Services Described Through User Actions

Traditional digital libraries take documentary resources as their descriptive objects, social network-based digital libraries take people as their descriptive objects, social media-based digital libraries take user-generated information as their descriptive objects, while socially simulated digital libraries take human behavioral activities in virtual spacetime as their descriptive objects. The metadata objects of social networks, social media, and social simulation thus differ substantially from those of documentary resources traditionally described by libraries. In-depth research into the metadata, resources, and services of these non-document resources can facilitate the development of new knowledge service systems and mechanisms for digital libraries.

Virtual worlds represent a distinct user experience from other information service systems—they are essentially Multi-User Virtual Environments (MUVEs) that encompass technical, immersive, and social experiences [?]. Virtual worlds exhibit characteristics of education, theming, specific communities, child-friendliness, and autonomous worlds [?]. Andreas et al. (2010) argue that virtual worlds can supplement and enhance face-to-face communication, improving remote collaboration and communication [?]. Bell et al. (2010) introduce a Virtual Worlds Region Agent Protocol Working Group and review the architecture, protocols, and operations of Second Life (hereinafter referred to as "SL") [?]. A notable feature of virtual world systems is their use of human behavioral activities within virtual worlds as metadata objects.

From a commercial perspective, an increasing number of people conduct various business activities in virtual worlds, presenting both opportunities and challenges for corporate social responsibility and commercial applications [?]. Ives et al. (2008) contend that virtual world technology, adapted from online game providers, offers social, visualization, and simulation capabilities for business applications of 3D technology [?]. Fantone (2009) critiques the stereotypical design of female-targeted games that encourage shopping and flirting as a form of 定向思维 (directional thinking) that fails to understand female users, arguing for greater user self-creation possibilities to replace developers' gender stereotypes and predetermined user behaviors [?]. Spaulding (2010) suggests that virtual communities can be used to approach consumers and obtain consumer data, while social contracts and trust determine the success or failure of businesses in transaction-oriented, profit-oriented, relationship-oriented, and fantasy-oriented virtual communities [?]. These studies demonstrate that digital libraries developing virtual world services must recognize fundamental psychological differences between librarians and users.

From an educational evolution perspective, Eschenbrenner et al. (2008), after reviewing various 3D applications, conclude that virtual worlds hold potential for providing interactive experiential education [?]. Ho et al. (2009) surveyed Singaporean students aged 17-18 about their educational perspectives in virtual worlds, examining the advantages and disadvantages of designing, planning, and implementing technology platforms in education [?]. Most scholars hold positive views on virtual worlds' potential to promote educational reform. For instance, Phillips et al. (2009) argue that technologically proficient students desire meaningful and effective distance education; as a medium for simulating dental patients, virtual worlds can enliven teaching demonstrations and competency testing, transforming problem-solving and communication-oriented distance education models [?]. Nakasone et al. (2009) demonstrate that users can play, pause, rewind, and annotate planet simulations, interactively tracking stars to gain understanding of dynamics and astrophysical phenomena [?]. Schmidt et al. (2009) discuss implementing virtual world technology to advance online nursing education [?]. Jarmon et al. (2009) review instructional design and learning support in virtual worlds, arguing that SL represents a new generation of experiential learning environments for interdisciplinary communication [?]. Conradi et al. (2009) utilize 3D technology to enhance campus-based, workplace-based, and paper-based decision-making skill training, adding realism, active decision-making, and adaptive environmental simulation for remote conferencing [?]. De Lucia et al. (2009) positively evaluate synchronous and collaborative learning mechanisms in SL' s campus, collaborative zones, lecture halls, and recreational areas [?].

However, scholars with reservations also exist. For example, Cheong (2010) studied independent and joint teaching effects in SL, finding through ANOVA analysis that participants perceived changes in individual teaching effectiveness, though the effects were not significant [?]. Lester et al. (2009) compared teaching effectiveness between classroom and virtual world settings, finding that online students enjoyed learning experiences comparable to traditional methods [?]. Jamaludin et al. (2009) quantitatively analyzed student transcripts and qualitatively analyzed log responses regarding euthanasia ethics, morality, and religion courses, discovering that students valued immersive virtual environment experiences over actual learning outcomes [?].

Most scholars agree that virtual worlds can innovate educational activities. For example, Twining (2009) argues that open SL can provide a virtual world education system for people with vastly different life experiences, making it an ideal tool for exploring educational reform [?]. Virtual worlds can provide 3D spatial buildings, enable students and teachers to act as avatars, and spark possibilities for educational creativity [?]. From an educational evolution standpoint, Eschenbrenner et al. (2008) conclude that virtual worlds offer potential for interactive experiential education [?]. Ho et al. (2009) examine the design, planning, and implementation of technology platforms in education [?]. Phillips et al. (2009) demonstrate that virtual worlds can transform problem-solving and communication-oriented distance education models [?]. Nakasone et al. (2009) show how users can interact with astrophysics simulations [?]. Schmidt et al. (2009) discuss virtual reality learning environments for nursing [?]. Jarmon et al. (2009) identify SL as a new generation experiential learning environment [?]. Conradi et al. (2009) enhance decision-making training with

3D technology [?]. De Lucia et al. (2009) evaluate virtual campuses in SL [?].

In library science, scholars recognize that virtual worlds provide an increasingly comprehensive landscape of user information. Ostrander (2008) uses semi-structured interviews to study information seeking in virtual worlds, arguing that librarians and information professionals strive to optimize virtual worlds and continuously innovate user-centered services [?]. Godfrey (2008) discusses methods, institutions, and training procedures for reference services in virtual worlds [?]. Parker (2008) contends that SL is simply another facet of the library, and since virtual life is so prevalent in universities, libraries and librarians must address user information needs in 3D worlds [?]. Hill et al. (2009) argue that virtual worlds represent a new information delivery technology for libraries, and that studying user information seeking behavior in virtual worlds has value for accessibility, security, and sustainability [?].

However, understanding virtual world mechanisms requires examining both user behavior and information technology, particularly empirical research on user socialization processes in virtual worlds. For example, Edirisingha et al. (2009) established an archaeology theory module in Leicester University's Media Zoo in SL, having students complete learning through interviews, observations, recordings, and conversations, while further observing their socialization processes in the virtual world [?]. Harris et al. (2009) conducted online interviews for six consecutive weeks with 80 users spending six hours weekly in virtual worlds, finding that while users' social networks continuously expanded, actions such as flying, flash mobbing, and chatting gradually decreased, indicating a shift from individual exploration to social interaction [?]. Zhao et al. (2010) conducted online surveys of SL users' identity relationships, noting the impact of interaction frequency, activity diversity, and interpersonal relationships [?]. Bell (2009) analyzed virtual worlds, examining SL built on emerging "vernacular nostalgia," capitalism-based economies, griefing phenomena, and everydayness account requirements [?]. Empathy and self-efficacy in virtual worlds are users' motivations for entering virtual worlds, and system fluidity that allows users to create joyful experiences is key to success [?]. These studies fully demonstrate the importance of integrating user behavior and information technology.

Building upon previous research, this paper uses SL as an example to analyze virtual world application programming interface technologies and explore user modeling and information system modules in virtual worlds. The findings can serve as references for digital libraries developing virtual world systems.

2. Technology: Virtual World Application Programming Interfaces

SL' s advantages include an easy-to-learn interface, availability across all major operating systems, non-aggressive social networking, and relatively extensive scripting capabilities [?]. As the world' s largest virtual world provider, SL undoubtedly offers an excellent system paradigm. Therefore, this paper analyzes

SL' s virtual world system technology.

2.1 Registration System [?]

Virtual world systems are information service mechanisms that use user actions as metadata description objects. Terminal user operations in browsers are directly accessed and computed by the server, indirectly controlling avatar behaviors in the virtual world. The registration system manages terminal user operation permissions in browsers.

SL' s Registration API (RegAPI) not only provides user enrollment but also handles account login, multiple employee registration, company or educational institution registration, account number limitations, and virtual land registration. It is a Representational State Transfer (REST) application that can define IDs (URLs) for all entities. RegAPI operations rely on functions such as `add_to_group` (adds a new user to a specified SL function), `create_user` (creates a new user), `check_name` (checks if a user is registered with a given name), `get_last_names` (returns last name suffixes), and `get_error_codes` (returns error codes). An HTML example is as follows:

```
<form action="https://cap.secondlife.com/get_reg_capabilities" method="POST">
<br/>Calls SL's registration system mechanism and adopts POST sending and return mechanism.
<table>
<tr><td>FirstName</td><td><input name='first_name'></td></tr> <!-- Surname -->
<tr><td>LastName</td><td><input name='last_name'></td></tr> <!-- Given name -->
<tr>
<td>Password</td>
<td><input name='password' type='password'></td></tr> <!-- Password -->
<tr>
<td align='center' colspan=2>
<input type='submit' value="GetCapabilities"></td></tr> <!-- Allows users to exercise -->
</table>
</form>
```

To coordinate with RegAPI' s input functionality, Linden Lab Structured Data (LLSD) supports loose, distributed, heterogeneous system architecture data exchange, providing data facilities similar to dynamic languages like Perl and Python. The LLSD specification defines many different data types (maps, arrays, strings, integers, floats, dates, etc.), corresponding to various native objects. For example, when creating a new user at the `create_user` URL in the registration system, the corresponding LLSD XML message combines with the registration system, including: date of birth (dob), region (start_region_name), username, user identification (last_name_id), password, and email.

The POST functionality implementation of the registration system enables interoperability between the terminal user' s browser interface and remote servers, allowing users' avatars in SL to engage in various social activities [?]. Research shows that virtual world residents who perceive themselves as producers possess higher social capital than those concerned only with themselves, though virtual world capital is unrelated to real-world capital [?]. The cross-domain mechanism connecting users in the real society to their avatars in the virtual world through the registration system represents a unique difference between virtual world registration systems and other systems.

2.2 Map System [?]

As previously discussed [?, ?, ?], virtual worlds are built within an artificially designed 3D space where users gain manipulation capabilities for an avatar through the registration system. User movement commands issued to avatars are recorded by this spatial system. Such systems that use (in-virtual-world) user actions as metadata description objects constitute virtual world map systems.

Map systems primarily include data transmission formats and 3D-to-2D computation components. The map system must maintain complete data for describing, storing, and computing user actions, while simultaneously converting virtual world 3D spatial parameter values to real-world 2D spatial parameter values for intuitive avatar operation.

Regarding data transmission formats, the Map API embeds maps into the user-side browser page, enabling actions such as clicking, dragging, zooming, and opening teleport windows on web pages to interact with the virtual world server. It invokes JavaScript' s `loadMap` function within the `mapInstance` parameter for map interoperability. An example follows:

```
var mapInstance;
function loadmap(){
mapInstance = new "SL" Map(document.getElementById('map-container'));
mapInstance.centerAndZoomAt "SL" Coord(new XYPoint (1027,0922),2);
}
```

The main functions include: - `goto "SL" URL(997,1002,mapInstance);` // Links coordinates - `mapInstance.disableDragging();` // Disables and enables dragging - `mapInstance.panOrRecenterTo "SL" Coord(new XYPoint(1027,0922),true);` // Pans map center - `var bounds = mapInstance.getViewportBounds();` // Gets current map boundaries - `var center = mapInstance.getMapCenter();` // Gets current map center - `mapInstance.clickMarker(marker);` // Triggers marker - `mapInstance.removeMarker(myMarker);` // Removes marker - `mapInstance = new "SL" Map(document.getElementById('map-container'),{onStateChangedHandler:doSomething});` // Sets event handler

The above represents image control outside the virtual world. For image positioning within the virtual world, the Amazon Simple Storage Service (Amazon S3) development platform mechanism is adopted. Since 3D positioning must be converted for 2D screen display, angular perspective algorithms are used to transform three coordinates into two coordinates. The 3D coordinates are marked as "Z-X -Y ", where X and Y represent the map' s X and Y axes, while Z indicates the zoom focus. The X and Y values are calculated as:

$$X' = X - (X\%(2^Z - 1))$$

$$Y' = Y - (Y\%(2^Z - 1))$$

If X and Y zoom values exceed one, they are stored as lower-left corner coordinates, while "Z-X -Y " represents the zoom-scaled map area included in the image.

The visual sense that virtual worlds bring to users primarily involves 3D imagery and operational controls on that imagery. This mechanism not only delivers enjoyment for learning [?, ?], research [?], and teaching [?, ?], but also provides simulation [?], deduction [?], and rehearsal [?] effects. The core enabling this mechanism is the map system.

2.3 Live Data Feeds System [?]

While the registration system provides user control capabilities in virtual worlds and the map system provides the virtual spatiotemporal environment, the interoperability of user avatars across terminals and remote systems relies on dynamic data transmission systems. The live data feeds system is designed to connect with other subsystems.

According to XML data exchange specifications, the live data feeds system format facilitates interoperability between heterogeneous systems. The data format can be described as follows:

```xml
<stats>
<status>ONLINE</status>
<signups>18,072,648</signups>
<logged_in_last_60>1,404,640</logged_in_last_60>
<transactions>3,065,550</transactions>
<inworld>38,836</inworld>
</stats>
```

Parameter meanings are shown in Table 1 :

Parameter	Meaning
status	Connection: indicates when the Grid is online
signups	Total registered resident population; updated daily

Parameter	Meaning
logged_in_last_60	Registered users active in the last 60 days; updated daily
transactions	Resident transaction volume in SL over the past 24 hours at average exchange rates; updated every 30 minutes
inworld	Currently logged-in registered users; updated every 3 minutes

As previously noted [?, ?, ?], because virtual worlds must provide immersive face-to-face communication experiences, and their distributed system architecture separates command operations (client-side) from computational responses (server-side), dynamic data transmission is required to maintain connections between commands.

2.4 Snapshot System [?]

Since virtual world systems provide a visual [?], experiential [?, ?], and immersive [?] virtual environment, images serve as an attractive service feature. The snapshot system in virtual worlds functions to digitally describe user actions in coordination with the registration system, map system, and live data feeds system.

The snapshot system' s Exchangeable Image File Format (EXIF) is an image file format specification. According to this specification, SL can parse snapshots to send blogs, social networks, images, and other information to other users. This encapsulated message includes headers providing metadata about the message itself and a body providing snapshot metadata content.

Parameter meanings are shown in Tables 2 and 3 :

Table 2: Snapshot System Message Header Parameters

Parameter	Meaning
X-Originating-IP	IP simulator in brackets
Subject	Email address
Sender	Combination of WWW data account simulator address and name (account name does not equal all avatar names)
Message-ID	Uses this field to prevent multiple attempts at processing the same message

Table 3: Snapshot System Message Body Parameters

Parameter	Meaning
agent_id	Universally Unique Identifier (UUID) of the avatar (agent) sending the message
username	Transformed name of the avatar (agent) sending the message
region_id	UUID of the region
global_x	East-west grid coordinate of the avatar
global_y	North-south grid coordinate of the avatar
local_x	East-west coordinate of the avatar
local_y	North-south coordinate of the avatar
local_z	Near-far height coordinate of the avatar

The `From` data message in the header identifies email readers. Since clients allow viewing "raw"messages (unconverted metadata codes), the header conceals different user identification mechanisms with varying permissions.

On the other hand, to coordinate with map system metadata, `local` XYZ refers to the geographic location (XY) and viewing angle (Z) where the client operates the avatar in the virtual world, while `global` XY refers to the 2D screen position calculated and fed back to the client by the server.

When users operate avatars to take snapshots in the virtual world, they can manipulate and move snapshots before transmitting them to another location. Because detached cameras allow shooting from positions other than the current location, `local` X, Y, Z metadata is preserved not only for 3D spatial user operations but also for camera angles.

2.5 Inventory System [?]

User permissions, avatar movement in virtual worlds, client-server interaction, and images are handled by the registration system, map system, live data feeds system, and snapshot system respectively. All these recorded user actions require an efficient mechanism for information organization, storage, and retrieval. The virtual world inventory system serves this purpose.

SL' s standardized inventory data structure originates from Linden language, designed with categories (which can contain items and other categories), items (pointing to valid assets in the system), permissions (permissions for specific items), and sale information (sales data for specific items). Categories and items are non-exclusive in naming, and all user-generated categories are null-valued for maximum extensibility.

To effectively tag massive data while avoiding constraints on future system migration, compatibility, or reconstruction, SL adopts the open-source Universally Unique Identifier (UUID) as identifier codes. UUID provides unique identification for all elements in distributed systems, allowing each system to create non-interfering identifiers.

In the inventory system, `agent_id` (agent identifier), `category_id` (category identifier), and `parent_id` (parent category identifier) all use UUID notation. Parameter meanings are shown in Table 4 :

Table 4: Inventory System Category Data

Parameter	Meaning
agent_id	UUID of the agent
category_id	UUID of the category
category_name	Textual name of the category
parent_id	UUID of the parent (superior) category
type_default	Value (distinguishing number) of asset type
version	Issue version number

Categories contain items, items extend permissions and sales information, and the inventory system interoperates with the map system based on category data. The snapshot system and inventory system share the same agent identifier, enabling cross-system interoperability. The standardized inventory data structure in the inventory system reflects designers' knowledge structures for organizing, storing, and retrieving user actions.

3. Architecture: User Modeling and Information System Modules

In the process of technological development and practical application, people gradually realize that various (virtual) social issues arising from commercially developed virtual worlds simultaneously extend to real society. For example, while 3D technology enables remote psychological clinical experiments and can enhance email, online chat, and video conferencing to convey more emotional clinical communication processes, privacy and personal safety mechanisms remain inadequately legalized [?]. In commercially built virtual worlds, people face fewer legal and moral constraints than in real society, creating (or exacerbating) more possibilities for undermining social ethical values. While Internet users generate increasing amounts of non-textual information that expands freedom of expression, it also produces undemocratic phenomena such as verbal abuse, hearsay, and mob behavior [?]. Therefore, when public institutions (such as libraries) develop virtual world systems, user modeling should consider that certain intentionally "incomplete designs" can avoid management difficulties.

Unlike traditional online games, Metaverses must dynamically provide content, particularly user-generated content and continuously changing user location data in virtual worlds [?]. This creates a different technical level for users, interaction types, and real-world modalities. Metaverses are immersive 3D virtual worlds where people interact through avatars and software agents—a simulation of the real world without physical limitations. They include five key elements: the Metaverse itself, people/avatars, technical capabilities, behaviors, and outcomes [?]. In other words, the server-side Metaverse is a virtual world management system supporting the client-side live data feeds system, enabling digital services that describe user actions as objects.

Moodle plug-ins can support synchronous collaboration of SL roles and capture and display textual information during retrieval processes [?]. Peer-to-peer network architecture, user preference management, mobile simulated avatars, region partitioning, and transmission-balanced servers, caching, prefetching, and other designs can effectively support avatar mobility and behavior patterns [?].

As previously discussed [?, ?, ?, ?], virtual world system technology can be applied to develop virtual research environments, enabling: (1) transforming complex disciplinary content from textual descriptions into 3D imagery for easier user comprehension; (2) 3D simulation of environments required for theoretical practice, allowing users to safely perform dangerous hands-on operations; and (3) providing an information exchange platform for user-user communication and collaboration. All these require user modeling and operational information system modules based on actual conditions.

4. Conclusion: Users as Non-Document Resources

Although users are not property that libraries can own, control, or alter, they are the most valuable non-document resources of libraries. This human resource can generate information resources and transform them into library knowledge assets. The "added value" resources produced solely through librarians' document processing are limited. Developing digital library systems that incorporate user participation, user generation, and user experience helps cultivate end users who specifically create property for libraries (social bookmarks, community multimedia, personal reviews, collective publications, etc.).

Traditional digital libraries take documentary resources (things) as descriptive objects, while social networks, social media, and social simulation take users themselves (people), user-generated content (events), and user actions (avatars—people doing things to things at certain times) as resource description objects. In-depth research into the metadata, resources, and services of these non-document resources can help digital libraries develop new knowledge service systems and mechanisms. For example, librarians and information professionals can help optimize virtual worlds [?], establish libraries in virtual worlds to serve users [?, ?], and study information seeking behavior in virtual worlds [?]. It can be further argued that libraries can reference SL’ s virtual world system to develop digital library virtual worlds: a virtual research environment to assist researchers, a virtual campus to assist educators and students, and a virtual knowledge society for the general public entitled to knowledge services.

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Invitation for Special Column Contributions

Modern Library and Information Technology is an academic journal supervised by the Chinese Academy of Sciences and sponsored by the National Science Library of the Chinese Academy of Sciences, focusing on computer information management technology. The journal has a clear positioning: tracking technology research, applications, and exchanges to serve information technology professionals.

Since 2004, the journal has established an irregular column–**Special Column**–where each issue publishes research articles concentrated on a specific technical topic, gathering scientific research results and focusing on research frontiers.

1. Special Column Operation Methods and Procedures

(1) This column invites renowned domestic and international experts, scholars, and professors to serve as column editors. Column topics are generally proposed through communication between the journal' s planning editors and invited column editors based on the development needs of library and information technology disciplines.

(2) Once a topic is determined, the invited column editor is responsible for organizing manuscripts, reviewing them, and writing the preface. Each special column typically contains 4-6 articles. During manuscript organization, planning editors maintain regular communication with column editors to monitor writing progress and provide appropriate suggestions.

(3) Manuscripts reviewed and approved by the column editor are submitted to the editorial department. Subsequent contact with authors and publication arrangements are handled by planning editors.

(4) Once a column topic is confirmed, a basic timeline is established. The typical operation cycle is 3-5 months. Starting from formal topic confirmation, authors and article titles are confirmed within 1 month, first drafts within 3 months, and final accepted manuscripts within 5 months.

2. Special Column Manuscript Content Requirements

(1) Articles should deeply reflect cutting-edge research results or major application achievements related to the column topic, focusing on theoretical research, technical analysis, system demonstration, or design, with attention to combining theory and practice.

(2) Special column manuscripts should primarily consist of original research papers, though one review article is acceptable. However, review articles must reliably cover the original core literature in the field.

(3) Articles should follow rigorous academic writing conventions: clearly and concisely define research problems, briefly explain research methods, systematically and concisely describe international and domestic development status, then detail the author' s own research technical route and results.

(4) A series of articles in a special column should cover various research directions and multiple research institutions related to the column topic, fully encompassing possible viewpoints and technical approaches.

(5) Articles should fully acknowledge predecessors' /others' work, fully cite referenced literature (especially original core literature in the research and the earliest domestic research literature), and strictly adhere to citation norms.

3. Special Column Manuscript Format Requirements

(1) For paper formatting, please refer to the "Paper Template" in the "Download Area" on the journal' s website.

(2) For multiple authors, please indicate the corresponding author and each author' s affiliation.

(3) Each manuscript should be approximately 6,000-8,000 words (including figures and tables).

Note: Figure translations are in progress. See original paper for figures.

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