Canyons, Deltas and Plains: Towards a Unified Sculptural Model of Location-Based Hypertext

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ABSTRACT

With the growing ubiquity of mobile devices, new ways of sensing context and the emergence of the mobile Web, digital storytelling is escaping the confines of the desktop and intertwinging in new and interesting ways with the physical world. Mobile, location aware, narrative systems are being applied to a range of areas including tour guides, educational tools and interactive fiction. Despite this there is little understanding of how these applications are related or how they link with existing hypertext models and theory.

We argue that location aware narrative systems tend to follow three patterns (canyons, deltas and plains) and that it is possible to represent all of these patterns in a conceptual sculptural hypertext model. Our model builds on a general sculptural mechansim (of pre-conditions and behaviours) to include locality and narrative transitions as first class elements, opening the possibility of standardised viewers, formats, and hybrid stories. We show how existing structures can be mapped onto this conceptual sculptural model, and how narratives defined in the model can take advantage of open data sources and sensed contextual data. To demonstrate this we present the GeoYarn system, a prototype which implements the model to create interactive, location aware narratives, using all three patterns.

Categories and Subject Descriptors

H.1 [**Models and Principles**]: General

General Terms

Standardization, Human Factors

24th ACM Conference on Hypertext and Social Media
1–3 May 2013, Paris, France

Keywords

Narrative Systems, Location Based Hypertext, Mobile Narrative

1. INTRODUCTION

Location-aware information systems (sometimes characterised as physical, or geographic hypertexts) were once the preserve of the research community, who connected together early GPS and other location technologies with laptops, early tablets and PDAs. These systems equated link anchors with hotspot regions, and interpreted link traversal as both virtual and physical movement.

Developments in mobile technology have meant that those early, cumbersome systems have been replaced with slick consumer devices, and experimental applications such as tour guides, physical annotations and performance pieces have been reinvented as apps that anyone with a smart device can download and use[1].

However, many of the available apps are far-less ambitious than their research system forbears, with interactions based around the simplest of hypertext models (for example, a single item activated in a single place). In addition, there are no open standards for the definition of location-based hypertexts, meaning that each app is a walled garden.

The problem is that there is no common conceptual model of location-based hypertext, and limited understanding about how location-based narratives could or should be constructed. This has restricted both the potential growth of such systems, and also their complexity, as it is rare for different approaches to be combined in order to create more complex interactions and experiences.

It has been common in the hypertext community to use models and frameworks to reflect on the state of hypertexts and hypertext systems, and to drive forward new developments. Classic conceptualisations such as the Dexter reference model [13] and the Flag Taxonomy of Open Hypermedia Systems [26] allowed early hypertext systems to be

[1]For example, see http://wanderluststories.com or http://www.thesilenthistory.com/

compared, and later attempts were made to unify different forms of hypertext in work on the Fundemental Open Hypertext Model (FOHM) [21] and to reconcile both services and data in an extensible way through the development of the Information Unit Hypertext Model (IUHM) [23].

In this paper we propose to take a similar approach to propose a unified conceptual model of location-based hypermedia. Our methodology has been to analyse a number of location-based hypertext systems in order to identify common patterns (canyons, deltas and plains), and the elements that support them. We have then proposed a unified model that can support these structures in a single conceptual model of location-based hypertext. In defining our model we have extended the standard mechanisms of sculptural hypertext [4] (pre-conditions and behaviours), to explicitly include locality (via location-queries), and narrative transitions (via Chapters, Timers and Stacks).

The rest of this paper is structured as follows: after describing related work in Section 2, in Section 3 we describe the three patterns we have identified and define our unified sculptural model. In Section 4 we show how a number of existing systems and applications map to the model, and in Section 5 we describe our prototype GeoYarn application that implements the model, and give examples of some of the possible stories. Finally Section 6 concludes the paper.

Our work has shown that using sculptural hypertext it is possible to create a conceptual model for location-based hypertext that can express many of the patterns currently used by bespoke proprietary systems, opening up the possibility of location-based standards for content, and an open and interoperable set of clients. Through the GeoYarn prototype we have also shown that it is possible to combine different location-based hypertext patterns to create hybrid stories, and that there is further potential to draw on open data to create new types of location-sensitive content.

2. BACKGROUND

Location-based hypertext systems combine physical context with virtual content, and allow authors to use a physical space as their digital canvas, or (from the opposite perspective) to augment a physical space with virtual objects. It is an approach that has been shown to improve immersion and enhance mental imagery [15] and has been used for a range of applications. The majority can be grouped into four categories: *Tour Guides*, *Educational Tools*, *Games* and *Fiction*.

There is work that falls outside of these categories, notably the Geo-Spatial Hypermedia information systems by Grønbæk [12][11] that merge organisational structures from the real and virtual worlds in the spirit of Spatial Hypermedia [20]. However, in our work we have focused on location-based systems where the person is the principle locus of activity, and interaction is accomplished by moving through a physical space (typically carrying a smart device with you as the interaction mechanism for the virtual space).

2.1 Location Aware Tour Guides

Tour guides are a natural application for location aware hypertexts, where curators or guides seek to inform visitors of their surroundings and engage them through immersion in the historical narrative of the surroundings and/or exhibits. These applications tend to favour either a more open style of narrative, with little or no structure, where participants can wander around an area or set of exhibits as they wish. These nodes are often designed to be consumed in any order and always be available, so that users can revisit nodes. Alternatively, linear narratives are provided, where the participant is guided along a specific route. The mobile devices will typically deliver context relevant narrative text, video, or sound when within a defined area.

Typical of this is the Louvre tour guide referred to in the development of the HIPS system [7], an application designed to allow for a range of location aware tour guides that are also connected to knowledge bases. The Louvre tour guide allows for users to connect to sections of narrative for each piece they visit in any order, each represented by a short audio piece. However HIPS also points to support for more structured tour environments where users may be guided along a particular route through a city to nodes in a specific order, emphasising a need to support both structures. Similarly, in REXplorer (a more playful take on the tour guide) players follow a linear trail of spirits through a city, unlocking content at each point through spells, and generating a web-accessible souvenir record that they can access once they return home [2].

Riot! [6] employs an open narrative structure where visitors to Queen's Square in Bristol were invited to listen to a location sensitive interactive play during their visit. The square was divided up into zones, which the users interacted with by choosing their own route, each new zone triggering the delivery of a section of narrative concerning a historical riot that occurred in the square. Some of the zones in *Riot!* incorporated a degree of structure by having multiple nodes associated with the same area. An area would either randomly return a relevant section of narrative or return sections in a given order on repeat visits to the area, thus building a combination of open and linear narrative.

We find more evidence of open narratives in tour guides in work by Nisi both in Hopstory [25] and 'The Media Portrait of the Liberties' [24]. Hopstory is a guide for a Dublin brewery based around a narrative within the brewery. Users are invited to collect narrative pieces from sculptures around the brewery and reconstruct them into narratives at a central hub. Hopstory is interesting in that from a system perspective it is an open narrative, in that users can visit nodes in any order and all nodes are available, but from a plot perspective it is linear as the narrative sections collected have a definite order. Hopstory introduces a further complexity of temporality in that, like Riot!, multiple narrative sections can be connected to a single node and cycle over time. Temporal sequencing of narrative sections can become a significant part of the narrative model of a number of different location aware systems where modelling the behaviour of a repeat visit is key, or when different interwoven linear narratives force a choice from the audience as explored in the location aware narrative authoring tool M-Studio [27].

'The Media Portrait of the Liberties' (MPL) is another large open tour guide, this time for the district of Dublin known as the Liberties (the area surrounding the brewery in Hopstory). MPL invited contributions of stories of the area from local residents which it then compiled into strings of story nodes associated with particular areas. The application was then distributed to visitors to encourage immersion in the culture and history of this area of Dublin. MPL also exhibits similarities with *Riot!* in that it supports linear narratives woven into an open narrative. MPL allows its users to freely wander the area and discover nodes, but also delib-

erately guides users to strings of nodes connected together so that they can explore multipart individual sub-narratives.

2.2 Location Aware Educational Tools

Location aware tours could be considered to be educational. However, some location aware narratives focus more explicitly on the educational process of learning rather than just guiding or immersion. For example, Ardito et al describe a mobile educational game for archeology based around *Gaius' Day in Egnathia* an excursion-game for a site in southern Italy [1]. The game takes the form of a sequence of linear treasure-hunts, after which participants are rewarded with a 3d model of the original remains on their devices and are invited to compare it with the ruins.

Location aware educational tools include location based augmented reality 'edutainment' systems such as Geist [19] but also context aware e-learning systems such as the Ambient Wood project [29] and the Chawton House project [31].

The Ambient Wood uses a card based metaphor [32] to create an outdoors learning experience focussed on contextual scientific enquiry. Children were encouraged to explore a wood with mobile devices to perform a scientific exploration. A probe device allowed them to gather sunlight and moisture readings and at various locations they were presented with different digital material relating to flora and fauna. The students collected together a range of experiences in the form of a 'deck' of cards that was later represented as a linear narrative for use in a classroom exercise. Much like some of the tour guides discussed previously collections of cards within the open narrative formed linear sequences attached to the same location, and could contain pre-requisite conditions of other visited cards, making the narrative structure more complex than a simple non-linear open narrative.

The Chawton House project [31][30] adopts a similar card based metaphor but in the setting of a literature field trip to a country house. Chawton House extends the work covered in Ambient wood by adding both interaction (capture cards allowed students to record activities) and more explicit instructional cards to direct movement around the space. While this changed the educational experience, the narrative structure of the cards remains much the same as it was for Ambient Wood. Both of these projects, and arguably the other nonlinear narrative systems mentioned, have their origins in sculptural hypertext as proposed in Bernstein's work on Card Shark [4].

2.3 Location Aware Games

Entertainment focussed location aware systems display a greater range of different narrative models and approaches. These range from location aware interactive games such as *Can You See Me Now?* [3] and *Viking Ghost Hunt* [22] to location aware fiction such as *San Servolo* [28] or *University of Death* [8]. Their narrative models range from open narratives through to heavily structured linear and branching narratives, where the focus is a particular entertainment experience rather than exploration and discovery.

Location aware games intrinsically take advantage of a game mechanic connected to the player's environment to make an immersive experience. In *Can You See Me Now?* [3] this is a mapping between the online player's virtual location and the physical location of the chasing runners on the street. The narrative formed is that of an exciting chase. There are also games that have woven more complex narratives. Nailuka et al.'s work on Viking Ghost Hunt (VGH) [22] demonstrated how a traditional adventure game consisting of quests to find ghosts in Dublin can be enhanced through contextual awareness of the player. VGH presents players with quests to locate ghosts around the city, directing to them to the locations through a variety of clues supported within narrative. The players can affect the state of the game by either succeeding or aborting challenges they face at triggered locations in order to create a branching narrative within which the player has agency. By requiring the players to explore different physical locations in order to participate, the game enhances its investigative aspect as well as immersing the players in the setting.

Location-based games often play with mixed and augmented reality. TimeWarp is an augmented reality edutainment game where players have to seek out the *Heinzelmännchen* of Cologne (small virtual elves) [14]. The nodes in TimeWarp are mini-games, which the players are permitted to seek out and play in any order. Also included are virtual portals that move the players into different timezones, so that the city can be experienced in different portions of its history. The Songs of the North is a mixed reality game where players move around a physical space and interact with a virtual spirit world through a shamanic drum (a game prop, actually shown as a virtual drum on their mobile device) [18]. In this case, the spirit world is in fact a persistent virtual world that supports different player roles and quests.

2.4 Location Aware Fiction

Location aware fiction often focuses on utilising narrative to immerse the reader in the setting. For example, the iLand of Madeira is a project to reveal the oral history of the island of Madeira to visitors [10]. Content is placed onto a map, and activated whenever a user nears that area.

In the domain of fiction we also see examples of more complex narrative structure. *San Servolo, travel into the memory of an island* is a location aware work of fiction set on an island housing an old sanatorium. It encourages its readers to explore the island while reading. Different chapters are unveiled when different contextual conditions are satisfied. These conditions are often locational, but can also be temporal or weather based.

San Servolo is built in a location aware narrative framework developed by Pittarello [28] that is in turn based on earlier work in machine readable models of narrative carried out with Carnielli [9]. The model focuses on supporting different contextual conditional checks for delivering 'situations' (sections of textual narrative) through a director agent that compares contextual data about the user as they traverse the location, and delivers material when the checks are satisfied. The 'situations' that comprise the narrative can also be divided into phases and can in turn change the currently valid phase in order to create more complex branching narratives based on choices the reader makes (such as going to a particular location) as well as changing context (such as changing weather).

Sam Servolo is an example of how complexity can be introduced into the narrative engine, but other systems have done this through the interactions of users, some (like REXplorer described earlier) use gestures or bespoke devices, but it is also possible to do this through the normal physical movement of the reader. StoryTrek takes the idea of located

content and extends it by allowing content to be linked to patterns of movement, for example straight lines, turns, or zigzags [16]. This allows the system to play with the poetics of turning away, or moving towards a destination, within the narratives themselves.

3. MODELLING LOCATION BASED NARRATIVE

3.1 Location Aware Narrative Structures

Each application of location aware hypertext adopts different narrative structures to support the desired experience. Kjeldskov and Paay classified these structures for tour guides as one of five different types [17]:

- *Treasure Hunts*: Linear narratives where the user explores and finds a serial route to a conclusion.
- *Jigsaw Puzzles*: Open narratives where the user can visit all nodes in any order, but requires visiting all nodes to fully understand the narrative.
- *Dominos*: Multiple linear narratives linked together by common factors.
- *Scrabble*: Open narratives where all nodes are available and the user visits sufficient nodes to make sense of the collecting story.
- *Collecting Butterflies*: Open narratives where all nodes are available but also entirely optional, user picks and chooses which nodes to collect based on interest.

Kjedlskov and Paay's structures successfully capture most tour based location aware narratives, but are not solely concerned with structure - they also consider content and usage. For example Jigsaw Puzzles, Scrabble, and Collecting Butterflies are all similar in structure in that there are open narratives with a range of individual story nodes that are all accessible and can be accessed in any order. What differentiates them is the way they are intended for consumption. When looking at a more general definition of structures for location aware narratives (not just tours) Kjeldskov and Paay's definitions also don't cover branching narratives sometimes used in location aware fiction and games such as in Viking Ghost Hunt [22]. As such we have refined Kjedlskov and Paay's definitions into three strictly structural definitions, taking inspiration from geographical features:

- *Canyons*: A linear narrative represented as a sequence of nodes accessed in a predefined order.
- *Deltas*: A start node that repeatedly branches to multiple other optional nodes accessed based on the choices of the user.
- *Plains*: A collection of nodes that are all accessible and can be accessed in any order.

Kjedlskov and Paay's *Treasure Hunt* and *Dominos* narratives broadly fit within our definition of *Canyons* whereas *Jigsaw Puzzle*, *Scrabble*, and *Collecting Butterflies* fit within our definition of *Plains*. It is to be noted that Kjedlskov and Paay's structures already suggest hybrids, for example, the *Dominos* structure might be more accurately interpreted as a sequence of *Canyons* rather than a single one. But it is equally possible to imagine *Plains* that may contain nodes that lead into *Canyons*, or sequential parts of *Deltas* that do not branch at all and form an internal *Canyon*. These three principle structures are represented diagrammatically in figure 1.

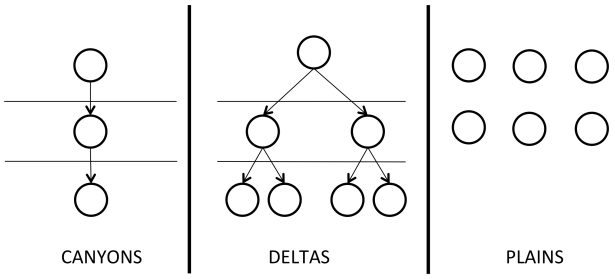

Figure 1: Canyons, Deltas, and Plains

3.2 Sculptural Hypertext

Given the importance of the three underlying structures it is clear that any unified model must support them, and a key question is therefore how to represent the links between nodes in Canyons and Deltas.

In traditional navigational hypertext a link combines two purposes: it moves the reader's view to a new piece of content, and it moves the reader's state conceptually through the narrative. These two functions are so tightly bound that we do not normally consider them as separate, however in a location-based model we must separate these functions as we have no absolute control over navigation in the physical space (as the user moves from one area to another) and instead only control the conceptual space (moving the narrative from one state to another).

Sculptural hypertext is an approach that helps us understand how links in a conceptual space can work. In sculptural hypertexts all nodes are initially linked, and a hypertext is created via the selective removal of links (at runtime) rather than their addition [4, 33]. Thus in sculptural hypertext links are really transitions in the narrative that are triggered when a reader activates a given node, changing the conditions, and thus revealing a different set of potential nodes (links). In location-based hypertexts we can interpret these narrative transitions as actions triggered by the reader activating a node by physically moving to it, which in turn makes new nodes available for visiting.

Once we have made this separation we can define Plains as narratives with no explicit narrative transitions, and where all the movement occurs in the physical space (between nodes that are always available). Canyons contain both physical and narrative transitions, but they are tightly bound, so that at each stage of the narrative a single physical transition is associated with a single conceptual transition (and only the next node is available). Deltas also combine both types of transition, but they are loosely bound, so that multiple physical paths may be available, leading to multiple narrative state changes (so that alternative next nodes are available).

Thus in our proposed sculptural model of location-based hypertext there are no explicit links between nodes, as these navigational links are replaced by the unconstrained move-

ment of the reader. Instead the primary structures are state transitions, modelled as nodes with constraints (pre-conditions) and assertions (behaviours) that trigger changes in the set of available nodes.

However, such a low-level model does not suggest any particular form or poetic to a hypertext author, rather what is needed is to promote certain constraints and assertions so that they become first-class elements in the model, and thus are able to establish certain norms and expectations [5]. Drawing on our Canyons, Deltas and Plains we see two important concepts to be promoted from general constraints to become key elements of the model: location queries, and narrative transitions (phase or chapter changes).

3.3 A Sculptural Model of Location-Based Hypertext

Figure 2 shows a UML Class diagram of our full sculptural model for location-based hypertexts. The main structure of the narrative (shown in grey) is a *Story* class that contains a set of *Chapters*, and a reference to the starting chapter. Within each chapter a set of *ChapterElements* (shown in white) determine what is available within that Chapter.

Nodes are content containers and come in two variants: *PinnedNodes* are nodes that are confined to a given geographic area, and *UnPinnedNodes* are nodes that are available from all areas. *Stacks* are sequences of UnPinnedNodes that can themselves be optionally pinned to an area, once a Node within a Stack is acknowledged it is popped from the stack and the next node becomes available. Nodes optionally contain a narrative transition to a new Chapter.

Canyons can thus be implemented using chapters to represent each stage, and transitions to move the reader from chapter to chapter (along the canyon). Stacks are a shortcut mechanism that allow simple canyons to be created without resorting to the transition mechanism, but they are also a way of allowing a sequence of nodes to be started that do not require further location triggers to progress (for example, allowing the sequence to be started in a given place, but completed regardless of where the reader moves from that spot.)

Finally, nodes can contain embedded *ContextualElements*. These are semantic queries that are executed at readtime, and whose results are substituted into the content. For example, a query might be 'the nearest major city', and if read in northern France could resolve to 'Paris'. ContextualElements allow for location-sensitive content, narratives that situate themselves in the context in which they are read.

The model uses the same location-query for location specifications in pinned nodes and stacks. The idea being that while it would be possible to define absolute positions for nodes (for example, using GPS positions) relative positions that get resolved at read-time would create more portable stories (using location specifications such as 'the nearest library' or 'a large park'). While our conceptual model does not specify how these queries are defined or resolved, in our own implementations we intend to use open data (such as dbpedia[2] and OpenStreetMap[3]) to resolve a number of specific query terms into local landmarks.

A nice consequence of moving from a model of explicit linking to one of narrative transitions, is that the sculptural location-based model can easily include temporal aspects. The TimedChapter class includes a timetrigger, which is a timer event (either a timelimit, or absolute time period) at the end of which a chapter transition is triggered. This allows for the possibility of real-time narratives that unfold in a physical space, while the reader moves around to experience them (in a similar way to the Thespis prototype described by Bernstein, but in a physical rather than a virtual space [4].)

Figure 3 shows how Canyons, Deltas or Plains appear using our sculptural location-based model. The lower right part of the figure shows how a hybrid story might be constructed, in this example a plain of five pinned and unpinned nodes are visible during Chapter 1 of the story and can be discovered in any order. Two of the pinned nodes trigger transitions to different chapters (the delta pattern). Chapter 2 contains a single pinned node, and a timer that automatically transitions to Chapter 3 after a given time period. In Chapter 3 there is a single pinned stack that culminates the story (the stack version of the canyon pattern).

Locations and narrative transitions (chapters, timers and stacks) essentially formalise two particular ways in which a general sculptural model could be used, foregrounding them as first class elements in our model. But despite the power of these elements to achieve all three patterns it is still possible that authors will want to use other methods to sculpt a hypertext. For these kind of advanced uses the *ChapterElement* in our conceptual model contains an optional list of pre-conditions that must be satisfied for a node or stack to be visible (the constraints), and a set of behaviours that can alter the story state to allow these conditions to be triggered (the assertions). Although we don't define the syntax of these, they do form a mechanism through which other more unusual sculptural patterns could be implemented. In this regard our proposed sculptural model builds on the work undertaken in Card Shark [4] and Chawton House [31], and is similar to Pittarello's narrative framework [28].

Taken together, the classes in Figure 2 form a content model, but we also assume that sculptural location-based systems will follow a common reading model where the application shows the user the set of all nodes that are available for a user to read given their location, conditions and current chapter (including the top node of all currently available stacks). Readers will indicate that a node has been read through an acknowledge action (which may or may not be explicit). We envisage that most systems will also record the reading, the ordered list of all nodes that have been acknowledged, and will make this available to readers either during or at the end of a given reading activity.

4. SUPPORTING THE EXISTING FORMS OF STORYTELLING

In this section we demonstrate how our unified sculptural model of location-based hypertext supports existing structures of location aware storytelling. We have taken a number of previous location-based fiction projects and speculated as to how their underlying knowledge structures would map to our proposed model. We perform this hypothetical reverse engineering with a view to exploring the breadth of support that might be achieved with our model.

We have chosen a selection of projects that reflect a range of styles of locative based fiction. Table 1 below presents

[2]http://dbpedia.org/
[3]http://www.openstreetmap.org/

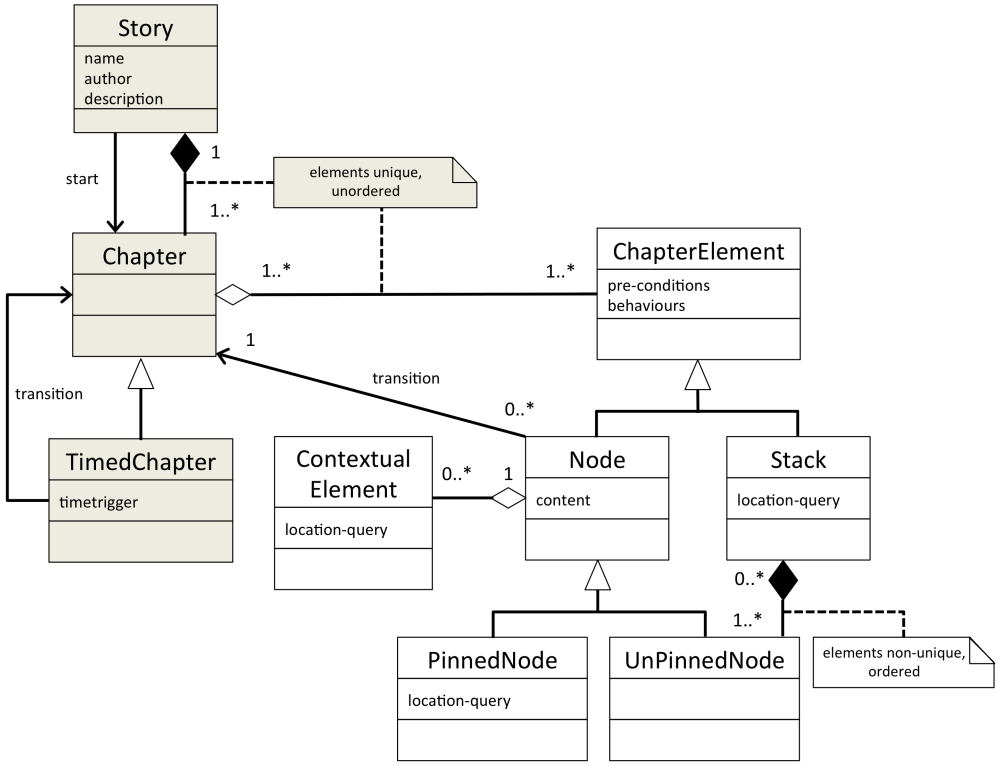

Figure 2: The Sculptural Model of Location-Based Hypertext

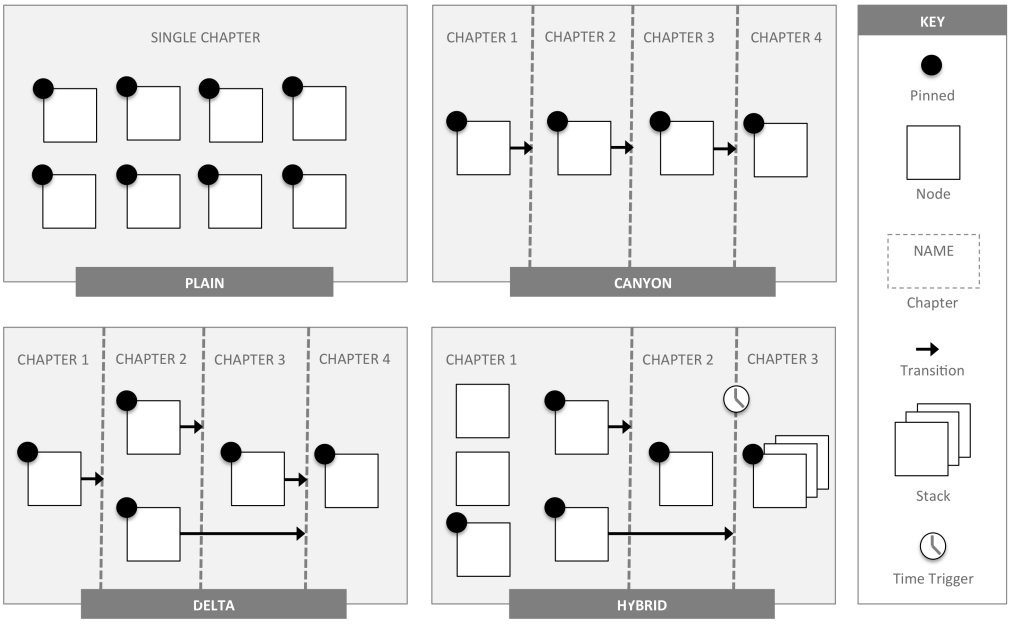

Figure 3: Sculptural Model supporting Canyons, Deltas, Plains and Hybrids

our mappings, examining correspondences with the core elements of our model (chapters, nodes, stacks, contextual elements and locative pinning) along with commentary on the overall style of the piece and implementations of readers and transitions between elements.

The five locative fictions we have chosen are Hopstory [25], Riot! [6], Pittarello's San Sevolo [28], The Chawton House project [30] and Viking Ghost Hunt [22]. These examples represent a range of styles of storytelling and have different objectives in their construction of user experiences.

Table 1: Validatory mapping of existing fictions to cartographic model.

Model Element	Hopstory [25]	Riot! [6]	San Sevolo [28]	Chawton House project [30]	Viking Ghost Hunt [22]
Overall style	**Plain**	**Plain**	**Delta**	**Canyons on Plain**	**Plain with Delta**
Objective	Amplify meaning and impact of historical content.	Provide a highly immersive, compelling experience.	Enhance emotional impact through contextualisation.	Augment a school field trip through situated learning.	Create an immersive experience.
Chapters	Temporal periods are defined to follow characters through the day.	Single scene setting, no chapters.	Phases of narration where only subsets are active.	Two different phases were used to move from exploratory discovery to focussed activity.	None.
Nodes	Each node is a collected story part for a character.	'Individual fragments (textual units) physically positioned in space.'	Short audio vignette.	Audio and textual descriptions or activities.	AR imagery or interactive virtual devices for locating ghosts.
Stacks	None.	None.	Described scenes in the narrative	Sequences of related description and activity cards.	None.
Pinned by	iButton interactions	GPS location	GPS location	GPS location and RF pingers	GPS location
Contextual Elements	None.	Spatially anchored with some prerequisites.	Different conditions of time, weather etc.	Previously viewed content.	None.
Reader	Linear movie of collected fragments presented at the end.	Audio clips played when fragments discovered.	Audio player.	Card interface viewer and recorder.	EMF meter and AR viewer to show ghosts.
Transitions	Dictated by sequence in which fragments were 'collected'.	Movement of the reader around the square where the fiction is set.	Moving between physical locations.	Stepping between cards and moving between locations.	Interaction with bespoke interfaces at specific locations.

5. THE GEOYARN SYSTEM

In order to test our model, a prototype locational narrative reader, GeoYarn, was implemented. The system consists of two parts: a server-side RESTful API that is capable of handling stories that are compliant with the model, and an Android application that gives users the ability to read these stories. We present it here as a proof-of-concept that demonstrates the expressibility of the model, and an example of how implementation decisions may be made in order to support both the content and reading parts of our sculptural model.

5.1 Server Implementation

GeoYarn implements the core of our model (Chapters, Nodes, location-queries and ContextualElements) but does not yet include support for Stacks or TimeTriggers (even so, it is fully capable of implementing all three patterns we have identified). Location-queries are implemented as a set of tags that indicate where it should be read. These can be any text, so could be explicit locations ('Big Ben', 'Eiffel Tower'), classes of location ('café', 'hotel'), or more abstract concepts ('quiet', 'green'). As an author, it is therefore possible to create a story without binding it to any specific locations, instead choosing to bind it dynamically to places with appropriate ambiences. The server stores the story elements in an SQLite3 database and provides them to the client as fragments of JSON.

GeoYarn matches location-queries against a set of known location regions. The regions for this prototype are represented as polygons of GPS co-ordinates. These co-ordinates are provided manually at present, but could potentially be obtained from services such as OpenStreetMap in future. As with nodes, locations have a set of tags. This decoupling of location queries from location regions means that location

regions can be added, edited, or deleted, changing the potential way that stories can be read but without requiring the stories themselves to be changed. If a new location is created with a tag 'café', existing nodes which match the tag will then be readable at that position.

5.2 Client Implementation

We also created a GeoYarn mobile client for Android (see Figure 4). The user selects a story from those available, and the client requests the first chapter of the story, providing the reader's longitude and latitude to choose suitable locations. The server returns a JSON representation of the current chapter, including the available pages, along with the GPS polygons that match the tags and that are nearby. Figure 5 shows an example fragment of JSON returned by the server.

The user is shown the story title, a short introductory text, and the list of pages that are potentially available (see Figure 4) expressed as a physical link, e.g. 'Read this at Building 32'. Each page link is only unlocked (changed to green) if the user is within one of the page's location polygons. Tapping on a green link then unlocks that node's content, and automatically invokes any narrative transitions (chapter changes and behaviours) associated with that node.

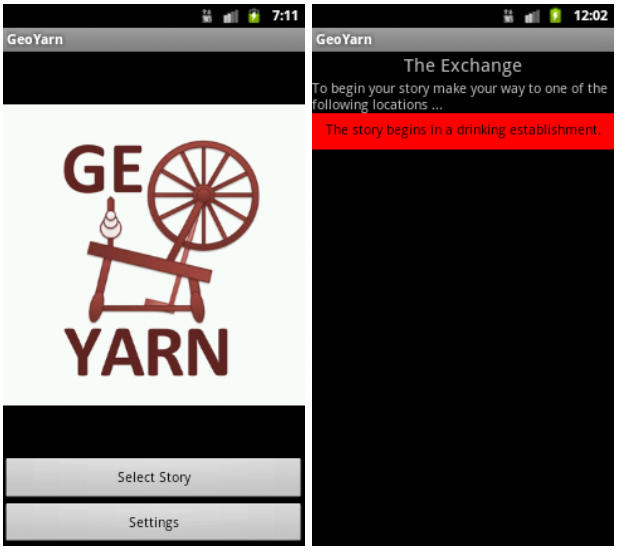

Figure 4: The GeoYarn application, and the beginning of story.

Once the user activates an unlocked page the content of the page is retrieved and displayed. Beneath the text the titles of nodes that are still available are shown (which may be new nodes if a narrative transition has just occurred), and as before the user can activate one of these once they are in a suitable location (see Figure 6).

5.3 Story Support

We have used the GeoYarn system to create a number of short, experimental stories, a selection of which are illustrated below:

Story 1: The Exchange. A canyon of 4 nodes. Each at a different tagged location (drinking establishment, quiet place, outside a building, bus stop). *It was on a wet Friday in September that they made their decision. Seats facing, a coffee cooling in a tension only deepened by the rain cascading outside.*


```
{"id": "1", "pages": [{"content":
"It was on a wet Friday in September that
they made their decision. Seats facing, a
coffee cooling in a tension only deepened
by the rain cascading outside.\nShe looked
at him through sharp glasses. \"So we're
doing this?\"\n\"I'll handle it.\"\nAnd then
she was gone. He had to think about this –
he knew the perfect place.", "locations":
[{"id": 1, "polygon": [{"lat": "50.9345783",
"lon": "−1.3974006"}, ... ]}], "id": 1,
"next_chapter": 2, "title": "The story
begins in a drinking establishment."}]}
```


Figure 5: Shortened JSON representation of chapter returned to the GeoYarn client

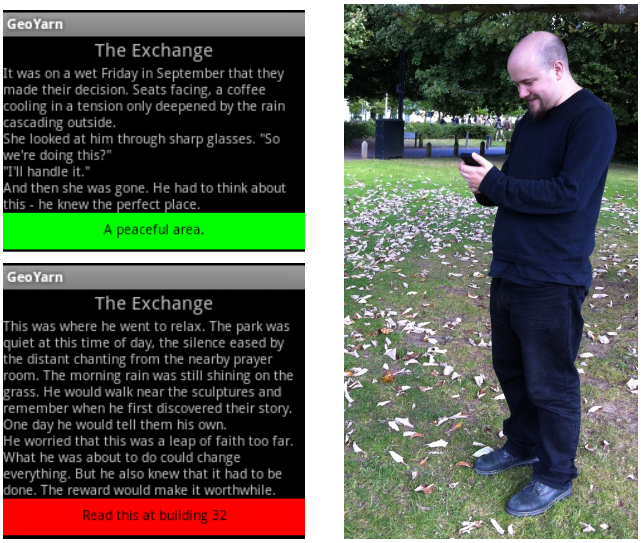

Figure 6: A reader navigates from one page of a story to another by being in a suitable location (a peaceful area).

Story 2: Vampires. A canyon of 5 nodes, restricted to the hours of darkness. Intended to guide the reader from a library, to a stream, to a cafe. *A full moon eased my navigation, but also gave me away to the stalking nightcrawlers.*

Story 3: Recoil. A canyon leading to a plain leading to a canyon, 6 nodes. The beginning and end nodes are set and the ones in the middle can be read in any order. *I wandered thoughtfully away for some time, away from the road, and the trees, until I saw it.*

Story 4. As You Look Around You. An unpinned stack of 7 nodes, with contextual elements in each node. *People simply heading from <next nearest building> over to <building serving food> to get an early <next meal>.*

We intend to develop GeoYarn to further explore the contextual aspects of the sculptural model. For example, as the phone includes several sensors (orientation, audio, visual, etc), it would be possible to use these in tandem with external sources to enhance the reading experience. For example, audio and bluetooth information could be used to determine the quietness of a location, or an external web service could provide weather information. We also plan to use GeoYarn as a testbed to begin to more formally evaluate the flexibility, expressivity and usability of the sculptural model.

6. CONCLUSIONS

As location aware smart devices become ever-more prevalent we will increasingly need to understand hypertexts that are location aware, and that use our physical surroundings and movement as part of the hypertext reading. But despite a rich history of location-based hypertext systems in the research community, most location-aware apps are underpinned by simplistic hypertext patterns, and there is a lack of understanding about how different patterns might be reconciled in order that standards could be defined, and richer hybrid stories created.

In this paper we have identified three key patterns of location aware systems: Canyons, a path of situated nodes that must be visited in order; Deltas, branching paths of situated nodes; and Plains, sets of nodes that can be visited in any order. We have also presented a unified sculptural model of location-based hypertext that is capable of representing all three patterns. The model builds on the general sculptural mechanisms of pre-conditions and behaviours to foreground location-queries (via contextual locations and content) and narrative transitions (via chapters, timers and stacks). Our approach is novel as it views narrative transitions as the primary structure of the hypertext, leaving navigation to occur in physical and temporal space.

We have shown how a number of key existing systems can be mapped onto this structure, and through a prototype system called GeoYarn, we have demonstrated that using the model it is possible to create hybrid stories (for example, Plains littered with Canyons, or Deltas that break out into the Plains). We have also described how attaching simple timers to chapter transitions could create narratives that unfold around a reader as they explore a physical space, as if wandering through a distributed play.

A key and novel feature of our conceptual model is that instead of encoding absolute locations, it uses location-queries that are resolved at readtime. Although these could be absolute, they are also allowed to be semantically relative (such as 'the nearest shop'), allowing a location-based hypertext to be read and reinterpreted in many different locations. In our GeoYarn prototype we have shown how open data and simple query languages could potentially support such a mechanism, but alternative implementations are also possible (such as downloading bespoke mappings for a given place alongside a story).

In our future work we intend to extend the ability of GeoYarn to understand more complex location-queries, and use new open-data sources to implement them. We also hope to develop new authoring systems that will help non-technical authors to create sculptural location-based hypertexts, and allow us to explore more organic and collaborative stories (one of the key advantages of the sculptural approach is that it is easy for sculptural hypertexts to grow over time, as new nodes can be added without impacting existing nodes).

Location-based hypertexts have huge potential to enhance our interaction with physical places, and offer new narrative forms that should entice writers and excite critics. But a lack of understanding over what is possible (and how location-based narratives could be formalised so that they are independent of proprietary formats and readers) is stifling innovation. The sculptural location-based model we have presented here is an early step in opening up the world of location-based hypertexts and showing what is technically and narratively possible. As such we hope that it will inspire others to build novel software, and create innovative new stories.

7. ACKNOWLEDGEMENTS

This research is funded in part by the EPSRC and AHRC PATINA project through the RCUK Digital Economy programme (EP/H042806/1), and in part by the EU DESIRE network.

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