Smartphones Let Loose – The Museological Potential of Wireless Technology

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Abstract

The use of wireless devices such as camera phones, PDAs and tablets tends to be restricted, if not subjected to a blanket ban, within art galleries, museums and other exhibition spaces. The reasons behind such restrictions are many, but are typically grounded in a fear of their disruption to other visitors and concerns over copyright issues and damage to sensitive artworks from bright lights e.g., camera flashes. In this paper, we demonstrate a non-invasive use of wireless technology to provide augmented information on artwork beyond the traditional paper-based media. We show how art galleries, should they be willing to encourage the use of wireless technology by their visitors, can exploit it to improve viewing conditions and collect valuable data on visitor sentiment and on traffic through the gallery.

1 Introduction

Traditionally, art galleries rely on a combination of labels, printed brochures, maps and audio devices to inform visitors about the collection of artworks on display. Such restrictive and non-interactive media limit the breadth of information that can be provided. As mobile Internet connectivity becomes ubiquitous through the continued democratization of smartphones[17], it is expected that online services supersede the use of printed materials to provide dynamic and interactive information. At the time of writing, online image recognition services (through the Android applications PlinkArt[6] and Google Goggles[9]) allow smartphone-carrying visitors to look up information about a piece of art simply by taking a picture of it. It can be envisaged that galleries may in future provide tailor-made applications that visitors can install on their mobile devices to obtain comparable Internet search capabilities, combined with new types of user-targeted information. For example, such applications could provide answers to some of the visitor's concerns, such as "which way should I go to find more paintings by this artist?", "is a guided tour that describes this artwork starting soon?" or "how congested is a particular room at this moment?"

Museology refers to the science or profession of museum organization and management[10]. In this project, usage data can be analysed to extract trends that can inform museological planning. In particular, sentiment analysis[23] can be applied using indirect indicators – metrics such as query volumes or time spent – which we propose exploiting for the purpose of valuation and dynamic pricing. We also propose a novel approach for determining the location of visitors in the gallery (where traditional geo-location techniques based on radio triangulation, particularly indoors, lack adequate precision) based on matching a Uniform Resource Locator (URL) encoded in a bar code to the known location of its corresponding artwork on the exhibition map. Such data can be particularly useful for exhibition planners as it can be applied to inform the optimal distribution of artworks, with the objective of limiting congestion and facilitating the flow of visitors through the gallery. Additionally, adequately designed visualization based on this data can help a visitor navigate the gallery and know, for example, which parts of the exhibition she has not yet walked through.

We will begin by introducing the various research questions we have explored in Chapter 2, and then provide a review of the literature in the applicable research domains in Chapter 3. Chapter 4 will describe how we designed and ran our experiment, what software we wrote for our prototype and what our simulation consisted of. In Chpater 5, we will evaluate the results of our experiment and draw conclusions from them, before suggesting further work to complete and extend this research.

2 Approach

Our work on this research took many twists and turns, and we examined a number of potential research questions before settling on the questions described further on.

One initial idea related to exploiting an image matching database such as PlinkArt's for an entirely different purpose: turning network traffic data (which plainly has nothing to do with visual art, although there is a myriad of ways to represent it graphically) into an actual painting. The goal was to establish whether it was possible to obtain an artistic representation that can convey elements of network traffic patterns. After some research and communications with PlinkArt's author Mark Cummins, we deemed this proposal to be too experimental and too unlikely to succeed. In Mark Cummins's words, painting similarity in Plink "is defined by a distance function which does not behave at all like human notions of similarity"[13].

Another thought experiment was whether it was possible to mine the contents of HTTP traffic packets inside the art gallery in order to gain insights into the activity and the interests of the visitors. The idea was to attempt to infer which paintings the visitors are looking at from the queries being sent from their mobile Internet devices to various image recognition services such as PlinkArt and Google Goggles, as these queries, being based on image capture, imply that they are standing in front of the corresponding paintings. If reliable, such data could be mined for museological applications such as route planning. This research question is fraught with practical difficulties, however. We determined that an experiment could be carried out by providing a free wireless Internet access point connected to a proxy which analyzes HTTP traffic, looking for patterns that identify a known artwork from the collection. In practice, the development complexity of this experiment combined with operational difficulties led us to abandon it and focus on the simpler experiment we discuss in further paragraphs.

This paper looks at the specific context of visitors within an art gallery.

Many aspects of our research, such as traffic pattern analysis, sentiment analysis and dynamic pricing, are in principle transferable to various other kinds of places where visitors are allowed to make their way at their own discretion between things that may or may not be of interest to them. Shops and cities are examples of such comparable scenarios. Indeed, the Google Goggles image search application supports not only paintings, but also landmarks and product logos[3]. As with our art gallery visitor who may capture the picture of an artwork to discover its story, its location on the gallery map and the location of related paintings, a supermarket shopper could photograph a product (e.g., a chocolate bar) from a shelf to find its reviews, its location on the supermarket floor plan and to find out where related products (e.g., cocoa powder by the same brand) are to be found.

3 Related Work

3.1 Artwork Valuation

The value of a piece of artwork is particularly difficult to evaluate. An individual painting rarely changes hands, and new paintings have no known market value until they are sold for the first time[18]. Added to this, the value of artwork can fluctuate greatly depending on the whims of the art market. Generally, the factors that affect the market value of a painting include:

1. Market direction
2. The reputation of the artist
3. The level of promotion by galleries and auctioneers
4. Trend-setting and evolving tastes

Research has attempted to predict stock value based on the level of Web traffic[21] and it can be envisaged that the same principle may apply to the valuation of artwork.

MacKie-Mason and Varian[22] introduce the concept of usage-sensitive pricing in order to reduce congestion by encouraging network utilization outside peak times. This concept is further explored by Paschalidis and Tsitsiklis[28], whose experimental data suggest that well-chosen time-of-day pricing schemes can be adequate approximations of dynamic time-based pricing.

Web search is one of the most important and widely used applications on the Internet. The majority of web search queries are keyword searches performed over textual contents. As media files of a variety of types are being published on the Internet, the need to search on non-textual content such as images, audio and video clips emerges. Two different approaches have been used to search on image collections. One is based on textual metadata attached to the images, the other is based on image content information[27]. While the first approach involves large amounts of effort for the manual creation of metadata for both the indexed images and the images to be searched, the second approach, which is also called Content-Based Image Retrieval (CBIR)[20], tends to be more practical and useful.

In a typical CBIR system, a data insertion subsystem is normally used to extract features from images that are to be added to the image store. A query processing subsystem then allows users to define query pattern either manually or by using an image. The query processing module then extracts a feature vector from the query pattern or image and calculates its similarity with the images in the database. The search results are stored images ordered according to their similarity[27]. Possible feature vectors include a colour histogram[25], a certain shape such as a curve[12], and texture. By applying different sets of feature vectors, search results may be different on the same image database[24].

In recent years, several CBIR systems have been built for both academic and commercial use. For this project in particular, two such applications on mobile platforms were studied: Google Goggles[9] and PlinkArt[6], both of which are available on the Android system. When searching images using Google Goggles, the image, usually a picture taken from the phone's camera, is sent to Google's data centre where a signature of the object is created from the image. It is then compared to the signature of known objects in Google's data store, which includes artworks, landmarks, wine labels, etc. The matched result is then returned to the user[3]. PlinkArt shares the same architectural design, but its database only stores a collection of artworks.

Information visualisation is a broad term which can be defined as the process of transforming data, information, and knowledge into visual form. Effective visual interfaces may help in discovering hidden characteristics, patterns and trends. Visualisation is an effective and powerful tool for data analysis, giving art galleries a insight into the emerging trends through an intuitive user interface.

Fry[16] suggests that the primary stages of data visualization consist of data acquisition, parsing, filtering, mining, representation, refinement, and interaction. Bertin[11] proposes that visualisations are made from marks and their graphical properties. The most common visualizations are marks in forms of points, lines, surfaces and volumes, retinal encoding including colour, size, shape, grey level orientation, and position. Some ways in which data can be visualized are the following:

1. Scientific visualisation - spatial representation of data.
2. Geographical Information System (GIS) visualization - mapping geo-coordinate variables to a two-dimensional surface.
3. Multi-dimensional plots - mapping variables that are not intrinsically spatial to a two-dimensional surface.
4. Node and link visualization - representing linkage of information between entities.
5. Multi-dimensional tables
6. Information landscapes and spaces

Of all the ways of data visualisation, multi-dimensional plots are more relevant to this study. One multidimensional way of data representation are star plots[15]. Star plots use coordinates axes and a circle with equal radius to represent lines originating from the center towards data points on each axis to form a star. Points are used as it is much space efficient and simple representation in comparison with connected lines, thereby making representation intuitive.

4 Implementation

4.1 Experiment Setup

Prints of a selection of eleven artworks from the National Gallery of Ireland[5] were used to set up the experimental environment for the project. In order to capture the interest of visitors with different preferences and tastes, the paintings were carefully chosen to contain a mixture of landscape and portraits from both Irish and foreign artists, created between 16th century and the early 20th century. The prints differ in size, ranging from approximately 35 × 25cm to 80 × 60cm, and are on either paper or canvas. We separated them into two groups and mounted them on the walls of two separate neighbouring spaces, where we expected them to be seen by two slightly different categories of visitors.

A group of seven prints are shown in the lobby area on the ground floor in the Lloyd Institute at Trinity College Dublin[8]. It is in the main entrance of a building that hosts offices for around 200 teaching and research staff and four frequently used lecture theatres. The paintings are displayed in a lineal arrangement due to space restrictions (the lobby is long room with staircases along one side). The site is a fairly open area and receives much footfall, as most of the building's visitors need to walk by the prints on their way to their destination. Another group of four prints is displayed in a staff meeting room in the same building. The meeting room can sit ten people and frequently hosts meetings of various groups of people.

Each print is accompanied by a tag, affixed below the print. This tag displays a shortened redirection URL hosted on bit.ly[1] and its equivalent in Quick Response code (QR code) format, which can be read by recent mobile phones by using assistant software. Figure 1 shows the print of "A River Scene" by Claude Monet with its tag on display in the lobby of the Lloyd Institute building. The shortened URL redirects visitors to a webpage that contains a short description of the painting. Once a visitor visits the webpage, details of the visit, e.g., the time, redirection source, and browser signature are stored in a database. A visualisation generated on the fly based on the database records is also displayed on the webpage. Figure 2 shows the screenshot of the webpage for the same painting.

4.2 Visualisation

Two types of visualisation are shown for the paintings – a chart illustrating the distribution of webpage visits in the painting group, and a map-based visualization tracking the locations visited by the user during the last ten minutes.

4.2.1 Webpage Visit Distribution

A pie chart that illustrates the percentage of painting webpage visits against the total visits of the webpages of paintings in the same group is generated and displayed right below the short painting description. As illustrated in Figure 3, the data is taken directly from the database regardless of when they occurred. The visualisation aims to show the attention a particular painting generates with visitors compared to the other paintings in the group. Figure 3 shows the webpage visit distribution visualisation for the painting "A Peasant Wedding".

Figure 1: “A River Scene” on Display with Tag

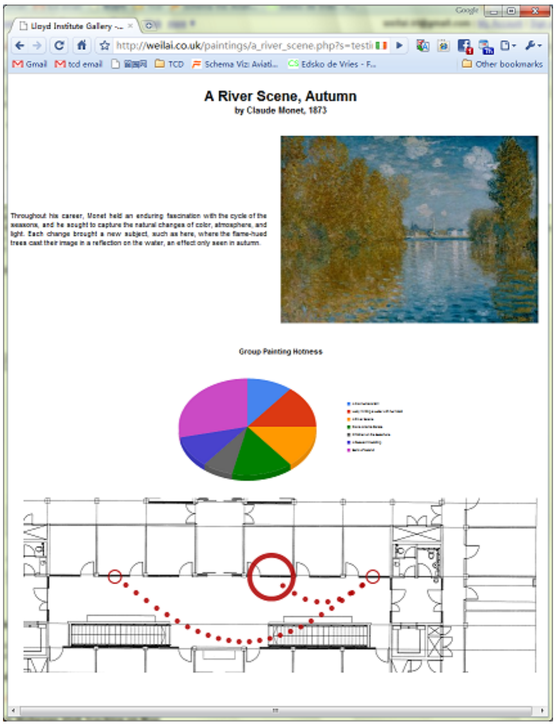

Figure 2: Screenshot of a Painting Webpage

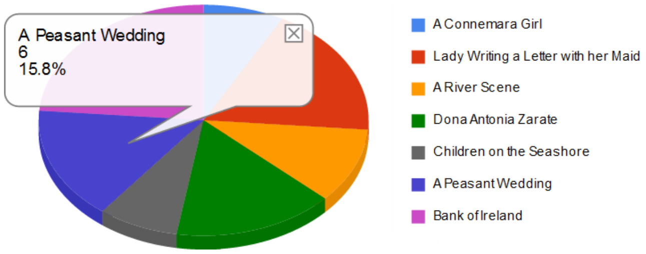

Figure 3: Webpage Visit Distribution Visualisation for a painting

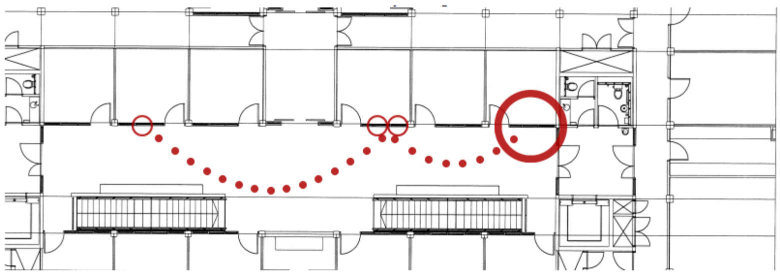

Figure 4: Floor Plan Visualisation of Lloyd Building

4.2.2 Map-Based User Tracking

A floor plan with dynamically-generated overlays is used to represent location information relating to a particular visitor. Our visualisation, illustrated in Figure 4, emphasises both the location of the artwork the user is currently facing and the historical path of the user's viewing pattern. The current location is marked by a large red circle, akin to the conventional 'you are here' markers commonly seen on maps, e.g., metro and public transport maps. The user's historical path is marked by smaller circles at each previously visited location, interconnected by dotted lines. The shapes and dotted lines were sufficient to convey the meaning of the markers, and we did not need to resort to different colours or text in order to distinguish them. There appears to be a universal understanding of such representations.

Our initial experimentation was in a rectangular room, where we found that straight dotted lines were adequate to illustrate the paths. However for our live experimentation most paintings were in the lobby and were disposed in a straight line, which meant that dotted lines between paintings would overlap each other and become illegible. As illustrated in Figure 4, curved lines were used to connect two distinct paintings, which adequately solved the legibility issue.

Each time the user queries an artwork, the visualisation is updated to show the continuation of the path and the new current location. This proves particularly intuitive to the user – it feels like tracing one's tracks – as the addition of a new dotted line and the displacement of the large circle immediately catches the eye while the remaining, unchanged markers are instantly recognizable. Such progressive visualisation has the potential to provide the added value of helping visitors orient themselves through the gallery.

This visualisation was generated using server-side image processing, implemented in PHP with the GD graphics library[2]. An alternative solution would have been to dynamically generate the visualisation as a Scalable Vector Graphics (SVG) image, however this client-side rendering solution is subject to browser incompatibility issues. As we could not prescribe a particular browser for our visitors, we therefore decided in favour of server-side rendering.

4.2.3 Simulation

In order to produce large amount of hits to simulate the visitors' activity in a busy gallery, a simulation service was used to generate webpage visits. These simulation visits can be easily distinguished from the actual webpage visits through the use of specific URL parameters.

The primary objective of the simulator is to simulate the flow of people into the art galleries based on characteristics obtained from the data we collected during our real-life experiment. The data was generated based on variation of three factors: queue length, average viewing time per person and visitor arrival rate. The queue length is the maximum length of the queue for a each painting, average viewing time is the maximum time allowed to view a paining and the the average arrival rate is the probability of the people arriving in the queue i.e., the rate at which queue is filled. These three characteristics were adjusted for each painting in coherence with the data collected by performing our real-life experiment.

To simulate traffic we developed a multi-threaded real-time traffic generator that mimics the arrival and circulation of visitors within our demonstration space. Using multiple concurrently executing threads, each representing a visitor, we generated actual HTTP traffic to our visualisation server, testing both its accuracy and its resiliency to multiple concurrent hits from different users. By applying basic queuing theory[19], we can model visitor behaviour using notional queues for each painting in the demonstration space. The size of the queue represents the maximum number of simultaneous visitors to each particular piece – large artworks, such as "Guernica" by Picasso, "Liberty Leading the People" by Delacroix, and "Marriage of Strongbow and Aoife" by Maclise can facilitate more visitors given their large size than more modest-sized pieces, or artworks located in narrow areas of a gallery. For our implementation, the two display spaces accord roughly equal display areas to each artwork, however the access and number of visitors to the two spaces is significantly different. Our simulator demonstrated that both the visualisation functions, as well as the underlying network and hardware, were capable of facilitating multiple visitors per second, without any noticeable reduction in service.

5 Evaluation

5.1 Conclusion

With merely 37 distinct webpage hits from 25 unique visitors, our real-world experiment has not produced data conducive to reliable analysis. Only 10 visitors out of the 25 visited webpages of more than one prints, which shows that visitors in the building did not have much interest in the collection and in the experiment itself. However our data shows that 51 percent of the total number of queries originated from barcode scans, which can be interpreted as a sign that participants choose to try out new technology when the occasion presents itself. We can conclude that, should an art exhibition encourage the use of new technology, for example by displaying QR code as we did, our experimental results suggest that uptake is likely to be high.

Most prints attracted at least one webpage visit, with the exception of one relatively famous Irish painting, "The Liffey Swim" by Jack B. Yeats in the meeting room group. On average, the painting group in the open area have almost three times more hits (4.5 hits per print) than the meeting room group paintings (1.5 hits per print), which generally represents the apparent accessibility of the two venues. The print that attracted most hits is a slightly less well-known painting. A small paper print of "Bank of Ireland" by James Malton recorded 9 hits, probably in part due to its advantageous location beside to the main entrance of the building. The distribution of webpage visits of the rest of the prints in the group generally reflects the notoriety of the painting and the size and medium of the print.

The visitor tracking data for the 10 visitors who recorded multiple hits shows some patterns of user visits. Only 2 visitors out of the 10 visited webpages of adjacent paintings. A pattern of visiting webpages of paintings with similar types of contents, either landmark or portrait, regardless the distance between the prints is apparent from 6 visitors. Empirical analysis of this nature might help an exhibition organizer in planning the locations of the items in the collection in a more informed manner.

Our simulation results show that the observed patterns can be matched and the data set interpolated, to improve clarity on the existing patterns. However, in some instances a contradiction between the simulated data patterns and the real data patterns was observed resulting in new trends. It brings us to the conclusion that simulation can be used to interpolate the result sets unreliably and simulation if necessary should be performed with greater care.

5.2 Future Work

The principal concern in analysing the data we gathered is that it may not accurately represent the actual level of interest for each painting. Firstly, our experimentation took place in university buildings, in locations where visitors are likely to be actively occupied by various activities; and secondly the participants could only show a certain interest in the artwork by scanning the barcode or typing the URL into their Web browsers. A significant difference is expected in the behaviour of visitors of an actual exhibition. Therefore, the next stages of research need to take place in actual art galleries. We visited the National Gallery of Ireland and the Douglas Hyde Gallery[7], but their current policies prohibit the use of mobile phones and cameras, partly due to artwork protection and licensing issues. However some galleries, such as the National Gallery, London[4], expressed an interest in permitting the use of a broader range of electronic devices on their premises when communicating with us.

Testing the assumption that network traffic analysis can derive geolocation information will need further research utilizing the relevant technology. Large-scale outdoor exhibitions could make use of Global Positioning System (GPS) positioning, while indoor exhibitions could make use of more suitable solutions such as Ubisense[26] or triangulation-based geopositioning systems using Wi-Fi or mobile telephony base stations. The use of Ubisense tracking was initially planned in our research, but could not be achieved due to the decommissioning of the Ubisense system in the Llody building, where we hosted our experiments.

Insufficient usage volumes and the informal nature of the experiment that we ran meant that we were unable to conduct a post-experiment survey on our visitors to ascertain the effectiveness of the visualizations in conveying meaning. Future experiments on a stastically significant population should use surveys to measure the quality of the visualizations. It would also be interesting to use A/B testing[14] to establish the intuitiveness of a variation of visual markers.

Future research should make use of Radio-frequency identification (RFID) technology to capture proximity information without user intervention.

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