CMP3035M
Cross-Platform Development
Assessment Item 1

“Haunted Lincoln”

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Concept

Overview

"Are you prepared? No, really! Are you truly ready to learn more about Lincoln's gruesome history? The Haunted Lincoln app is an interactive experience, designed to show you the haunted locations around the city of Lincoln, UK. On the "virtual tour", you will uncover Lincoln's blood splattered past and secrets, seeing the city from a totally new perspective. Each location comes with enlightening information, with audio clips and images to truly immerse yourself in Lincoln's grim past. But if you fancy yourself as a ghost hunter, switch to the "ghost cam" at each location and see if you can spot any ghostly inhabitants on your travels!

The Haunted Lincoln app offers the following features:

- A virtual ghost tour, showing you haunted locations within Lincoln.
- Route customisation, allowing you to decide what locations you want to visit and in what order (based on your current location).
- Audio and written information about each location, including images.
- An augmented reality (AR) experience, allowing you to spot ghosts and ghouls on your tour."

"Haunted Lincoln" was inspired by the local Lincoln ghost walk experience (Lincoln Ghost Walk, 2018) and was motivated by the fact that learning history may be boring to some (stereotypically "young") people. The ways in which history can be told may disengage some users according to one survey (Schug et al, 1982). This application aims to create an interactive experience for users that brings Lincoln's history to life. However, what this application does further (compared to *traditional* tourism applications) is that it adds a "haunted" spin on Lincoln's history, selecting the parts of history that users may find interesting.

Requirements

This application corresponds to a tourism/exploration mobile moment, in that the application allows users to explore Lincoln's history, but from a "paranormal" perspective. The application is aimed at visitors or residents of Lincoln who want to learn more about Lincoln's history.

An example of a usage scenario for the application is as follows:

"Katie is a final year undergraduate student at the University of Lincoln. Not having very long left to stay in Lincoln (and with graduation looming), Katie decides to have one last look around Lincoln before she heads home. Looking for activities to do online and asking her friends, she discovers the Lincoln ghost walk. They meet up and visit the various locations around the city with the tour guide, listening to each location's history. They return home at the end of the day, feeling satisfied that they have uncovered the haunted history of popular and discrete locations around Lincoln."

The application could be used by visitors to Lincoln (while touring Lincoln). However, the application can also be used in a variety of contexts by the *residents* of Lincoln, like Katie above. They could walk around Lincoln at their leisure (and get notified when they are near a haunted location), or they could specifically go to locations around the city (with a group of friends). Multiple people could use the application on their own devices, or one person could, for example, play an audio clip hands free, while looking around and exploring the location itself. To further engage the user more with the location, augmented reality (a suggestion by a feedback participant described further in the "prototyping" section), could be used to unlock ghostly characters and hear about their stories.

As a result of this user scenario, the functional requirements are derived as follows:

- To create an application that showcases 6 core haunted locations around Lincoln on a map and allows tourists/visitors to go on a “virtual ghost tour” to each one.
- Each location should come with audio clips, to allow the user to listen to the on-screen text output via speakers or headphones, while they are looking around. Imagery should also be used to show the user specific areas of interest in each location.
- Each location should have it’s own “ghost” that can be viewed in AR at each specific location, providing further information about that ghost’s story and past.
- The application should facilitate a form of navigation, to guide the user to each location.

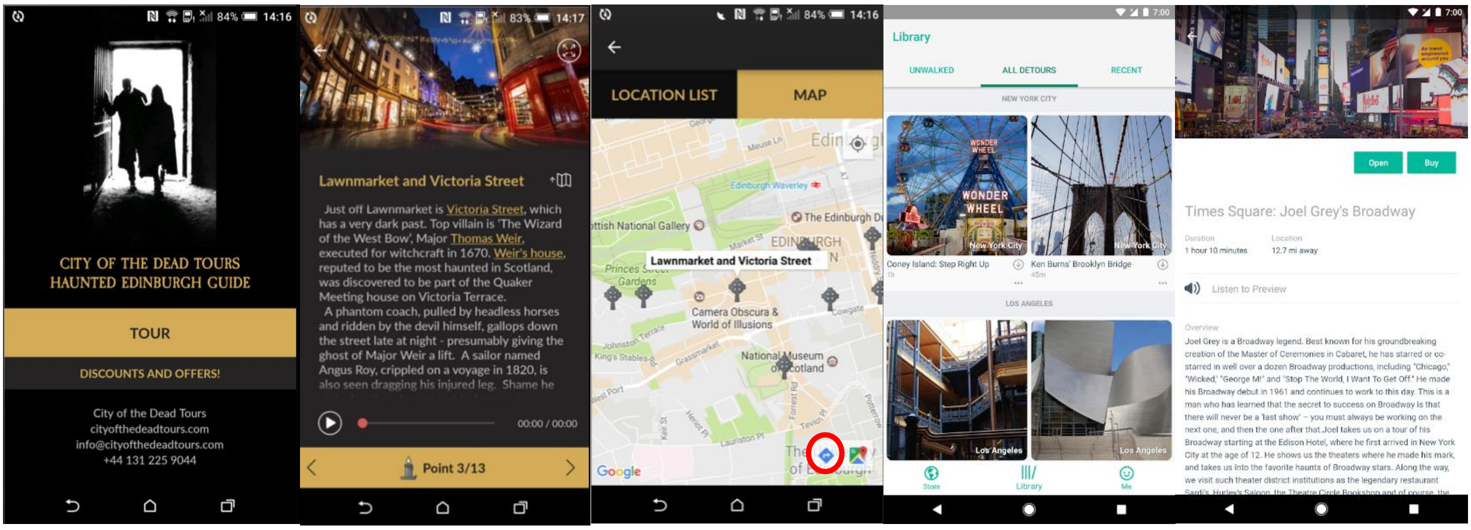
The non-functional requirements are as follows:

- The interface should be clear and easy to navigate.
- The interactive experiences should be memorable.
- The application should perform equally well on a variety of iOS and Android devices and be indistinguishable from a native application.

Competitors

“Haunted Edinburgh” (City of the Dead Tours, 2018) and “Detour” (Detour.com, 2018) are 2 applications that provide similar functionality to the Haunted Lincoln app.

Functionality, user experience and lessons learned



City of the Dead Tours
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Just off Lawnmarket is Victoria Street, which has a very dark past. Top villain is 'The Wizard of the West Bow', Major Thomas Weir, executed for witchcraft in 1670. Weir's house, reputed to be the most haunted in Scotland, was discovered to be part of the Quaker Meeting house on Victoria Terrace.

A phantom coach, pulled by headless horses and ridden by the devil himself, gallops down the street late at night - presumably giving the ghost of Major Weir a lift. A sailor named Angus Roy, crippled on a voyage in 1820, is also seen dragging his injured leg. Shame he

Times Square: Joel Grey's Broadway

Duration
1 hour 10 minutes

Location
12.7 mi away

Overview

Joel Grey is a Broadway legend. Best known for his groundbreaking creation of the Master of Ceremonies in Cabaret, he has starred or co-starred in well over a dozen Broadway productions, including "Chicago," "Wicked," "George M!" and "Stop The World, I Want To Get Off." He made his Broadway debut in 1961 and continues to work to this day. This is a man who has learned that the secret to success on Broadway is that there will never be a 'last show' – you must always be working on the next one, and then the one after that.Joel takes us on a tour of his Broadway starting at the Edison Hotel, where he first arrived in New York City at the age of 12. He shows us the theaters where he made his mark, and takes us into the favorite haunts of Broadway stars. Along the way, we visit such theater district institutions as the legendary restaurant Sardi's, Hurley's Saloon, the Theatre Circle Bookshop and of course, the

Figure 1: From left to right, the Haunted Edinburgh (City of the Dead Tours, 2018) “main menu”, “information” and “map” pages (with the navigation button circled in red), alongside the Detour application (Detour.com, 2018) “library” and “information” pages.

Haunted Edinburgh was an application by “City of the Dead Tours” to create “the capital’s first self guided ghost tour” (City of the Dead Tours, 2018). The application features an interactive Google map with markers which, when pressed upon, shows that location’s name (see figure 1). These markers are quite a nice feature, as they give a quick overview of where the locations are within the city. However, one problem with the “bubble” that appears above the marker, is that it simply shows the location’s name. It could be better, from a user experience perspective, to have button within the bubble that the user can click on, which takes the user to the location’s information page, or allows for the user to directly navigate to the location, instead of looking for the small “navigation” button in the bottom right (circled in red in figure 1). This is something that could be implemented into Haunted Lincoln, when presenting a map with markers.

The list of locations in Haunted Edinburgh could be quite useful, especially if users want to learn more about a location before physically going to it. However, it doesn’t display which locations the user has and hasn't visited, which could be confusing from a user experience perspective. A feature that Haunted Lincoln should have is the ability clearly to know when a user has visited a location, and to keep track of it on their behalf. Furthermore, users can't customise their route extensively in Haunted Edinburgh, which Haunted Lincoln should do.

A big advantage Haunted Edinburgh has is that it has fifteen pages information that include facts and figures about each location, written by a historian of Edinburgh. Haunted Lincoln will utilise the same audio and visual resources (in line with the aforementioned functional requirements). But to further distinguish itself from this competitor, Haunted Lincoln will have *multiple* images (as opposed to just one image in Haunted Edinburgh) to help show the user exactly what area within the location is being referred to in the text/audio. Furthermore, Haunted Lincoln should have AR characters to enhance the experience further at each location (distinguishing Haunted Lincoln from competitors).

Finally, in terms of functionality, the application is available both on iOS and Android and works on many different screen sizes (from mobile phones to tablets). This is great (and something Haunted Lincoln will certainly need to do) as it provides a consistent layout between both operating systems.

The second competitor, Detour, is less of a tourist application, and more of an audio guide, that the user can listen to while walking around a specific location (Detour.com, 2018). By far the best aspect of this application is the audio tours for specific locations. The audio clips are fully immersive, giving an almost cinematic experience. This, from a user experience perspective, can engage and make the user fully experience each location. In this context, due to limited resources in terms of audio engineering, this can't be replicated. However, in the future, the goal would be to emulate this immerse users in the haunted history of Lincoln.

When looking at the application reviews (particularly on the Google Play), several users have noted reliability issues. For example, one user said that the application crashed at specific waypoints in during the audio tour, another user had GPS issues during their tour, and so on. Learning from this, Haunted Lincoln must be thoroughly tested if it released publicly. Other users noted that one disadvantage of the application was that they couldn't do a trial run "unless your GPS tells the app you're physically there". Haunted Lincoln should allow the user to listen to each audio clip, regardless of location. One user also stated that they had run out of mobile data for the month as the application had used 800 MB (due to the large size of each audio file). Again, learning from this, Haunted Lincoln should have small, manageable audio clips.

In terms of user experience, the application has "image based" option menus, with white text on top (see figure 1, "library" page). At times this can be difficult to read from a user experience perspective. It may be better in Haunted Lincoln to have a clear colour scheme, with colours that can be viewed clearly together, instead of using light images with white text. However, the "image, audio, text" layout could be quite nice to incorporate into Haunted Lincoln, as it organises the interface well from a UX perspective, which users may appreciate.

Overall, if Haunted Lincoln combined this level of audio immersive-ness, as well as having AR, text and multiple images, it could really help to engage the user with Lincoln's haunted history and stand out from competitors. Many lessons have been learned that have been taken forward into the prototyping section, into the designs themselves. For example, to add buttons in the marker bubble, to the "image, audio, text" layout, not to use large audio files, and so on.

Prototyping

When designing the application, a low fidelity paper prototype was designed based on a hybrid of the Detour and the Haunted Edinburgh applications.

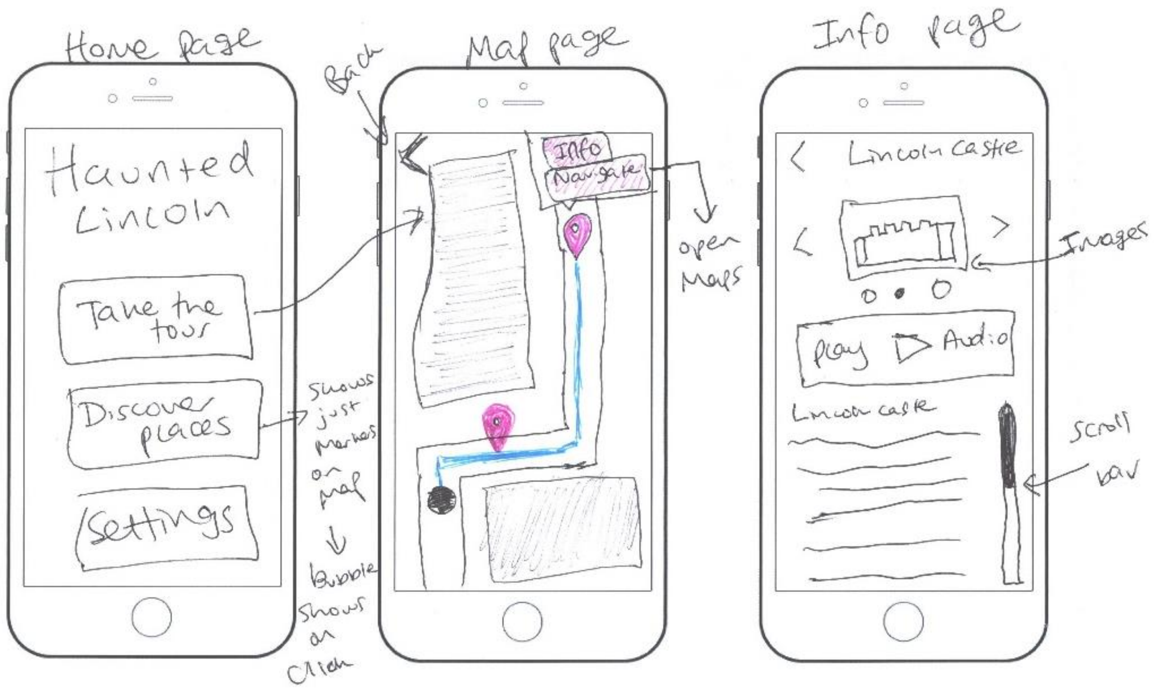


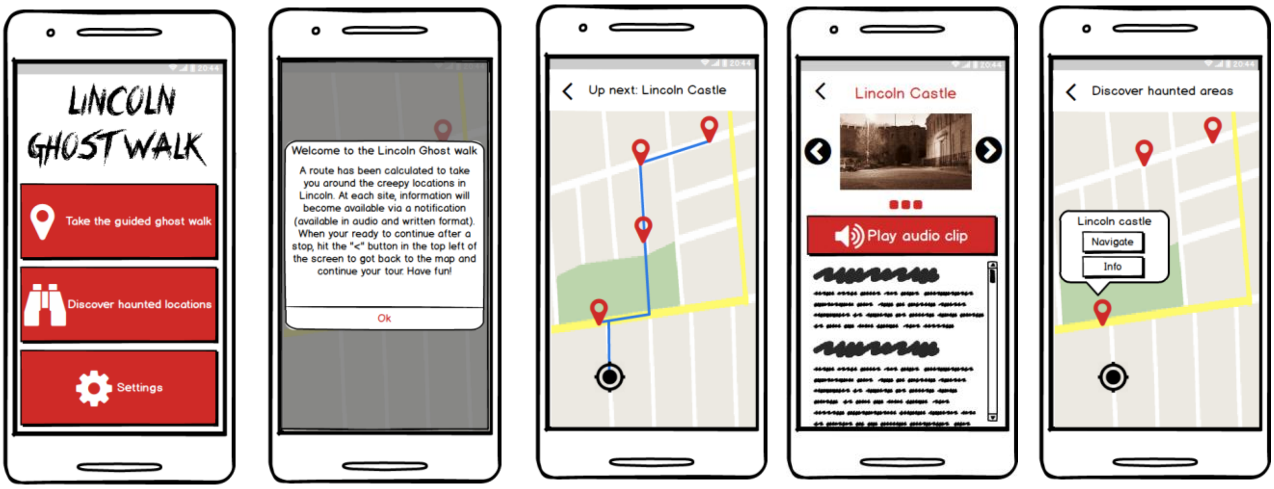
Figure 2: The Haunted Lincoln low fidelity prototype.

The menu (inspired by the Haunted Edinburgh app menu) was used, to allow the user to take the tour from their current location to haunted locations, or to discover all the places on the map by themselves. When the user clicks on the tour button, it takes their current location and plans out the best route to each stop on the tour. The user can click on each marker and decide to navigate to it or to go to that location's "info page". The markers tie in with the "6 core locations" functional requirement. The name of the location, along with the "image, audio and text" layout was used in the "information page" (as used by Detour and Haunted Edinburgh). However, Haunted Lincoln shows multiple images instead of just one (unlike Haunted Edinburgh) in a slide show element. The user can play and pause audio, as well as scroll through that location's text information (meeting the "audio clips, image, text" functional requirement). At the early stages of interface design, the idea for augmented reality (AR) didn't come until a user suggested it as an interaction type (when analysing the Balsamiq prototype) as a way to stand out from competitors.

Initially, three Lincoln residents (the target audience) aged between 20 to 23 were asked to give very brief user feedback. The technique used was the "think aloud technique" (Charters, 2003). Users were asked open ended questions about the sketches, such as what they thought of the overall application concept, what they thought about specific parts of the interface, such as the marker "bubble", and so on. All three participants said that they really liked the idea overall. One user commented that that it would be nice to have the "next location coming up" appear at the top of the map screen "so that I know where I am about to go". Another user noted that a tutorial at the start of the tour could be a nice addition, to understand what is going on, before launching the map.

When discussing what should happen when the user reaches a location, all three said that they expected a notification to come through on their phone. One user also noted that a nice feature would be to get a notification in the background when wandering around Lincoln when the user is near a haunted location.

As a result of this feedback, an interactive high fidelity prototype was produced in “Balsamiq”.



Welcome to the Lincoln Ghost walk

A route has been calculated to take you around the creepy locations in Lincoln. At each site, information will become available via a notification (available in audio and written format). When your ready to continue after a stop, hit the "<" button in the top left of the screen to got back to the map and continue your tour. Have fun!

Ok

Figure 3: The Haunted Lincoln high fidelity, “Balsamiq” prototype. From left to right, the “home” screen, the “tutorial” screen, “Take the guided ghost walk” map navigation screen, the “information” page for Lincoln Castle, and the “Discover haunted area” map screen.

Four participants were recruited to critique the prototype, all within the target age range and the types of people who the app is targeted at (Lincoln residents). A think aloud session (Charters, 2003) and a “system usability scale” (SUS) survey (Brooke, 2013) were used to evaluate the users feedback. Firstly, after allowing the users to explore the application and give verbal feedback and thoughts (discussed later) respondents gave their SUS scores via the SUS survey. Using the calculation method detailed in the academic paper (Brooke, 2013), the user scores were 92.5, 85, 47.5 and 72.5, giving 74.375. The average industry standard, according to Brooke (2013), is 68, which places this prototype at slightly above average.

Looking further into these results, while using the system, participants gave a plethora of feedback to justify their scores. All users complained that the take the “guided tour” and “discover haunted location” menu options were confusing at times. When questioned further, all participants said that it would probably be better to have one map on the screen that the user can use. One user a particular gave feedback saying that it would be nice to customise the route in some sort of “location manager”. This feedback in particular was taken on board for the next “wireframe” prototype by removing the menu screen and providing a simple interactive map.

Regarding the “bubble” one user commented would be very difficult *not* to hit the other button within the window. This is known as the “fat finger problem” (Siek et al., 2005), where the user’s finger may hit a button unintentionally. They said that one button within the bubble should be enough, and that they could go to the location manager to learn about a location instead.

Three users said that they did not find the tutorial useful, with one user explaining that “specifying the back button as “<” in the tutorial bubble caused confusion”. They said that it is obvious that the back button in the top right is to go back to the previous screen. When asked, all three users said that the tutorial was pointless. The fourth user said that he didn’t mind either way.

One final passing comment that a user made was to perhaps add augmented reality capabilities to increase interaction and engagement with the user. The user suggested that when a user reaches a location, they could unlock a “ghost character”, and view that character in that location using augmented reality. This aspect was added to the concept and functional requirements, and was an excellent suggestion to make the application stand out from other haunted/tourism apps.

Taking this feedback into account, an initial wireframe was designed in jQuery mobile.

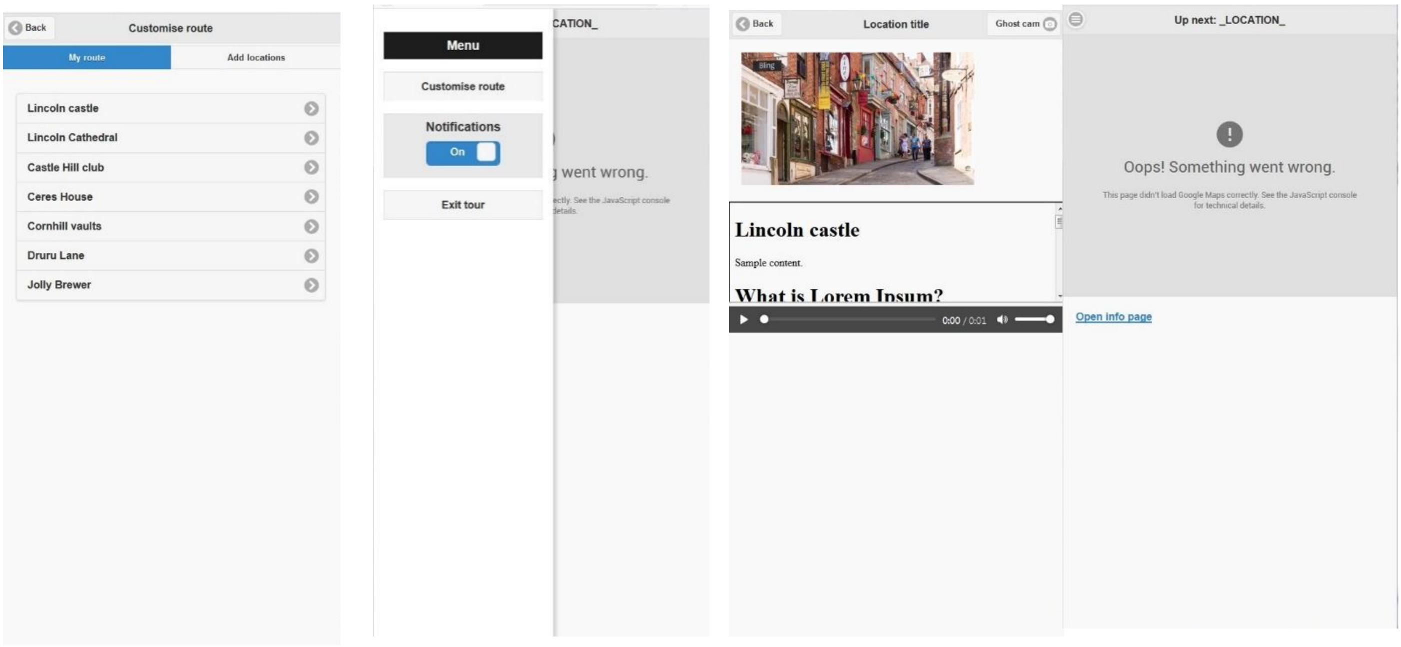


Figure 4: From left to right, the "location manager" screen, the "side panel", "information page" screen and "main map" screen.

The reason for using jQuery mobile directly and not Balsamiq was due to time constraints. Making an interactive mock up took equally as long as making a wireframe in HTML in this context.

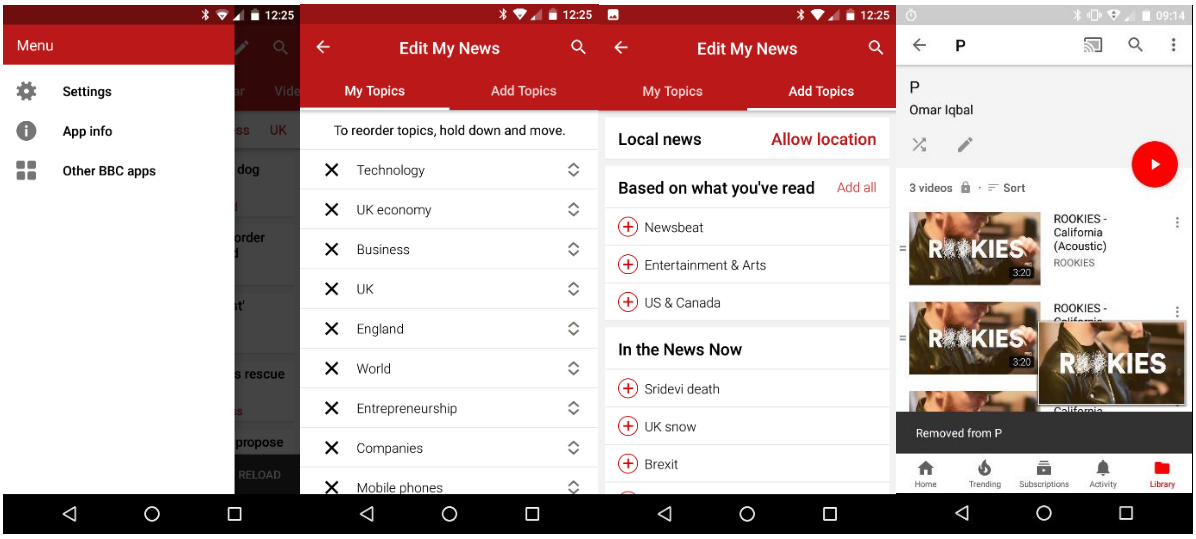


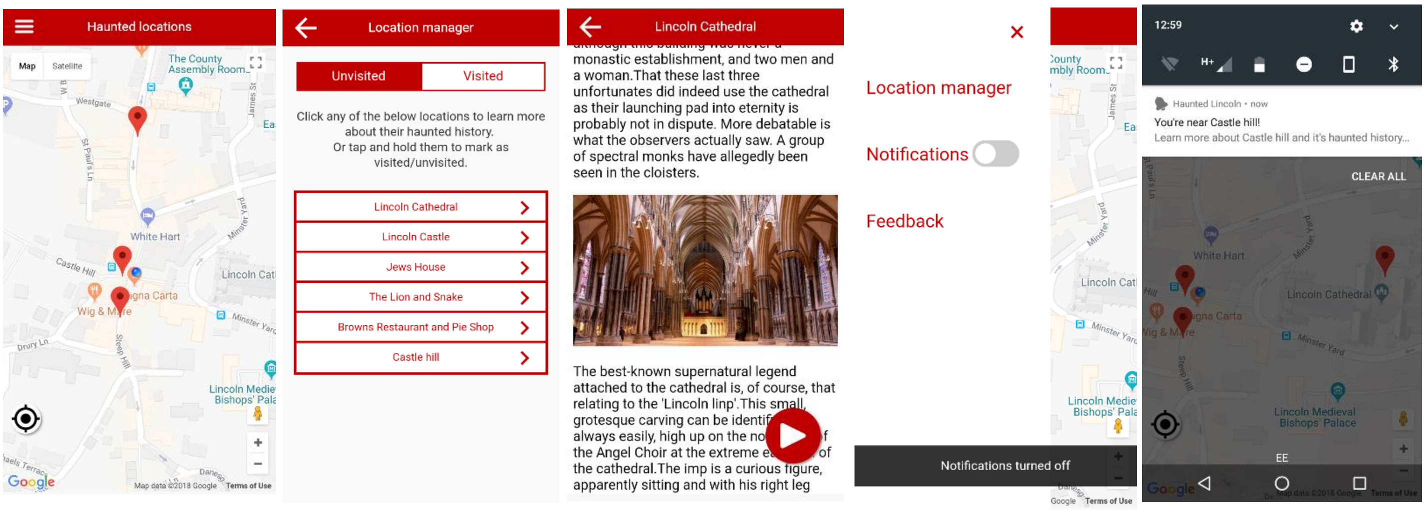
Figure 5: From left to right, the BBC News app (Media Applications Technologies for the BBC, 2018) "menu" side panel and the "my topics" and "add topics" tabs, alongside the YouTube app (Google LLC, 2018) "Playlist" screen, with a play button and "snack bar" message example.

One major inspiration behind the aesthetic and design of the overall app (also taking into account the new user feedback) was the BBC news app, due to it's (arguably) clean interface. As can be seen in figure 5, the main source of inspiration for the "customise route" screen in the wireframe came from the BBC news "topic manager". In the BBC News application, the user can change the order of the topics via the "up down arrow" icons, or can delete a topic by pressing the "X". On the right-hand tab, the user can add topics that are available. The wireframe tries to mimic this using the jQuery mobile "tab" and "ListView" assets. Furthermore, because the "menu" screen isn't needed due to one map being utilised, an alternative way of presenting a menu structure would be to use a "side panel" menu. As can be seen in figure 5, the BBC News menu only has "Settings", "App info" and "Other BBC apps" as its options. This was emulated in the wireframe.

The information page (containing a location title, “slideshow” place holder image, “iFrame” and media player) in the wireframe was designed around the “image, text, audio” layout (used in Detour and Haunted Edinburgh), initially to see how this layout would perform in practice. Furthermore, because there is only one real setting within the application, the “notification” setting was moved to the side panel, where the user can switch notifications on or off (as a separate settings screen would be redundant). Finally, a button for augmented reality called the “ghost cam” was added to the top right of the “information” page. If the user has unlocked the character for that particular location, then they will be able to see the ghost in augmented reality.

A think aloud session was arranged with two users before the main application functionality was implemented. One user immediately stated that “you can immediately tell that’s a web app”. This didn’t tie in with the “make the application feel like a native app” non-functional requirement. This would later be rectified using CSS. In terms of user experience and general layouts, almost everything was acceptable. However, when it came to the information page, there were many critiques made by both users. They both felt that the “image text and audio” layout felt quite cramped. One user commented that using the default media player on the mobile phone didn’t make it feel like a native app. They explained that a standalone “play pause” button would probably be a much better interaction (an example of which can be seen in in the YouTube app in figure 5).

Taking this final feedback into account, a new interface with CSS styling was applied. Many of the default jQuery assets were discarded and *custom* implementations (such as custom tabs and a custom “ListView”) were manually implemented instead. The final styling of the application can be seen in figure 6. Many of the default jQuery Mobile icons were replaced to make it feel like a native app (inspired by the BBC News app). This process was very time consuming.



Click any of the below locations to learn more about their haunted history.
Or tap and hold them to mark as visited/unvisited.

monastic establishment, and two men and a woman.That these last three unfortunates did indeed use the cathedral as their launching pad into eternity is probably not in dispute. More debatable is what the observers actually saw. A group of spectral monks have allegedly been seen in the cloisters.

The best-known supernatural legend attached to the cathedral is, of course, that relating to the 'Lincoln linp'.This small, grotesque carving can be identif always easily, high up on the no f the Angel Choir at the extreme e of the cathedral.The imp is a curious figure, apparently sitting and with his right leg

Notifications turned off

You're near Castle hill!
Learn more about Castle hill and it's haunted history...

Figure 6: From left to right, the main “map” screen, the “location manager” screen, the Lincoln Cathedral “information” page, the side panel (with a “snack bar" message example), and an example of a notification.

When implementing a gesture to mark each ListView item, a swipe gesture was used initially. However, because there was no direct visual feedback, this detracted from the native feel of the app. Instead a tap and hold gesture was used, with a highlight animation providing visual feedback. The side panel was restyled to look more like the BBC news app menu, with a slide out CSS animation and a “tap off” gesture, to let the user close the side panel. The iFrame was styled to fill the entire information page, with a floating play button. “Snackbar” messages were added and used when the user turned notifications on or off, GPS was lost, etc (inspired by the YouTube app, as seen in figure 5). These were more appropriate than using alert messages from a user experience perspective, as they are passing notes of information that don’t require explicit user confirmation.

An augmented reality prototype was tested but unfortunately, the library used, AR.js (Etienne, 2018), didn’t work as expected. The library would not load on browsers properly, and the application would crash when the user tried to use the library within the application. A test was conducted using the AR.js demo site, however, it didn't work as expected on most devices, distorting the image (as seen in figure 7). This made the library unusable. Alternative libraries were investigated, but due to time constraints, AR wasn't implemented, thus the AR and "memorable experience" requirements weren't met.

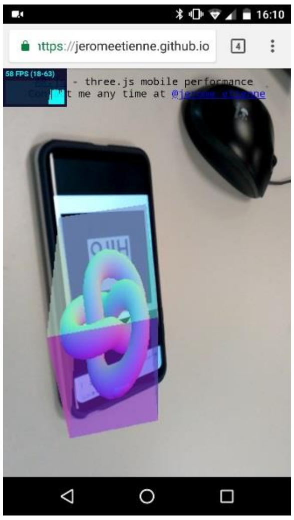


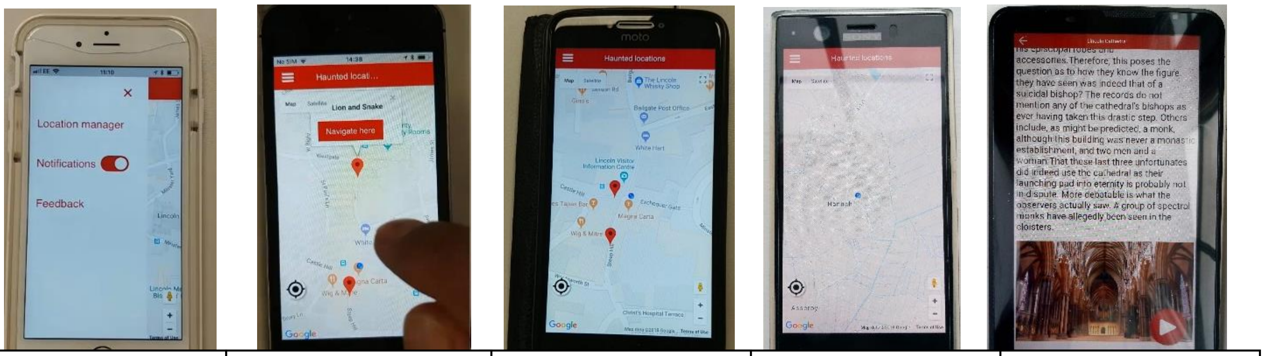
Figure 7: The WebAR demo website not displaying a 3D cube asset correctly.

When asking four users for feedback (initially using the think aloud technique) specifically on the new interface, all four users preferred the tap and hold gesture over the swipe gesture. When asked, all four users said they liked the side panel, toast messages and audio clips, with one user saying that the app looked clean and native (meeting the "native application" and "clear interface" requirements). When looking at information page, one user mentioned that "it would be nice to have forward and rewind buttons". This was very valid feedback. Unfortunately, due to time constraints, this wasn't implemented. However, the overall "audio" and "text" functional requirement was met. Another user found that on lower end Android devices (their own) that the CSS animations appeared slightly jittery. This was down to the user's phone but was acknowledged for future development.

When asking participants to complete a final SUS survey on the final application design, the final scores were, 87.5, 90, 77.5 and 85, giving an average score of 85. This was much better than the Balsamiq prototype score, but there is still room for improvement, as the feature set of the application expands in the future (such as fixing animations, adding augmented reality, and so on).

Final app

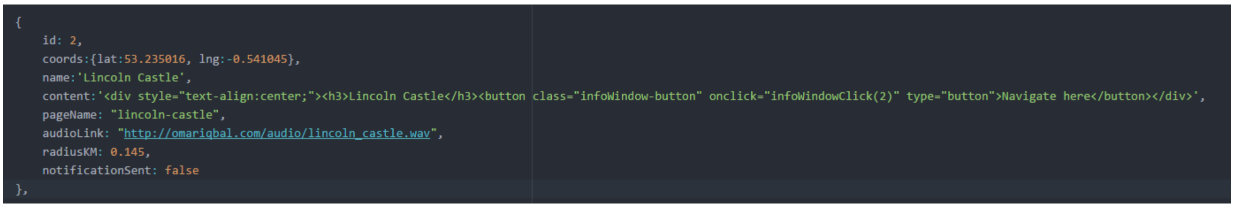
Firstly, the application works on many different devices of varying size (as seen in figure 8):



4.7'' iPhone 6s	4'' iPhone SE	5.5'' Moto E4 Plus	4.6'' Sony Xperia XZ1	10.1'' unbranded tablet

Figure 8: Several iOS and Android devices of varying screen sizes and budgets (low, medium and high end).

One of the main elements of Haunted Lincoln is the Google Maps functionality. This was by far the most challenging aspect of development. The application contains a number of location objects within an array (an example of which can be seen in figure 9). Each location has an ID, a coordinates object (holding the latitude and longitude), location name, HTML content to go into the marker "information window", information page name (which is used when referencing the location information page on a custom website server), the link to the audio file on the server, the location's radius in kilometres, and finally a variable that checks whether the user has already been notified that they are near specific location (at runtime). The IDs for each location are stored within the local storage. At runtime, only the "un-visited" locations are shown on the map.



```
{
    id: 2,
    coords:{lat:53.235016, lng:-0.541045},
    name:'Lincoln Castle',
    content:'<div style="text-align:center;"><h3>Lincoln Castle</h3><button class="infoWindow-button" onclick="infoWindowClick(2)" type="button">Navigate here</button></div>',
    pageName: "lincoln-castle",
    audioLink: "http://omariqbal.com/audio/lincoln_castle.wav",
    radiusKM: 0.145,
    notificationSent: false
},
```

Figure 9: The "Lincoln Castle" location object declaration (within the array).

One major feature to implement was to create custom navigation, allowing the user to see directions to particular location on screen using Google maps (much like Detour does). When looking for solutions online, many brick walls were hit. Eventually, it was understood why it was so difficult implement this. Google has stated that using Google maps API for real-time navigation is against their terms of service (Google, 2018). Taking this into account (and adapting the "navigation" requirement), the application was redesigned around opening an "intent" to the Google maps application, or to the Google maps website via a browser. This requires a user to click on a "navigate here" button for each location marker. This was easy to implement as Google have created a URL scheme which automatically opens Google maps (if it is installed on the device), or in a third-party browser (if Google maps isn't installed). This met the overall "navigation" functional requirement.

The next step was to allow the user to see their current location in real-time on the Google map. The application initially placed markers on the map every time the user moved. The issue with this however was a trail of markers was left behind the user every time the users position updated. The most challenging part of the whole development process was figuring out a solution as to how to get the user's previous location, and to remove the previous marker from the array. This took several days to work out. After many attempts, an approach was eventually taken where each location is assigned a unique ID based on their longitude and latitude. For example, if a location had a longitude and latitude of 53.1 and 29.1, the ID would become "53.1_29.1". Using the previous position's longitude and latitude, one could look up the previous position's ID, remove it and replace it with the user's current position. This was a much more elegant solution compared to using predefined IDs (predefined ID's would get mixed up when the user marked markers as visited or unvisited). A custom "centralise" button was then created, resetting the map onto the user's current position.

Initially the "navigate here" buttons for the info window (using the no CSS) was not user friendly (see figure 10, left), due to the "fat finger problem" (Siek, 2005). Users ended up missing the button press. Buttons were enlarged and styled in line with the application aesthetic (as shown in figure 10 below). When shown to the four participants conducting user feedback (in the prototyping section), they all agreed that the navigation button was easier to press, and was clear and easy to read.

The second (most significant and time consuming) element in the application was the notifications feature. The user, when near a haunted location, is notified which location they are near. This adds to the native feel of the application, using OS specific notifications. Each location has a radius in kilometres. When the user falls within range of this radius, a notification should be triggered, letting them know that they are near a haunted location. Lincoln Castle and Lincoln Cathedral both have a larger radius compared to Brown's pie shop or Castle Hill (as illustrated in figure 10, right).

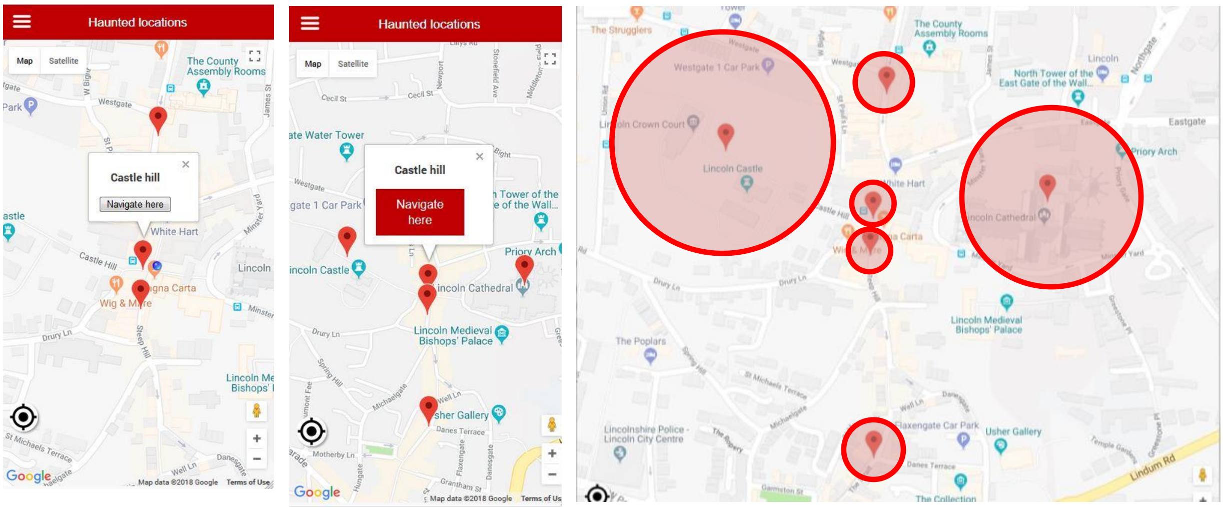


Figure 10: From left to right, the un-styled and styled "navigate here" buttons within each marker's "information window", alongside an illustration of the radius of each location on the main (represented by circles).

Each time the user moves, a “for” loop checks to see whether the user is within the radius of a particular location. If the distance (in KM) between the user’s current position and the location is less than the location’s “radius threshold”, then it will send the user a notification (an alert was used temporarily). Setting up this logic was very straightforward. However, the most challenging aspect of this core feature was getting the notification plug-ins to work as expected with Phonegap.

A plug-in was found and investigated to be used “locally” within the application (MacDonald, 2018). After hours of trying to get the plugin to work, it was eventually discovered that problem lay in the “config” file. The way in which the third-party plug-in was declared was incorrect. Once this was corrected, the plug-in was working as expected with both operating systems. The next task was to implement the notification “on click” listener. This plug-in *did* have a notification “on click” event. However, this wasn’t working as expected. It didn’t take the user directly to the location’s information page. Documentation for this plugin was scarce, making development even harder.

An alternative, well documented plugin was eventually found (Katzer, 2018). This plugin took several hours to implement as well, as the declaration syntax used for the previous plugin didn’t work with *this* plugin. It was eventually found, in the documentation, that using a certain syntax (with a version number and “source”) enabled the plugin. The “on click” listener for this plugin was implemented and working expected. Notifications are now fully integrated into the application.

The only issue with the notifications is that the application doesn’t run in the background. The GPS appears to switch off when the user minimises the application. This prevents notifications from being triggered in the background, when the user walks past a haunted location. After several hours of trying to find a solution, this bug had to be abandoned due to time constraints. However, as a proof of concept, notifications work during runtime, when the application is open.

Reflection

Cross platform was very difficult at times. Making the application feel and look native (in this instance) took up a significant part of development. Using jQuery mobile’s default assets did not make the application look native, thus custom implementations of default assets (such as tabs and ListViews) were implemented. In the future, an alternative framework should be used, such as Ionic (Ionic, 2018) or React (React, 2018). Furthermore, making the application work with different screen sizes and browsers was difficult. For example, on Android Chrome, the custom ListView was displayed as expected. However, on iOS Safari, the borders were missing. This was time consuming to debug, showing that cross platform development can *cause* bugs in and of itself.

Another disadvantage of using Phonegap is the reliance on third party plugins. If Cordova doesn’t have default plugins for your purpose, you are at the mercy of the developer’s documentation and maintenance. This became particularly apparent when implementing notifications in this context. Moreover, Phonegap desktop was unreliable. On the rare occasion that the application worked on Phonegap desktop, the third-party plugins didn’t seem run as expected. Because of this, each time a third party plugin needed to be tested, it would need to be done using Phonegap Build, which was an incredibly slow and tedious process, but the most reliable overall.

As a result of this, such a development approach should be taken if you have time to create a native looking application (using ionic or React to speed up styling/development), or if practicality is more important (in, say, a business to business setting). Only one code base needs to be maintained, making long term development/maintenance potentially more cost/time effective. However, testing the application runs on both operating systems, for different screen sizes, can be time consuming. From a business perspective, particularly for consumer products, it may be better to prove the concept on Android, having large market share (Statista, 2017). Then, once the concept has been proven on one OS, revenue earned could be invested into cross platform development for iOS.

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