THE DIGITAL PATHFINDER
A Plug-and-Play Approach to Local History Instruction in the Field

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Abstract: The Digital Pathfinder is an open source "plug-and-play" mobile electronic guide in field trials as an interdisciplinary project in the Hudson River Valley National Heritage Area. This paper introduces the project, its motivations, operational, instructional, and technical facets, and experimental results.

1   INTRODUCTION

The Hudson River Valley, beginning 45 km north of New York City, is home to the largest concentration of nationally recognized historic places in the United States. In 1996 the U.S. Congress designated this region as a National Heritage Area as "the landscape that defined America" (Clark, 2002). The Staatsburgh State Historic Site in Staatsburg, New York, is but one of the sites in the Hudson River Valley National Heritage Area (HRVNHA). It has an existing landscape architecture tour that was previously offered by appointment only and remained largely unavailable to the 60,000 people who enjoy the site's grounds each year. The Digital Pathfinder is a mobile electronic guide. The project is an interdisciplinary collaboration motivated by a perceived opportunity to provide greater public access to local history resources starting with the landscape tour at Staatsburgh as the model for potential replication elsewhere.

Unlike related apps, the Digital Pathfinder was not designed for casual use in urban environments. Instead, it has been developed for more pastoral settings such as estates, graveyards, cemeteries, nature preserves, etc. which perhaps because of their remoteness and lack of Internet access have received little attention in efforts to apply mobile guide technology. However, the relative quiet of these venues offers unique instructional and immersive opportunities that are generally impractical in metropolitan areas (Yost, 2006). While some users will be "traditional" visitors, we anticipated other individuals who are not tourists, namely, teachers, students, researchers, and others (e.g., hikers, campers, dog walkers, joggers, site employees, etc.).

The thematic nature of the "plugins" (i.e., the site-specific/instructional content) has been designed by humanities scholars and subject matter experts in close partnership with media artists and computer scientists. Thus, the deployment in the field is more like an on-location history tutor and less like a tourist application. For a synopsis, see the YouTube video, "The Gilded Age Meets the GPS Age in Staatsburgh," (Bass, et al., 2010).

In the remainder of this paper we review related work, instructional facets, the operational and technical designs, and the field trial experiments which may be useful for others seeking to replicate our results and/or benefit from the anecdotal and statistical data we've gathered. We conclude with a discussion of the open source and future activities.

2   RELATED WORK

Kenteris, et al. (2010) study several electronic mobile guide projects and find that most have navigational maps, positioning methods, and require constant network connection to access online map

services and other functions like "friend finding," ticket eservices, group messaging, etc. Unfortunately, this network-bound approach may incur "phone minutes" or other charges; slow performance; complicate the software architecture, and consume more battery power which shortens the operational runtime in the field. They also perform unreliably where there is limited network service or fail entirely if there is no network service which is often the case in pastoral settings.

The Digital Pathfinder has navigational maps and GPS positioning but it does not require network access Smith, 2006; Jones and Dharbriya, 2007; Coleman 2008b). It does not offer social networking or similar services. Instead it is completely self-contained. For this reason the app is perhaps not as flexible as many of those in Kenteris, et al. (2010) but then historic sties by their nature don't change very frequently. Consequently on balance network access offers little advantage in the field. In view of the diversity of our target audience, we opted for an implementation that helps simplify the user interface, facilitate deployment logistics, and improve and/or extend the operational runtime and reliability.

Kenteris, et al (2010) furthermore indicates most mobile guides are unique to the platform in which they are developed because of the absence of standards and fragmentation in the mobile marketplace. The Digital Pathfinder sidesteps these issues through reusability which is the basis for "plug-and-play." Namely, it separates site-specific/instructional content and the reusable software framework which interprets the plugin properties. While the plugin format is nonstandard, it may be converted to a standards-based format should one emerge or become necessary for future compliance.

Finally, the systems in Kenteris, et al (2010) appear to target casual tourists in cities. The Digital Pathfinder was not designed for metropolitan area deployment. Instead it emphasizes conveying in-depth humanities themes using dramatic, rich media presentations that are mainly practical in more bucolic settings like those in the HRVNHA and many other places in the U.S. and internationally. This does not rule out urban or even suburban applications but these were not within the scope of our requirements.

Rossetti (2008) surveys efforts that have sought to exploit themed location-based learning (Epstein, 2008; Dieterle, Deaded, and Shrier, 2007; Raessens, 2007; Schmidt-Belz, et al, 2002; Stark, et al, 2007). Rossetti (2008) concludes that the designs differ

mainly in the emphasis each puts on functional goals, which Abowd, et al (1997) categorized as cartographer, navigator, librarian, and messenger. The Digital Pathfinder incorporates these functional goals plus innovations not anticipated by Abowd, et al, for instance, the surveyor, marketeer, and master of ceremonies (M.C.) which we discuss below.

3 FIELD TRIALS

The field trials are a series of experiments the purpose of which is to gather data about the application and testers. Individuals who participate in the experiment contribute to our understanding of the project in a manner that is only possible by deploying the application in the target environment where we can observe both operational and technical parameters which we describe in section 5.

In exchange for their time and help, participants receive information about landscape architecture in general, the historical landscape design at Staatsburgh, the Milles, their neighbours, and the surrounding town.
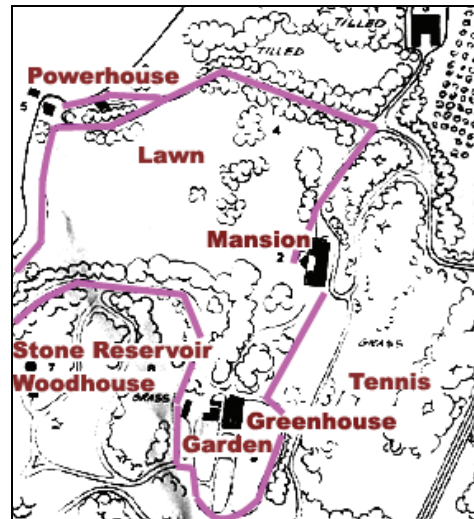

Figure 1. Staatsburgh landscape tour

The Staatsburgh site is more than 1,600 acres. A partial map of the property comprising roughly 100 acres is shown in the figure above with some of the landmarks and an overlay of the landscape architecture tour which is approximately 2.6 km in length. The guided tour walkway consists of lawn, partially paved and gravelled carriage roads, and wooded trails.

3.1 Experimental design

The basic unit of the experimental design is a "visit" in which the participant borrows the PDA at the Staatsburgh gift shop and takes the guided tour. A "trial" is a series of visits using a version of the plugin and the reusable software. The software is programmed to collect survey and usage data directly from the user in the field. In fact, this capability is one of the unique features as we explain further in section 4. We also collect data of a more anecdotal nature through informal observations of and discussions with participants. Finally, data also comes to the project through online enhancement requests, reviews, and bug reports that are input online at open source code repository (Geoplicity, 2010).

3.2 Trials

In general, the field trials represent a staged roll-out of the application to increasingly larger audiences of participants. In our opinion, the earlier field trials are more important even though they encompass fewer visitors. We suggest this because the opportunity value of finding and resolving flaws and significant issues at the outset is greater compared to later phases.

Trial 0 involves team members other than programmers but in close consultation with them using the PDA in the field. The objective is to identify and fix mainly technical bugs in the plugin or software. This phase was completed in August 2010.

Trials 1 and 2 consist of visits by third parties not formally associated with the project such as faculty members, students, and others. The objective is to identify any technical bugs but also to get usage feedback about the plugin directly from the visitor and as close to real-time experience as possible.

Trial 3, the final phase, consists of volunteers from the general public.

We completed Trial 1 and Trial 2 in October 2010. We report our findings in section 8.

We expect to initiate Trial 3 which will be ongoing through spring of 2011. We plan to complete Trial 3 by June 2011.

4 HOW IT WORKS

This section provides an overview and suggests through informal use cases and actual screenshots how the app works from the user's perspective.

4.1 Running the app

The user launches the app, the pilot implementation of which runs on an HTC P3470, an unlocked cell phone running Microsoft Windows Mobile 6. From the start menu, the app presents the splash screen.
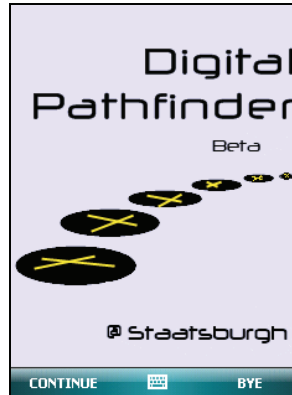

Figure 2. Splash screen

The user presses "BYE" to exit or "CONTINUE" to go to the main touch screen as shown in the figure below.
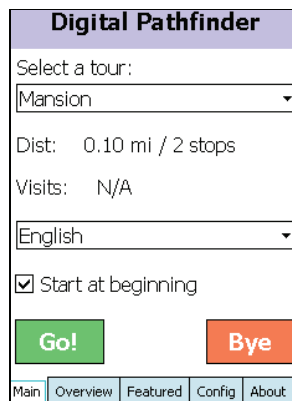

Figure 3. Main screen

The user has the option to select different tours of different lengths and number of stops (see section 5.1). The user can select the language option and toggle if they are starting at the beginning of the tour or roaming the grounds serendipitously. The other tabs provide additional information about the tour and its configuration, featured events, and information about the plugin and software.

The user presses "Bye" to quit and "Go!" to start at which point the screen in the figure below pops forward.
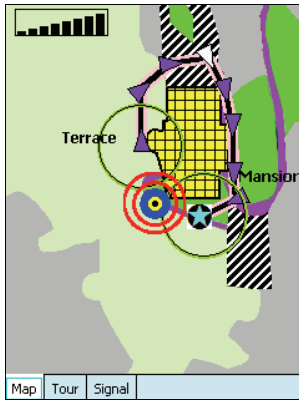
Figure 4. Navigation screen

This screen shows the navigation map with the user's geospatial position, tour path, and landmarks which activate dramatic episodes or "dramasodes," short videos with dramatic readings by actors.
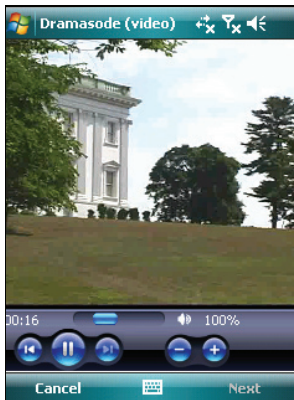

Figure 5. Mills Mansion dramasode

After each dramasode, the system queries the user through a functional unit called "Back Talker."
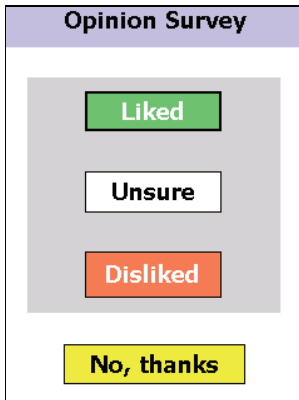

Figure 6. Back Talker survey

At the end of the tour, or when the user quits, Back Talker presents a demographic survey as shown in the screenshot below.
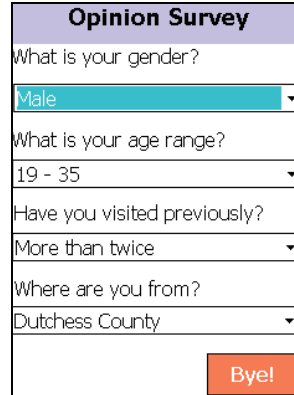

Figure 7. Back Talker demographic survey

As the reader may find, the user interface is fairly straightforward with relatively few actions the user initiates except, of course, the "embodied" ones to walk the indicated paths on the display.

5 THEORY OF OPERATION

The Digital Pathfinder was developed as a reusable means to convey historical information and enrich the visitor's experience at sites like Staatsburgh in the HRVNHA. In general the application is conducive to rural or pastoral settings where the relative remoteness and quiet means the dramasodes can be appreciated outdoors and unobtrusively. To entertain the user at specific locations and times we also introduced period music, in this case, ragtime recordings of Scott Joplin (Berlin, 1996). The appreciation of these short soundtracks also benefit from bucolic tranquillity.

5.1 The Matrix

The theory of operation depends on the matrix, M:
$$M: S \times H \qquad (1)$$
where S is a collection of geospatial landmarks or "stops" related to humanities themes, H. Each cell, $M[i, j]$, is an estimate of the amount of content for a given theme, H_j, at stop, S_i. Thus, when the user encounters S_i in the field, the device interactively retrieves zero or more dramasodes tagged with theme, H_j. For instance in the case of Staatsburgh, if the user is interested in understanding leisure of the

gilded age, when the user arrives at the mansion landmark, those dramasodes linked to the mansion and related to gilded age leisure will be retrieved from the device's storage and presented interactively to the user. This gives rise to a multi-layered presentation that allows the user to specify the focus of learning at the outset.

An example of the themes matrix is shown in the table below for Staatsburgh.
Table 1.

Theme (H_j)	Stop (S_j)			
	1.MA	2.WF	3.GC	4.GH
1. AA	4	3	1	3
2. AI	1	4	1	5
3. IM	1	--	2	2
4. LA	3	2	2	4
5. LE	1	1	--	2
6. TE	1	3	3	3
7. TR	2	2	--	--
8. SC	2	1	1	2

The table below contains the themes (1-8).
Table 2.

Code	Theme (H_j)
1. AA	Arts and architecture
2. AI	Agriculture and industry
3. IM	Immigration
4. LA	Landscape architecture
5. LE	Leisure
6. TE	Technology
7. TR	Transportation
8. SC	Society and culture

The landmark stops (1-4) are in the table below.
Table 3.

Code	Stop
1. MA	Mansion
2. WF	Waterfront
3. GC	Gardener's cottage
4. GH	Green house

We note that the values in the cells are not necessarily the number of dramasodes. Rather the values represent a relative estimate of the amount of available material in the archives to produce the dramasodes. For instance, we identified considerable archival material for arts and architecture for the Mansion stop and no transportation-related material for the Green house stop.

Having this kind of summary view of the raw data proved invaluable as a general guide to developing the plugin. It told us foremost that the archival material was not necessarily evenly distributed for a balanced presentation. This sent us back to the archives in search of additional source material. It also influenced the geospatial layout of the stops. For instance, rather than presenting the Mansion landmark in multiple dramasodes at the Mansion stop, we distributed the Mansion presentation over a series of intermediate stops along the way to the next major stop. Thus, the first-level presentations were more or less the same length which helped to smooth-out the flow of the entire tour.

5.2 Back Talker

The Digital Pathfinder has cartographer, navigator, librarian, and messenger functions just as Abowd, et al, (1997) outlined. However, the Digital Pathfinder adds categories not envisioned by Abowd, et al: namely, a surveyor, marketeer, and master of ceremonies (M.C.).

Back Talker is a two-tier survey system that captures and logs feedback from the user in real-time for off-line analysis. In the pilot we use this data to improve the plugin and design new ones.

The first tier captures immediate qualitative feedback from the user at each landmark. The system asks the user whether he/she liked, disliked, or was unsure about the presentation. An example is shown in figure 5.

The user can also opt-out by choosing "No, thanks" at any time which disables Back Talker. Provided Back Talker is enabled, the second tier of Back Talker captures demographic information after the last stop has been encountered or if the visitor aborts the tour.

5.3 Marketeer

The marketeer provides an experimental way for local enterprises (e.g., restaurants, gift shops, etc.) to underwrite plugin development by purchasing time on the device as a "featured" sponsor. At present the marketeer consists of just one unobtrusive screen on the "Featured" tab (see Figure 3). For us the concept represents a human-computer interface challenge because of the need to balance instruction and commerce on a resource-limited device. To our knowledge this is an open research question (Jones and Marsden, 2006; Zwick, et al, 2005).

5.4 M.C.

The M.C. is an experimental functional category that Abowd, et al (1997) did not anticipate. The primary role of the M.C. is to interact with user through audio. For instance, there are audio cues and two pre-recorded electronic personalities, "Paul" and "Kate," that welcome the user, give verbal instructions, etc.

There are also 67 ragtime tunes of Scott Joplin (Berlin, 1996) managed by the M.C. The app uses this period music to help engage the user's imagination and establish historical ambiance.

6 INSTRUCTIONAL FACETS

We propose that the Digital Pathfinder is less like a tourist application and more like a mobile history tutor, that is, in the hands of users who are not necessarily tourists in the usual sense. We suggested in the introduction section different types of visitors who might fit this model, for instance, middle school teachers and their students. Thus, the tutor conception is not merely a matter of semantics. We developed the plugin content with instructional potential based on major educational themes and goals from the HRVNHA and the New York State Board of Regents. This section examines how these instructional facets are related to the humanities matrix which we discussed in the previous section.

6.1 HRVNHA

The HRVNHA was established in 1996 "to recognize, to preserve, to protect, and to interpret the nationally-significant history and resources of the Valley for the benefit of the nation" (Clark, 2002). Its master-plan called for a virtual campus, which has been supplied and supported by the Hudson River Valley Institute (2010), and delineated the major thematic foci of the region's history: Freedom and Dignity, Nature and Culture (including architecture, artists of the Hudson River School, and landscapes and gardens), and the Corridor of Commerce. The first focus applies primarily to the American Revolution and to the abolition of slavery. They are covered by themes 3, 6, and 8 from the matrix, Table 1. The second focus applies to our natural and cultural heritage – specifically to the Hudson River School and those artists' primary roles in developing a distinct American vision and identity. They are covered by themes 1, 2, 4, 5, and 8 in the matrix. The last theme pertains to our region's history of transportation, industry, and technology. They are covered by themes 2, 3, 6, 7, and 8 in the matrix.

6.2 Board of Regents

The New York State Board of Regents approved a new set of learning standards to prepare students for the 21st century that "represent the core of what all people should know, understand and be able to do as a result of their schooling." As such, they are relevant to our work both as guidelines for how best to serve students as well as adult visitors. A short overview of the most applicable standards to our pilot and collaborating sites is useful to illustrate our application of student learning standards to a more general audience as well.

History Standard 1 is titled: History of the United States and New York, and addresses "major ideas, eras, themes, developments, and turning points in the history of the United States and New York," (themes 1-8 from the matrix). In the category of "Math, Science, and Technology," Learning Standards 4-6 address the environment and evolution of thought about it, the application of technology to "satisfy human and environmental needs," and "the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning." They are covered by themes 2,6, and 8. Learning Standard 4 for the Arts states that "Students will develop an understanding of the personal and cultural forces that shape artistic communication and how the arts in turn shape the diverse cultures of past and present society." These are covered by themes 1, 4, 5, and 8. See New York State Board of Regents (2010) for more detail on history learning standards.

7 TECHNICAL DESIGN

A fundamental idea, as we pointed out in section 2, is the logical separation of site-specific content and the mobile platform. As a proof of concept, the software in field trial at Staatsburgh is written in C# for the .NET Compact Framework and runs on Microsoft Windows ® Mobile 6 devices. A Java version of the software for Google's Android device (Rogers, et al., 2009) is in alpha-test. In no way have we had to modify the Staatsburgh plugin for Android since by design the plugin contains no hardware or operating system properties.

This approach on the one hand frees the plugin level designer (Kermers, 2009) to concentrate the layout of the plugin (e.g., where to place landmark proximity alerts, walkways, etc.) without regard to the platform or the look-and-feel. This approach also provides a way to manage technological obsolescence which has been a criticism of location-based services (Rosetti, 2008). The figure below gives a logical summary of the different modules for the desktop and mobile sides of the project.
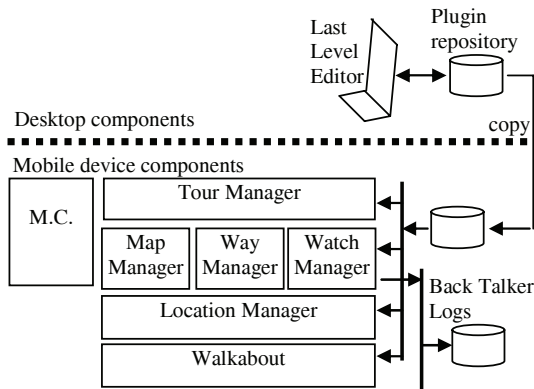
Figure 8. Plug-and-play software design

7.1 Desktop components

The desktop components consist of the Last Level Editor which is a collection of graphical user interface tools for rapidly and reliably authoring plugins. These tools, written in the Java Standard Edition (Oracle, 2010), were designed to be used by level designers with no background in programming.

The Last Level Editor produces a plugin content file which is a conventional property file of key-value pairs. We chose this design as opposed to XML (WC3, 2011) or JSON (IETF, 2006) mainly for simplicity and performance. That is, property files can be parsed very efficiently using simple string methods and property files have a direct implementation as hash maps with O(1) complexity.

The properties contain meta-data about landmarks, walkways, and the map. The properties only point to dramasodes through landmarks. The Last Level Editor does not create or playback dramasodes; they are produced outside the Last Level Editor using other tools.

The user does not use the Last Level Editor to create map images which must be JPEG or PNG formatted files produced through other means. However, the map is more than an image. It is also consists of meta-information, specifically, *ground control points* that are specified through the Last Level Editor. (A ground control point is a reference on the map that associates known longitude and latitude coordinates with known x and y coordinates. See the "Location Manager" section below.)

7.2 Mobile components

The mobile components consist of all those modules and libraries that run on the mobile device, interpret the plugin repository, and interact with the user in the field. The survey and logs are output repositories where diagnostic log information and Back Talker replies are stored.

7.2.1 Walkabout

As the lowest layer subcomponent, Walkabout interfaces directly to the positioning device, whatever it happens to be. It is itself based on the plugin concept. Namely, we have developed plugins for three different devices: an internal GPS device, an external Bluetooth GPS transceiver, and a simulated device that plays pre-recorded NMEA Standard 108-formated streams (Coleman, 2008a). We use the simulated device for testing and debugging. Walkabout generates raw location data, namely, longitude, latitude, bearing, satellites in view, speed, etc.

7.2.2 Location Manager

The Location Manager consumes Walkabout geospatial information and converts it to positions on the map. That is, it computes the function, G,

$$G: \text{lon, lat} \rightarrow x, y \qquad (2)$$

where *lon* is a geospatial longitude, *lat* is a geospatial latitude from Walkabout, and *x* and *y* are coordinates in map image pixels. The Location Manager computes *G* using pre-compiled Delaunay triangulation (i.e., computed by the Last Level Editor) and the "jump and walk" algorithm (Devroye, et al., 1996) invoked in real-time on the mobile device. The Location Manager also computes landmark proximity for listeners (i.e., see section, "Way Manager") that have registered for these events.

7.2.3 Map Manager

The Map Manager's function is to render, scroll, and orient the map on the device's display. It also renders the user's position. There are two possible map configurations: static and dynamic. The static map is always oriented with zero degree bearing and the user geospatial position is at the centre of the display. The dynamic map rotates with the user's bearing and the user's position is at the bottom of the display.

7.2.4 Way Manager

The Way Manager renders, animates, and orients the tour and landmarks that are within view of the map on the display. The Location Manager calls the Way Manager when the user nears a landmark. The Way

Manager in turn delegates the handling of proximity events to the Watch Manager.

7.2.5 Watch Manager

The Watch Manager renders, animates, and orients the walkway and landmarks that are within view of the map on the display. The Location Manager signals the Way Manager when the user nears a landmark. The Way Manager in turn delegates the handling of this event to the Watch Manager. The Watch Manager is also responsible for managing Back Talker. However Back Talker, once it is invoked, is responsible for presenting the query, capturing user responses, and storing them in the log.

8 EXPERIMENTAL RESULTS

At the time of this writing, the project has been in progress for approximately ten months and in the field for three months. In this section we report the anecdotal and statistical results for two PDAs in field tests from Trial 0 and Trial 1 over a total of seventeen visits.

8.1 Anecdotal results

We assumed the device would be used in daylight and under normal operating conditions that exclude high moisture and extreme heat (Adobe, 2008). The optimal conditions are indoor- and climate-controlled environments. Thus outdoor use required special considerations in the design of the user interface: namely, screen glare/washout and audio volume. To compensate for these we used high-contrast colours for the map and maximum volume for the M.C.

We used several techniques to compensate for the former. First, we customized the map using high-contrast colours. (This incidentally is another limitation of online standard map services: they are not generally designed for outdoor application.) Second, we designed the virtual walkway with stops in shaded areas. Finally, we kept dramasodes as short as possible, breaking them into multiple segments if necessary. This allowed us to keep the user moving in general and toward shaded areas in particular.

Users reported no problems viewing the display in high light or overcast conditions.

Although we did not measure the ambient noise level, York (2006) indicates 30 db for quiet rural settings and >70 for urban centres. York does not, however, take into account wind and/or water noises which are regularly present at Staatsburgh which is on the banks of the Hudson River in the Catskill Mountain valley. The best we could do was set the maximum volume.

Users reported no problems hearing the M.C.

8.2 Statistical results

The device collected survey data through Back Talker in accordance with Figure 6. We subsequently downloaded the results for statistical analysis. To obtain unbiased results, we used only Trial 1. The raw data for N=90 responses is shown in the table below with the corresponding p-values.

Date	Liked	Disliked	Unsure	p
11-Sep	10	0	1	0.0005
17-Sep	5	0	1	0.0156
19-Sep	9	0	1	0.0009
24-Sep	50	0	0	$<10^{-15}$
25-Sep	13	0	0	$<10^{-15}$

Table 4 Raw survey data.

To estimate the p-value we used the Binomial test (Conover, 1980). That is, we treated the individual responses as Bernoulli trials by clustering the data as {Liked} and {Disliked, Unsure}. This simplifies the analysis; represents a viable interpretation of the data for practical purposes; and finally, provides a reasonable estimate of statistical significance which is adequate for our purposes. In other words, if the data were more varied across input responses, we might invoke a more sophisticated analysis but we do not believe such is warranted or necessary here.

As the reader can see from this data, users expressed overwhelmingly positive feedback. The results are statistically significant.

9 OPEN SOURCE

The mobile software and the level editor have been developed as open source through the Geoplicity community (Geoplicity, 2010). All the WM6 and Android codes, issues, reviews, etc. are available via the Google code repository referenced on the Geoplicity home page.

10 FUTURE WORK

First, we plan to conduct more field trials and study the data as we mentioned in section 3. Second, we want to complete the Android alpha-test version and deploy it into the field as an experiment alongside the WM6 version for study. Finally, we hope to begin researching and planning the development of experimental plugins for other sites in the HRVNHA.

ACKNOWLEDGEMENTS

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