Virtual Handrail: Using Technology to Increase Park Access for the Blind

Funded by the Arthur H. Keeney Ophthalmic Fund and the American Printing House for the Blind

"It is one of the great purposes of the Park to supply to the hundreds of thousands of tired workers, who have no opportunity to spend their summers in the country, a specimen of God's handiwork that shall be to them, inexpensively, what a month or two in the White Mountains or the Adirondacks is to those in easier circumstances."

Frederick Law Olmsted

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EXECUTIVE SUMMARY

In the last 20 years, great strides have been made in building access to public accommodations for the handicapped. At the same time, enormous advances in technology have empowered the creation of a wide variety of aids for people of different abilities, from spell-check for the spelling-averse to digitally controlled limbs for amputees.

The Arthur H. Keeney Ophthalmic Fund (Keeney Foundation) believes technology can be developed that will enable the visually impaired to more fully and independently enjoy public parks. The foundation has named this project Virtual Handrail (VH).

Here are my conclusions based on research for this project:

- There is no product currently in the market that does what Virtual Handrail is conceived to do.
- The smartphone provides the best platform on which to base VH.
- VH should be developed first for Apple iOS, for reasons of both ease of development and size of installed user base.
- For safety and accuracy, the VH app should use both Assisted GPS and digital beacons.
- The VH app does not need to be developed as a stand-alone guide for the user. It should provide directions and a kind of "big picture" look at the park and user's destination, while tapping or a service dog provides step-by-step guidance.
- There is significant existing technology that may be applicable to VH, opening the possibility of great savings in both cost and time-to-market.
- There exists in the Louisville area the technical expertise to build and maintain VH
- Development should be a lean (or agile) environment with an emphasis on putting prototypes in the hands of users as early as possible.
- While VH as currently conceived makes navigating inside parks easier, it leaves as a primary barrier travel to the park.

Should the Keeney Foundation and APH decide to go forward with this project, the next steps in the development are:

1. Engagement of an app development agency to run a discovery process that will define the scope and plan for the project. This will cost $5,000 - $15,000, and result in a scope-of-work document, a plan, and an accurate budget for the app development.
2. Using the document produced in Step 1, engagement of an app development agency to build the app. This does not, by definition, have to be the agency retained to run the discovery process. In fact, depending on the results of the discovery process, it is possible that agency and client would determine that the best route is application of existing technology rather than the development of new.
3. Development is the actual creation of working code and database.
4. Alpha testing to validate various app components. This takes place within Step 3, creating an opportunity for technical refinement and limited user input. It will also require the creation of a small "testbed" that is mapped and otherwise marked for testing the app.
5. Revisions and final mapping.

6. Beta Testing makes the app available for real-world use by a select group of users. Its goal is to confirm the app meets technical specs and is appropriately useable in the real world
7. Commercial deployment

The process of definition, development, and deployment will likely take six months and cost, in the aggregate, $100,000 - $200,000. Keep in mind the time and budget estimates are inherently inaccurate until after Step 1, and that before formal definition of the scope of a project, agencies present rough estimates that are safely high.

“It’s easier to tell a client it’s going to cost less than more,” according to one agency president.

GOALS

The goal of this research is to give the Keeney Foundation, the American Printing House for the Blind (APH), and other interested parties the information they need to understand the applicable technologies and general feasibility of the Virtual Handrail project.

The assumption, worked out between the Keeney Foundation and the APH, is that the resulting technology should be useful in real-world application. To do that it must be:

- Easy to operate and fully controllable by a totally blind user
- Economical to develop and maintain
- Adaptable to specific user needs
- Protective of users' safety and privacy

In the digital world, technical possibilities are for all practical purposes limitless. The answer to the question, "Is it possible to…" is almost always "yes", given enough time and money. Completion of a research project like this is only possible if limits are self-imposed. For the sake of discussion, the ambitions of this app are relatively modest. (We will discuss future expansion possibilities in a later section of this document.) The assumed app has the following capabilities:

- Guide users within the park to defined points – monuments, shelters, toilets, bus stops, etc.
- Enable casual strolling within the park
- Have sufficient redundancy that a user will not be "abandoned" by technical failure
- Be able to add more parks by simple exchange of data set rather than changes in the app itself

PLATFORMS

There are three basic platforms to consider for Virtual Handrail: smart phones, dedicated devices, and wearables. Here is a general outline of the attributes of each.

Smart Phones

More than 77% of all mobile devices are smart phones. That market is divided almost perfectly, with Apple and Android's operating systems each controlling about 44% of those phones.[1]

The last several generations of smart phones are hard-wired to interface with both GPS and beacon-based navigation systems. The competing technologies are iBeacon for Apple products and Eddystone for Android.

Because Apple's iPhone customers replace their phones more often than Android users, there is a larger base of beacon-friendly iPhones than Android devices. As many as 90% of iPhones are set-up to work with iBeacon. By some reports[2] 20% of Androids are equipped with Eddystone.[3]

[1] https://www.comscore.com/Insights/Market-Rankings/comScore-Reports-July-2015-US-Smartphone-Subscriber-Market-Share

[2] Based on market share information. Developers interviewed believed the installed user base for version 5.0 or better Androids to be as low as 5%.

[3] https://www.netmarketshare.com/operating-system-market-share.aspx?qprid=10&qpcustomd=1

That said, the underlying capabilities of Eddystone are likely more powerful than iBeacon, enabling the app to run more functions in the background as the phone is used primarily for other purposes.

Wearables

Wearables like smart watches work with smart phones to deliver hand's free services. They can provide vibration and audio to communicate with the blind.

Dedicated Devices

As smart phones get smarter, the market for dedicated devices like dashboard GPS, music players, or step-counters is shrinking. There appear to be no ready-made, dedicated devices that would out-perform smart phone navigation without considerable product development and manufacturing costs.

GEOLOCATION TECHNOLOGIES

There are several available technologies that help people navigate through the day-to-day world. Here is a list of those technologies, along with information about their applicability to this project:

GPS (Global Positioning System)

GPS is familiar to most people. It has been a standard feature on both iPhones and Android devices since 2008. GPS was developed by the U.S. Department of Defense. It is based on a network of 24 satellites orbiting 12,000 miles up. The satellites transmit distinct codes to the GPS units. GPS devices compute the user's position by triangulating a minimum of four of these satellites.

Amazing as GPS is, everyone who has used it is familiar with its shortcomings. Most importantly, its signals can be blocked by buildings or trees, and can even echo off tall buildings in a way that makes calculation of a position impossible. It is also, by the standards of people on foot, not terribly accurate. According to research published in *The Journal of Navigation*,[4] the horizontal accuracy of standard GPS on a smart phone is 5.0-8.5 meters. (Military versions are much more accurate, but use different, higher frequency signals that require a security key to decode.) While a five meter error is not terribly significant to someone driving on the open road, for a pedestrian it is the difference between being safely on a sidewalk and wandering out into traffic.

Assisted GPS (A-GPS)

A-GPS is a system developed to improve accuracy and decrease the time-to-first-fix (TTFF) – the time it takes for a GPS to calculate the user's initial position, which takes standard GPS systems 30-40 seconds. A-GPS reduces that by roughly 50%.

A-GPS uses standard GPS signals along with data from external sources: cell phone towers, known wifi networks, or other fixed network nodes. A-GPS is dependent on connection to the Internet and – since it uses cellular network providers – can result in additional charges on some cell phone plans.

[4] Paul A. Zandbergen and Sean J. Barbeau *Journal of Navigation,* July 2011

A-GPS identifies nearby, identifiable sources of electromagnetic radiation which it then couples with data from an online database. This information includes precise locations of cell towers or other points of reference, atmospheric conditions that might distort the satellite signals, and orbital data about specific satellites in range. The location calculation can be quite complicated, and A-GPS shifts that heavy computational lifting from the relatively slow processor of the smart phone to powerfull cloud computing processors. The unit can also locate and lock onto other nodes, creating additional data points that increase the accuracy of the reading.[5]

To work, A-GPS features depend on an internet network or connection to a service provider – either ISP or CNP.[6] Without one of those resources, it can't connect to the A-GPS servers usually provided by CNPs.

S-GPS
S-GPS is a system that empowers simultaneous voice and GPS transmissions. It is more accurate than GPS and used primarily for the delivery of location-based services.

Digital Beacons
Digital beacons are tiny electronic devices that trigger activities on nearby smart phones. Using Bluetooth, a technology standard on almost all smartphones, beacons transmit a unique code, over and over, for as long as they are in use. That unique identifier triggers a targeted app to do something: ring an alarm, search the web for relevant information, tell a story, tally miles run, or any of thousands of other things. Museums use beacons to cue narration for people standing in front of specific exhibits. Marketers use beacons to track consumer behavior inside a store. Retailers use beacons to send coupons to window shoppers.

Beacons digital broadcasting devices approximately the size of a thumb. They emit low-energy Bluetooth (BLE) data bursts several times a second. Those signals are designed to carry no more than approximately 300 feet. Based on the strength of that transmission, a phone within range of a beacon can calculate how far the user is from that beacon. Under favorable circumstances, a phone within the range of three or more beacons can triangulate the user’s location within a few centimeters.

The signal from the beacon triggers an action in a properly outfitted phone. All calculation, mapping, media, and search functions take place either in the phone or in a database/server accessed through the web. Individual beacons can simultaneously trigger events in many different apps.

Beacons cost between $15 and $30 each, depending primarily on the capabilities needed and number of beacons ordered. The number of beacons necessary to cover Waterfront Park is impossible to calculate without knowing what the beacons will be expected to accomplish. Purely as navigational aids, the park might need 25-50 beacons. To provide a fully enriched experience could take hundreds.

Installation is not complicated, though care must be taken. Installation costs vary widely based on the difficulty of installation and density of network. If used for precision navigation, the beacons must be

[5] http://www.windowscentral.com/gps-vs-agps-quick-tutorial
[6] “ISP” is an Internet Service Provider and “CNP” is Cellular Network Provider

precisely located and laid-out so the user is always (or nearly always) in the overlapping footprint of three. They can be attached to light poles, park benches, mail boxes, or any other fixed object. Because the weak BLE signal can be blocked by almost anything – a bush, a bicycle, a jogger – it is more effective to place the beacons high than low. Beacons come with adhesive backs to make installation easy, but most are attached using twist ties or plastic bands. A network sufficient to cover Waterfront Park at a Version 1.0 density would take two to three days to install.

Beacons are powered by batteries designed to last up to two years. (New batteries on the market claim to last four years.) Prudent management dictates that batteries be replaced every 18 months. Because outdoor beacons are in sealed, one-piece cases, it is impossible for the user to replace the batteries. Used-up beacons are usually replaced and recycled.

Problems with beacons are detected very quickly after installation and are generally the result of poor configuration rather than mechanical failure. Outdoor beacons are manufactured to withstand temperatures from -50F to 125F. No one interviewed had experienced the failure of a beacon after its proper installation.

Visual Navigation

The primary consumer-use of visual navigation is in automobiles. A camera or cameras monitor the position of the auto relative to the painted lines on the road. The camera detects when the vehicle begins to drift to one side or the other, and either sounds an alarm or self-corrects to the center of the lane.

Visually-based anti-drift technology is well-developed and has been used in European commercial vehicles since 2000. It has significantly reduced car-truck accidents.

Visual navigation works only if guiding lines are in high contrast with the underlying pavement. If lines are faded, blurred by rain, or covered with snow or mud, the system shuts down. In automobiles, their use is generally restricted to speed above 40 miles per hour, when the road ahead is surely clear and uncluttered.

Sonar/Echolocation

While several attempts have been made to adopt sonar to navigational aids for the blind, they have not been consistently successful. It is not a primary navigational tool, as sonar only locates the user relative to objects within 3 meters. That is, sonar can alert the user to the presence of a tree, but can't identify the location of that tree within the larger park.

LOCATION

Louisville Waterfront Park is an 85-acre municipal park along the Ohio River adjacent to downtown Louisville, Kentucky. It is Louisville's most heavily trafficked park, with an estimated 1.5 million visitors enjoying its diverse facilities and spaces every year. Its walkways are broad and even, made mostly of recently-poured concrete. It is wired for wifi. Its signage is award-winning.

The park is, in many ways, Louisville's front yard, sloping gently toward the river from downtown. There are dozens of civic events held in the park every year, including Derby Festival, music festivals, carnivals, athletic tournaments, and concerts. It is traversed by some of the most popular walking and bike trails in the city, and via the Big 4 Bridge reaches across the river to Indiana.

There are areas of Waterfront Park that have no GPS coverage, notably beneath or beside Interstates 64 and 65.

It is an urban park: busy, noisy, with widely varied activities and facilities. It is not adjacent to any significant residential neighborhoods. It is a two-block walk from Main or Market Street bus routes.

The Waterfront Development Corporation, which controls the park, has given its enthusiastic blessing to this project.

RELATED SOFTWARE FOR THE BLIND

There is an ever increasing number of apps designed to help the blind function in a sighted world.

Ariadne GPS (http://www.ariadnegps.eu/) – Developed in Italy, Ariadne GPS is a highly capable, GPS-based tool for navigating urban environments. It is specific to the iPhone platform. It is basically an audio-driven map program that works with both Apple and Google maps, neither of which provide park sidewalks.

Blind Navigator (https://play.google.com/store/apps/details?id=com.blindnavigator&hl=en) – An app for Android platform, it was developed to work with smartphone-powered proprietary hardware. That hardware would "see" impairments ahead of the user while guiding the user. The app was poorly reviewed and has not been updated in two years. The hardware does not appear to be commercially available.

Blind Assistant (http://www.phonescience.eu/cgi-bin/WEB/index.pl) – Blind Assistant is an echolocation app that uses sound to locate obstructions. It is available for both Apple and Android devices. It is only moderately well reviewed.

TapTapSee (http://www.taptapseeapp.com/) For Apple devices, TapTapSee is designed to help the blind and visually impaired identify objects. The user double taps on the screen to take a photo. The app uses algorithms to identify the object.

Able Road (https://ableroad.com/) – Able Road is a social media-based app that aggregates user knowledge of accessibility in public accommodations.

Guide Dogs NSW ACT (http://www.guidedogs.com.au/what-we-do/mobility-devices/miniguides) – The MiniGuide is a small, handheld electronic device that uses ultrasound scan for obstacles. The user swings the device back and forth, receiving either audio or touch cues noting objects ahead. The cues become more frequent as the object grows nearer. It is most often used in conjunction with another navigational aid, like a canes or guide dog.

The Seeing Eye GPS (https://www.senderogroup.com/products/shopseeingeyegps.htm) – Available for Apple devices, The Seeing Eye GPS is a highly developed app for pedestrian travel. It draws data from FourSquare, Google, or TomTom maps. This app is the closest to the expressed vision of Virtual Handrail, but is based on map databases that do not contain park information.

Google Maps (https://www.google.com/maps) – Google Maps has awesome power. It interacts well using voice input and output, but the underlying data set does not include pedestrian paths through parks. It is a valid tool for getting users to the entrance to the park, but once inside is not helpful.

MAPPING

Virtual Handrail is going to require detailed maps of Waterfront Park. The building of those maps from scratch would require time-consuming and expensive surveying of the area. Fortunately, the maps do not need to be created from scratch.

There is likely no better place in the world to prototype Virtual Handrail than Jefferson County, Kentucky. For several decades, various public and private agencies have digitally mapped *everything*: manhole covers, light posts, sidewalks, sewer grates, street corners, stoplights…all the parts and pieces of a city that might need to be identified, taxed, or maintained. It includes data from all significant private and public utility, surveying, and mapping agencies, with the exception of Louisville Gas & Electric.

The geographic information system for Jefferson County is referred to as LOJIC – the Louisville/Jefferson County Information Consortium. LOJIC is paid for by its users. The LOJIK data is publicly available and fully prepared for applications such as Virtual Handrail.[7]

The level of detail in that mapping is amazing. The database takes a full terabyte of storage, enough space for more than 400 high-definition feature films. There are known GPS coordinates for every permanent fixture in the city's infrastructure. This information is paired with "flattened" satellite imagery that neutralizes the effect of the curvature of the Earth and makes it possible to precisely plot points within the Metro by tapping a map on a computer screen.

Creating a navigable, GPS-ready map of Waterfront Park would, according to mapmakers, take no more than a few days. The only site visit necessary would be a quality control walk-around once the map has been plotted. There are several local firms well practiced with the LOGIC system; finding a contractor for this part of the project should be no problem.

In addition, members of the University of Louisville faculty expressed interest in using VH development to give geography students real-world experience. There is a cost to that in quality and time – students learning as they go do not work as quickly or precisely as professionals. But when it comes to laying-out the maps and/or beacons in the first stage of development, student involvement might be beneficial both from cost and community relations standpoints.

[7] http://www.lojic.org/main/

USER INTERFACE (UI)

In the words of Larry Skutchan, "finding a way to guide a person using maps is where the hard part is going to be." The hardest thing about the development of VH is going to be the user interface (UI). Get that wrong, and the app will fail to find an audience.

There are enough navigational aids for the blind that UI development would not have to start from zero. An early part of app discovery should be a best practices study of UIs for the blind. In general, the UI should conform to the following:

The User Must Be Able to Control All Aspects of the App's Operation
There are several workable UI protocols for operation by the blind.

Command Buttons Must Be Easily Located
Some well-intentioned apps for the blind have menus that are difficult to navigate without sight. They're oriented to the center of the screen, or bundled at the bottom of the screen, or otherwise occupy an area of the phone a sight-impaired user can only find by trial and error. The UI of VH should be laid out so that fingers can locate buttons relative to screen edges, corners, or other touchable "landmarks" on the phone. This will likely result in an app that is aesthetically displeasing to the eye – but the delight of the sighted is not the goal of this project.

Touch and Audio Cues
All communication from the app to the user must be based on touch or audio cues. In most smart phones, "touch" means vibration. Audio cues require the development of a database of spoken words and phrases particular to the app itself. User input should primarily be by voice command.

The Amount of Information Provided Should Vary
Users will inevitably want more information during their first visit to a park than for subsequent visits. The first time anyone – sighted or unsighted – visits a new place, he or she is highly attuned to every detail. Think of driving through a new neighborhood in search of a specific house. A first time visitor reads every street sign, checks address after address, and moves slowly to not miss anything. A tenth-time visitor has an instinctive feel for how far the right street is, and all that detail becomes less important.

Of particular interest should be the app Seeing Eye GPS (https://www.senderogroup.com/products/shopseeingeyegps.htm), which has an intuitive and well developed interface that is very much like what Virtual Handrail requires.

GENERAL INFORMATION ABOUT APPLICATION DEVELOPMENT

Software development is a methodical process of creation and testing, creation and testing. It is most efficient when a project is well defined before work begins.

The general steps in app development are:

- Define – Who are the users? What is the problem the app is designed to solve? What are the resources available? What is the definition of success? (This report should enable the completion of the definition process.)
- Plan – Who is doing what, when? What are the milestones along the way to the stated goal? How are approvals going to be managed? How long will it take? How much will it cost?
- Develop – The actual work of coding the app and underlying database.
- Test – Some use of all or part of the technology to make sure it conforms to expectations. This can be a small, internal process or a public user test.
- Refine – As a result of testing, changes are ordered. This circles back to the Development stage or, in extreme cases, can result in changes to the Definition or Plan. (The better the thought process early, the lower the chance of having to redefine the project or plan.)
- Release – Making the app available to the public.

Even developing Version 1.0 exclusively as an iPhone app, expect development to take six months or more.

While it is impossible to estimate cost before capabilities are defined, all parties interviewed estimated (very roughly) a cost of between $50,000 and $200,000.

LEAN DEVELOPMENT AND MVP

Conventional app/software development is geared toward the production of a nearly perfect consumer product. This method requires a great deal of faith in the creator's vision, as that is the primary guide for the development process. This is perfectly acceptable for an app performing an already-demonstrated set of functions for an already-developed market. If one were developing an app for, for example, used car rental, there is no proof of concept required. The low-risk path would be to go to market with a fully formed product.

Because Virtual Handrail is an app plying uncharted (metaphorically) territory, all parties interviewed recommended a "lean" development process. Lean Development is a highly disciplined creative process designed to minimize work driven by unproven assumptions. Lean Development breaks projects into small increments, each with a defined milestone. Anything that doesn't pertain to the achievement of that milestone is eliminated or deferred, and prototypes are tested often to eliminate missteps caused by faulty assumptions.

If the defined goal of Virtual Handrail 1.0 is to learn whether the app can provide navigational aid valued in the real world, the testing of that thesis should be the project's *only* focus. Planning or even brainstorming improvements to Version 2.0 should be deferred until that question has been answered.

A key concept of Lean Development is Minimum Viable Product (MVP). MVP is the development of the smallest, least expensive and complicated app that can demonstrate the ability of the software to solve the targeted problem. The result of that development process is usually a beta test – putting the software in the hands of a small number of users for real-world use. Those users' experiences are closely monitored to decide A) if the app is technically functional, B) if the app contributes significantly to the solution of the stated problem, and C) what final improvements are necessary to make the product commercially viable.

This method decreases risk and enables management to defer commitment of resources until the last possible moment, while improving quality by giving stakeholder feedback a more prominent place in the process.

FUTURE APPLICATIONS

Beyond the basic, Version 1.0 features of Virtual Handrail, the following possibilities have been discussed:

1. The development of a base of point-of-interest (POI) content. This would call the user's attention to interesting features nearby, and invite the user to listen to information about that POI. For example: the app could call a strolling user's attention to the presence of a river overlook only a few feet away. That platform reaches out over the river and is a place of cool breezes and relative calm a blind walker might otherwise miss. Once the user was out on the platform, they would be given the option of listening to a story about commerce on the river.
2. The creation of a "social" component enabling users to discuss aspects of the park with each other. Locations could be rated for access, noise, busyness, POIs, or whatever the user base desires.
3. Map import is the ability to expand the footprint of Virtual Handrail to parks other than Waterfront. This should be an easy download.
4. Use of outbound beacon tech (that is, the use of the phone as a virtual beacon) to enable the blind to find each other in the park. Users could agree to meet at a certain point, and would know as they approached each other.
5. The creation of audio-based art installations users could travel through.

CONCLUSION

Louisville has awesome parks. Developing technology that would make those parks more accessible to the blind could have far-reaching benefits, not just for the people of Louisville, but as a demonstration for parks everywhere.

This is, by nearly any measure, a highly doable project. It requires no invention of new technology and can be hosted on a technical base that is already installed.

While researching this report, I found that the pure idea of Virtual Handrail captured the imaginations of almost everyone I described it to. They loved the challenge and the possibilities and the fact that it was local and the ways in which it could help people. Several people contacted me days after their interview with new ideas and questions. Virtual Handrail was under their skin.

That is a sign of a project destined to have an impact.

INTERVIEWS

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READINGS

Along with the resources cited in the report and its footnotes, the following material also contributed to this report.

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