Government Information Quarterly 31 (2014) 6–16

Contents lists available at ScienceDirect

Government Information Quarterly

journal homepage: www.elsevier.com/locate/govinf

Enhancing the government service experience through QR codes on mobile platforms

David Lorenzi [a,*], Jaideep Vaidya [a], Soon Chun [b], Basit Shafiq [c], Vijayalakshmi Atluri [a]

[a] Rutgers University, 1 Washington Park, Newark, NJ 07102, USA
[b] City University of New York, College of Staten Island, Staten Island, NY 10314, USA
[c] Lahore Univ. of Management Sciences, D.H.A Lahore, Pakistan

ARTICLE INFO

Available online 10 January 2014

Keywords:
QR codes
Mobile government services
Location-based information services
Smartphone services

ABSTRACT

Digital government is universally gaining acceptance as the public becomes more technologically advanced. It is critical for the government to embrace new technology for minimizing costs and maximizing utility of services to the taxpayers. While administrative services have been easily ported to the digital world, there are still many important citizen-centric services that have not yet been effectively migrated. Quick Response codes (QR codes) provide a means to effectively distribute many different varieties of information to the public. We propose to integrate QR code systems and corresponding smartphone applications into existing government services with the goal of providing a new level of interactivity for the public. We illustrate this through two case studies, examining the National Park Services and the Mobile Environmental Information Services (MENVIS). The focus is on developing a QR code waypoint system for park navigation, as well as incentivizing park use through gamification of site attractions. The system provides increased safety for park goers, disseminates information more effectively and accurately, and improves feedback.

1. Introduction

Cell phones and smartphones continue to advance at a rapid rate—increasing in computational power and number of sensors available to the user (GPS radio, camera, gyroscope, compass, etc.). Most cell phone capabilities do not necessarily depend on the use of a network connection of some kind (cellular, 3G etc.), for example, the camera, gyroscope, and compass are physically located within the smartphone and do not require external networks to perform their functions. GPS is the notable exception, which must receive a signal from the GPS satellite network in order to function properly. Given these mobile sensors, the onboard computing power of a smartphone, and increased power capacity, there has been an explosion of mobile apps (application software and services that can be installed on the mobile devices) that benefit and entertain the public. The sensor capabilities are used to allow mobile phones to provide location based services, aid in navigation, and gather data such as images from camera. One of the newest developments is the use of Quick Response codes (QR codes) to quickly facilitate the uptake of relatively large amounts of data in a compact fashion. A Quick Response code (QR code) is a type of matrix barcode (or two-dimensional code) that is much faster than traditional UPC barcodes (see Fig. 1). It is also known as a *mobile barcode* since it can be scanned and read by a *QR-Code reader*, software that is installed on a mobile phone (Mobile Barcodes.com, 2012).

QR codes are entering the cultural zeitgeist – nowadays they are used in marketing promotions such as discount coupons, advertisements and supply chain management – areas far beyond their original imagined use cases which were tracking automobile parts in the auto manufacturing industry. QR codes provide a cheap, easy, and secure method to transmit information in a "push" format to individuals who have the ability to read the symbol. Open source libraries exist for generating QR codes from a variety of data sources, as long as the data can fit into a fixed number of characters (alphanumeric strings) depending on the revision version of the QR code. If a program can read a particular revision of QR code data, the individual programs/applications can decide how to handle the data after it is extracted from the QR code. This essentially allows the smartphone application to parse the incoming data from the tag and use it in a manner the programmer desires. Because each code revision has its own standards for data integrity, redundancy, and availability, as long as the revisions are supported by the application (being able to read the QR code itself) the codes can be used with any smartphone operating system that will support the encode/decode libraries. Also, by having users not enter in any data manually, data accuracy can be ensured.

With the growing push towards technology, digital government has gained increased adoption as a way of redefining the relationship between government and the public. Offering innovative public services builds citizen participation thus increasing trust as well as improving transparency and public understanding of government agencies and

* Corresponding author.
E-mail addresses: dlorenzi@cimic.rutgers.edu (D. Lorenzi), jsvaidya@rbs.rutgers.edu (J. Vaidya), Soon.Chun@csi.cuny.edu (S. Chun), basit@lums.edu.pk (B. Shafiq), atluri@rutgers.edu (V. Atluri).

0740-624X/$ – see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.giq.2013.05.025

(a) Coordinates (b) URL (c) URI

Fig. 1. Example QR codes.

their missions. While traditional administrative services have been easily offered in digital form, many other citizen-centric services have yet to be migrated. Given the availability of mobile devices with diverse data ingestion and computing capabilities, QR codes, when appropriately used, can serve as a way of broadening the scope of government services, and improve the level of service to citizens.

QR codes make data entry and data management easy from a government perspective. A standardized database of QR codes for important information that needs to be disseminated to citizens or government agencies can be created with existing off the shelf tools and for comparatively little cost. The option to use open source tools, especially for database creation and management, is also an ancillary benefit as it keeps the costs of maintenance and/or support contracts low and prevents the government from getting locked into a service contract with a proprietary solutions vendor. This database can also be a centralized method for storing information placards that are distributed in the form of informational bulletin boards for park goers. Since this information is now available in digital format, there are many more options for making the information engaging and interactive. This also provides the ability for users to access it through the application outside of the park, as supplemental materials for education.

In this article, we explore the potential impact of QR codes used in conjunction with mobile services/applications and web services for government agencies. Specifically, we focus on the system design requirements/parameters, implementation/integration of the system, and the policy issues surrounding it. We illustrate the effectiveness of QR codes in enhancing government services through two case studies. The first is that of the National Park Services, which is a prime example of a government organization that will benefit from an accelerated transition toward this new technology. The second is the Mobile Environmental System (MENVIS) developed at Rutgers University which delivers auto-guided environmental tour information for New Jersey and New York City government agencies that take initiatives on restoring degraded environment in urban areas. MENVIS is intended not only to support staff engineers and scientists to collect data from the field using mobile devices, but also enhance the exploring, learning and discovery experience of visitors, eco-tourists and students, while moving in and around urban environmental preservation areas.

While some of the discussion is specific to these example cases, the core concepts can be extrapolated and tailored to apply to any government agency in need of a "push" style, centralized information system for interacting with the public. The following is a brief list of functionality the platform can provide in the context of the example system for the NPS and MENVIS:

- Waypointing system: While navigating the park trails, visitors may get lost not knowing where they are or where to find the next trail posts. We develop a system of QR codes and standards to deploy to U.S. National Parks that aid in navigation of park trails—helping hikers get their bearings in the events of a GPS failure or loss of cell signal. The trail markers will have QR codes that have map coordinates to a map already contained within the parks application on the device. It may even be possible to have high level code in a series of QR codes and compile it on the phone. There will also be additional "calibration" codes to ensure the correct location is being used for map navigation and to detect in case the codes used for navigation are compromised.
- Mapping data from QR code for Mobile Map Visualization: QR codes can contain thematic map data (e.g. minerals, flora, trail route and distance planning) that can then be overlaid onto the base map on the cell phone for visualization services for citizens. There is also the potential for using augmented reality via the camera function on the mobile device for visualizations based on data provided by this map and the GPS.
- Gamification using the QR codes: Hiking and park-related activities can be combined with gaming for rewards seeking activities and increased scientific exploration competition. The public can do check-ins at trail markers with QR codes that contains game-related instructions and clues to find rewards. One such example of gamification would be providing a reward to visitors who locate and contribute to tagged galleries of local park flora and fauna stored in the NPS/MENVIS database. Once approved, the user receives a reward for their contribution encouraging them to continue playing the games. By implementing this system throughout the parks and sites managed by the NPS/MENVIS, it will aid in achieving the goal of increasing visibility of the parks and the NPS/MENVIS managed site awareness, public involvement and donations.
- Facebook/Twitter integration: use existing social networks for sharing information to park goers and to receive feedback from them.

The rest of the paper is structured as follows. In Section 2, we provide an overview of QR-codes and a discussion of the related work. Section 3 discusses enhancing the National Park experience through the use of QR codes, which focuses on the framework and design of the system components. Section 4 presents an overview of the existing MENVIS system, and the integration of QR codes into the system. In Section 5, we discuss system implementation and integration ideas. The goal is to demonstrate the flexibility and utility of a QR code system used in a generalized manner for supporting e-government functions. Finally Section 6 concludes the paper and offers several recommendations for implementing a QR code system, or identifying candidate systems for expanded QR capability.

2. Preliminaries and related work

In this section, we first provide a brief overview of QR codes, including the data types and storage capacities they can support, followed by a discussion of some of the work related to this paper.

2.1. Overview of QR codes

A QR code (Quick Response code) (D.W. Inc., 2010a, 2010b) is a mobile phone readable barcode that can contain small set of data. If a mobile phone has QR Code decoding software installed, it can scan a QR code, and open up an appropriate application to handle the encoded data. QR codes are established as an ISO (ISO/IEC18004) standard. QR codes are capable of handling all types of data, such as numeric and alphabetic characters, symbols, binary, and control codes. Up to 7089 characters can be encoded in one symbol. QR code data capacity varies based on data type. Numeric data only allows for a max of 7089 characters, alphanumeric data with a max of 4296 characters, binary data (8 bits) has a max of 2953 bytes. It can encode a website URL, a YouTube video URL or any social media links, geo-coordinates, email addresses, email message, a PayPal Buy Now Button link, and so on. QR codes have error correction capability that can vary based on the desired use case, to a maximum of 30%. Data can be restored even if the symbol is partially dirty or damaged. Once the type of data that is desired to be encoded is chosen, you can select the appropriate version QR code required to store the data. From this information, the mobile tag/barcode is generated and can be used.

QR codes are capable of 360° (omni-directional), high speed reading. QR code can perform this task through position detection patterns located at the three corners of the symbol. These position detection patterns guarantee stable high-speed reading, circumventing the negative effects of background interference. QR code can be divided into multiple data areas, based on the encoded information.

One of the key goals of this project is to get information the government has out to the public in a timely and meaningful manner. This goes beyond traditional methods of data disbursement with a combination of digital access along with a new static symbology that will improve the speed and accuracy of data uptake by the public by utilizing the ubiquity of the smartphone. In this paper we focus on the case of the NPS, and the tasks and services they provide to the public. As such, the data types we focus on are directly related to information the NPS gathers or publishes, along with cross governmental organizational data exchange (i.e. pulling data from the weather service about forecasting park weather, USGS maps etc.). More specifically, the data types (numeric, alphanumeric, or byte/binary) of the information are critical, as this determines how much information can be stored in the QR code.

One of the reasons why QR codes are a good choice for this type of problem is that they are non volatile, meaning they are a static and non-powered method for delivering data. Once the important information is put into the code and the tag is generated and printed, it no longer needs supervision. This allows for the users to take a picture of the tag, uploading its data to their device of choice and use it, while the provider of the tag (the government) has “pushed” the relevant data out to the user, fulfilling their obligation.

2.2. Related work

There is significant work conducted on improving the government through the use of technology. Fedorowicz, Dias, and Sawyer (2009) state that digital government research often centers on information technology artifacts designed for the purpose of improving access to or processes within government. The purpose of their research is to provide an overview of design science principles guiding the construction of technological artifacts.

Much research work has been done with QR codes, and we chose some of our system design parameters based on existing research applicable to the challenges faced in creating a digital government solution. Kan et al. proposed an augmented reality system where QR codes are used in place of more traditional AR symbology to provide users with a generalized, flexible, and more convenient platform (Kan, Teng, & Chou, 2009). Work has also been done on using QR code systems as the calibration method for an AR system, more specifically linking a “real” location (i.e. coordinates) with a QR code (Nikolaos & Kiyoshi, 2010).

Huang, Chang, and Sandnes (2010) studied QR codes for information transfer across platforms with the goal to make the transferring ability ubiquitous. They used the example of a museum guiding system which allows tourists through handheld devices to browse exhibition contents including text, pictures, audio, and video. They point out that often tourists cannot easily share information with each other when they come across interesting items. In order to help simplify sharing, they present five information encoding types based on QR codes that facilitate the connection of independent systems implemented on different platform such as smart phones or Java phones. QR codes have also been used successfully in information retrieval based systems on cell phones and smartphones for genetically modified foods (Shiang-Yen, Foo, & Idrus, 2010).

Research into improving methods to educate with QR codes and interactive applications has been tested. Rouillard and Laroussi (2008) presents an adaptive pervasive learning environment, based on contextual QR codes, where information is presented to learner at the appropriate time and place, and according to a particular task. The experiment was conducted in a zoo and was meant to enhance classroom activities. This paper discusses adaptability and context awareness system as strategies to provide support for learners in mobile pervasive situations. QR code security has also been investigated to a satisfying degree, with a series of attacks based on SQL injections for reader applications, reminding us that sterilizing database queries is extremely important when interacting with externally stored information (Kieseberg et al., 2010).

Waypointing systems have also been experimented with. Chang, Tsai, Chang, and Wang (2007) developed a wayfinding prototype system based geo-coded QR codes for individuals with cognitive impairments. The design draws upon the cognitive models of spatial navigation and consists of wayfinding devices and a tracking system. Compared to the sensor network approach, it is easy to deploy because of low cost and short time frame. The prototype is tested with routes on a campus where a rehabilitation trained job coach oversees the process. The results show the prototype is user friendly and promising with high reliability.

There have been growing uses of mobile barcodes in government sector (Using QR-Codes in Government, 2012). The combination of easy generation of QR codes and the mobile scanner/reader has been an enabling tool for promoting real-time data sharing of government administration and for marketing government services and programs. The QR-code allows the government officials and the public to access web links, add contacts, navigate maps, and much more. Table 1 shows some examples of QR-code uses in government.

Gamification with the blurring of the line between digital and real rewards is also growing in importance, such as educational environments (Raymer, 2011), in intelligent systems (Liu, Alexandrova, & Nakajima, 2011), and non-gaming context (Deterding, Sicart, Nacke, O'Hara, & Dixon, 2011), all which improves the engagement of the people who use the system.

3. Enhancing the national park experience through QR codes

In this section, the discussion consists of four parts: First, a discussion of the design parameters and goals of the QR code & waypointing system, and its function as a core component of the mapping and gamification systems. Second, a discussion of the application constructed around utilizing all of the QR code system features and functionality. Third, the application component comes with additional capabilities provided by a computing device (smartphone, tablet, etc.) and these are also covered in detail herein. Finally, the data resources and subsequent information system architecture required to drive this platform is outlined and analyzed.

3.1. QR code waypointing system

First, we focus on a discussion of the waypointing system. The goal of this system is to provide park visitors with the ability to locate

Table 1
QR-code uses in government.

Administration	• QR code business cards
	• Commissioner's/councilperson's information onto the residents phone
	• Employment opportunity advertising
	• QR-code on marketing and newsletters
Land use permits	• QR codes for building permits
	• QR codes on zoning notification signs help sharing any zoning changes
Recreation	• Reserve a park facility
	• QR codes on signs and buildings provide sports or other events.
Public safety	• Promote sign up for email or SMS message notification of emergency
Passport	• QR codes on a passport for detailed information and instructions (Barber, 2012)

themselves should their GPS units fail to work (no signal or device failure) and/or cellular coverage is lost. The waypoints consist of a series of four QR codes, in an equilateral triangle shape with the primary code in the central point in the triangle. These codes will be posted on the trail markers and other locations throughout the park at the discretion of the park management and feedback from the park visitors (see Fig. 2 for different waypoints in a park).

This data is expressed as a string of numbers. For example, the latitude and longitude of the building 1 Washington Park, Newark, NJ is 40.74518, −74.17040. The primary QR code, which contains the latitude and longitude of the location of the trail marker post it is scribed on, is used for acquiring coordinates to identify the user's current location on the map. The compass application can then be used once this information is received from the QR code to guide the user to the next waypoint, until they reach their final desired destination or the entrance/exit of the park.

The other three QR codes function as a form of “calibration” allowing the user to make sure the primary code has not been tampered with by attackers. They will be spaced at known intervals so that visitors will be able to determine if the primary post has been tampered with. If the other three codes do not make sense in respect to spatial data provided by the primary code, one can determine the integrity of the code has been compromised. Security can be built into the QR code tags however, as a 256 bit hash can be embedded into the code to be checked against hashes embedded within the mapping applications' approved waypoints. If they do not match, the user knows they are receiving bogus data and the tag has been compromised. The final security check is to simply have a park ranger audit the sites on an appropriate time interval basis to minimize individuals tampering with the codes.

3.2. QR codes for linking citizen-driven map data with park application services

In order to promote cross governmental organizational collaboration, a partnership between the U.S. Geological Survey (USGS) and the National Park Service should be fostered. The desired outcome of the collaboration will be towards the goal of generating high quality digital maps and geospatial datasets for the public of NPS parks and historical sites. The USGS already has produced many detailed maps for the NPS in the past, most of which are topographical maps (USGS, 2005).

Each of these maps, some of them with shaded relief, feature a national park, national monument, or other National Park System unit. The maps are much like the standard quadrangle maps of the same scale, but they highlight recreational features that are of interest to park visitors. While this information exists today as paper maps or paper maps converted to PDF, it needs to be transformed into a dataset that can be used in a widely available, modern mapping program (such as Google Maps).

Ideally, the different types of maps can become overlays of a single “supermap” and the user can turn on or off information based on radio buttons or some other form control. For example, if a user wants to see the mineral map or the hydrology map (or both at the same time), that information is provided as an overlay over a vector based map that scales in accordance with the data. Creation of this dataset is involved and expensive, requiring surveying experts, computer programmers, and cartographers collaborating on a single digital product. Once developed, it provides a powerful platform for geospatial analysis for the many departments of the government and the public that use maps towards this end.

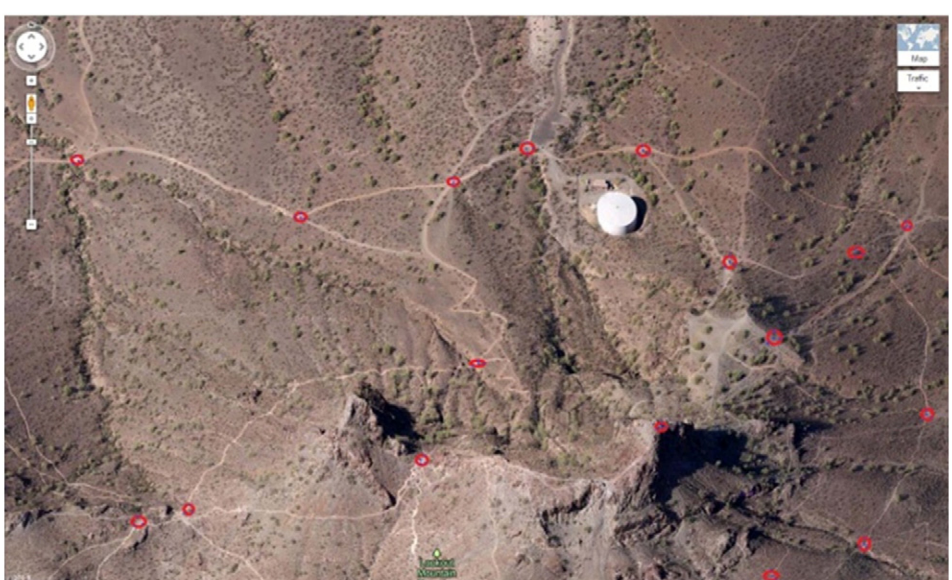

Fig. 2. Illustrative example of park trail map with QR code waypoints.

The primary mapping system used by today's most popular smartphones has been developed by Google. Google Maps API provides the ability for the programmer to interact with two dimensional geo-spatial data for the purpose of providing an overlay of information on an existing map (see Fig. 3).

This is how the application translates data from the QR code system into usable coordinates or waypoints on the map. The java script version of the API (v3) provides the most features and flexibility available for the mapping tasks relevant to this project. Once the data is available, it can be used for derivative calculations, such as route distance calculations, or link to a park point of interest review database and show a heat map of the places in the park visitors enjoy the most. The possibilities are endless, which is why pushing for the creation of this information is vital to the success of this digital government initiative.

More importantly, however, is the task of creating a “street view” for all of the NPS park trails. This requires developing a system that can perform tasks related to geo-visualization. Geo-visualization is the term used for the creation and manipulation of images, maps, diagrams, charts, 3D views and their associated tabular datasets. Currently, there are a number of GIS packages that provide such tools, giving static or rotating views, draping images over 2.5D surface representations, providing animations and walkthroughs, dynamic linking and brushing as well as spatio-temporal visualizations.

All these facilities augment the core tools utilized in spatial analysis throughout the analytical process, which are exploration of data, identification of patterns and relationships, construction of models, and communication of results, in this case in the form of a map or an application that utilizes the generated maps. This latter class of tools is the least developed, reflecting in part the limited range of suitable compatible datasets and the limited set of analytical methods available, although this picture is changing rapidly (de Smith et al., 2009).

It would not be a stretch to develop a 360° view camera harness system that could strap to a hikers back along with a GPS connected to a route logging device aiming to create a three dimensional virtual walkthrough map of the entire park that is fully coordinate referenced and bound to imagery captured. This can be done for each of the four seasons, giving a complete idea of what the park site is like at any given time of the year. The Google maps API provides this capability, if the data is available. The dataset generated can be packed with park specific data and waypoints that show all of the best attractions and fun facts specific to the particular site. As of this writing, this type of project has not been explored fully, but would be feasible for little additional time and money using existing tools and would provide great utility to the public, especially potential park visitors.

3.3. QR codes for geocaching

Due to the increase in the number of technology devices incorporating a GPS receiver, the sport of “geocaching”, an outdoor treasure hunt, is seeing a growing popularity towards mainstream acceptance with the general public, who now wish to use the capabilities of their GPS enabled devices.(O'Hara, 2008) As a meshing of both the QR code waypointing system and the gamification system (described in detail in the following section), traditional “geocaching” can be reimagined using a system of QR codes scattered about the parks. The QR waypointing system can be divided into two types of codes, the primary code system designed for true park navigation and a geocaching clues system. The geocaching system can have varying degrees of precision in the clues/coordinates provided, with the “easy mode” having the greatest degree of precision, an intermediate mode, and “hard mode” with the least degree of precision. Since there is enough space for three sets of coordinates inside of a single QR code, the application can provide all three and the user can decide on which set suits their preference.

Inside of the cache, laminated QR codes can be printed for scanning by the smartphone application. The QR code provides a URI that rewards seekers with badges for finding caches. This is a unique twist on a recent trend called BIT caching, which is a container less geocache that contains a URL the finder can visit in order to record their log. Since you need the application to interpret the QR code, it will help speed adoption of the application by park visitors who have both smartphones and enjoy geocaching. Park approved geocaches can contain special materials that reward users for being “good patrons” of the geocache and following the rules set by the community. The cache can also contain emergency supplies that can be used by park visitors who are lost but cannot reach help, yet have the application and the ability to find a geocache. As another safety feature, we have created a twist on the traditional USB cache, also known as a dead drop cache, which is a paperless cache stored inside a USB drive and embedded into a structure of some kind. The cache is retrieved by connecting a device that has a USB port and that is able to read the files. Our version of this is designed to be embedded into the trail marker posts with ruggedized versions of the data cables for the most popular/common smartphones and contain a read only version of the parks application, in the event the park visitor

Fig. 3. Illustrative example of Google Maps API map with overlays.

does not have the application before they become distressed. Since the USB storage device is powered by the device it is connected to, it requires no additional power to maintain. This geocaching example serves as just another way to use the QR code system for civic engagement in the park system while providing utility to the NPS.

3.4. QR codes for gamification

The gamification program is the other component of the QR code system implementation. This system is designed around the idea of a unique QR code placed somewhere in the park providing a URI to some resource stored in the NPS game database. Fig. 4 shows an example of game QR codes on a trail information plaque. Each "reward" is linked to one or more QR codes that must be scanned in order to unlock the system. Most of the QR codes for the games will be integrated into existing park informational signage, as this is the fastest, least expensive method for deploying the system.

However, some game tasks are more esoteric in nature (beyond just taking a picture of a QR code) and require additional input. One example would be where photos of flora or fauna that must be taken and subsequently correctly identified by an expert before the corresponding unlock QR code can be sent to the user. In the case of our previous example, a park ranger could receive five pictures of different local flora from a checklist that must be verified before the badge can be rewarded. At the end of the tour, the ranger can see who completed the game challenge and submitted their pictures. If they met the requirements, the badge will be rewarded.

While the benefits of gamification are many, the data generated by users playing the games has many useful applications within the system. For example, in the previous use case with park visitors taking pictures for a reward, these pictures contain data that can be used by other portions of the application. Essentially, in this specific case, the NPS has park visitors generating a contextually tagged (i.e. this tree is a redwood @ national park/site xyz), geotagged (redwood @ x lat, y long), and timestamped (taken on 01/01/2012 @ 2:30 pm) database of images of specific flora. By mining this data, it can provide relevant local data for the map visualizations that will grow in volume and quality over time. By structuring different games around user data acquisition and using this data to fill in map visualizations, the gamification element serves as a supplementary data gathering agent beyond traditional means employed by the government. This enhances the overall volume of information the park is providing to visitors, rangers and scientists alike via an altruistic relationship of rewards for game task achievements.

Fig. 4. Example of park information plaque.

Once this type of data is being generated and stored in the NPS database, augmented reality can be implemented by combining information from the tag database with the camera & GPS map overlay functions. Augmented reality in this capacity can serve as a "virtual" tour guide, by providing all of the information that would normally be provided by a person. This is possible since this information is now stored and retrieved from the NPS database by the smartphone application.

Naturally, quality checks needs to be put into place to ensure factual accuracy of reported data. However, designing an auditing program to ensure factual accuracy of the user generated data by professional rangers/surveyors who visit the parks on behalf of the government would be trivial. The application could have a login for each park and query the database for whatever relevant images needed to be audited and their related information. The auditor could then verify the information in person as they make their rounds through the park.

The game system consists of categories that aid in fostering the goals outlined by the NPS mission statement. NPS states that anyone can be a Volunteer-In-Park (VIP). Individuals, couples, families, students, and organized groups can volunteer. Those under 18 years of age may volunteer with the official, signed permission of a parent or guardian. NPS welcomes Volunteers-In-Parks from all over the United States and the world. There is a PDF available online at the NPS website for those seek more information about volunteering their time with the National Park Service. Table 2 shows the categories and the example tasks usually asked of VIPs that can now be morphed into tasks required of park visitors to earn merit badges within the game system. Thus, from these examples, we can see that the gamification program acts to supplement the existing volunteer program by guiding behaviors of park visitors to be in line with the goals of the NPS.

4. QR codes for mobile environmental services

Our second case study focuses on the "Mobile Environmental Information System" (MENVIS) (Chun, Adam, & Artigas, 2005; Chun, Adam, & Atluri, 2007), developed at Rutgers University, which is similar in spirit to the use cases discussed earlier for the National Park Service. MENVIS is a system intended not only to support staff engineers and scientists to collect data from the field using mobile devices, but also enhance the exploring, learning and discovery experience of visitors, eco-tourists and students, while moving in and around urban environmental preservation areas. The system has been tested in the New Jersey Meadowlands wetland preservation area, gathering of environmental data (e.g. birds, fish, and plants; a particular geographic location and presenting them) via a web enabled mobile device. A QR code based information retrieval system provides a convenient and practical extension layer to this system as well. The services provided by MENVIS can now be more easily realized with the wide adoption of QR code technology and the corresponding ability to easily use them, e.g. web enabled smartphones.

QR codes can be generated to provide a precise and accurate way to disseminate the information to users via embedding URLs/URIs/GPS coordinates into QR codes. Within the framework of the application, these QR codes link to whatever data is deemed relevant—in the context of this system, it would link to databases for geo-referenced individual data components, including text document collections, video

Table 2
Gamification categories and tasks for volunteers-in-park.

Awareness	• Make a Tweet or a Facebook post about challenges facing national parks • Link 3 friends to an article about conservation efforts in a park
Donations	• Give $25 to a park in your home state. • Give $100 to a conservation effort working with NPS
Safety	• Submit an itinerary for a park trip and have it authorized by a park ranger • Image all the QR codes on the official park trail • Warn a park ranger about bears at a campsite.
Public engagement and education	• Image all the QR codes at the park relating to geographic features • Image the QR codes at the park relating to local wildlife
Volunteerism	• Work at an information desk and answer 25 visitor questions • Present a living history demonstration in period costume • Build 250 ft of fences or paint 5 buildings • Give 10 guided nature walks • Assist with preservation of 3 museum artifacts • Help Maintain 7 trails and/or building boardwalks • Design 3 computer programs or park websites • Serve on a bike, horseback, or beach patrol 3 times
Sales	• Buy a park pass online • Buy a hunting license or fishing license online • Purchase a sponsored item in the information center that sponsors a conservation effort

collections, images (still photos and satellite imagery), maps, sediment chemistry, and water quality data. Other data also describes birds, fish, air quality data, fine-grained vegetation, and impervious surfaces, among others. This information can be retrieved in the field by users after it is associated with a corresponding QR code on an informational placard. It is easy to imagine that in the near future, park placards could be entirely digital, as opposed to traditional static designs currently in use. Digital signage allows for updates to QR codes that could be done in real time to provide the most current park data to the public, along with ensuring the codes are not being tampered with by mischievous park goers. One such example could be bird photographs. A verified crowd-sourced image of a specific bird species could have a QR code generated for it after being verified as an example when it is committed to the database. This data could then be streamed to the placard and accessed by users via its newly generated QR code.

To integrate these databases with geo-location information, a light-weight data and service warehousing approach called a "virtual data warehouse" is used by MENVIS. The virtual data warehouse serves as a repository of web links, called a service link cube (link cube in short), to each database services with the input and output parameters (Chun et al., 2005, 2007). Each one of these links in the link cube can be associated with a table that stores the generated QR code, which can then be placed in the park and used by individuals to fetch the data from the original link directly onto their smartphone within the

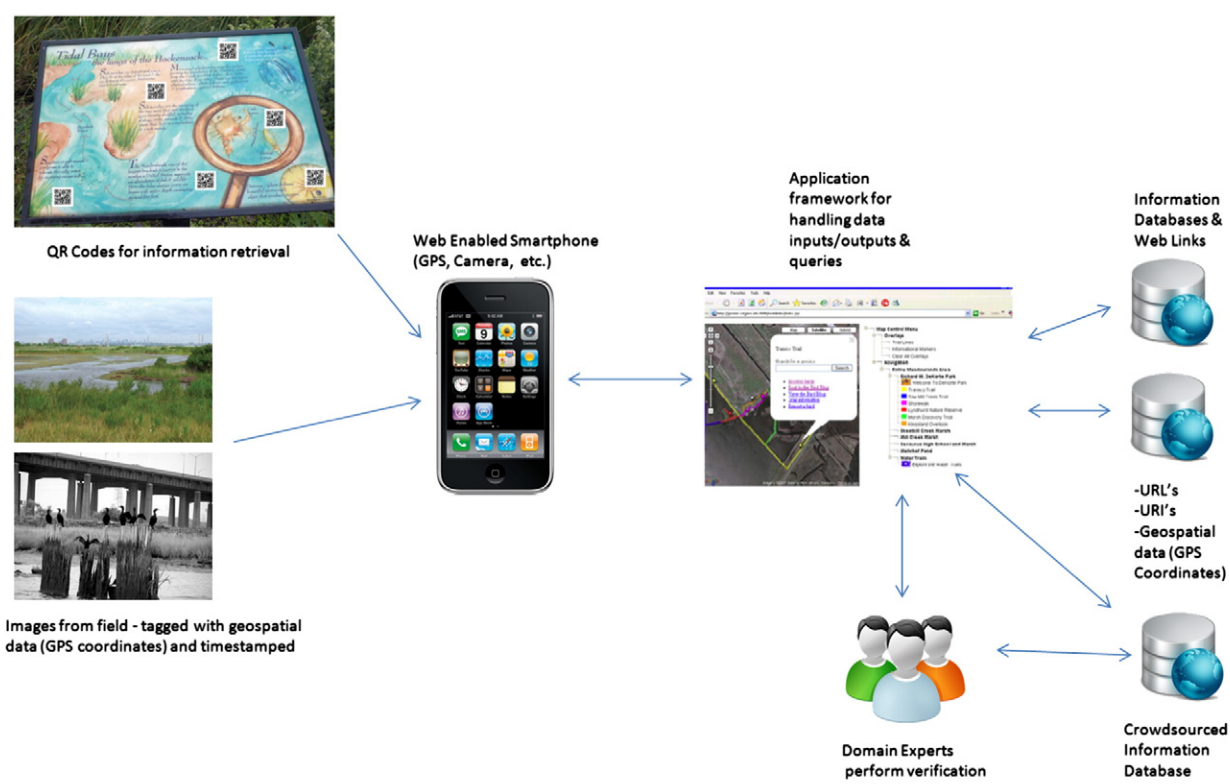

Fig. 5. QR code integration into MENVIS.

application. Each individual database interface is considered as an environmental data service. External web and data services that are relevant for a particular Meadowlands location are also considered and can be embedded in QR codes and cross referenced with existing database resources in a similar fashion. Fig. 5 depicts how QR codes could be seamlessly integrated into MENVIS.

5. QR codes platform development and scenarios

In this section, we describe how the QR code platform can be developed and deployed. We describe the QR code-based service platform and its architecture that can be easily deployed for little to no cost and utilizes the existing system currently in place. In the case of NPS, the costs involved are primarily related to development of the NPS application and related online services it provides for smart devices (phones, tablets, PDAs) to park rangers and NPS personnel. The amount of money required to finance these projects and deploy the QR code system would be relatively trivial in the context of a traditional government budget. For MENVIS, the costs are also quite small, as the system exists in its current form is relatively easy to extend with QR codes. The smartphone applications will be delivered to the appropriate digital marketplaces for the public to download, such as iTunes App Store, Android Marketplace, and Blackberry Marketplace. Utilizing the existing distribution networks built by the smartphone vendors for getting the application to users will help in reducing costs and raising application visibility. A link to the marketplaces can also be placed on the NPS website to drive park visitors to download and use the application.

The ideal scenario for the utilization of this system would be for U.S. National Parks Service (NPS) to deploy at the parks and historical sites under their management. The NPS has an integral mission to make resource preservation and conservation its primary goal, while maintaining and improving the recreational and educational experiences for park visitors. Specifically, it is charged with “protecting the habitats for endangered and native species, targeting non-native species for removal, inventorying natural resources and monitoring their condition, monitoring air and water quality, collaborating with other natural resource experts, and utilizing parks as scientific laboratories and classrooms” (The National Park Service, 2012). The National Park Service takes care of approximately 400 national parks with more than 275 million visitors each year. By adopting a QR code system with a supporting IT backbone infrastructure along with using QR codes throughout the parks and sites the NPS manages, they can increase citizen participation and provide an enhanced experience.

The general idea would be to develop an application for all popular smartphone platforms (Android, iOS, Blackberry, WP7) that would provide QR code processing, maps, location information, and other relevant information (weather, park status, rangers on duty etc.) to people visiting the parks. The application system consists of two parts, a digital component that is dynamic (contacts a server to download updated information) and provides a constant stream of information for the user. The other half of the application is a static component, the QR code system that is used to store data for the park visitors to use to gather information. See Fig. 6 for the overall general architecture of the prototype system.

5.1. Scenario for National Park Services

Park Finder allows the visitor/ranger to select a site based on state. The user picks a state and is then presented with a list of sites managed by NPS in that state. The user then selects the park of choice at which point the application can fetch all of the location based information related to the site (maps, weather, park status etc.) from the NPS servers.

Park visitors can create a park itinerary that will be sent to the park rangers and tour guides. Not only does this provide park rangers and tour guides with a more accurate assessment of the number of people at the park at any given time, it also allows for the NPS to conduct statistics tracking, demographic analysis, and measure other performance related metrics. This information is critical to enhancing the functions of digital government as it provides data for managers to use to drive down costs and improve quality of service. After an itinerary has been flagged as completed, NPS can send a survey to the visitor inquiring about this visit, providing them with more direct, timely feedback. This functionality also serves as a bonus safety measure. For example, if a park visitor chooses to explore a large park alone and submits an itinerary where his campsite and/or planned route is and becomes disabled during his visit, after a set interval of time, the park rangers can dispatch search and rescue to aid the park visitor and will have a greater chance of success in finding that person more quickly, assuming that individual stuck to the itinerary.

Weather related information can be provided (both current data for the site and a seven day forecast). This provides the park visitor with the ability to plan their trips around the weather and acquire specialized gear that is weather related if needed. This forecast will also help aid in lowering incidents related to bad weather catching people off guard and causing potentially life threatening problems while visiting parks. The weather information also helps park rangers make better judgments on when parks can be opened or closed based on weather, and provide warnings to people currently in the parks, or to tell people who had planned an outing via itinerary to cancel and save themselves a wasted trip.

Maps provide an overview of the park and give the visitor the ability to find what they are looking for. One of the key features of using digital maps is that they can be more “interactive” than a basic paper map. Many different types of maps, (such as topographic maps created by the USGS) can be added and used by the system along with the default maps. Overlays created can show points of interest on the map and highlight approved trails. The benefit of integrating maps with the QR codes provides the ability to determine where you are if the phone GPS fails and/or has no connections to cellular networks. The possibility for integrating an augmented reality system that functions in conjunction with the maps (i.e. if you reach a QR code post at Manassas battlefield, the camera function can be called and you can see an animated overlay of soldiers fighting while viewing the area in real time). Augmented reality provides for a greater level of visitor engagement and educational interactivity when visiting historical sites. The NPS can also measure statistics from map usage, determining the most frequent points of interest people visit, most frequently scanned QR codes, and more. The main purpose of the QR code integration into the maps feature is a safety fallback, so people can locate themselves when other methods of communication fail.

Gamification system: The game component provides an incentive for visitors to explore sites and engage in behaviors that allow for a greater level of exposure to educational material offered by the information centers, as well as engage in behaviors that are conducive to NPS. The goal of this portion of the application is to use the QR code system to provide links to digital repositories of information stored on NPS servers related to placards at the sites. For example, an informational placard at Yellowstone on Old Faithful can have a QR code added to it for minimal cost and visual impact that would provide the application user with URI that provides facts on geysers, information about Old Faithful, schedules for eruptions, a video of it erupting etc. Then, as an incentive to get people to see this attraction, they can be rewarded with a “merit badge” showing they have completed a particular task (see old faithful erupt). This can be linked with their profile within the application and also feature the ability to post to their Facebook page or their Twitter feed. This concept can be extended to areas such as donations (donate $100 to NPS to earn the “Gold Level Sponsorship” badge), volunteerism (pick up 5 pieces of trash to earn the “Green Earth badge”), and safe behaviors (stay on the approved trail for “good hiker”, submit an itinerary for “super planner” badge, report a bear near campsite for “lions, tigers and bears, oh my” badge). Public engagement will increase as a result of deploying this system, as people now have a reward based system to encourage them to visit NPS parks and historical sites.

5.2. Scenario for mobile environmental system

We now look at a scenario where MENVIS can be extended by using QR codes within its existing framework.

5.2.1. Geolocation based QR codes for integrated information service

The goal behind creating a geolocational based QR code is to provide easy access to locationally relevant data, with the ability to grab specific information the user desires from all of the information available about that specific location. It achieves this by combining information from the many different databases, data repositories, and data gathered by crowd-sourced methods with traditional coordinates (latitude and longitude) to form a single QR code. The applications for this type of QR code are many, and a few select styles will be demonstrated by example in the following section, along with a description of the process of creating these types of QR codes.

Imagine a park that covers a large, diverse area of land. Specific geographic areas of the park may be home to unique natural features (mountains, rivers, lakes, rock formations etc.), certain species of flora and/or fauna, or may be the site where some historically significant event took place. Rich multimedia, detailed in-depth information, measurements (river depths, temperatures, vegetation density, soil chemistry etc.) and even temporally (time sensitive) relevant information for example, recent stream depth measurements, photos and locations of bird flocks are all available in various databases and the World Wide Web. The challenge of getting this information to individuals who would utilize it in the field has traditionally been the barrier to full utilization of these informational databases. Static approaches have been in existence for some time; they used copies of informational databases stored locally on a mobile device, and were largely unable to effectively generate data in near or at real-time without great expense (both in dollars and instrumentation). The recent technological advances in both wireless data streaming technologies (3G, LTE etc.) combined with the rapidly evolving smartphones (camera quality, GPS accuracy, gyroscopes, accelerometers etc.) market have provided the means to manifest a near or at real time system into reality.

Fig. 7 illustrates the process flow of the QR code integrated MENVIS system. A user may generate data by taking a picture with a smartphone camera that is geotagged. The image can then be shared with the user's social media contacts as well as sent to domain experts for review and eventual commitment to a long term database. The intent of this process is to crowd-source current park data that can be used by researchers, scientists as well as park

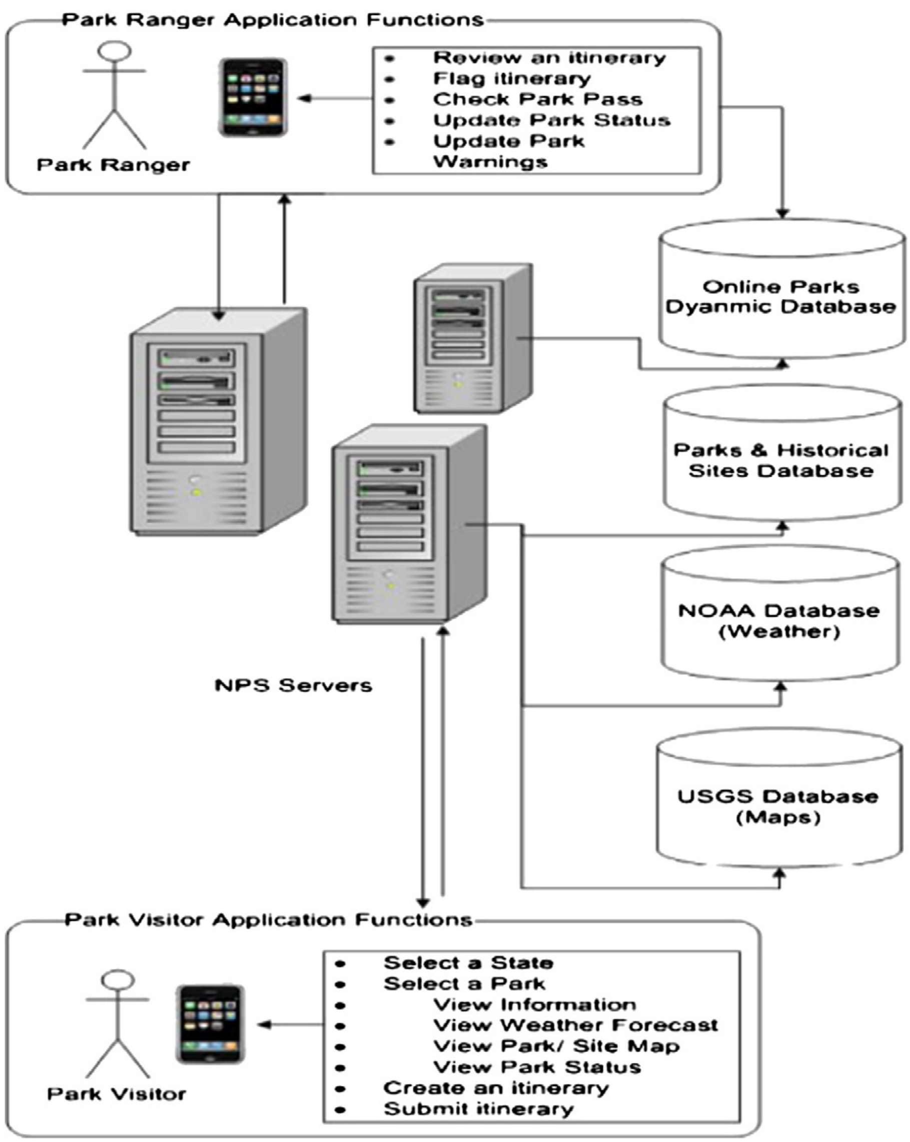

Fig. 6. QR code based NPS mobile service architecture.

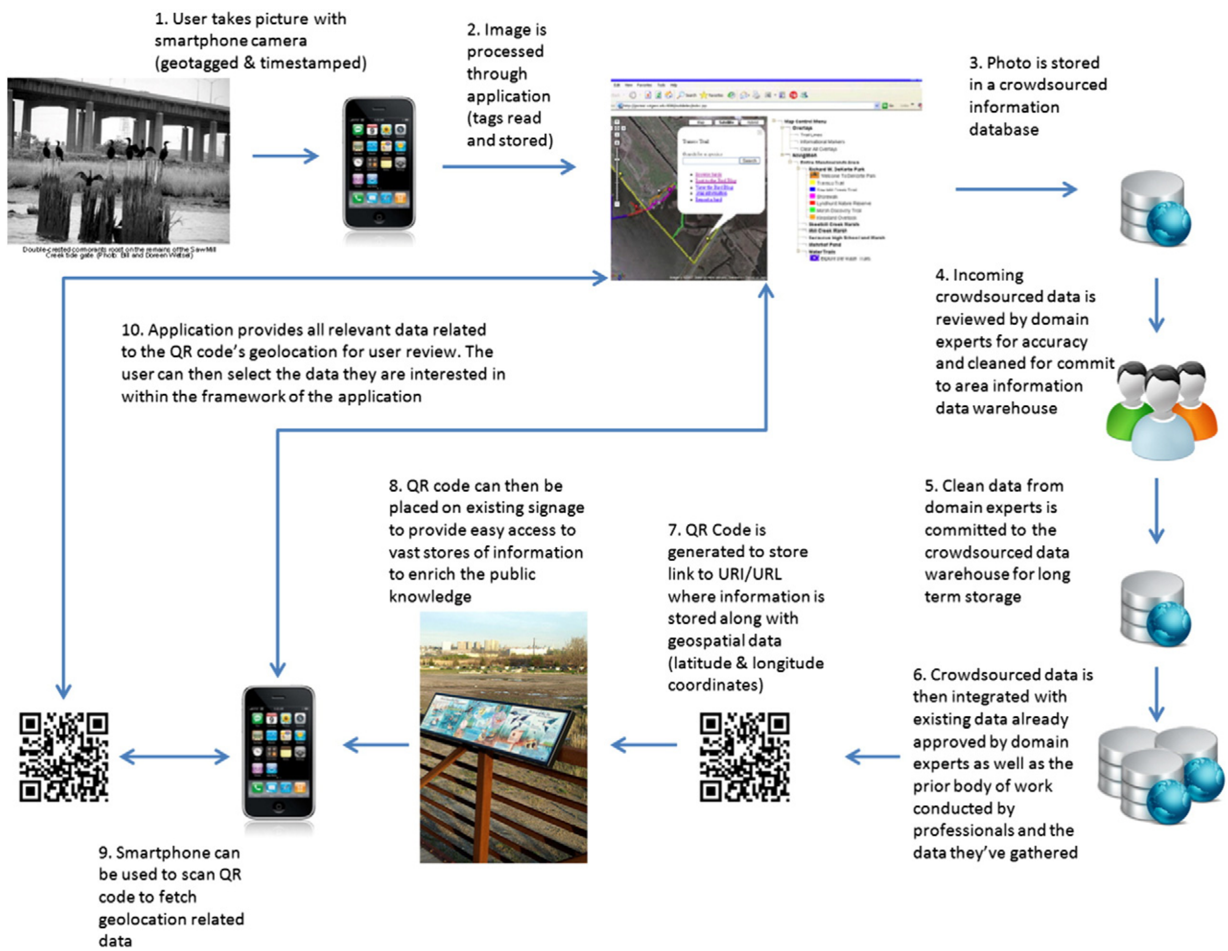

Fig. 7. Process flow of the QR code integrated MENVIS system.

visitors. The QR code is constructed as follows: the URI/URL is combined with the particular latitude and longitude coordinates for the desired area. These coordinates are used as a means to construct a query to retrieve all of the relevant information that relates to that specific geographic location. Upon returning the results of the query, the user is then able to see all of the data about that particular location. They can then drill down through the data to retrieve the particular type of data they are looking for, for example, types of animals that live in that area or the soil chemistry in that region.

This additional geolocation based QR code functionality can be easily achieved with existing database systems, as it only requires a small amount of new information (the coordinates) to implement and use successfully. A traditional RDBMS or an online semantic tagging system is required to associate the existing informational resources with the coordinates so they can be retrieved appropriately when queried by the system via the QR code.

5.3. Deployment and adoption issues

The application has two modes of operation: online mode and offline mode. Each mode comes with its own set of features and capabilities. It is important to distinguish between the two modes and the capabilities of each, as information networks (voice, data, GPS) are not always available in all areas of national parks (if at all).

5.3.1. Online mode

The first mode is online mode, where information can be received (sent) via cellular or Wi-Fi networks to the phones. This mode can be used to download the application to the phone, as well as handle the large data transfers required by the application that would normally tax a cellular data network or be impossible without a data connection of some type. This is also the mode to use when planning a trip to the park, and to submit the relevant information to park rangers about the specifics and duration of your trip. A restrictive, throttled version of online mode will run when the smartphone or tablet device is on a cellular data network as opposed to a Wi-Fi network, as the larger data transfers will take too long and/or potentially cost the user a large sum of money based on their contract with the phone company. Online mode is important for the gamification component, as some game tasks can be very data intensive (uploading images). The switch in modes will be unnoticeable to users, and will occur in the background. When an operation that has been determined to use too much data occurs, the user will be warned about the potential consequences before being able to ultimately proceed with the action.

5.3.2. Offline mode

Offline mode is for when the application does not have any external connections to data/voice networks and must rely on information generated or stored locally on the phone. As cellular and data coverage are questionable at best in many of the larger parks, it is wise to embed functions that aid in navigation into the application when in offline mode. Offline mode is designed to work with the QR code system in place on trail markers for helping people find their way around the trails in the event they become lost. Thanks to built-in features that come with almost all modern smartphones such as a camera and a compass, trail goers can figure out where they are from the QR codes posted on the trail markers and use the compass and other data to make it to the next trail marker, eventually getting to where they need to go. The key is that the map data and the waypoint data are stored with the application, so that an initial download of the application will provide the park visitor with the information required to navigate any one of NPS's 397 parks and historical sites.

5.3.3. Adoption issues

As the awareness of QR codes increases and mobile smartphones become more pervasive, we expect the government would be more willing to adopt the QR-based communication and application systems. The best practices of the QR code-based systems (Van Velsor, 2011) that the government should keep in mind in adoption of this particular technology include:

- Make sure QR codes should link to an action-oriented or otherwise compelling content experience, so that the citizens may experience more participation in government matters.
- Clearly state what the code will do when scanned.
- Place QR-codes in visible places and channels with the instructions on how to use them. Monitor and analyze the uses to ensure learning from the successes.
- Have a strategy for accessibility and late-technology adopters.

One topic we did not touch upon is how to ensure the security (especially, integrity) of the mobile codes so that it contains the original content, instead of linking to phishing sites or to materials that were not intended. A possible way of dealing with this is to have the information to be disseminated be digitally signed by the disseminating agency, and the signature included within the QR code itself, which can then be verified by the reading device. We plan to explore this as a future work.

6. Conclusions and recommendations

In this paper we have explored ways in which QR codes can be used to improve the quality of services provided by various government branches to the public. Our use case of the National Park Service and Mobile Environmental Services (MENVIS) demonstrates that branches that traditionally deal in low tech solutions can, in fact, benefit greatly from technological advances implemented into their organizational tasks when properly aligned with their goals. We show how relatively low cost, low maintenance digital government systems can provide greater interactivity for the public, raise awareness about issues, and allow the government to disseminate more information to the population in an effective manner.

We believe that the government can benefit greatly from implementing a QR code system to offer advanced data services to the public. Implementing this system will be a small additional cost, and the process integrates well with existing systems. To identify existing systems that can benefit from the use of QR codes, one must look for any place where the government has a desire to disseminate information to the public at large. Existing database systems can be layered with QR code capability quickly and easily. In the future, we plan to extend QR code capabilities to other applicable systems.

Acknowledgments

The work by Chun was partially conducted while she was on sabbatical leave at Computer Science Department, Columbia University. The MENVIS project was originally funded by MERI, New Jersey Meadowlands Commission.

References

Barber, J. (2012, Feb). Government chooses QR codes for passports. http://outputlinks.com/html/columnists/Joe_Barber/copi_Government_QR_Codes_Passports_050109.aspx
Chang, Y. -J., Tsai, S. -K., Chang, Y. -S., & Wang, T. -Y. (2007). A novel wayfinding system based on geo-coded QR codes for individuals with cognitive impairments. *Proceedings of the 9th International ACM SIGACCESS Conference on Computers and Accessibility, Assets'07* (pp. 231–232). New York, NY, USA: ACM.
Chun, S. A., Adam, N. R., & Artigas, F. (2005). Mobile web for environmental information guide: Case for New Jersey Meadowlands Commission. *Proceedings of the 2005 KMIS International Conference on Information Systems for a Ubiquitous Society, KMIS 2005 Nov 24–26, Jeju Island, S. Korea* (pp. 236–239).
Chun, S. A., Adam, N. R., & Atluri, V. (2007). MENVIS: Mobile environmental information system. *Proceedings of the 8th annual International Conference on Digital Government Research: Bridging Disciplines|& Domains (DG.O '07)* (pp. 286–287). : Digital Government Society of North America.
D.W. Inc. (2010, Jan.). *Quick response code features.*
D.W. Inc. (2010, Jan.). *Quick response code standardization.*
de Smith, M. J., Goodchild, M. F., & Longley, P. A. (2009). *Geospatial analysis: A comprehensive guide to principles, techniques and software tools.* ISBN-10: 1848761570.
Deterding, S., Sicart, M., Nacke, L., O'Hara, K., & Dixon, D. (2011). Gamification. Using game-design elements in non-gaming contexts. *PART 2 Proceedings of the 2011 Annual Conference Extended Abstracts on Human Factors in Computing Systems, CHI EA'11* (pp. 2425–2428). New York, NY, USA: ACM.
Fedorowicz, J., Dias, M., & Sawyer, S. (2009). Design in digital government research. *Proceedings of the 10th Annual International Conference on Digital Government Research: Social Networks: Making Connections between Citizens, Data and Government, dg.o'09* (pp. 293–301). : Digital Government Society of North America.
Huang, Y. -P., Chang, Y. -T., & Sandnes, F. E. (2010, March). Ubiquitous information transfer across different platforms by QR codes. *Journal of Mobile Multimedia*, *6*, 3–13.
O'Hara, K. (2008). *Understanding geocaching practices and motivations. In Proceedings of the twenty-sixth annual SIGCHI conference on Human factors in computing systems (CHI '08)* (pp. 1177–1186). New York, NY: ACM.
Kan, T. -W., Teng, C. -H., & Chou, W. -S. (2009). Applying QR code in augmented reality applications. *Proceedings of the 8th International Conference on Virtual Reality Continuum and its Applications in Industry, VRCAI'09* (pp. 253–257). New York, NY, USA: ACM.
Kieseberg, P., Leithner, M., Mulazzani, M., Munroe, L., Schrittwieser, S., Sinha, M., et al. (2010). QR code security. *Proceedings of the 8th International Conference on Advances in Mobile Computing and Multimedia, MoMM'10* (pp. 430–435). New York, NY, USA: ACM.
Liu, Y., Alexandrova, T., & Nakajima, T. (2011). Gamifying intelligent environments. *Proceedings of the 2011 International ACM Workshop on Ubiquitous Meta User Interfaces, Ubi-MUI'11* (pp. 7–12). New York, NY, USA: ACM.
Mobile Barcodes.com (2012, Feb). QR-code readers. http://www.mobile-barcodes.com/qr-code-software/
Nikolaos, T., & Kiyoshi, T. (2010). QR-code calibration for mobile augmented reality applications: Linking a unique physical location to the digital world. *ACM SIGGRAPH 2010 Posters, SIGGRAPH'10*. New York, NY, USA: ACM (144:1-144:1).
Raymer, R. (2011). Gamification: Using game mechanics to enhance elearning. *eLearn, 2011.*
Rouillard, J., & Laroussi, M. (2008). Perzoovasive: Contextual pervasive QR codes as tool to provide an adaptive learning support. *Proceedings of the 5th international conference on Soft computing as transdisciplinary science and technology, CSTST'08* (pp. 542–548). New York, NY, USA: ACM.
Shiang-Yen, T., Foo, L. Y., & Idrus, R. (2010). Application of Quick Response (QR) codes in mobile tagging system for retrieving information about genetically modified food. *Proceedings of the 9th WSEAS International Conference on Data Networks, Communications, Computers, DNCOCO'10* (pp. 114–118). Stevens Point, Wisconsin, USA: World Scientific and Engineering Academy and Society (WSEAS).
The National Park Service, nps.gov, Feb 2012.
USGS (2005, Apr.). *USGS maps online edition.*
Using QR-codes in government. http://www.708media.com/qrcode/using-qr-codes-in-government/. (2012, Feb).
Van Velsor, S. M. (2011, April). QR code best practices for Gov 2.0. http://blog.ogilvypr.com/2011/04/qr-code-best-practices-for-gov-20/