Is your mobile app context-aware?

Considerations for Building a Context-Aware App

Every developer dreams of his application being downloaded, used and opened often by his entire target audience. To inform the audience about that app requires a marketing strategy and promotional campaign. But to design and build an app that will be used frequently by many involves a rigorous design and development process. This process includes defining the app’s goals and objectives, determining its features and functionality, designing a user experience that is both engaging and delightful, and building the underlying architecture and analytics that will support the functions of the app—even before writing the first line of code.

In today’s world of omni-channel marketing, study after study shows that advertisers get better responses when their messages are tailored to targeted users. Messages are most effective when sent at the most opportune time and location—when the user has the mindset to receive the information and the power to act on it. And, because it is always on and nearby, a mobile device is arguably the best agent to deliver messages at the right time and place. So, when building a mobile application that will be useful and engaging to its user, why not make the app context-aware?

Context-aware applications, or CAAs, are the next generation of intelligent mobile applications. When allowed by their users, these apps use contextual data: from historical information about the user’s demographics and behavior profiles to data about the current surroundings obtained through the smartphone’s microphones, accelerometers, gyroscope, cameras and other sensors. Combining these inputs with the current time and location via GPS, CAAs paint a picture about the user’s immediate context, and use the information to deliver tailored experiences in the form of timely, relevant and appropriate information, notifications and/or functionality.
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Why build a CAA? Because compared to other apps, CAAs are:

1. More engaging, by sustaining the user’s attention for repeated interactions;
2. More relevant and responsive to the user’s needs at the right time, place and situation;
3. More effective at influencing or changing behavior; and
4. More capable of providing a superior mobile experience.

So you’ve decided to deploy a CAA. How, then, should you design and build it? Before doing so, you’ll need to understand what is context, what is context awareness, and how to use context in applications. To support our own process of building CAAs, we have researched the field of context-aware and ubiquitous computing, leveraged foundational concepts to understand the meaning of context awareness, and constructed a framework that facilitates the design of superior CAAs.
Theoretical Foundations for Context-Aware Computing

**What is context?**

Many researchers have suggested varying definitions of context. In general, context can be described in the following terms:

- **Who** uses the application (user)
- **What** is the user’s situation (activity)
- **When** (time)
- **Where** (location)
- **How** the application is being used

These researchers’ definitions provide hints on how to structure CAAs as well as a process for building context-awareness in the app. In many definitions, the “why,”—as in the user’s purpose or intent—is not addressed. We hypothesize the reason to be that a user’s intent, emotion or sentiment (i.e., “internal” state) is hard to capture accurately enough to be useful in computing applications. With recent advances in affective state detection using mobile phone cameras and other sensors, a more comprehensive definition of context is needed. Thus, for our purposes, we will use the definition from Dey and Abowd:

> Context is any information that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves.

**What is context awareness?**

Having defined context, what is context awareness? What makes a mobile application context-aware? The term “context-aware” was first mentioned in a paper by Schilit and Theimer in which they describe context-aware computing as “...the ability of a mobile user’s applications to discover and react to changes in the environment they are situated in...”
Dey and Abowd further refine the definition as follows:

A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the task.

Thus, a context-aware mobile application is an app that uses context to provide information and services relevant to the task. By the definition of context, relevancy to the task must consider when and where the information and services are provided.

Whether acting as strategic consultant or mobile app developer, context awareness is important to Mobiquity in order to:

1. optimize the user’s experience relative to the task;
2. increase frequency of app usage and engagement; and
3. leverage context data to influence new, desirable behavior.

Thus, in Mobiquity’s point of view, “context” is any relevant data or information that may influence user engagement with the application and their subsequent behavior. An application is “context-aware” whenever context—whether implicit (sensor data, user profile or historic behavior) or explicit (entered/chosen preference)—is used to improve the user’s experience, resulting in increased engagement and a change in behavior.

Current Trends in Context-Aware Applications

As referenced in the preceding section, researchers (e.g., Schilit and Theimer) were already studying context-aware computing as early as 1994. However, the applications at that time lived in research laboratories and had not reached mass-market penetration. We believe that today’s technological and market conditions have changed, making context-awareness technology ready for mass adoption. In this section, we will explore some of the key drivers for wide distribution.

Markets&Markets valuates the Context Aware Computing market at $120 billion by 2018, estimating a 34.4 percent compound annual growth rate. We believe that context awareness will be a key aspect to a new revolution of mobile technology. As appification transformed communication-only mobile phones into smartphones, so will context-awareness transition current mobile solutions.

A perfect storm of technological advancements are driving context awareness to the mass market. Scoble and Israel in *Age of Context* attribute the imminent computing revolution of context awareness to five main forces:

- **Mobile:** At more than 7.3 billion, the number of mobile devices have surpassed the number of people on the planet. Mobile and wearable devices are now pervasive.
- **Social:** With the popularity of social networks, for the first time in history anyone can share their personal information—who they are, what they are doing, what they will be doing next, their likes and dislikes, and their connections to others—information that was not easily available before social media.
Data: Fast pattern matching, contextual search (e.g., Facebook Graph) and semantic extraction from unstructured data have made data malleable and information rich.

Sensors: The evolution of sensors has been a long road, with one of the first being invented by Evangelista Torricelli in the mid 1600s: the barometer. Today, sensors are inexpensive and connected. An average smartphone sports seven sensors, and sensor fusion technology provides further meaning to sensor data. Vast amounts of—and more meaningful—data is produced more than ever before. In addition to mobile sensors, there are now more fixed sensors, or beacons, installed in retail and public areas that communicate with the mobile sensors.

Location: Due not only to the maturity of GPS technology, but also to the availability of maps, point-of-interest databases, context and micro-location information, location data has become a rich source of contextual information.

Moreover, the maturity of key emerging technologies and the adoption of applications will allow gathering of even richer contextual information, and provide contextual experiences with transparency to the user. From a technological lens, the following trends are supporting the enablement of rich context awareness in the market:

Maturity of emerging technology: Emerging technology that should provide contextual information has matured and is not science fiction anymore. Location information, predictive analytics and biometric authentication are already mature technologies according to Gartner’s Hype Cycle.\(^8\) Other technologies that will provide contextual richness, such as M2M communications, Content Analysis, Complex-event Processing, Big Data and Internet of Things (IoT), are in the five- to ten-year maturity horizon at most.

Inclusion of digital technology in physical transactions: The intersection of the digital and physical world is a reality. Walmart’s in-store mode, Uber’s “God view” and PayPal’s hands-free payments are examples of digital technology enhancing physical transactions and/or services.\(^9,10\)

Maturity of mobile computing: Mobile computing is reaching maturity with faster processors and computing capacity.\(^11\) An example is HTC M8, which was launched in early 2014, with an 8-core processor and sporting LTE Advanced. LTE Advanced promises network speeds of up to 1 Gbps and has been deployed in several U.S. cities; Chicago’s deployment yielded 112 Mbps in early 2014.

Wearable technology: In addition to determining the user’s location, wearables can collect rich data (e.g., heart rate or gait) directly from its sensors, and can be used to infer user emotions (e.g., Empatica).\(^12\) Head-mounted displays used with augmented reality applications like Daqri’s Smart Helmet will provide more impactful modes of context-aware interactions because relevant information is immediately available to the user.\(^13\)

Adoption of the IoT: The IoT will provide new avenues to infer and interact with context as high velocity data from diverse data sources is available and actionable. It is estimated that there will be 26 billion connected devices by 2020.\(^14\) This adoption is being accelerated not only through the deployment of new IoT-enabled devices, but also with new technology to make devices smarter, such as Electric Imp, a WiFi enabled SD card that allows control of a specific connected device, or Freescale, a swallowable ARM-powered KL02 microcontroller unit.

Table 1 on the following page presents a sampling of CAAs currently available in the app market, along with the functions and features that make these applications context-aware.
Table 1: Selected Examples of CAAs

<table>
<thead>
<tr>
<th>Application</th>
<th>Description</th>
<th>Context-Aware Features &amp; Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahold (Stop &amp; Shop, Giant Food Stores)</td>
<td>Grocery app that helps users with their shopping needs, from providing store locations and hours to creating an e-shopping list to sending coupons</td>
<td>Uses past purchases and user profiles to recommend products in the shopping list, and promotes products with coupons while the user is in the store</td>
</tr>
<tr>
<td>Cover</td>
<td>Available only for Android, uses the information from the device sensors and other apps to reveal only the most relevant apps (inferred by location and time of day) on the home screen for easy access</td>
<td>Like Aviate, uses information from other apps, but location is determined by geofencing with WiFi and celltowers (not GPS) so the app knows whether the user is at home or work, and uses the device’s accelerometer and gyroscope to determine whether the user is walking or in a vehicle</td>
</tr>
<tr>
<td>EasilyDo</td>
<td>Another personal contextual assistant that organizes work and personal life from to-do lists, contacts from work and social networks, and notifies user to prepare for upcoming events</td>
<td>Uses data from the user’s phone apps, e.g., calendar, social media, weather, travel, Salesforce, etc.</td>
</tr>
<tr>
<td>Expedia</td>
<td>A hospitality app that sends reminders and alerts for upcoming trips that lets the user know when to leave from home to arrive on time at the airport</td>
<td>Uses travel and hotel arrangements to schedule alerts. Provides travel recommendations that matches the user’s preferences based on past and current arrangements</td>
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<tr>
<td>Google Now</td>
<td>A collection of about 40 “cards” within the Google Search app that provide information, e.g., appointments, birthdays, transit times, weather, etc., relevant to the user</td>
<td>Requires a Google account, and the user’s repeated interactions with Google apps like calendar appointments, places, locations and search to determine relevant information</td>
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<tr>
<td>Siri</td>
<td>A voice-activated personal assistant app that retrieves context information from other apps to streamline operation of other features or apps on the device</td>
<td>Can be asked to call (phone app) a contact (in the user directory), or use the context of a phone call (such as the person called) to send a text message to the same person, without the user having to explicitly specify the recipient of the text message</td>
</tr>
<tr>
<td>Songza</td>
<td>A streaming music app that recommends playlists appropriate for the user’s situation (at the office) or activity (working out, sleeping)</td>
<td>Concierge feature uses information about music titles and genres and user’s previous selections to infer user interest and organize selections by activity, thus matching situational context with an expertly curated set of playlists</td>
</tr>
<tr>
<td>Tempo</td>
<td>A calendar app that helps the user navigate meetings and appointments not only with reminders about the time and location, but also information about people in the meeting</td>
<td>Using information from calendar, location services, and social networks, the app anticipates the time, location, and information about the people the user is about to meet to have a successful social interaction</td>
</tr>
<tr>
<td>Walmart</td>
<td>In store mode, the app recommends products based on the user’s past purchases</td>
<td>Uses augmented reality to promote products</td>
</tr>
<tr>
<td>Xenagos</td>
<td>Designed for museums, expos and visitor-oriented situations, the app combines information about the location and the user to recommend things to do while visiting</td>
<td>Uses geo-location and user demographics to provide contextual information or recommend activities while onsite in the exhibition hall or museum</td>
</tr>
<tr>
<td>Yahoo Aviate</td>
<td>Available only for Android, automatically organizes apps on the device’s home screen, showing content and information when and where the user needs it</td>
<td>Integrates with other apps on the device for context and with Yahoo! search capabilities to retrieve information</td>
</tr>
</tbody>
</table>
Considerations for Designing CAAs and UX for CAAs

Compared to the usual process of building an app, how does one build an app with context awareness?

At Mobiquity, we believe that mobile applications need to be designed through a multi-disciplinary lense, including business strategy, user experience and technology considerations. Context awareness, however, presents an opportunity to build disruptive mobile solutions by leveraging and combining new data sources. Organizations need to include contextual information as a key component in the application design to build new mobile solutions or enhance existing ones.

We recommend starting from a catalog of contextual variables to spur initial ideas, and adopting an iterative approach to identify and refine user stories that leverage context awareness, using the following practices:

- **Set initial target:** Determine the key goals to enhance with context awareness, from either an existing application or new business requirements.
- **Divergent thinking:** Review a catalog of available contextual variables such as the one in the next section, and brainstorm how these can enhance the target goals.
- **Convergent thinking:** Select relevant context variables and create related user stories to tackle target goals.
- **Iterate:** Expand the catalog of contextual variables if needed (e.g., inclusion of additional contextual information) and the derived use cases, and refine user stories.
- **Assess value:** The value of contextual variables depends on their application. Determine the added business and customer value to prioritize which contextual variables to include in the mobile solution.
- **Assess feasibility:** Determine the method and technology necessary for top contextual variable considering information accuracy, ability or cost of gathering that information, and the impact on user experience.

Because building an effective CAA necessitates the collection of personalized, location-based data, make clear the benefits of providing such information so that the user will grant access. UX designs must consider how to communicate the trade-off between the benefits to the user of providing personal information and concerns about the potential loss of privacy or data security. If this trust between app owner and user is not established at the outset, the user may disengage immediately. Thus, the goal of providing transparency about data usage is to build trust instead of raising fear.

Mobiquity’s research identified user segments with different attitudes regarding sharing personal information. Depending on the user segment, which can be inferred from other context data, the paper suggests the best approaches to engage the user.
Variables for CAAs

In order to build effective CAAs, it is important to deconstruct context awareness into its elements, i.e., the factors or variables that provide context-awareness. Based on context-aware computing research, we developed a taxonomy of context-aware variables (see Table 2). This table can guide app developers with selecting context data that will be useful and necessary for an application to achieve its goals. Depending on the app, some of this information may not be needed if it will add overhead to the packet of information to be delivered. When it comes to CAAs, timeliness of information is an important consideration.

Instead of a long list of variables, we have focused on seven categories that could include most, if not all, context variables: user, time, location, interactions, physical, historical, social and activity.

- **User** variables comprise information directly about the user of the app. These include the identity of the user; demographics such as age, gender and ethnicity; affect or mood of the user, past or current; and intent or goal based on surveys, cognitive ability or state of mind based on tests. More recent research has tried to infer personality traits based on mobile phone and app usage patterns.

- As in early definitions of context, **time** and **location** are important context variables. Time can be “chunked” into periods that are relevant to human activity, such as day parts, or weekends. Raw location data from GPS needs to be interpreted relative to the user, e.g., home, workplace, shopping or retail, dining or recreational area to be useful for an application.

- **Interactions** are those variables that describe the modes the user “interacts” with via the application, and can be the device (smartphone, tablet, desktop or TV), channel (mobile or web) or medium in the channel (video, podcast, text, etc.).

- **Physical** context provides information about the environment. This includes weather or indoor temperature, landscape and light (intensity from dark to bright, color), environmental noise, direction or even movement.

- **Historical** information includes any data collected about the user’s experiences, activities, app usage behaviors, products viewed and purchases, including loyalty data.

- **Social** context includes any connection with another person that has been provided by the user, and can be determined from historical data or “heard” by the microphone, etc.

- **Activity** is a huge category because it includes any user activity that can be interpreted from data captured by the myriad sensors in a smartphone or wearable. For example, the kinds of apps active on a user’s phone, e.g., streaming music, running tracker, etc., may indicate the user’s activity at the moment. It is possible to interpret user interests based on an app graph. The phone’s accelerometer and other cellular data can determine whether the user is running, walking or stationary, standing or sitting. Such activity can be further interpreted as working or exercising when combined with location.
Table 2: Context Awareness Variables

<table>
<thead>
<tr>
<th>Category</th>
<th>Context Variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>User</td>
<td>Identity, Demographics, Affect/Mood, Intent/Goal, Cognitive Ability, State of Mind</td>
</tr>
<tr>
<td>Time</td>
<td>Time of Day, Day Parts (Early Morning, Morning, Midday, Afternoon, Evening, Night) Day of Week, Weekend/Weekend, Holidays</td>
</tr>
<tr>
<td>Location</td>
<td>Home, Workplace, Commuting (in public transit, private vehicle), Stores, Restaurants, Recreational Areas</td>
</tr>
<tr>
<td>Interactions</td>
<td>Channel (mobile, web), Medium (text, video, audio), Device (smartphone, wearable, tablet, desktop/laptop, TV set, game console)</td>
</tr>
<tr>
<td>Physical</td>
<td>Temperature, Precipitation, Humidity, Light, Landscape, Noise</td>
</tr>
<tr>
<td>Historical</td>
<td>Experience, Loyalty, Purchases, Products Viewed, App Engagement, Favorite Locations</td>
</tr>
<tr>
<td>Social</td>
<td>Alone, Special Someone, Friends, Family &amp; Children, Colleagues</td>
</tr>
<tr>
<td>Activity</td>
<td>Any number of user activities such as: driving, working indoors or outdoors, shopping, dining, passive entertainment (watching TV, seeing a movie, listening to music), active recreation (playing sports, walking/running), etc.</td>
</tr>
</tbody>
</table>

Technical Considerations for Building a CAA

What are the challenges in building CAAs? What are technical considerations?

As previously stated, CAAs are the next generation of intelligent apps. While these apps go beyond personalized, location-based messaging, it is not a bad idea to begin building context data by linking user profiles and demographics with past activities, app behaviors and purchases as a starting point. In our list of context variables, user identity heads up the category of user context variables because the app needs to accurately identify the user in order to collect from and send the contextual information. Thus a lot of effort should be poured into correctly identifying the user. In the case of privacy-sensitive applications such as HIPAA compliant medical apps, the user can be de-identified while keeping a record or token that allows the app to still learn personal preferences and provide contextual interactions.

A smartphone’s sensors can be used to receive additional context data. For example, the GPS to determine location, the microphone to pick-up ambient noise, the camera to capture images and QR codes, and the accelerometer to detect motion patterns. The more context data an app can collect, i.e., big data, the more information can be provided to the user. However, there is a price to the volume, variety and velocity---the 3Vs of big data. In order to be useful to the app and the user, the data has to be processed and analyzed quickly. Otherwise, the information becomes stale and irrelevant if it cannot be sent soon enough to the user.

Another potential big challenge is the accuracy of context inference. In the process of deriving context from raw data, what if the derived context is so far from expected values, that the app behaves unexpectedly? What can be done to mitigate such an event, and achieve a reasonable user experience under such risk?
A big data architecture is required for the app to process, analyze and return information quickly. Because a mobile phone or wearable can interact with beacons, an architecture or data fabric more suited for the IoT would be ideal.

That discussion, however, we will revisit at a later context.

Summary & Conclusions
This white paper has only scratched the surface of building CAAs. However, we believe that starting with defining context, identifying market trends, listing a few good examples and creating a framework for context variables will provide a solid foundation for designing CAAs that provide superior user experiences.

We have adopted Aboud & Dey’s definition of context as “any information that can be used to characterize the situation of an entity...relevant to the interaction between a user and an application, including the user and applications themselves” because it encompasses all of the available information that can be gathered and delivered with today’s smartphones and information technology, in general.

We define an application to be context-aware when it uses context to optimize the user’s mobile experience, increase app usage and engagement, and induce a change in behavior. These goals can be achieved simultaneously. Context is directly relevant to habits, i.e., automatically triggered user behaviors without conscious decision-making. If we build applications that can induce desired user behaviors because they provide useful features and relevant information under specific context frequently enough, we may help users form a habit that leads to much stronger engagement. For example, retail apps can push notifications about specials when the user enters the store, or even personalized coupons when the user is in close proximity to the item’s location within the store. These notifications can result in an increase in cross-selling or impulse purchases on-site while the user is in shopping “mode” and exhibiting less mental resistance to marketing of related products. If the user receives enough reminders, provided the mobile experience is rewarding, then it is reasonable to expect that behavior will be repeated enough to form a habit.

Today’s technological and market conditions have changed, such that context-awareness technology is ready for mass-market adoption. An adoption driven by the maturity of mobile, social, data, sensors and location-based solutions. Furthermore, the rise of supporting technologies and applications, such as mobile computing, IoT, the intersection of digital and physical experiences, and the maturity of key emerging technologies (e.g., predictive analytics, biometric authentication) will allow apps to gather even richer contextual information, and provide contextual experiences with transparency to the user.

We provided a few examples of CAAs out in the market today—noting why these apps made the short list—to illustrate context variables used for building CAAs. We organized context variables into seven categories. This scheme allows app builders to concentrate efforts on integrating data only from the necessary context variables.

In this paper we only touched on a few technical considerations. The information and data technology used for the IoT—such as the big data systems used to collect, integrate, manage, analyze and recommend data from
phone sensors and beacons—will go a long way toward building effective context-aware apps. We reserve this discussion for a follow-up paper.

The advantages of context awareness come also at a price, partially due to potential data leakage, identity theft and missing user expectations. Whether it is recorded information from past activities or the current location, specific data about the user is required for CAAs to be effective. Thus, there are many potential hazards associated with handling the information, such as:

- **Identity theft:** CAAs promise convenience with seamless call-to-action functionality. However, this brings higher risks if user identity is supplanted.
- **User data access:** Relaxed privacy policies for data mash-up are necessary (e.g., Google Now cross-service data access to email, calendar, G+, sites, etc.), which can result in privacy breaches and subsequent consumer backlash, as happened with Uber’s “Creepy Stalker View.”

Even when the data is handled securely, a CAA may pose some risk to the user or the app’s owner:

- Machine logic might drive wrong recommendations or send too many false positives, so that messages are ignored even when relevant.
- A poor user experience design that sends too many messages may lead the user to ignore the app or delete it entirely.

To conclude, just as automation has become standard in computing, context is becoming an essential user expectation of mobile, and the opportunity window to innovate and differentiate ways of leveraging context is quickly narrowing. Contextual features are more automated and transparent to the end user, which is speeding up the commoditization of contextual information. Organizations need to act fast to build competitive advantage and reap the most benefits from a highly competitive and fast moving market.
Endnotes


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