Context in Mobile Computing:

Improving Human Computer Interaction through Context

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# What is Context?

Imagine walking into a crowded room with everyone staring at you. How do you react? If everyone is formally dressed and applauding your entrance, you would probably react better than if you see twelve people frowning at you from a juror’s box. The context of the situation gives you the clues you need to properly assess it. Whether consciously or unconsciously, we use context every day to gauge our reactions to our environment.

Context is also an important consideration in the design of computer applications. In the dawn of computing, computers and their users only had one context: scientific computing. Business computing brought computers out of the lab and into the office, and programmers had to consider the users’ context. Microcomputers brought computing to the home, and with the invention of the laptop, computers became mobile. Smartphones and tablets have made computers omnipresent and ubiquitous, and context in design has become more important than ever.

# Context in Computing

In 1998, researchers at the University of Kent defined context awareness as “a term that describes the ability of the computer to sense and act upon information about its environment, such as location, time, temperature or user identity. This information can be used not only to tag information as it is collected in the field, but also to enable selective responses such as triggering alarms or retrieving information relevant to the task at hand [1].”

The GUIDE project at Lancaster University further refined the definition by identifying two class of context: personal and environmental [1]. Personal context is user defined, such as preferences and profiles, and environmental context includes time, location, activity, and even the current weather.

McMaster University defines four areas of context in computing: User context, Time context, Physical context, and Computing context. The user context includes information about the end-user such as user-defined profile information, location, nearby people and objects, and social situations. The time context can include the absolute time, date, or even weekday versus weekend and season. The physical context is everything measurable in the user’s environment: temperature, ambient noise, lighting, elevation, motion, and current weather and traffic conditions. Finally, the computing context is the computation resources available: such as Wi-Fi, bandwidth, and nearby computational devices [3].

Context is used to refine user experience. Ambient light levels can be measured to adjust screen brightness automatically. Automatic connection to trusted Wi-Fi networks saves the user time and hassle. Given enough information, context can be used to anticipate a user’s reactions, perfecting the human computer interface. Mobile computers, with their surfeit of sensors, bring us closer to that.

# Context in Mobile Computing

Chances are, you are carrying a computer right now. 77% of Americans own smartphones, according to the Pew Research Center [7]. With the advent of these handheld computers, context design possibilities have grown exponentially. Even applications written for mobile computers provide context: if you’ve ever visited a website on a smartphone or a tablet, your browser’s user agent string identifies the browser, version, and OS that are being used [2]. The website can use this context to redirect you to a mobile optimized version.

## Sensors and Context

However, the true potential of context driven design can be found in the abundance of sensors found in smartphones: proximity sensors, accelerometers, digital compasses, barometers, biometric sensors, GPS chips, and gyroscopes [5]. These sensors measure the user’s environment and anticipate the user’s reactions. Proximity sensors disable the display and touch input when a phone is held to the ear, such as when in a call, to save battery life and prevent accidental activation of applications. The accelerometer and gyroscope recognize the orientation of the phone or tablet, optimizing the display for the user automatically. The barometer and GPS refine a user’s location, enabling turn by turn directions, and biometric sensors can increase security through fingerprint locks, and monitor health through heartrate sensors.

## Sensor Fusion

Sensors can combine to improve accuracy in a method called sensor fusion. A gyroscope measures the rate of angular velocity change over time but exhibits a growing angular error that also increases with time [5]. This accumulating error could cause your phone to constantly change orientation, even when resting on a flat surface. However, by combining the gyroscopic data with accelerometer readings, that error is discounted [9]. Sensor fusion can also be seen in location accuracy. The United States Department of Defense states GPS-enabled smartphones are accurate to with 4.9 meters, under open sky. This accuracy can be degraded by buildings and natural features blocking or reflecting satellite signals and is unreliable indoors and underground [4]. Smartphones combine GPS data with network location data and improve location accuracy by up to 70% [10].

Sensor fusion is most famously seen in the improvement in pedometer technology. Original pedometers used a pendulum and had to be worn at the hip. Variations in stride, angle of walk, or errors counting steps created false readings. Improvements in Micro-Electro-Mechanical Systems, or MEMS, meant accelerometers could measure 3 axis of acceleration and be small enough to fit in a smartphone or smartwatch. Steps were no longer measured mechanical with every swing of a step; instead movement was measured multiple times per second. This fusion of accelerometer, gyroscope, and magnetometer also meant pedometers could be worn on the arm or wrist without introducing fatal errors [6].

Sensor data is combined in several different ways in sensor fusion. They are common divided into three major categories:

**Complementary:**The individual sensors do not depend on each other directly, but their data can be combined for more complete information. An example might be using multiple video streams from security cameras to give complete coverage of a home or workplace.

**Competitive**: Each sensor in a network delivers an independent measurement of the same property. A fault tolerant flight control system might incorporate three distinct feedback loops and make decisions based on a majority vote, allowing it to operate correctly if a single path fails.

**Cooperative:** The combined network uses information from multiple independent sensors to develop information that would not be available from any single sensor. Stereoscopic vision, for example, uses two-dimensional data from two cameras to form a three-dimensional image of the scene being observed [9].

# Beyond Sensor Fusion

However, combining sensors to improve individual accuracy isn’t the limit for context. All of these sensors can combine to map the entirety of the user’s environment. More sensors mean more environmental information. More information about the user’s environment means applications can create a more accurate simulation of real-world conditions. The goal is to create such an accurate simulation of the real world that every user reaction is anticipated [1]. This would be context in perfection.

A calendar application can combine absolute time with local traffic data to create responsive alarms, alerting the user of potential delays. Fitness trackers can monitor sleep habits and recommend bed times. Smart thermostats can track which rooms of a house are in use and only heat or cool occupied areas. An application can track your restaurant purchase habits and pop-up recommendations when you are walking in a new area of town….

# Context and Privacy

With the amount of data being collected on every user, everywhere, it is no longer a question of if an application can use your historical data as context for future actions. The question now is should it?

The goal of emotive human computer interaction is to use context to create truly adaptive computing; computing that preemptively adapts to the user [1]. With enough sensors and computing power, the user’s environment can be emulated perfectly, but this simulation would be missing a very important part necessary for context: experience.

Experience is the difference between a safe shortcut and a dangerous alley. Experience is individual and hard to quantify. Compiling historical information can help add a rough approximation of experience to context but this information comes with a loss of privacy. The Pew Research Center found, in the 2014 survey *Public Perceptions of Privacy and Security in the Post-Snowden Era*, that an overwhelming 91% of American fell that consumers have lost control of their data. 81% had taken active steps to limit or remove their digital foot-prints [8]. Designers of context computing need to balance the use of user data with user control.

# Conclusion

Context computing can add immeasurably to user experience. Advancements in miniaturization of sensors and increases in computing power have given designers a whole new suite of tools to add to contextual options for users. However, the privacy desires of users must be balanced against context possibilities in design.

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