Navigation Aids for the Elder Population
‘Never Lost’

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Introduction

Goal of the Project / Research Paper

The goal of the Never Lost application is to help senior citizens defined as 65 or older (Mineta, 2006) to effectively and easily navigate unknown indoor spaces such as finding a doctor's office, exhibit in a museum or a gender-specific bathroom. The Never Lost application will also be able to track people in an indoor space.

The Typical User and Key Issues

The typical person in the senior citizen age group has a higher likelihood of being confused in an indoor environment and the goal of this project is to help them navigate in these areas. This group can have difficulty seeing in low light conditions as the pupil shrinks and is less sensitive to light. This age group also has difficulty differentiating between colors. The sense of touch and hearing can also be diminished, requiring more effort to accomplish everyday tasks like typing, reading and / or writing. (Berhard, 1996)

Figure 1: Barbara Kaim in New York City.

This group's fine motor skills may also be reduced, leading to longer response time to the external environment, for example this group will do fine navigating through familiar building spaces. However, navigating through new buildings will be challenging for this group, and may result in increased chance of getting lost or accidental fall. This project is centered on a hypothetical subject, Barbara Kaim, who is 86 years old. She lives alone in a 1000 square foot apartment in Port Washington, New York. Barbara is an independent, active and intellectually sharp woman for her age, but has begun to show signs of diminished vision as is evident in Figure 1, where she is wearing prescription glasses and has trouble reading the New York Times.

Her sensory memory is excellent for her age, but she has not driven a car since she hit a parked car in a minor accident a few years ago. The accident was caused by her inability to depress the brake pedal fast enough, a result of her diminished fine motor skills. She now uses the city sponsored Call-A-Ride program to get to her doctor's appointments and daily chores like grocery shopping and visiting art galleries.

Her long-term memory is also showing signs of decline. This is evident when she sometimes gets lost, for example going from the shuttle drop off point to a new store, doctor's office or the art gallery. She visits 2-3 specialist doctors within the hospital and has difficulty keeping track of their locations.

Barbara is also facing short-term memory loss. She has started to carry around a small pad of paper to be able to write information down like her grocery list as well as phone numbers. Technologically, Barbara is ahead of her peers, using email, Internet games and applications like Facebook daily. She has no phobia of computers, but does struggle to learn new computer applications. She represents a majority of users of the elderly population in terms of *diminished cognition* due to age as she has *diminished fine motor skills*, *diminished eyesight*, *diminished short and long-term memory*. (Mather, 2010) The Never Lost application does require some minimal visual, haptic and audio sensory abilities. However, the authors feel that the device can be used by younger people to navigate indoor spaces and by other persons if they choose to.

Solution to the Key Issues

The device that will implement the Never Lost application will have hardware and software capabilities that will help the target user, Barbara, to navigate in unfamiliar indoor spaces.

The device needs to be able to determine the location of the device and also the layout of the building in real-time. Some techniques for location sensing are triangulation (distance measurement from static points), scene analysis (taking real-time pictures and comparing those to historical pictures to ascertain location) [citation?] and proximity sensors (monitoring cellular access points - 911 caller location identification). (Hightower, 2001) There are many technologies that can be used in indoor navigation, these technologies may use one or more location sensing techniques mentioned earlier. The major location determination systems are: Infrastructure Radio Frequency (RF) based systems, Ad-hoc / sensor RF systems, Wireless Propagation systems, Global Positioning System (GPS) and Cellular based systems (Global Systems for Mobile Communications or Code Division Multiple Access). (Moustafa, 2005)

Technologies

The following technologies were considered for the Never Lost application. These technologies will help the user navigate an indoor space faster and more intuitively than conventional means which usually means using the office directory with names and room numbers.

Wireless Local Area Network (WLAN) Triangulation

A Wireless Local Area Network (WLAN) is a wireless computer network, not only does it let devices connect to a network, but it can also be used for triangulation of devices in the networks range. WLAN triangulation is based on access points within a building and their Received Signal Strength (RSS).

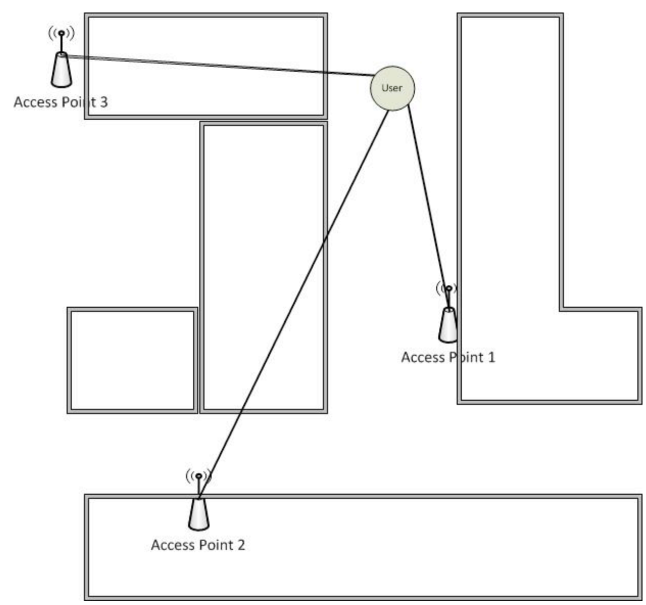

Figure 2: WLAN Triangulation for Indoor Navigation

The RSS measured in dBm at the device can be used to determine the distance of the device from the AP. WLAN signals can be broadcast to cover an area ranging in size from a small office to a large university campus with the use of multiple APs. Most commonly, a WLAN access point provides access within a radius of 65 to 300 feet. (Indiana University, 2012) With signal strength the device can triangulate a position in a building because each location in the building will have a different signature. The more access points available, the more accurate the location reading can be, usually up to 2 meters. However, the strength of the signal that the device can detect can vary from manufacturer to manufacturer. This can be an issue, however, Microsoft Labs has come up with an algorithm that can take into account for how the received signal strength might be different because of the device. This is achieved in their algorithm by parameter G that takes this into account. (Chintalapudi et al., 2010)

The concept used in the implementation of this project is a “client-based” (Moustafa, 2005) location determination system which uses “probabilistic techniques” (Moustafa, 2005) to find the average signal strength of the top five AP’s within the range of the device at specific locations. The average signal strength information was entered in the Never Lost application database (offline mode), which the device can query to find a location match (location determination mode). It was found that the signal strength varies in strength over time due to a number of factors such as how much pedestrian traffic there is or objects in the way, so signal strengths were collected at different times of the day to get an average strength value. Once a location is determined then the device can load appropriate visual, audio and haptic directions to the user. This will be covered in the interface design section later in this paper.

Some other approaches that other researchers have used for WLAN location determination are EZ Location by (Chintalapudi et. al. 2010), dedicated access points, and Horus WLAN location determination.

The EZ location determination uses the existing WLAN access points in a building and builds a layout of the building using the Received Signal Strength (RSS) at the mobile device. In this way the cost of setting up the infrastructure is significantly reduced. The advantage of this system is that it is faster to deploy and computationally less intensive as compared to the Horus location determination system, but the accuracy is lower.[As you are forward-referencing to Horus, it is hard to know how Horus compares to this system.] The map of the building can also be updated by user volunteers that walk through the space and share their data. (Chintalapudi et. al., 2010). This feature is similar to many modern GPS navigation devices from TomTom and Garmin, where users send their modifications and usage data anonymously to the company to improve the existing maps and routing algorithm.

The dedicated access point location determination system uses dedicated AP's, whose sole purpose is user triangulation and indoor navigation. The technology for navigation is similar to Horus, but the accuracy is significantly higher as the AP's signal fluctuation is known and the location of the AP's is also known. An example of this kind of commercial application is Navizon indoor triangulation system (www.navizon.com). The disadvantage of this system is longer deployment times and is more expensive to setup with the use of dedicated AP's, which have to be configured and deployed in an indoor building space. The Horus location determination system works in a similar way to Never Lost.

Global Positioning System (GPS)

Global positioning system (GPS) uses a number of satellites to triangulate the devices location based on the length of time the signal takes to go from the satellite to the receiver. Even though GPS is widely used and can be used in a lot of different applications, one issue with GPS is that the receiver needs to have a clear line of sight to the satellite. This is one issue with using GPS in an indoor environment because one would not be able to get line of sight to the satellite. The WLAN system has greater accuracy and precision in indoor localization than GPS, because GPS signal may not be available inside an enclosed building. (Djuknic, 2001) GPS can still be useful and can be used to transition from the outdoor space to the indoor space and mark the initial reference point for indoor navigation system. The Never Lost application will prompt the user to load the indoor floor plan before the user walks into the building. In some instances the device may get a GPS lock even when the device is in the building for example, near a window or entrance to the building. This can be used to get an "absolute location fix" to create an accurate and precise location of the device. (Chintalapudi et. al., 2010)

Agent Knowledge (Humans in the Environment)

The idea behind this navigation aid is to allow agents in the environment to add extra information. This option is available so that the user can allocate their short term memory for more important tasks like navigating the indoor space. Short-term memory can be thought of as a 'scratch pad.' Remembering telephone numbers would be a good example of short term memory recall. Long term memory is where humans store factual information. This is the brain's main resource for remembering information. It is often said that human's long-term memory can be thought of as a computer hard drive. (Dix, 2003)

When one is lost in an indoor space often time's people will stop and ask others in the environment for directions. This important information source is crucial for overcoming deficiencies in the technology. The idea behind this is to be able to voice record the conversation using the "public record" function built into the device. This will enable the user to be able to listen to the directions that an agent has just said. This is to solve the problem of the agent saying "go out of my office and turn left. Walk to the end of the hallway and turn right. Walk to the end of the hallway and turn right again. The men's bathroom is the second door on the right." Clearly the elderly user will struggle to remember these directions when they are navigating as even twenty year olds would struggle to remember these directions.

One thing that would make the agent knowledge more beneficial would be to add audio to text so that the agent directions could be uploaded onto the Never Lost application and help the elderly navigate in real time. While there are design limitations with this approach, there are also potential benefits. Apple's Siri has developed a smart agent that is audio enabled.

Another suggestion for a potential improvement to the Never Lost application would be to incorporate user knowledge into the device so that the technical limitations of the device could be mitigated. If the user knows where they are and can add this information that could be used to help bring the accuracy of the indoor navigation system to a higher precision. It is possible that the user knows where they are, but not where they want to go. If the user was able to add information and tell the device where they were actually located this might help the overall system to be more accurate and have higher precision. This can be implemented in conjunction with the agent knowledge system where the user acts as the agent, since they know with a high level of accuracy where they are. The Never Lost application can leverage the user's knowledge as well as the external agent's knowledge of their environment to find an accurate and precise location fix for indoor navigation.

Global System for Mobile Communications (GSM) or Code Device Multiple Access (CDMA)

The concept of this type of navigation uses the proximity to known cell tower points. The user's location can be triangulated within the range of the cell phone towers. The drawback of this type of navigation is that the accuracy is not as high as if there is also wireless local area network (WLAN) within a building. (Varshavsky et al., 2006) The accuracy of GSM ranges from 2.48 to 5.44 meters in large multi-floor buildings. This can be good for determining a user's approximate location, but may not be helpful for precise indoor navigation.

Interface Design

The main goal of the interface was to demonstrate that a senior citizen could navigate an indoor environment using wireless local area network (WLAN). Because senior citizens are more likely to have diminished cognitive and visual ability, an important requirement of the interface was to incorporate as many modalities as possible to help the user navigate. Another requirement of the interface was to employ good HCI principles, striving for consistent input and output methods as well as brief yet informative output from the device that allows the user to navigate with minimal cognitive load.

The interface design process began with an analysis of the target demographic, followed by the development of storyboards, which were then more formally expressed as use cases. From the use cases, work-flow diagrams were developed which included application states. The final interface design was driven both by the use cases, specifically, by tasks a target user should be able to accomplish, and by the application states, to include the error states, that were possible as a user interacted with the Never Lost application. The three case scenarios chosen were based on typical behavior within an indoor space: 1) finding a static location such as a doctor's office, 2) finding the closest bathroom using the most efficient path, and 3) finding dynamic objects, for example, people walking through the building.

Other personalized options were included in the design so that users could tailor their experience to their physical attributes, skill level, and preferences. A user profile was created for Barbara, storing her gender information as well as her preferences to enable or disable the three modalities of output: visual, audio and haptic. The interface would then display the appropriate information according to the user's personalized options, for instance, Barbara's gender would only allow her to navigate to a female or unisex bathroom.

Visual

The interface was designed for a tablet because of the larger screen size as compared to a smart phone. Although the Never Lost application could be loaded on a smart phone, the tablet's larger screen can more easily accommodate larger buttons and visual aids to help mitigate possible motor and visual deficiencies of the Never Lost application's target demographic. Planning for the larger screen allowed for larger button sizes, with the size of the buttons customizable under each user's settings.

Colors will be customizable using a profile setting that will be stored so that the user does not need to change the color every time that the user turns on the device. The default will be a black background with white text because this is easier to see for the aging user. (Shneiderman & Plaisant, 2010)

The font will be customizable as well, with the default set to the sans serif font Arial for readability. (Kurniawan et al., 2005) The default font size will be set at 24pt for header text and in changes in application states where it is important to gain the user's attention (Shneiderman & Plaisant, 2010), while 16pt is used for normal text. There will be options for no more than four distinct sizes of fonts because of good human-computer interaction principles.

Never Lost will also have a visual navigator indicator to help guide the user to a location. This visual navigator aid will give more information to the user in case they need to add information to the device or they want to determine their location. The destination is highlighted with a square or triangle and the route is also highlighted to the destination. For example, if the destination is denoted by an inverted triangle, then the destination is lower in elevation to where the user is located. If the triangle is regular shaped (not inverted), then the destination is higher in elevation than the person. If the elevation of the destination and the person is the same, then the destination is denoted by a square marker as shown in figure 4.

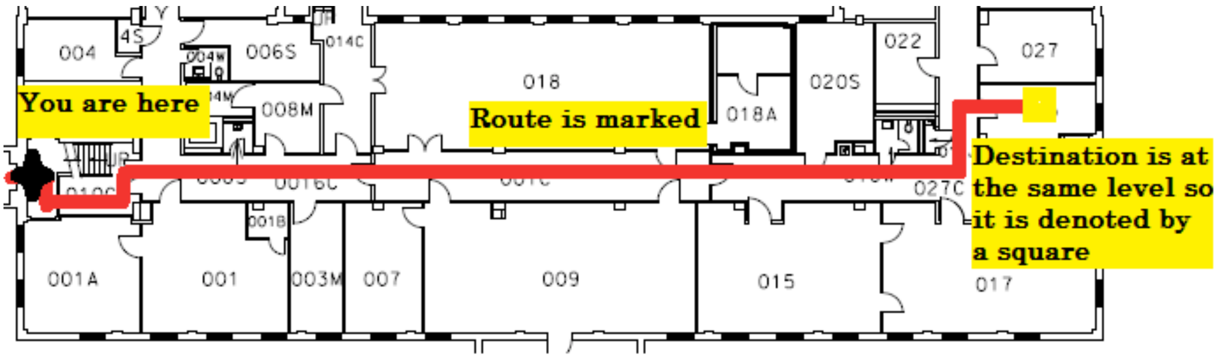

Figure 4: Compass Interface Design: This will be based on the shape of destination marker (Square, Triangle Inverted Triangle)

The last visual aid in the Never Lost application is a text output for turn by turn directions. This will help with the short term memory of the user, as the user has the option of reading the directions if they miss the audio cue.

Audio

Audio is another modality that is incorporated in this application. This modality can be turned off if the user does not want to hear audio cues, for instance if the user is in a public museum and may need to rely only on the visual and haptic modalities. Looking at multimodality there is no question how important auditory cues can be. This is one reason audio cues are used. Audio will both be used as an input channel as well as an output channel, with different voice profiles available so the user can choose between different voices. Some people find listening to a male voice more intuitive, while others find listening to a female voice easier. The default voice is a female, but the user can customize the voice that they like the most under user settings.

Never Lost will also have 3D audio cues to the destination based on the current location. If the application wants the user to turn left, then sound would come from the left speaker. If the application wants the user to turn right, then sound would come from the right speaker. The device will also have to know its own orientation to give correct directions to the user. The device's orientation would need to be known in order to give correct directions. Tablets already keep track of this through the embedded gyroscope/s. This functionally is important for facilitating hands and eyes free navigation. Audio warning signals will be used if the user missed or passed the end location.

Speech recognition as an input channel will also be implemented in Never Lost. The speech recognition software is a smart agent so that the software learns the nuances of the user's voice and thus can achieve better accuracy the more the function is used. Another possible audio cue for navigation can be a beeping sound that increases in frequency and intensity as the user approaches the destination within a building. Different directions have different sound patterns. When the application wants the user to turn left that sound is different than if the application wants the user to turn right. Also when the user reaches the destination the device should announce the same to achieve closure of the navigation process which is a good HCI principle.

One of the important usability features of the application is constant feedback, especially when the application is in a waiting state. The navigation device can give feedback on the application states such as downloading maps, waiting on user input, enter the destination, main menu and so on. This will be in addition to the visual and haptic cues used in the device. It is important to notify the user of critical audio feedback. The device can also give some critical audio alarms like low battery, no connectivity, and system error so that the application can alert the user of a non-functional device. This is helpful to alert the user of whether the application is not functioning correctly.

Haptic

In today's market, haptics are the most underutilized of the three modalities employed by Never Lost. One of the novel features of this application is the use of vibration to give feedback for direction of movement. The device and interface will give feedback to the user on the direction they need to go. If the direction that the user needs to go is forward the device will vibrate from back to front and similarly for going right the vibrations will go from left to right. This is already been developed and there is a working android app called PocketNavigator that uses vibro-tactile feedback to help the user navigate. This works by changing the intensity and frequency of the vibration to let the user know which way to walk. (Pielot et al., 2012)

The planned target tablet for Never Lost can be controlled using touch. This will be useful so that the user can type in destinations or choose among different destinations. The touch pad will also act as an input device for the user. This will let the user type the destination or change user settings with a touchscreen keyboard. There will also be a suggestion button in the settings menu so that users can make suggestions quickly and easily to improve the application even more. Feedback from a wide variety of users with different abilities and preferences will help create a large universe of potential application improvements. This suggestion button will be linked to a feedback form that the developers can read.

Interface Implementation

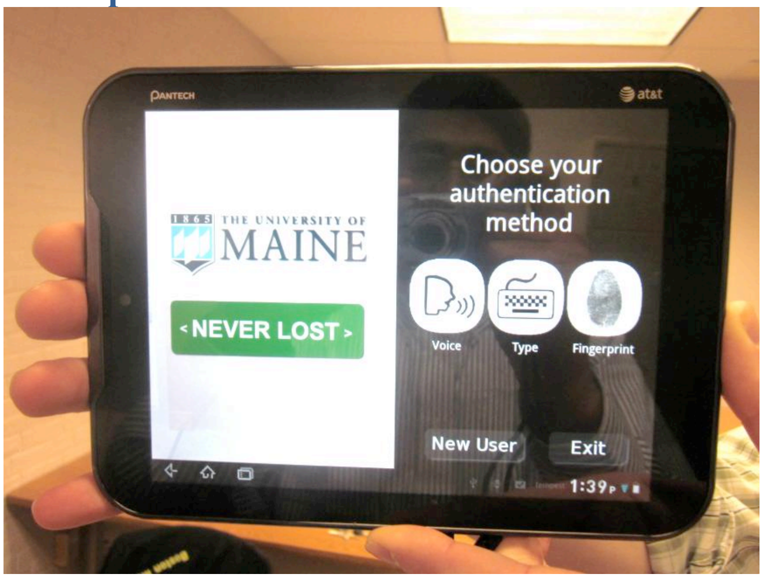

Figure 3: Never Lost application loaded on a Pantech Element tablet

For the proof of concept, an application was developed for the Pantech Element tablet, a device running the Android 3.2 (Honeycomb) operating system. A device on the Android platform was chosen because the authors had experience with Android programming and the Element was specifically chosen because of its 3-D haptic capabilities. One of the novel portions of the application was the implementation of haptic feedback using Immersion's TouchSense 5000, which includes 16 different actuators for haptic feedback on the Element.

Development preparation included a few steps: first, ensuring that the workstation was enabled for Java development using an Android-compatible IDE (Eclipse Java EE / Indigo RS1 was used), then installing the Android SDK to leverage the Android emulators to debug the application. Because the target device used Android 3.2, the Android SDK API 13 was installed instead of the most recent API 15, which is not backwards compatible with Honeycomb. Extra steps taken were to install the Immersion Haptic SDK for development with haptics and the Pantech Element drivers to enable debugging on the physical device instead of the emulator.

After successfully testing connectivity to the device, the first code was written. The application design took a few iterations, but the final design separated out control for the audio, video and haptics into different objects. Only three standard visual layouts were used in the application for consistency, each using the same 50/50 horizontal screen split in landscape mode as well as informational only visual output on the top of the screen and input buttons always at the bottom of each layout. Each layout was only subtly different from the other two: the pre-authorization layout included a button for creating a new user profile, the post-authorization layout included buttons for viewing and changing the profile, and the navigation layout included a 2-D overview map on the left and a 3-D representation of the user's approximate location on the right. After the three layouts were created and the images uploaded to the application, the implementation to get started included only a few lines of code. See Appendix 1 for code on class objects.

In further support of consistency across the application, global settings were created so that the user could expect the same audio, visual, and haptic experience each time they encountered a similar situation. For instance, for each error state, the same haptic output played, which could help develop a catalog of haptic memory for the user so that they could more quickly feel in the future when an error condition arose, just by feeling the vibration of the device. These settings could have been implemented using a properties file, an XML file, or a database, but the Never Lost implementation used the 1GB of RAM available, storing in the settings in a static Java class utilized by this application at runtime. See Appendix 2 for code on global settings.

The implementation of the application mirrored the design of the application: flexibility was required to tailor the settings to the specific user, while consistency, multimodality, and ease of use were emphasized. While only a proof of concept, the initial application was well-received during a demonstration in class, as users with no previous knowledge of the application successfully navigated through Boardman Hall from an outside building entrance to the SIE library.

Experiment Design and Goals

The goal of this experiment is to learn how the elderly might use this application and how much faster a subject participant using the application could find a static location then using conventional methods (using the office directory by the front door). Most office buildings have a directory that has names of people and their office number. This experiment will compare using the application to using the mental map that a user remembers and see which approach is faster at finding an indoor location that they have never visited before. The null hypothesis is that there is not a difference between the name directory and the application. The alternative hypothesis is that there is a time difference between the two ways methods of navigating. The experiment would use a pseudo-random sample technique, excluding subjects under 65 years of age. Equal numbers of males and females would be important, as well as are different cognitive abilities so that the sample population proportions match the larger population.

Data that would be helpful to collect would be name, gender, age, address, and which guidance method they used. Variables analyzed and collected would be the time each individual took to find the destination and whether the individual took a wrong turn or got turned around. The time to destination and the accuracy of navigation are dependent variables. The independent variable is the method the person is using to navigate like the device and the physical directory. Each test subject will try both navigation methods. Interviewing subjects afterwards would be helpful to learn more information about what they thought about the route and if they got confused at any point. With the entire attribute data there are a number of questions that could be answer. An unpaired one directional t-test could be used to see if one method was faster than the other. ANOVA can be used to do more in-depth statistical analysis and look at gender or age had an impact on how long it took the individual to get to the destination. At the conclusion of this experiment, it should be clear which method produced the fastest time. Often experiments lead to more question then they answer so other questions that would be interesting to look into would be why this method was faster than the other.

Future work

The initial work for any indoor space that would be able to implement Never Lost would be to map the space for its RSS signature. Future work on this topic could be novel ways to quickly gather the signature of any building for quick integration with the Never Lost system. More testing should be accomplished to make sure that the application can work with the target audience, the elderly. This testing is likely to provide the authors with large number of new suggestions for future improvements and features. The authors will do this by having focus groups and also track user information if the user allows us to do so. The team also needs to work on agent knowledge and make it so that audio to text is possible. This way the agent directions could be uploaded onto the application and help the elderly navigate in real time. The technology and implementation plan for moving object locator also needs to be finalized by the authors.

Appendix

Appendix 1: Responsibilities

Luke contributed to researching the ideas for the interface design, experimental setup, coding of the demo application, and technologies in the final application. Luke contributed to brainstorming and writing a significant portion of the interface design and also reviewing the final report and presentation.

Navneet contributed to researching the ideas for the technologies and interface designs to be used in the device. Navneet contributed to brainstorming and writing a significant portion of the technology, coding of the demo application, and also reviewing final report and presentation.

Ben Maynard led and reviewed the team's coding and application development work for the demo of the application. Ben also contributed to researching, brainstorming, writing and reviewing the final report and presentation.

Appendix 2: Code for Class Objects

```
package edu.umaine;

import android.app.Activity;
import android.content.Intent;
import android.os.Bundle;
import android.view.View;
import android.view.Window;
import com.immersion.uhl.Launcher;

public class NeverLostActivity extends Activity {

    //The Immersion Haptics class
    private Launcher launcher;

    //Homegrown helper classes
    private VoiceHelper vh;
    private TouchHelper th;
    public static NavigationHelper nh;

    /** Called when the activity is first created. */
    @Override
    public void onCreate(Bundle savedInstanceState) {

        launcher = new Launcher(this);
        vh = new VoiceHelper(this, launcher);
        th = new TouchHelper(this, launcher);
        nh = new NavigationHelper(this, launcher);

       super.onCreate(savedInstanceState);
       requestWindowFeature(Window.FEATURE_NO_TITLE);
       getWindow().setBackgroundDrawableResource(R.drawable.backgroundsplit);
       setContentView(R.layout.a_preauth_start);
```

```
            VoiceHelper.playAudio(R.raw.audio_welcome);
        }

        //More code here for state behavior, closing connections and cleanup

    }
```

Appendix 3: Code on Global Application Settings

```
package edu.umaine;

import java.util.ArrayList;
import com.immersion.uhl.Launcher;

public class DataHelper {

        //global settings
        public static boolean SOUND_ON = true;
        public static boolean HAPTICS_ON = true;

        public static int VOICE_REQUEST_CODE = 1234;
        public static int VOICE_NAVIGATION_REQUEST_CODE = 1235;

        public static int SUCCESS_HAPTIC = Launcher.STRONG_CLICK_100;
        public static int ERROR_HAPTIC = Launcher.EXPLOSION2;

        public static int BUTTON_HAPTIC = Launcher.IMPACT_RUBBER_100;
        public static int BUTTON_AUDIO = 700;

        //new user settings
        public static int NEW_USER_HAPTIC = Launcher.BUMP_66;

        //navigation settings
        public static int SIGNAL_TOLERANCE = 8;
        public static int MATCH_TOLERANCE = 5;
        public static int NAVIGATION_FREQUENCY = 1000;

        //loop settings
        public static int LOOP_DELAY = 700;
        public static int LOOP_HAPTIC = Launcher.IMPACT_RUBBER_66;
        public static int LOOP_FINAL_HAPTIC = Launcher.WEAPON9;

}
```

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