Flexible Solutions for New Generations of Touch Screen Interfaces:

The Future of Home Appliance Control

Advisor: Dr. Mani Mina
Department of Electrical and Computer Engineering

Client: Dr. David Ringholz
Chair, Department of Industrial Design

Final Report
Senior Design Group:
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Iowa State University
Department of Electrical and Computer Engineering

Team Members:
**Tamara Bartlett, CprE
Andrew Hoyt, EE
Katarina Mitchell, CprE
James Rich, CprE**

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Project Plan

Acknowledgments

Throughout the development process, several people have been key to the success of this project. We would like to thank Dr. Mani Mina for his advice and guidance throughout this project. Additionally, our team would like to thank Dr. David Ringholz, the liaison to Freescale Semiconductor, who has not only helped us communicate with our client, but also offered us his design expertise. We would especially like to thank the Industrial Design teams that did the initial field and market research and concept art for this project. Lastly, we would like to thank Freescale Semiconductor and the Electrical and Computer Engineering department at Iowa State for their funding and for helping us achieve our goals.

Problem Statement

With the advent of smart devices, customers are expecting a richer experience out of the appliances they interact with daily. Freescale, in conjunction with Iowa State University's Industrial Design Department, has noticed a market opportunity to use touchscreen interfaces for interaction with home appliances. During the course of this market research, the need for an interactive touchscreen prototype was discovered.

Our goal as an engineering senior design group was to provide a prototype platform for use in research to measure reactions to a home appliance touchscreen interface. The approach that our group took was to interpret the compiled research and develop prototype appliance interfaces to be used on an Android tablet for continued testing and development. In order to fit the project's time constraints, the appliance interfaces that we chose to simulate are for a washing machine and Heating Ventilation Air Conditioning (HVAC/thermostat) Controller.

Preliminary Research and Design

An industrial design class performed market and consumer research for a new line of appliances that would feature touch screen interfaces. They determined the current opportunities within the market and obtained user preferences regarding appliance features and component placement. Their consumer research consisted of conducting surveys about desired appliance features, menu setup, the placement of the touchscreen on the appliance, and the size and shape of the touchscreen. From their research they constructed menu designs and layouts, flowcharts, and wire charts for the home appliance applications. Their final designs were then passed on to us, the engineering team, so that a prototype could be created for usability testing.
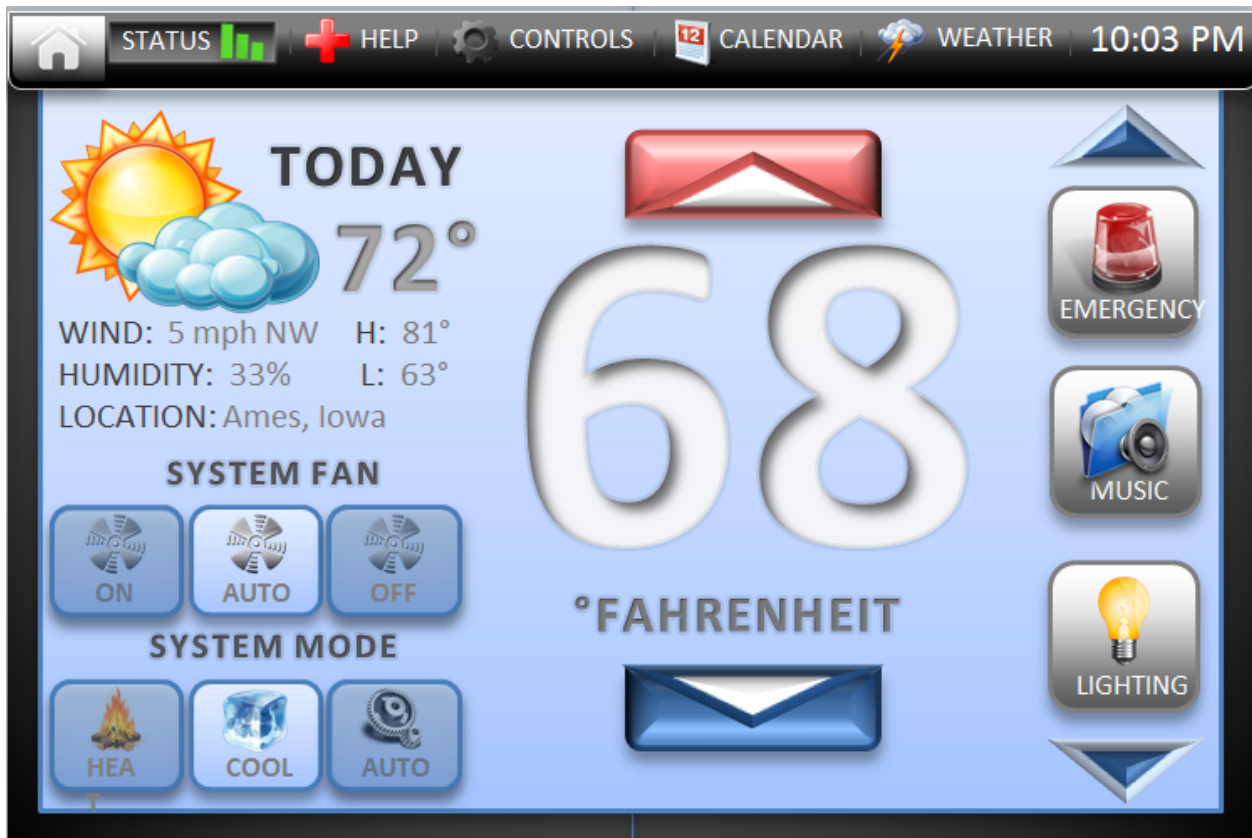
Mockup of the HVAC Main Screen, created by Industrial Design
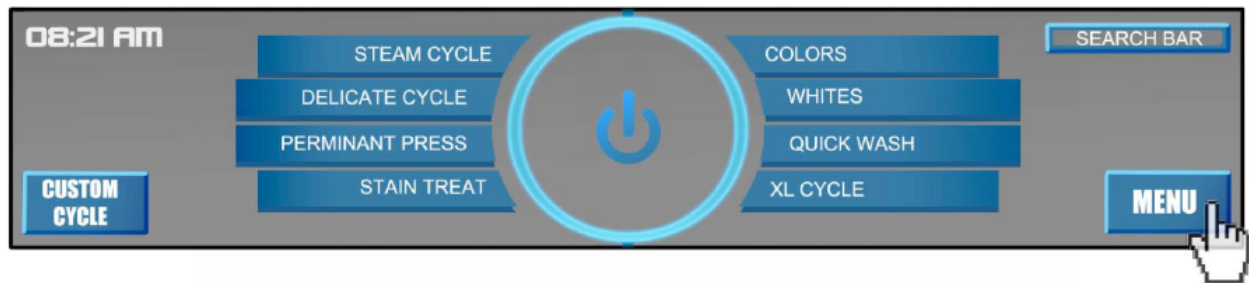
Mockup of the Washer Main Screen, created by Industrial Design

Standards

The standards adhered to throughout this project can be divided into two distinct categories.

Android Design Recommendations

Android also does not force users to follow the guide on the Design website, http://developer.android.com/design/index.html, but these guidelines give the user a consistent android-style and make the interface intuitive. Some examples we used are:

- Utilizing Android's themes like Holo Dark for consistency
- Providing haptic feedback for clicked buttons
- Use of the Roboto typography family, made for high-resolution screens
- Creating multi-view layouts, specifically with fragments

UI Heuristics

Finally, there are heuristics in place that aim to make the interface intuitive, easy to use, and aesthetically appealing. The heuristics that we focused on most were:

- Visibility of system status
- Match between system and the real world
- Minimalist design
- Help documentation

Project Timeline

- Pre Semester 1
    - Prior to our group receiving this project, Iowa State Industrial Design student teams completed initial market research and prototype mock up.
- Semester 1
    - January
        - Project introduction and definition
        - Initial meeting with client liaison
        - Determined development platform
    - February
        - Established regular meeting schedule
        - Commonality and Variability planning
        - Decided on two appliance interfaces
        - Module design
        - Android research
    - March
        - Met with Industrial Design teams to discuss prototypes and workflows
        - Development started
            - James, Andy, Tamara - HVAC
            - Kat - Washer
        - Documentation (Design document and project plan)
    - April
        - Development continues
            - James - Weather
            - Andy - Scheduler

- - - ▪ Kat - Washer backend
        - ▪ Tamara - HVAC
      - ▪ Hardware requirements reconsidered
  - Semester 2
    - o September
      - ▪ Development progress
        - ▪ Andy - Scheduler backend
        - ▪ James - Weather fragments
        - ▪ Kat - Dial interface and Program Customization
        - ▪ Tamara - Energy efficiency
    - o October
      - ▪ Testing instrument/script developed
      - ▪ Development progress
        - ▪ Andy - Scheduler views, Events
        - ▪ James - Washer progress bar, HVAC button groups, layout improvements
        - ▪ Kat - Washer Stain and Maintenance guides database, front and backend
        - ▪ Tamara - Energy efficiency
    - o November
      - ▪ Usability testing
      - ▪ Testing results tabulation
      - ▪ Development revisions from testing
      - ▪ Documentation
      - ▪ Finalize code
    - o December
      - ▪ Present project deliverables

Work Break-Down

Phases of Implementation

Throughout the course of the two semester of Senior Design, we stepped through the design process, starting at concept art and ending with a working application for our client. Our work can be broken down into a few key segments: Design, Initial Development, Progress and Schedule Analysis, Secondary Development, Testing, and Final Development.

Design

This stage was the beginning of our project. In it, we began by familiarizing ourselves with the project, the client, and their goals. We met the Industrial Design teams that had designed home appliance controls and worked to understand their goals of their project. In this phase, we

narrowed the scope to designing an HVAC/thermostat application and a washer application. Next, we decided on some designs and basic layouts, workflows, and features for these two applications.

Initial Development

After the initial design stage, we moved into primary development. We began to create the two applications, using older Archos tablets that ran Android version 2.2. We developed two rudimentary applications that both had similarities to our final applications. Both applications had a menu bar at the top. The washer had a painted dial as well as skeletons for stain and maintenance guides; the HVAC had the large temperature display and some state buttons. At this point in the spring semester, our first semester of Senior Design was finished.

Progress and Schedule Analysis

When we returned for our fall semester to resume our Senior Design project, we needed to analyze where we sat and where we believed we could go with only one semester left. First, we met with our advisor and our client to discuss possibilities with them. Then we analyzed the features we created in the previous semester, the worth of them to the project, and the difficulty of implementing each of them. We weighed this information, and created a prioritized list of features, and an accompanying schedule for developing these.

Secondary Development

This stage involved rapid development, along with a repository choice change. We chose to move our code to Github for ease of use. In addition, we moved to using Nexus 7 tablets that ran Android 4.1.Throughout this phase, we met as a team to do group development; we reviewed our goals, and we analyzed our modules, identifying risks as we went.

Upon returning to development, we realized that the weather module had stopped working. The Google weather API that we had utilized was shut down without warning so we switched to a different API from WeatherUnderground.com. This API shift actually provided richer features and weather data, which we were able to incorporate into our weather module. Additionally, the initial design for the HVAC's schedule feature was not viable. The font sizes were too small to read, and we needed to redesign the module with accessibility in mind.

In the Washer application, the original dial lacked the aesthetic we wanted for our final application, so the dial design was reworked using a rotating dial image. Other program options were also added to the main screen to allow the user to further customize their basic wash programs.

In order to complete the Stain and Maintenance guides on the Washer, databases needed to be populated to show the capabilities of the modules. The maintenance instruction items were populated by hand from various sources on the Internet. The stain removal instructions were all gathered from the same source, the University of Illinois (uiuc.edu) Extension's "Stain Solutions" website. There were too many items in the database to copy by hand, so we wrote a web-crawler to parse and collect the data.

Testing

After this secondary stage of development, we moved into a brief period of user testing. This stage was important in its ability to give us new insight to the work we had been doing. Using our tablets and testing documents we administered tests to a wide range of users. This gave us outsider's perspectives on the usability of our app and provided us with information about improvements that could or should be made.

Final Development and Wrap-Up

Finally, we began a period of quick development, fixing or altering issues identified in testing. This very quick iteration provided us with more intuitive applications. Improvements made in this iteration included adding clearer button icons and labels, fail-safe internet for weather access, larger font sizes, and sound-based feedback for the dial interface. In addition, we wrapped up the semester by creating our final documentation on the progress we made throughout our senior design project.

Design

The design methodology for this project was to make the applications as intuitive and aesthetically pleasing as possible. We developed workflows and features that would complement our methodology.

The modules for HVAC are: Home, Weather, Settings, Calendar and Energy Efficiency. We have the following screenshots to show the layout, color scheme, and form factor:
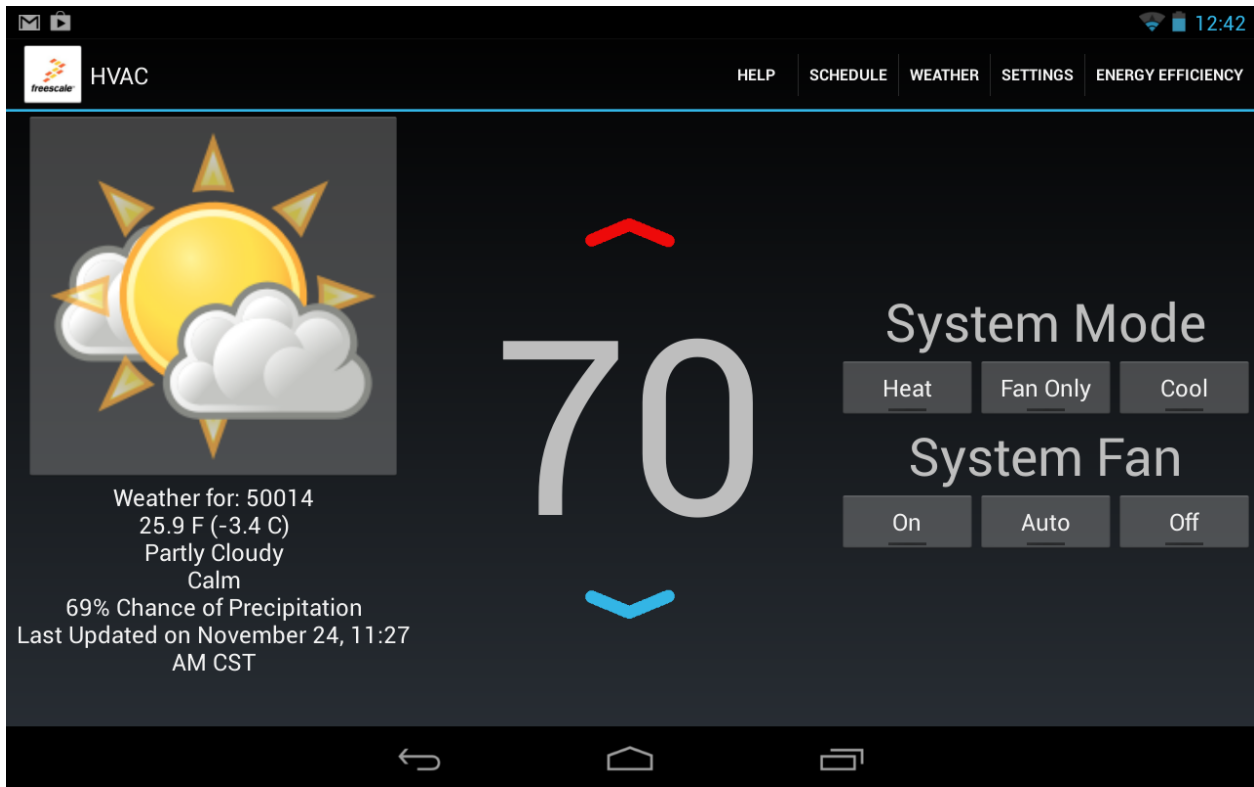
HVAC Main Screen

HVAC Weather Screen
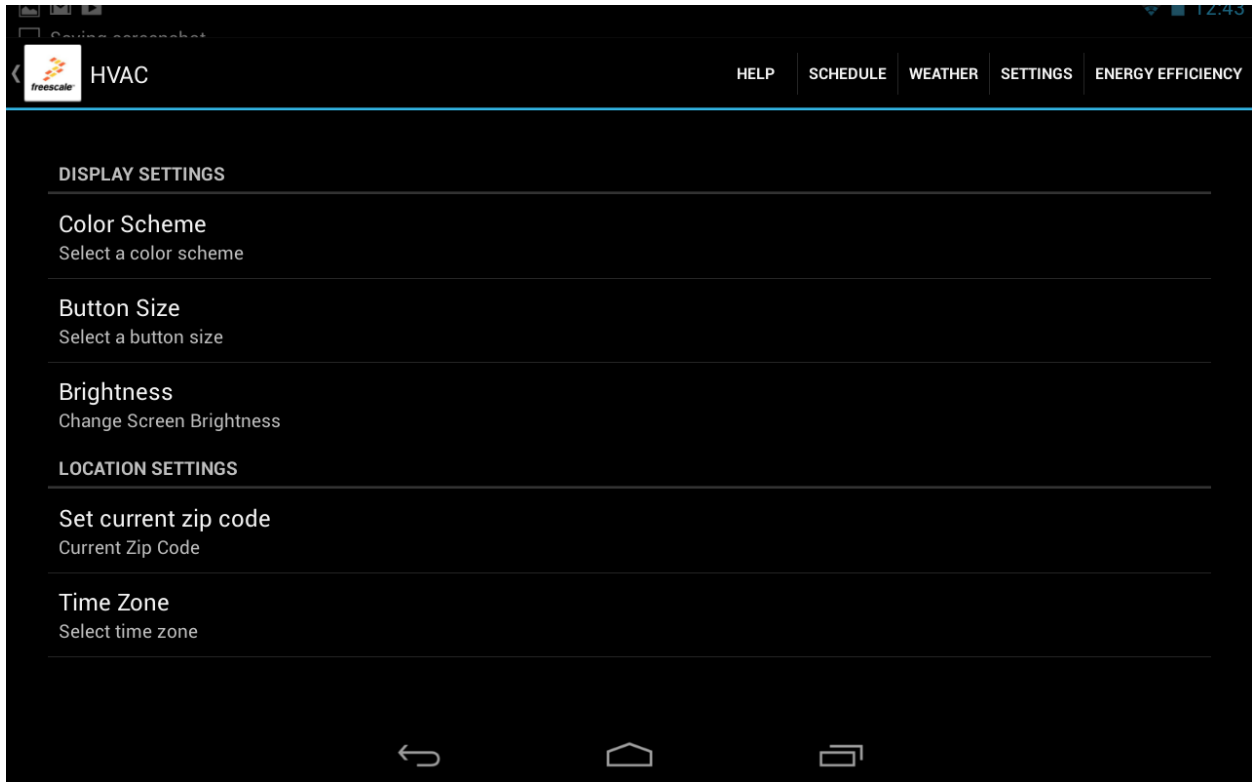
HVAC Setting Screen
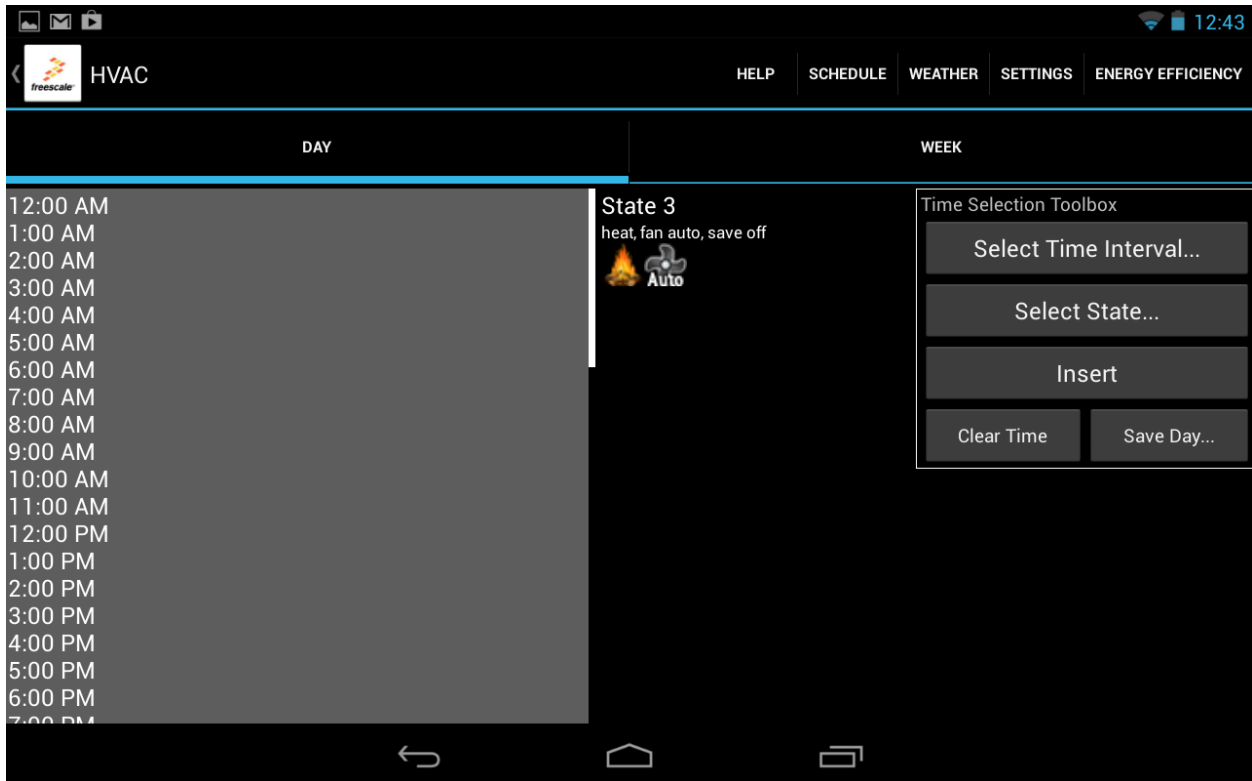
HVAC Schedule Screen
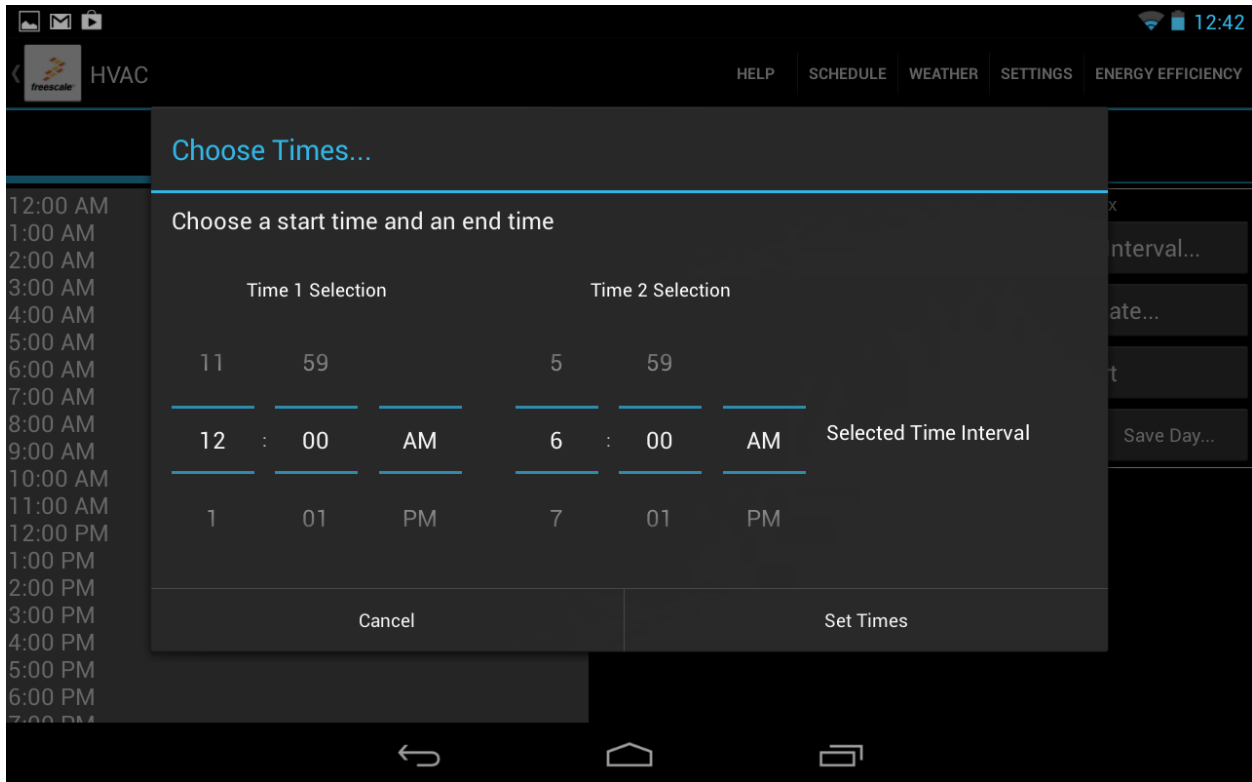
Calendar Screen: Time Selection
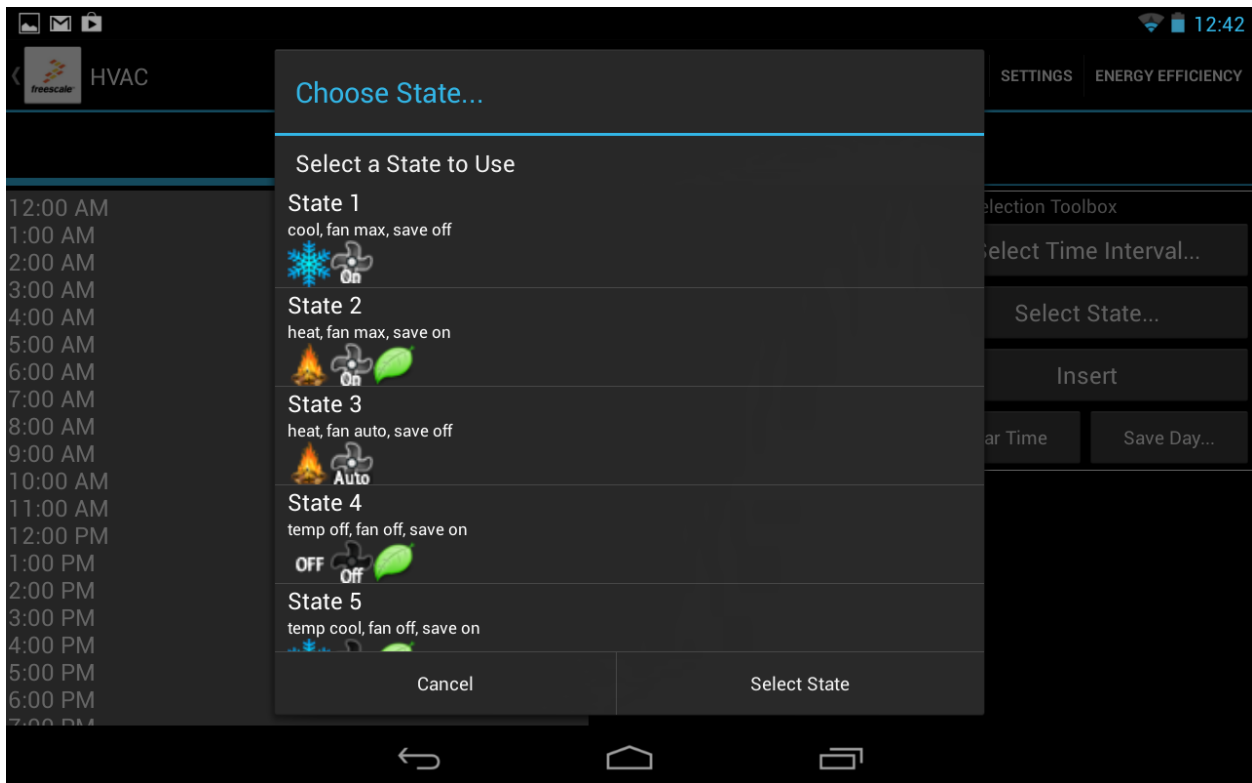
Calendar Screen: Mode Selection
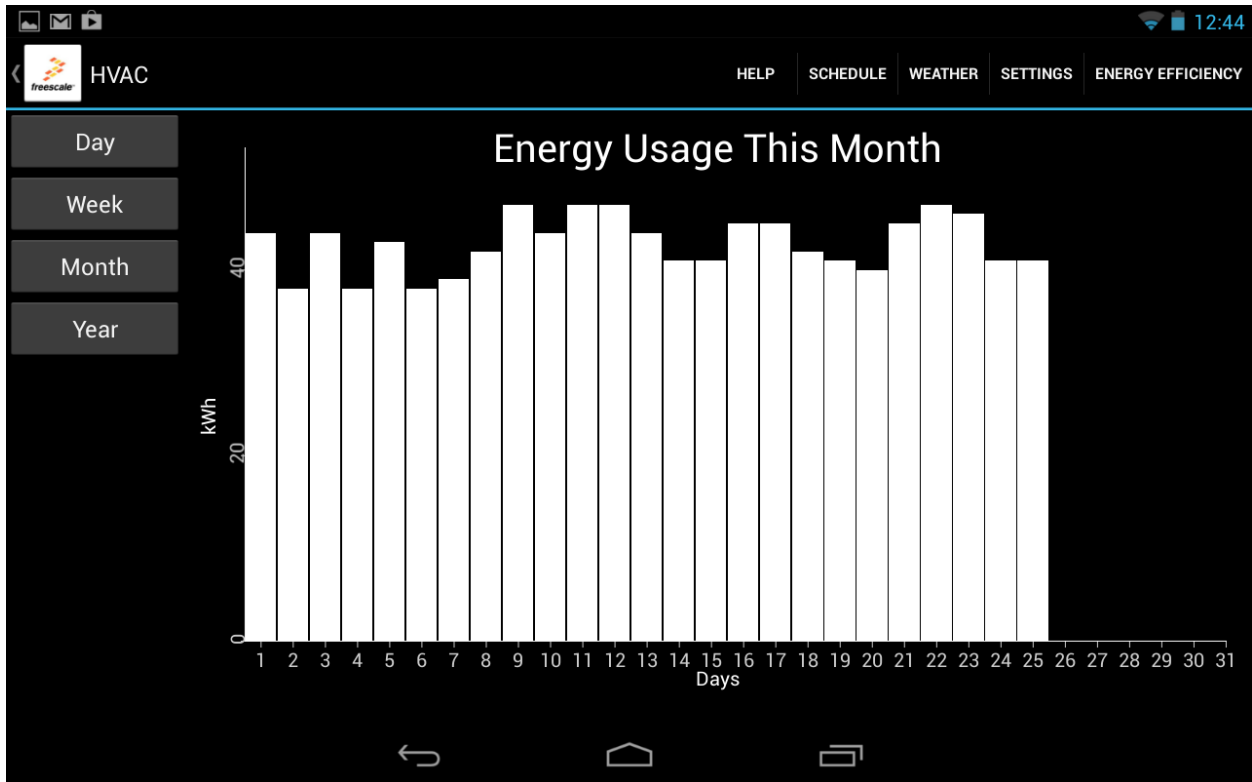
Energy Screen: Monthly Energy Usage

The HVAC also has the following workflow diagram:
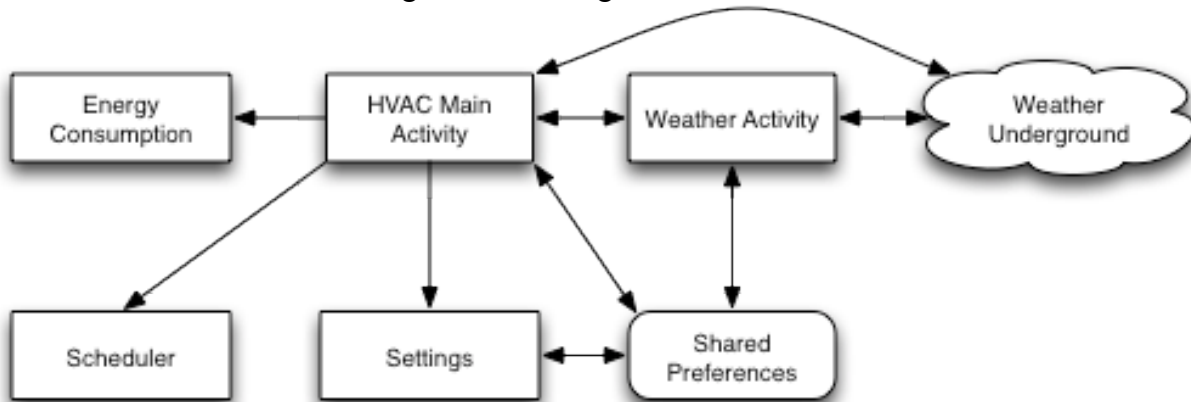
Next, we'll look at Washer. The main screens for Washer are the Home, Stain Guide, Maintenance Guide, Weather, and Customize Program. We have the following screenshots to show the layout, color scheme, and form factor:
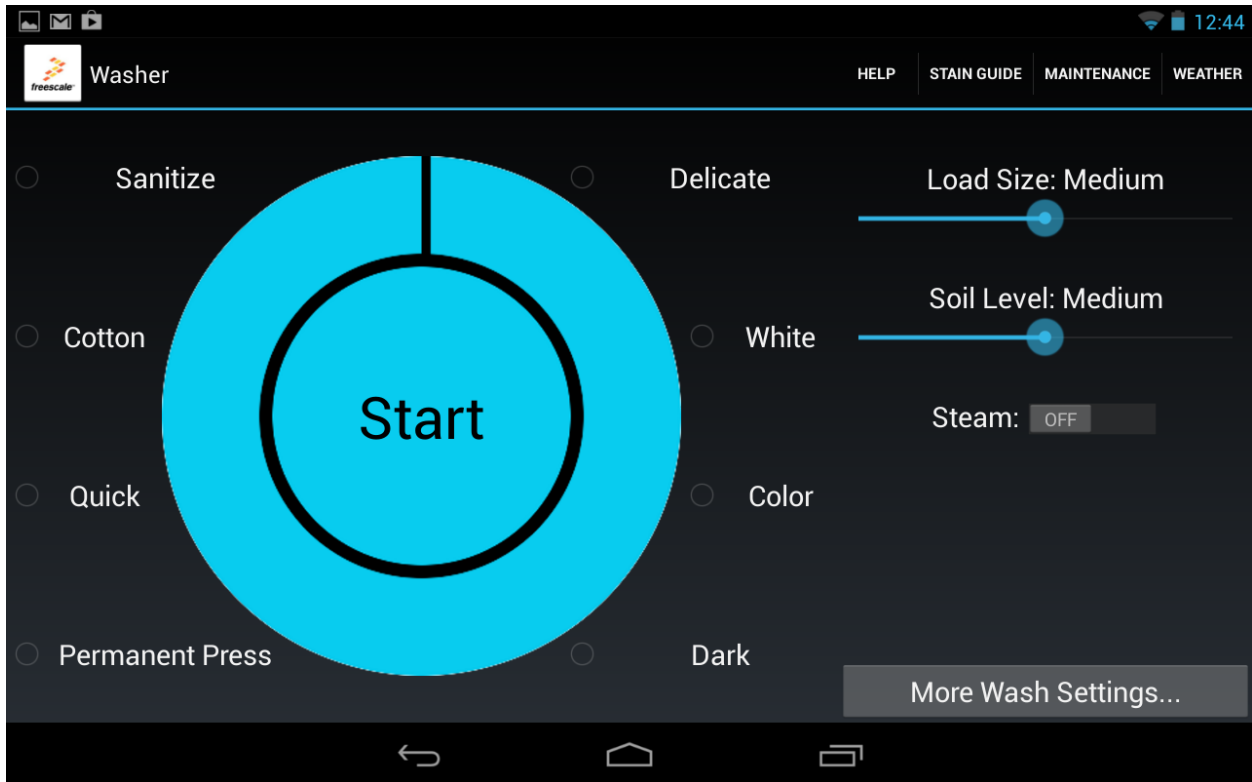
Washer Home Screen
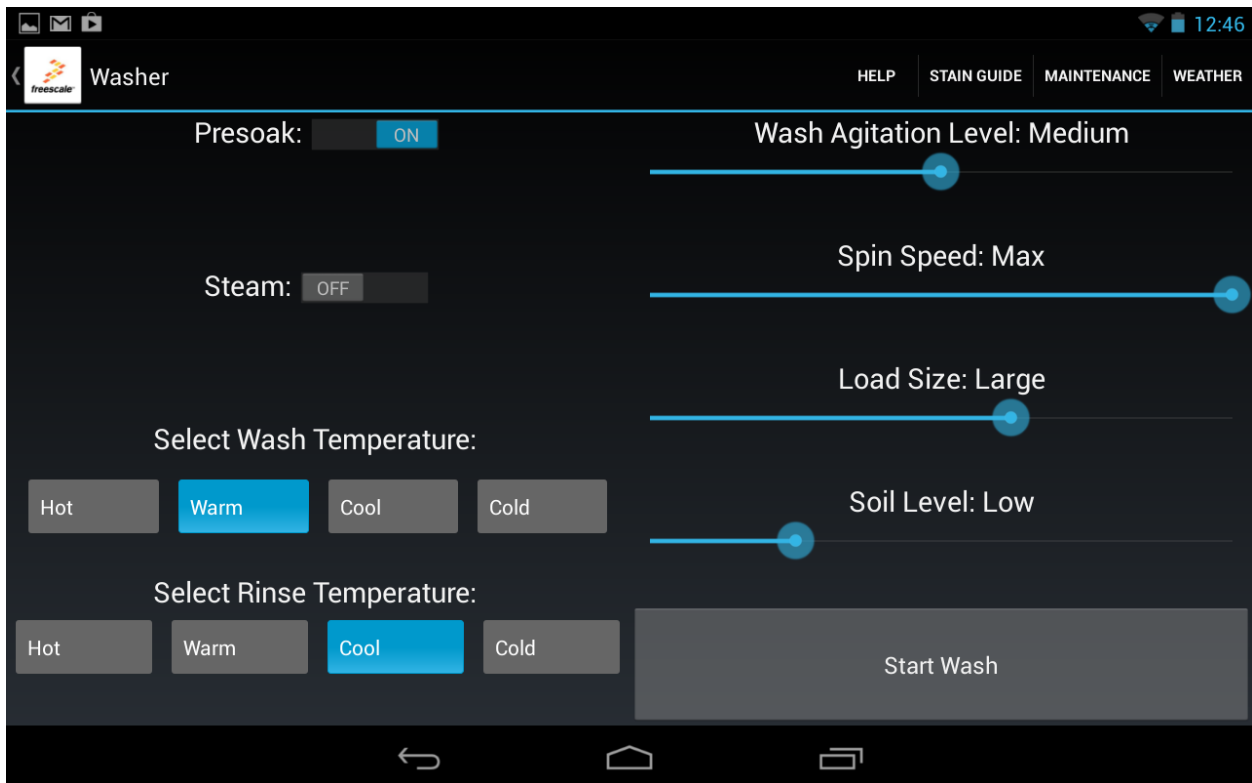
Washer "Customize Wash" Screen
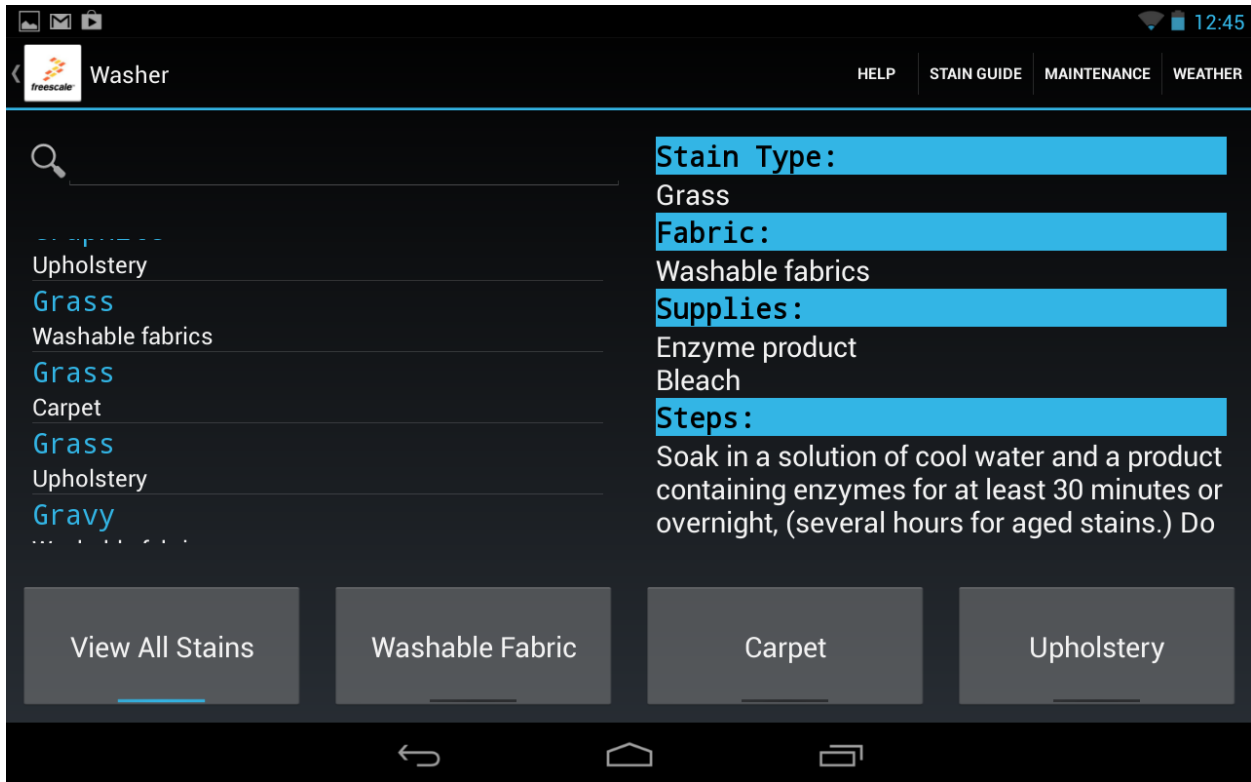
Washer Stain Guide
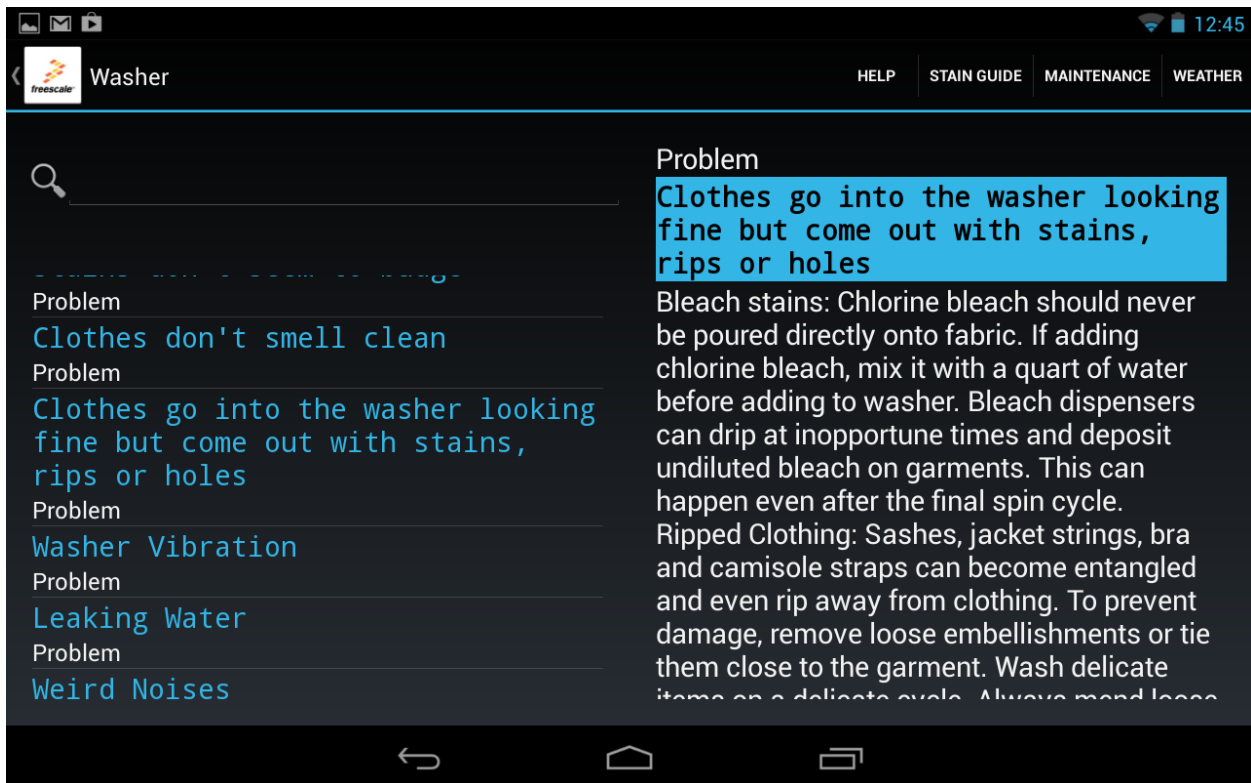
Washer Maintenance Guide

Washer Weather Screen
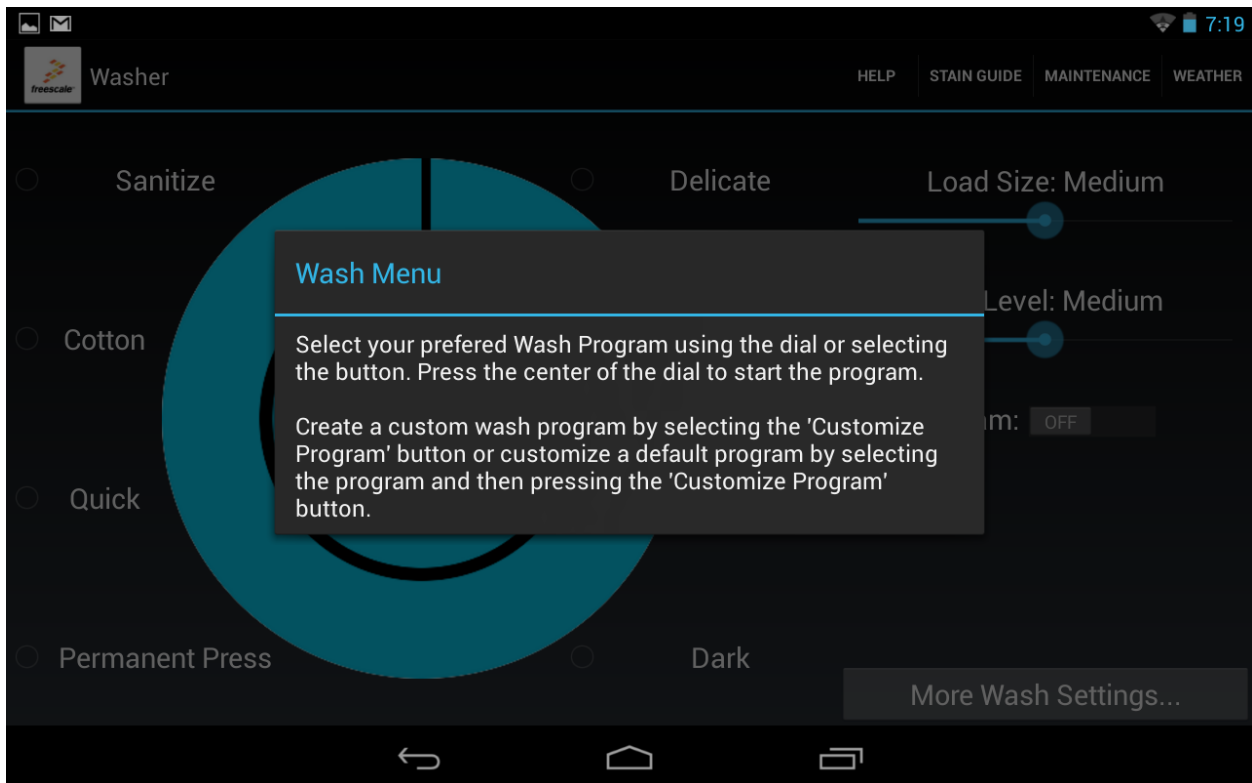
Sample Washer Help Screen

The architecture of the Washer application is as follows:
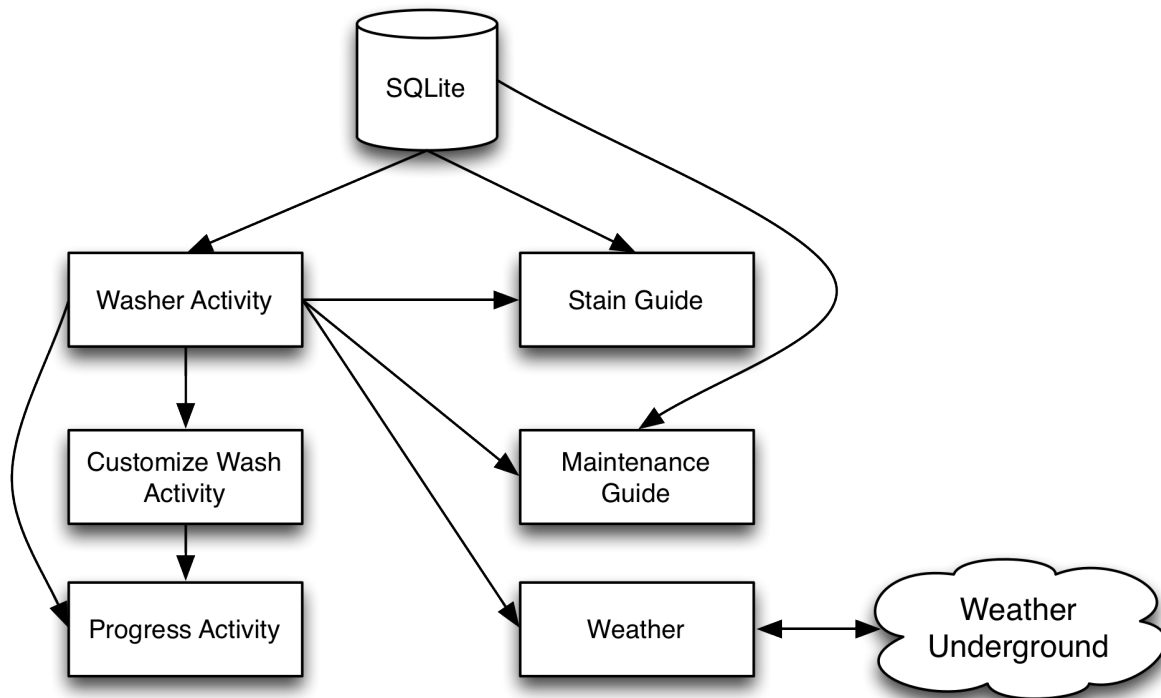
Washer Architecture Diagram

Risks

This project carried a number of risks. While not all risks would lead to the project's failure, some of them created time sinks which, if not properly managed, would lead to an incomplete project. The biggest risk this project had was its size and scope. We could have chosen more than two appliances, but then we ran the risk of poorly implementing each device. Another risk is lack of communication, since our advisor and client have very busy work schedules. While we were concerned about the consequences of poor communication, we were able to maintain good communication with both our advisor and client.

To keep the scope of the project manageable, our team relied on a number of external resources. However, we ran the risk of discontinued support for these libraries and APIs, or incompatibility of resources due to version updates. In our project, one of these risks came to fruition; support of the Google weather API we had been accessing to provide weather data was discontinued. We overcame this by shifting to WeatherUnderground's API. While an initial setback cost us some time to redevelop, we ended up with a richer weather module.

The industrial design team invested a number of hours in researching and designing mockups for

the touch screen applications. In interpreting their designs, we ran the risk of our implementations falling short of their expectations. We mitigated this risk by consulting Dr. David Ringholz who provided his design insight for our project.

Testing Process

Once we had created the initial version of the prototypes, we designed a usability test process. With Dr. Ringholz's guidance, we first created a testing instrument for each application. These instruments, inspired by an industrial design practices, described tasks that each user would perform and denoted fields for data collection. The data we sought was both quantitative and qualitative. The quantitative data collected was the time to accomplish each task, number of false starts, and help guide usage. These data provided us with metrics we used to improve our programs. The qualitative data we collected focused on general feedback, layout opinions, and user frustration. We also created a testing script to make sure that each user was taken through the same testing process. After creating all of the test documents, we performed the tests with users from a variety of age groups and backgrounds. These test documents and their findings can be found in Usability Testing Results.

Summary

In the past two semesters, our senior design group gained experience with interdisciplinary collaboration, project planning and documentation, and design and implementation of a product. The design and implementation of the HVAC and Washer prototypes went through the following cycle: Planning, Development, User Testing, and Revision. Initial collaboration with the industrial design teams provided us with ideas and market research used in planning our project. Once we reviewed the research, we decided to focus on the HVAC and Washer appliances. We then identified requirements and chose which features to implement. Development started with concept drawings, and progressed to crude prototypes with few features, to a testable user interface, finally we incorporated user-feedback to create a deliverable prototype.

Design

Problem Statement

With the advent of smart devices, customers are expecting a richer experience out of the appliances they interact with daily. Freescale, in conjunction with Iowa State University's Industrial Design Department, has noticed a market opportunity to use touchscreen interfaces for

interaction with home appliances. During the course of this market research, the need for an interactive touchscreen prototype was discovered.

Our goal as an engineering senior design group is to provide a prototype platform for use in research to measure reactions to a home appliance touchscreen interface. The approach that our group has taken was to interpret the compiled research and develop prototype appliance interfaces to be used on an Android tablet for continued testing and development. In order to fit the project's time constraints, the appliance interfaces that we chose to simulate are for a washing machine and Heating Ventilation Air Conditioning (HVAC/thermostat) Controller.

Concept Sketch

Because our aim was to create Android applications that acted as controls to an HVAC/thermostat and a washing machine, we based our prototype on the user interface designs created by Industrial Design teams. Their menu designs served as a model as we designed and tweaked our layouts. The wireframe diagrams and flowcharts guided us as we finalized the workflow our prototype would follow. We knew that the extensive consumer and market research that they did would be the foundation of our design.

Because the Industrial Design teams researched many different home appliances, we had to narrow the appliance scope to complete the project in two semesters. In order to make this decision, we considered the following traits for each appliance and its touch screen concept: a well defined design and workflow created by Industrial Design, room for advanced features within the appliance controls, and the most overlap between appliance features to promote module reusability. We chose the HVAC/thermostat controller and the washing machine interface based on these traits.

The choice to develop with Android was driven by a number of factors. First, due to the limited amount of time, we wanted to use a technology that we were comfortable with. Android was what we knew best. Secondly, Android is both portable and flexible which allowed us freedom. Finally, Android has built-in features that worked well with our plans for implementation.

In addition, the appliance, layout, and form factor decisions were influenced by Industrial Design team decisions and our budget. While the industrial design teams suggested numerous sizes and shapes of touchscreens, we were limited to touchscreens that were on the market. We were also influenced by the fact that development for the HVAC application and washing machine application would be displayed and tested on the same size touch screen. We chose to develop the applications in a landscape view to mimic the short, wide screen suggested by the both teams. Thus, we focused on matching the form factor presented by industrial design and choosing a product that was available on the market.

In our process of creating prototypes that implement the basic features of the HVAC/thermostat and washing machine, we interpreted their research and designs, molding them into a design that

could be programmed in an Android application. In respect to visual design, our intention was to utilize Android's built-in design, for example their color scheme and button style on a device that matched the form factor suggested by Industrial Design teams. As the Industrial design teams' designs recommended, the home screen of the HVAC/thermostat would feature basic thermostat features and settings. Similarly, the washing machine application would focus on their suggested dial-centric layout. Using their creativity and research and our technical skills, we were able to create an idea of how our project would unfold.

Specifications

Project Constraints
- Work in interdisciplinary teams.
- Propose alternative interface strategies and graphical user interface.
- Create a platform(s) for rapid prototyping and implementing different interfaces.
- Intended Uses
- Conduct user testing to understand issues of human factors, user response, and user reaction.
- Participate in data gathering to develop insights and define opportunities.
- Functional Requirements
- System must be stable through application life.
- Application must simulate interaction with a home appliance.
- Application must allow user to customize appliance settings.
- Application must allow user to alter interface display settings.
- Application must interface with application data storage.
- Non-Functional Requirements
- Application must be intuitive to the user.
- Code must be modular

User Interface Heuristics
Within our applications, we sought to follow user interface heuristics to make the interface intuitive, easy to use, and aesthetically appealing. The heuristics that we focused on most were: visibility of system status, match between system and the real world, minimalist design, and help and documentation.

Visibility of system status is meant to keep the user informed about what the application is doing. This was applied to the HVAC application by making the system temperature and states visible to the user on the main screen. This was also applied to the Washer application by allowing the user to view the current wash program's progress in the progress screen.

Match between system and the real world was achieved in the Washing Machine application by implementing a dial interface that should be familiar to users who are used to using a hardware dial to interface with their appliance. Also, in the HVAC, red is used on the button used to increase the temperature (head), and blue is used on the button used to lower the temperature (cool).

Minimalist design has been used throughout both applications to insure that the user can use the appliance with ease and so irrelevant features do not hinder them.

Help and documentation were incorporated in all modules within both applications. A help menu can be accessed through a help button from each screen. These help menus describe how to use each of the different screens, so the user has reassurance on how to use their appliance.

System Description / Operating Environment

The applications were developed on the Android 4.1 platform to be tested on 7" touchscreen tablets. The Google Nexus 7 tablets were selected for their display size, touchscreen capabilities, and operating system version. By using the Android 4.1 platform for development, we were able to access newest features available. Our team primarily used the Eclipse IDE and used the Github repository for version control. We utilized other libraries including the AChartEngine Library, SQLiteAssetHelper Library and the WeatherUnderground API to add features and functionality to the applications.

User Interface Description

The following sections break down the User Interface elements that can be found in each screen and how the user interacts with these elements.

Menu Bar

Both applications have a menu bar with tabs for each module as well as a Help and Home button.

Weather

Both applications include a Weather screen. The days are laid out in a side scrollable view so all ten days can be viewed. Large weather icons and high and low temperatures for the day are shown at a glance.

Washing Machine Main Screen

The washing machine main screen contains a dial interface which can be used to select a program cycle as well as two seek bars and a switch which can be used to customize the program cycle. The dial interface was chosen to maintain the look-and-feel of washing machines with static interfaces, which regularly make use of the component. The match between system and the real world makes the interface easier to understand by new users.

Washing Machine Customize Program Screen

If the user selects the "More Wash Settings" button from the main screen, they will be taken to the Customize Program Screen where they can use seek bars, radio buttons and switches to customize every detail of the wash program.

Washing Machine Progress Screen

After selecting and starting a program cycle, the washing machine application displays a progress screen, which contains a countdown timer, progress bar, cancel button, and program details. The countdown timer and progress bar offer two options to visualize the progress of the current wash program.

Washing Machine Stain Guide

The stain guide in the washing machine application contains 4 main components. First, there is a list of stains on the left that can be scrolled up and down by flinging the field with one's finger. Second, there is a stain viewing area on the right, which becomes populated with stain removal instructions when a stain has been selected from the list on the left. Third, there is a search field within the menu bar so that the user can quickly search for the appropriate stain. Each change within the search field updates the stain list on the left. Fourth, there is a panel of buttons that allow the user to narrow their search to find only stain removal instructions for the appropriate fabric type.

Washing Machine Maintenance Guide

The maintenance guide in the washing machine application contains 3 main components. First, there is a list of maintenance instruction items on the left, which can be scrolled up and down by flinging the field with one's finger. Second, there is a maintenance instruction viewing area on the right that becomes populated with maintenance instructions when an item has been selected from the list on the left. Third, there is a search field within the menu bar so that the user can quickly search for the appropriate maintenance instructions. Each change within the search field updates the list on the left.

HVAC/Thermostat Main Screen

The main screen is the first screen presented to the user. This screen presents three interactions with the user. Firstly, the user is presented with the current thermostat operating temperature, and quick temperature adjustment controls. Secondly the user may select the fan speed and system mode. Finally, quick weather for the current day is also displayed.

HVAC/Thermostat Energy Efficiency Screen

The energy efficiency is displayed upon touching the Energy Efficiency tab Menu bar. This feature allows the user to view the amount of energy used by their HVAC system throughout the

day, week, month or year. While the default view is week view, the user can select which graph to view using the column of buttons on the left side of the screen.

HVAC/Thermostat Settings Screen

The settings screen, accessible from the tab on the Menu bar, allows users to customize different aspects of their user interface. Currently, the settings menu offers the user the choices to change the screen brightness, the zip code, and the time zone. Selecting one of these options will expand another small screen to change this setting.

HVAC/Thermostat Scheduler

The scheduling functionality provided by HVAC is presented as a main screen with auxiliary functions inside the "Time Selection Toolbox." The Time Selection Toolbox is a floating panel that allows users to bring up a dialog for times and system modes. The times and system modes calibrate a preview panel appearing next to the day's events. An insert button allows users to take the preview and change it into an event, which populates the schedule.

Functional Decomposition

The following sections describe the components within each module and how they behave within the system.

Weather

This module connects via Internet with Weather Underground to acquire and display a ten-day weather forecast. By clicking the weather icon, the user is shown a detailed text forecast for the day.

Washing Machine Main Screen

From the main screen of the Washing Machine application, users can select a program cycle, customize the program details, and start a wash program.

Washing Machine Customization Screen

Users can customize a program cycle to fit their own needs including: water temperature adjustment, agitation level selection, and steam setting.

Washing Machine Progress Screen

The progress screen displays the progress and details of the current wash program. The program can be cancelled by selecting the Cancel Wash button.

Washing Machine Stain Guide

The Stain Guide can be used to search and find stain removal instructions for a variety of stains and fabric types.

Washing Machine Maintenance Guide

Users can solve their washing machine issues by searching and reading information within the built-in Maintenance Guide.

HVAC/Thermostat Main Screen

From the main screen of the HVAC/thermostat application, users can view and change the current temperature, as well as set the system to heat/fan/cool the state to on/auto/off, and check the daily weather.

HVAC/Thermostat Settings Screen

The Settings Screen allows the user to change the color scheme, screen brightness, zip code or time zone.

HVAC/Thermostat Energy Efficiency Screen

The user can view the energy usage of their HVAC system for the day, week, month and year from this screen.

HVAC/Thermostat Scheduler

The scheduling feature allows users to program their thermostats with different modes, which are states corresponding to heating, cooling, fan speed, and energy saving settings. Each mode has a time frame associated with it, and the two together is called an Event. Events are used to completely define the programming features in the thermostat scheduler, and allow the user to customize their settings for different time periods, such as when on vacation or at home.

Testing

Goals

First we aimed to quantitatively measure time needed to accomplish each task as well as the number of times the user needed to restart the task, if any, before they could complete it. Also, we wanted to analyze qualitative aspects of the user experience. This included evaluating the users' frustration level with the new interface and control paradigm and determining the users' preferred look and feel of the application. Finally, we hoped to verify the applications have the expected functionality of the appliance they control. For example, the washing machine application would need to give users a way to choose water temperature and load type, and the HVAC control would need to allow the users to change the system temperature and fan settings.

More about the approach used for testing and results can be found in the Usability Testing Results document.

Results

After finishing the testing and analyzing the results, we found that the prototypes were a good first step for intuitive touchscreen controls for appliances. Overall, users were able to complete tasks without much difficulty or confusion. We heard several test subjects say "[I] didn't need detailed directions to figure it out." when referring to the tasks they were instructed to carry out.

The applications had features that the users believed the HVAC/thermostat and washing machine should. They also appreciated other non-essential features, such as the weather. While the testing did expose some areas for improvement, they were manageable. Indeed, some of the changes were implemented right away, based on user feedback. These included changes to the overall font size and button and screen labels, as well as modifications to make the modules to be fail-safe. In short, this period of testing gave us insight to users' responses to our prototype.

Standards

Due to the lack of concrete standards in application development, the standards of our project relied heavily on user interface heuristics recommended by specialists.

We examined guidelines suggested by Doctor Jakob Nielsen, a guru in software usability research. We weighed his 10 Usability Heuristics, found at http://www.useit.com/papers/heuristic/heuristic_list.html, and found seven that we felt were especially applicable to our project. Below, each section discusses a heuristic and how it is applied in our project.

Visibility of System Status

"The system should always keep users informed about what is going on, through appropriate feedback within reasonable time."

HVAC
- o Displays current temperature on main screen
- o Displays current system settings on main screen
  - ▪ Heating, Cooling, or Fan Only
  - ▪ Fan On, Fan Off, or Fan Auto
- o Pops up a notification immediately after one of these states are changed

Washer
- o Displays progress screen upon start of wash program
  - ▪ Time remaining in wash
  - ▪ Type of load
  - ▪ Load size

- ▪ Other program settings

Match Between System and the Real World

"The system should speak the users' language, with words, phrases and concepts familiar to the user, rather than system-oriented terms. Follow real-world conventions, making information appear in a natural and logical order."

Our goal in meeting this heuristic focused on using common icons and symbols were appropriate, and making our terminology match that of the users.

HVAC
- Prominent current temperature
- Red up arrow to increase temperature
- Blue down arrow to decrease temperature
- Date selector in Schedule has a roll selector like other products (Apple & Blackberry)

Washer
- Washer Dial
- Wash progress bar
- Magnifying glass for search in stain guide and maintenance guide
- Use of washing machine terminology
- Delicate
- Color
- Dark
- White

User Control and Freedom

"Users often choose system functions by mistake and will need a clearly marked "emergency exit" to leave the unwanted state without having to go through an extended dialogue. Support undo and redo."

Both Applications
- Inclusion of a home button

HVAC

- Inclusion of Cancel buttons on Schedule Time "Select Time Interval" and "Select State"

Washer

- Putting all wash settings on one screen to prevent the need to Undo
- Inclusion of Cancel Wash button

Consistency and Standards
"Users should not have to wonder whether different words, situations, or actions mean the same thing. Follow platform conventions."

Both Applications

- Use of similar terminology throughout each application
- Use of a toolbar & home button to follow the platform conventions of applications

Error prevention
"Even better than good error messages is a careful design which prevents a problem from occurring in the first place. Either eliminate error-prone conditions or check for them and present users with a confirmation option before they commit to the action."

Both Applications
- Inclusion of a popup screen to alert the users they don't have internet access for weather, instead of allowing the application to crash

Washer
- Inclusion of popups that alert user if they have not selected a wash when they click the start button

Recognition rather than recall
"Minimize the user's memory load by making objects, actions, and options visible. The user should not have to remember information from one part of the dialogue to another. Instructions for use of the system should be visible or easily retrievable whenever appropriate."

Both Applications
Inclusion of a help button that is available from every screen

Aesthetic and minimalist design

Dialogues should not contain information that is irrelevant or rarely needed. Every extra unit of information in a dialogue competes with the relevant units of information and diminishes their relative visibility.

Both Applications
Followed suggestions from Industrial Design team

Help and documentation

Even though it is better if the system can be used without documentation, it may be necessary to provide help and documentation. Any such information should be easy to search, focused on the user's task, list concrete steps to be carried out, and not be too large.

Both Applications

Inclusion of a help button that is available from each screen

Commonalities and Variabilities

When prioritizing the features and modules used in each application, we created the following document at the suggestion of Dr. Ringholz. It defines all uses for the modules we created to show the reusability of each component.

Module	Behavior	Type (UI, Backend, etc.)	Tech/Language	Application(s)
Weather	Retrieves up to ten days of weather data on location described by zip code and displays the data	UI and Backend	Android	Refrigerator, HVAC, Dishwasher, Oven, Microwave, Washer, Dryer, more
Statistics Graphing	Creates bar graphs to display energy usage, water usage, or other statistics associated with appliances	UI	Java / Android	Washer, Dryer, Dishwasher, Oven, Microwave, Refrigerator, HVAC, more
Maintenance Guide	Reviews instructions on appliance maintenance	UI and Backend	Android	HVAC, Washer, Dryer, Fridge, Oven, Microwave, Dishwasher, more
Preference/State	Saves/Recalls variable state	Backend	Android - Shared Preferences	HVAC, Washer, Dryer, Fridge, Oven, Microwave, Dishwasher, more
Database	Stores query-able data	Backend	SQLite / Java	Washer, Dryer, Dishwasher, Oven, Microwave, Refrigerator, HVAC, more
Auto-complete	Searches	UI and Backend	Android	Washer, Dryer,

Search	database			Dishwasher, Oven, Microwave, Refrigerator, HVAC, more
Timer	Shows a countdown timer	UI	Android - CountDownTimer	Washer, Dryer, Dishwasher, Oven, Microwave, Refrigerator, more
Wash Progress	Shows progress of wash cycle	UI	Android	Washer, Dryer, Dishwasher, Oven, Microwave, more
Scheduling	Set times and events, scheduling, trigger events	UI, Frontend, Backend	Java / Android	Dishwasher, Oven, Refrigerator, HVAC, more
Dial Selector	Selects from a list of options, use center as a button	UI	Java	Washer, Dryer, Oven, Dishwasher
Stain Guide	Reviews instructions on removing stains from a variety of fabrics	UI and Backend	Android	Washer

Test Script

Introduction:

Hi, my name is _____ . I'm a member of an Iowa State Engineering Senior Design group. Today we're here to evaluate a touch screen interface to collect data and user feedback. We're going to be testing it by going through a few tasks. But first, please sign the informed consent document.

<informed consent>

Background:

Our task was to create touchscreen interfaces for household appliance controls. These prototypes would take the place of traditional manual controls on your **<Washing Machine / Thermostat>**. Instead of this **[show picture]**, the touchscreen would be here. **[point to buttons]**

While accomplishing the tasks, please imagine that these tablets control a real <**washing machine/thermostat>.**

[Display tablet]

We will ask you to perform 5 or 6 tasks and will be taking notes and recording data as we go. If you need any instructions repeated, please ask. After all of the tasks, we'll ask you a few final questions.

Do you have any questions before we begin?

Washer Tasks:

Task 1:   Start a cotton wash cycle with a medium sized load, medium soil level and no

            steam.

Task 2:   Cancel the current wash cycle.
Task 3:   Find out how to remove a nail polish stain from washable fabric
Task 4:   Find out how to level the washing machine
Task 5:   Return to the main screen **[wait]**. Start a custom wash cycle with the

            Following settings: presoak, hot wash temperature, high agitation level, and xsmall
            load size.

Task 6:   Check the high temperatures for the upcoming weekend.

HVAC Tasks:

Task 1:   Turn up thermostat temperature by 5 degrees, turn heat on, and set fan to

            auto.
Task 2:   Check detailed weather 5 days from today
Task 3:   Set the schedule for a day

            (3a) Set an off state between 2:00 AM to 6:00 AM.

            (3b) Set a heat state between 6:00 AM to 12:00PM.

            (3c) Set a cooling state that is energy efficient between 12:00PM to 10:00 PM.

**(Jump in when the user has correctly set a time period, let them know they can move onto the next task)
Task 4:   View monthly energy consumption
Task 5:   Change zip code to your hometown's zip code.
Task 6: Return to main screen and refresh the weather.

[After the final task]

- Please, rate your experience with this product: Did you find it: Very Easy, Easy, Neutral, Difficult, or Very Difficult?
- Did you find this experience: Enjoyable, Satisfactory, Neutral, Not Enjoyable, or Frustrating?
- Did the product behave as you expect a Washer / HVAC (circle one) to behave? Please explain.
- What did you like about the product?
- What did you dislike about the product?
- What would you improve?
- What features would you like to have in the product?

Thank you for participating today!

HVAC/Thermostat Testing Instrument

Task 1:   Turn up thermostat temperature by 5 degrees, turn heat on, and set fan to auto.

False Starts (Tally) _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min ____sec

Implementation Errors _____

Comments: (Record any comments by user):

_____

_____

Task 2:   Check detailed weather 5 days from today

False Starts (Tally) _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min ____sec

Implementation Errors _____

Comments: (Record any comments by user):

_____

_____

Task 3:   Set the schedule for a day: (1) choose times, (2) select state, (3) click insert button, and (4) set a 24-hour cycle.

False Starts (Tally) _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min ____sec

Implementation Errors _____

Comments: (Record any comments by user):

_____

_____

Task 4:   View monthly energy consumption

False Starts (Tally) _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min   ____sec

Implementation Errors   _____

Comments: (Record any comments by user):

_____

_____

Task 5:   Change zip code to your hometown's zip code.

False Starts (Tally) _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min   ____sec

Implementation Errors   _____

Comments: (Record any comments by user):

_____

_____

Task 6:   Return to main screen and refresh the weather.

False Starts (Tally) _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min   ____sec

Implementation Errors   _____

Comments: (Record any comments by user):

_____

_____

Washing Machine Testing Instrument

Task 1:   Start a cotton wash cycle with a medium sized load, medium soil level and no steam.

False Starts (Tally)   _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min   ____sec

Implementation Errors   _____

Comments: (Record any comments by user):

_____

_____

Task 2:   Cancel the current wash cycle.

False Starts (Tally)   _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min   ____sec

Implementation Errors   _____

Comments: (Record any comments by user):

_____

_____

Task 3:   Find out how to remove a nail polish stain from washable fabric

False Starts (Tally)   _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min   ____sec

Implementation Errors   _____

Comments: (Record any comments by user):

_____

_____

Task 4:   Find out how to level the washing machine

False Starts (Tally)   _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min   ____sec

Implementation Errors   _____

Comments: (Record any comments by user):

_____

_____

Task 5:   Start a custom wash cycle with the following settings: presoak, hot

        wash temperature, high agitation level, and xSmall load size.

False Starts (Tally)   _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min   ____sec

Implementation Errors   _____

Comments: (Record any comments by user):

_____

_____

Task 6:   Check the high temperatures for the upcoming weekend.

False Starts (Tally)   _____

User Referenced Help Guide (Circle One)   No   1-2 times   >2 times

Task Accomplished (Circle One)   Yes   No

Time to Finish Task   ____min   ____sec

Implementation Errors   _____

Comments: (Record any comments by user):

_____

_____

User Interface: Usability Testing Results

In the efforts to make the best use of our testing, we followed a number of steps to standardize our process. We first created a uniform testing script and testing instrument for both appliances. These documents ensured that each test participant would hear the same instructions and allowed us to collect more accurate data. After creating these instruments and scripts, the tests were performed by users. The findings were recorded and analyzed. After gathering data, we performed analysis to determine the changes that need to be made to the applications.

Both Applications

Weather Forecast
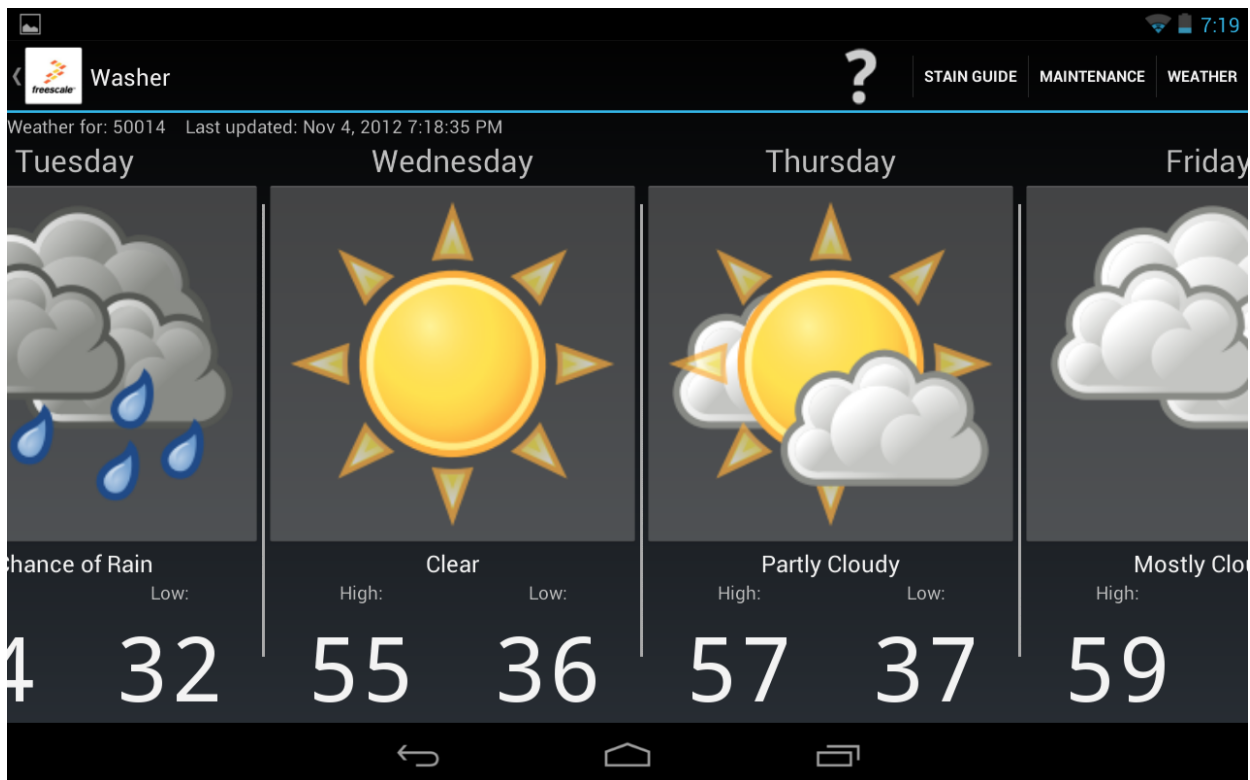
The Weather Forecast shows weather predictions from Weather Underground for the next 10 days. A weather image as well as high and low temperatures are displayed for each day. Users can view detailed forecasts by clicking on the weather image.

Task Performed

The tasks performed for the weather involved having the user open the Weather Forecast activity and viewing detailed weather information for a few days in the future. The task tested the visibility and functionality of the Weather Forecast activity.

Data

Minimum time to find weather forecast: 5
Average time to find weather forecast: 20 sec
Maximum time to find weather forecast: 1 min

Feedback

The overall response to the Weather Forecast feature was very positive, even surprising some users, "Oh, weather!" Users also made comments on how "the weather could be useful to plan your settings".

Improvements

On testing, we noticed a few implementation problems with the Weather Forecast activity. First, there needs to be some kind of graceful notification when the device does not have an Internet connection. Secondly there are a few missing weather icon graphics to match all of the differing conditions. Users noticed that there was no graphic for the condition of "ice pellets".

Menu Bar

Each application has a menu bar used for navigation. On the Washing Machine's menu bar, there is a help icon, represented by a question mark, as well as links to the Stain Guide, the Maintenance Guide, and the Weather Forecast.

On the HVAC's menu bar, there is a help icon, represented by a plus sign, as well as links to the Scheduler, Weather Forecast, Appliance Settings and Energy Efficiency.

Washing Machine Application

Main Screen
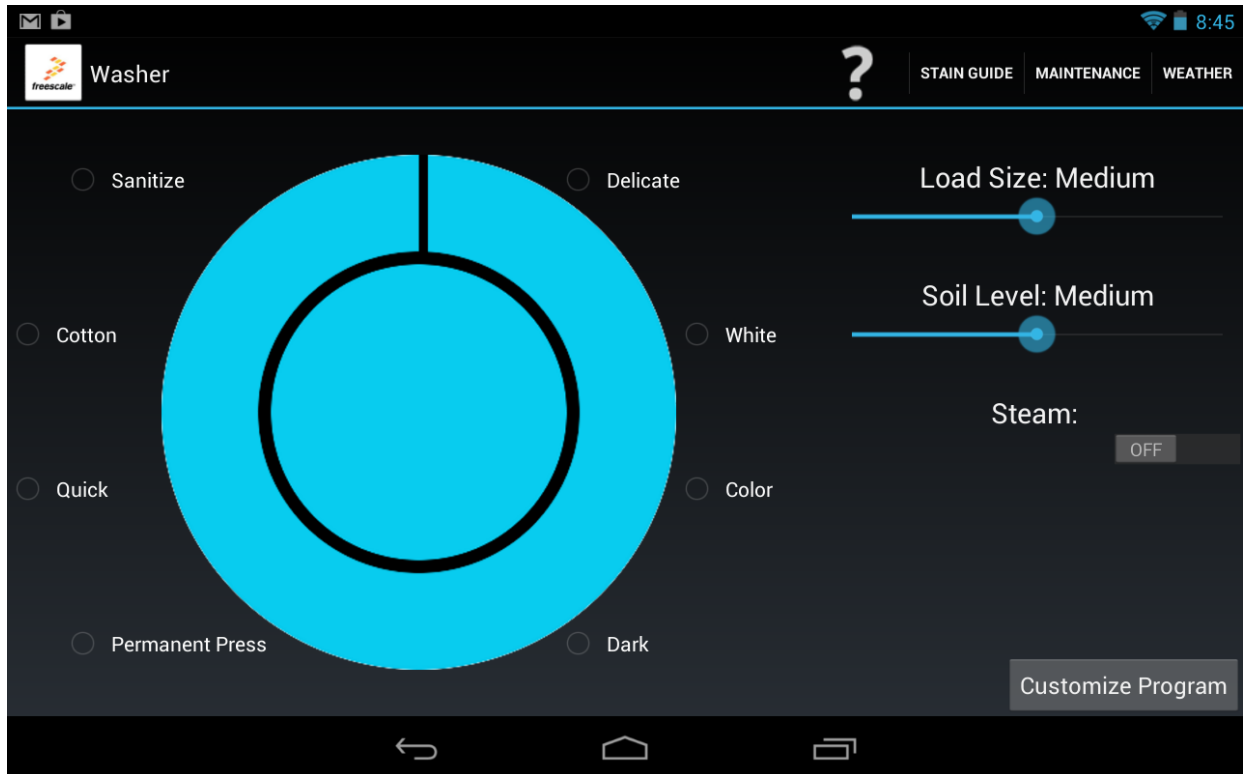
The Washing Machine Application opens with the wash program settings screen. On the left, is a dial controlled by finger movement in the outer ring, which is used to select the wash program. Selecting the center of the dial starts the currently selected wash program. On the right, are slider selectors used to select load Size and Soil Level as well as a switch to turn steam on and off. In the lower right, there is a navigation option to move to the customization screen.

Task Performed

The user's first task was to start a cotton wash cycle with a medium sized load, medium soil level, and no steam. This task tested the user's ability to use the dial for program selection as well as starting the wash.

Data

Minimum time to start wash program: 15 sec
Average time to start wash program: 31 sec
Maximum time to start wash program: 1 min 15 sec

Feedback

"looks [sic] like traditional controls"
"Customize program was unclear, 'More Settings' might make more sense"
"Selecting center of dial to start wash is not obvious"
There should be a 'Start' label on the dial.
Should offer the user recommendations of what program to use for different kinds of clothing.
"Needs more emphasis on starting wash"
"font size around the dial is too small"
Steam button is hard to see

Improvements

The main concerns on the Main Screen are clarity and font sizes. First, there needs to be some indication that selecting the center of the dial starts the wash program. Second, the program selections need to have a larger font size. Finally, the 'Customize Program' button should have a different title and must stand out more.

Help Menu
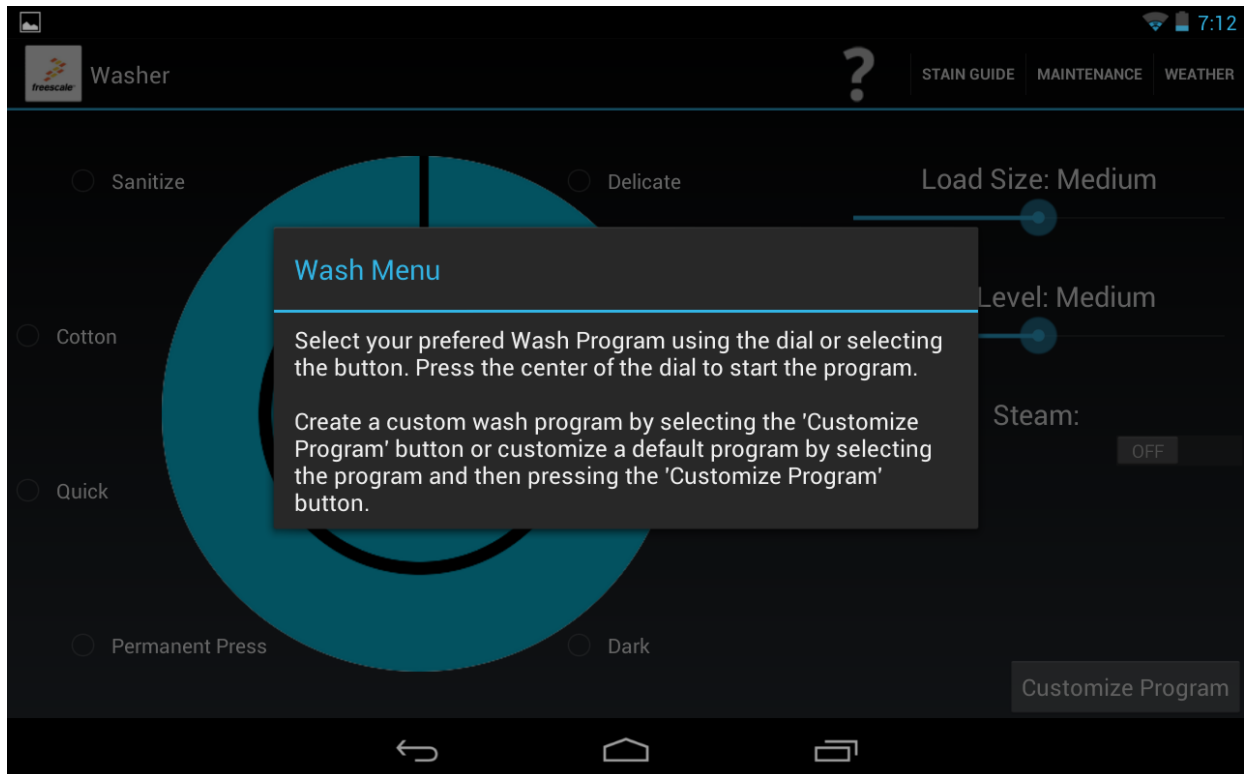
Each Activity includes instructions on how to use the current screen. These instructions are accessed by selecting the '?' in the menu bar.

Task Performed

One of our testing metrics was the number of times the user opened the help menu, although we created no tasks that required the user to open the menu. Very few users opened the help menu during testing and a few asked what the help icon did when they were done.
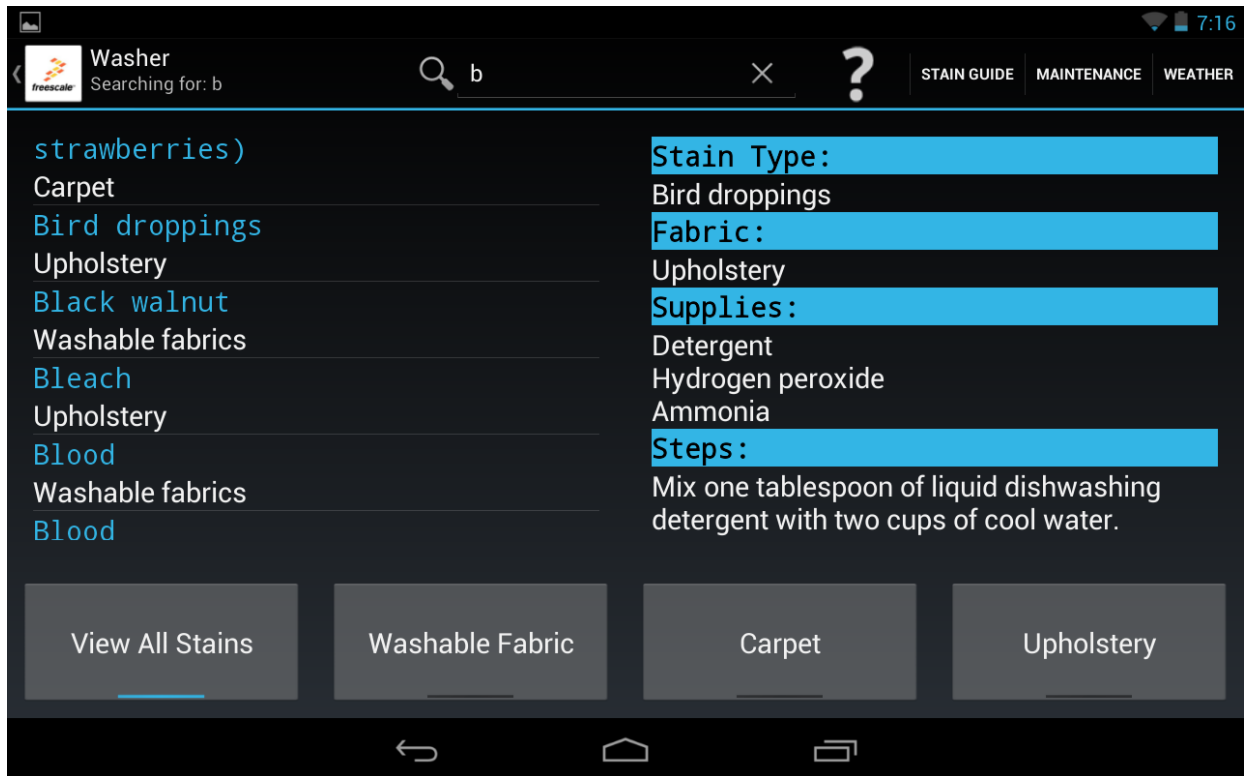
Data

Out of 7 testers, only 2 referenced the help guide.

Feedback

"Change ? to 'help'"

Improvements

The word 'Help' should be added to the button for the help menu, to make finding the menu clearer.

Stain Guide

The Stain Guide contains 4 major components: stain selection on the left, stain view on the right, stain search in the menu bar and fabric type selection at the bottom of the screen. The left screen can be scrolled up and down and each item can be selected. When an item is selected in the left panel, the stain removal instructions appear in the right panel. Users can search for stain types by entering text in the search field at the top of the screen. The left panel is updated after each change in the search field. Searches can also be limited by selecting a fabric type at the bottom of the screen.

Task Performed

For the user's third task, they were asked to "Find out how to remove a nail polish stain from washable fabric." This task verified that the user could: find the Stain Guide and navigate the list of stains. (Many users also used the search function as well as the fabric type selection."

Data

Minimum time to find stain removal instructions: 40 sec
Average time to find stain removal instructions: 1 min 40 sec
Maximum time to find stain removal instructions: 5 min 24 sec

Feedback

Fabric type buttons were easily overlooked.

Item listings were confusing. Stain type should be a larger font size than the stain fabric.

"[I would like to] type in vinegar and see the things that vinegar cleans."

"[I've] never seen a washing machine with a stain guide."

"not real familiar" - user did not realize the list scrolled.

"I'm not finding menu of stains."

Improvements

The fonts used in Stain listings needs to have greater contrast to aid the user in finding the correct stain. The fabric selection buttons at the bottom of the screen must have more contrast, so that they are more easily noticed.

Maintenance Guide

The Maintenance Guide functions very similarly to the Stain Guide. There is a maintenance selection on the left, maintenance view on the right, and maintenance search in the menu bar.

When maintenance entries are selected in the left panel, the maintenance view is updated with maintenance instructions. Users can search for maintenance items by entering text in the search field at the top of the screen. The left panel is updated after each change in the search field.

Task Performed

Users were given the task to find out how to level their washing machine. Since this task was completed after a similar task using the Stain Guide, users were able to accomplish the Maintenance Guide tasks without much trouble.

Data

Minimum time to find maintenance instructions: 7 sec
Average time to find maintenance instructions: 20 sec
Max time to find maintenance instructions:45 sec

Feedback

Add buttons to limit search, like in Stain Guide.

Have washer alert user when maintenance is needed.

"That was kinda nice, the maintenance guide", "wouldn't have to go back and find that" [extra guides that came with washer]

Improvements

Like in the help menu, buttons should be added to allow the user to narrow their search based on search topic.

Android Keyboard
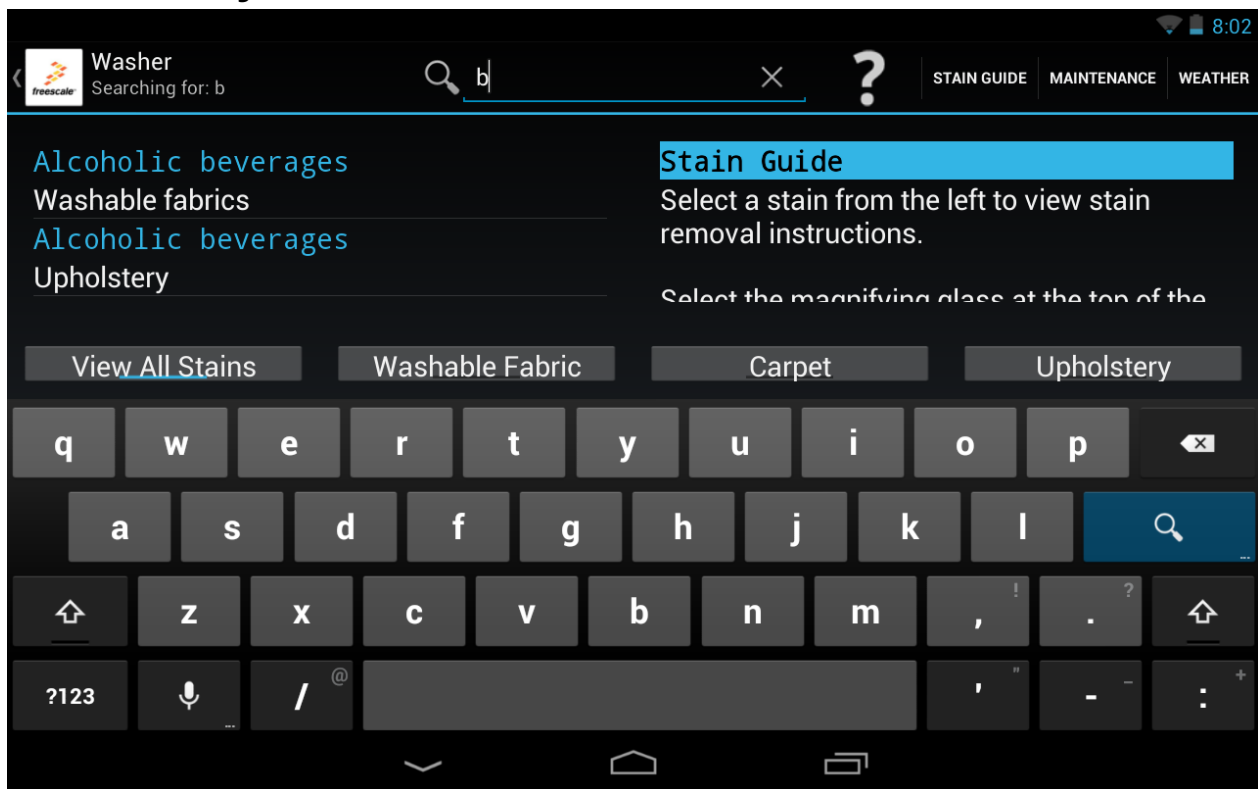
The keyboard built into the Android OS was used for text entry into the search fields for both the Stain Guide and the Maintenance Guide.

Feedback

The user should be able to exit the keyboard by selecting the search icon on the keyboard or by selecting the screen away from the keyboard.

"I need to 'Enter'"

"The keyboard made me panic"

The full sized keyboard is too big.

Customization Screen

Users can customize the wash cycle by making selections from this screen. If a wash cycle was selected before selecting Customize Program on the main screen, the user automatically customizes the program settings.

Task Performed

The user was asked to start a custom wash cycle with the following settings for their fifth task: presoak, hot wash temperature, high agitation level, and extra-small load size. Many users spent upwards of 30 seconds looking for these settings on the main screen, but eventually moved onto the Customization Screen.

Data

Minimum time to start custom wash program: 42 sec
Average time to start custom wash program: 1 min 1 sec
Maximum time to start custom wash program: 1 min 54 sec

Feedback

"Needs more emphasis on starting wash"

"not real familiar" - some components were difficult to use like, seekbar and switches

Improvements

The 'Start Wash' button needs to be larger and have more contrast.

Program Progress
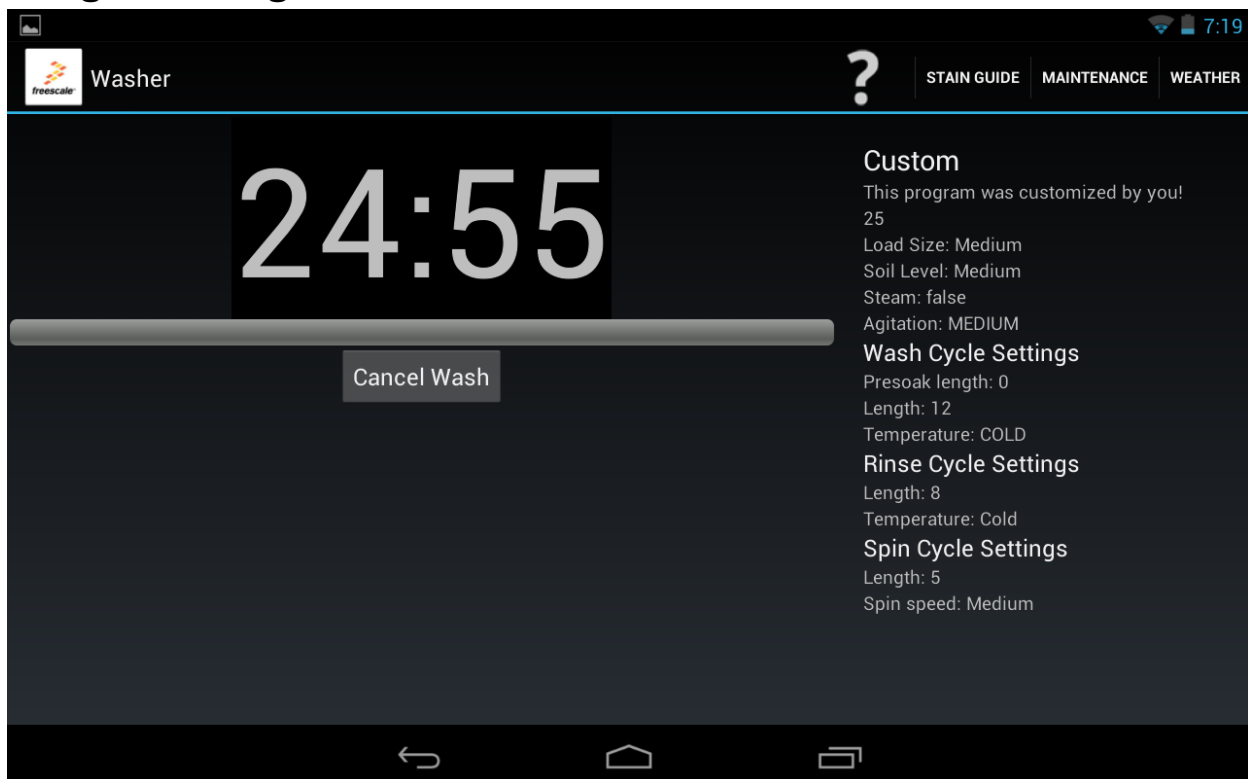
When a wash is started, the progress screen opens and displays the remaining time for the current wash cycle as well as the details of the wash program.

Task Performed

Users had no problems accomplishing the task. The only task for this activity was to cancel the current wash.

Data

Average time to cancel program: 2 sec

HVAC/Thermostat Application

HVAC Home Screen
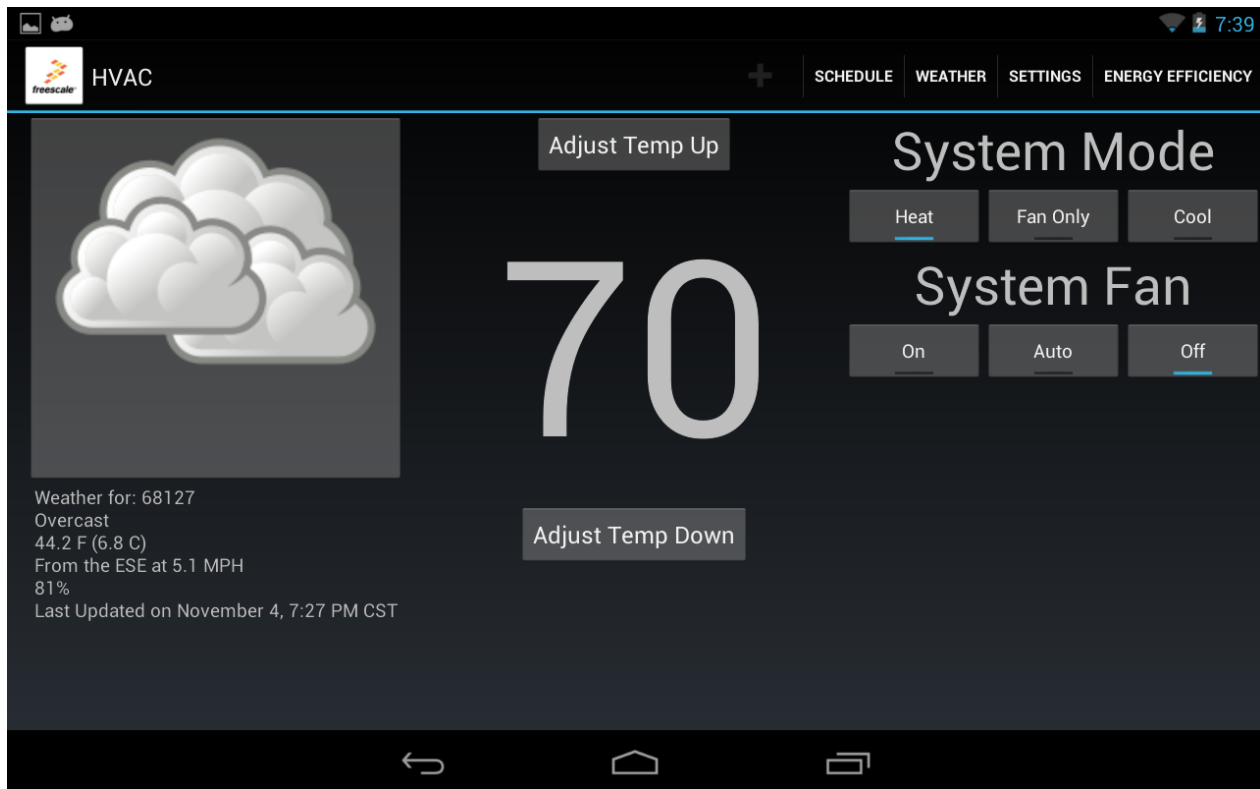
This is the main screen for the HVAC system. It is the screen that initially appears to the user and is the base for many basic functions. The home screen allows the user to view the current temperature, adjust the temperature up or down, check the current weather, set the HVAC system settings to Heat, Fan, or Cool and On, Auto, or Off.

Task Performed

The first task asked of the user was to turn up the thermostat by 5 degrees, turn on the "Heat" and set the fan to "On". This task demanded that the user be able to change basic thermostat settings on the home screen.

Data

Minimum time to change the thermostat and settings: 10
Average time to change the thermostat and settings: 11.5
Maximum time to change the thermostat and settings: 12

Feedback

"up and down arrows would give the thermostat some graphical emphasis"

Improvements

Red up and blue down arrows on temperature adjustment buttons to indicate hotter/colder
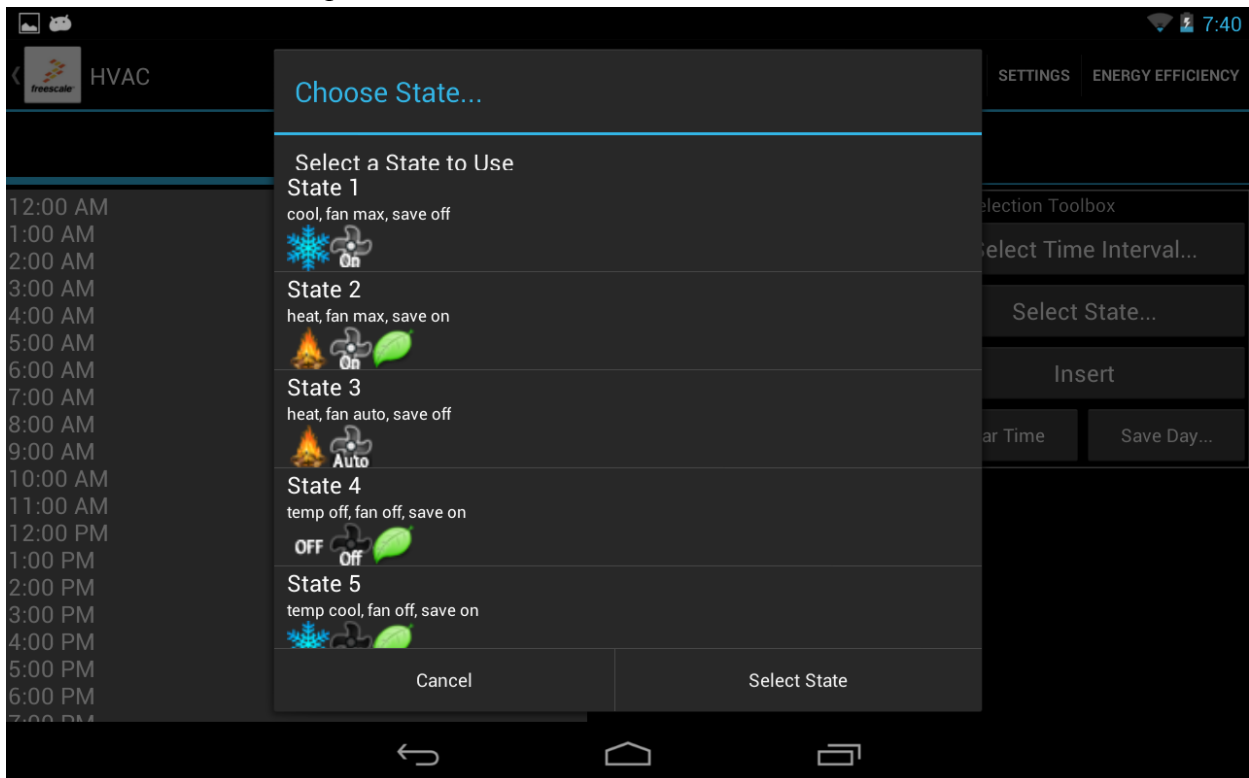Scrollable control for temperature adjustment

Scheduler
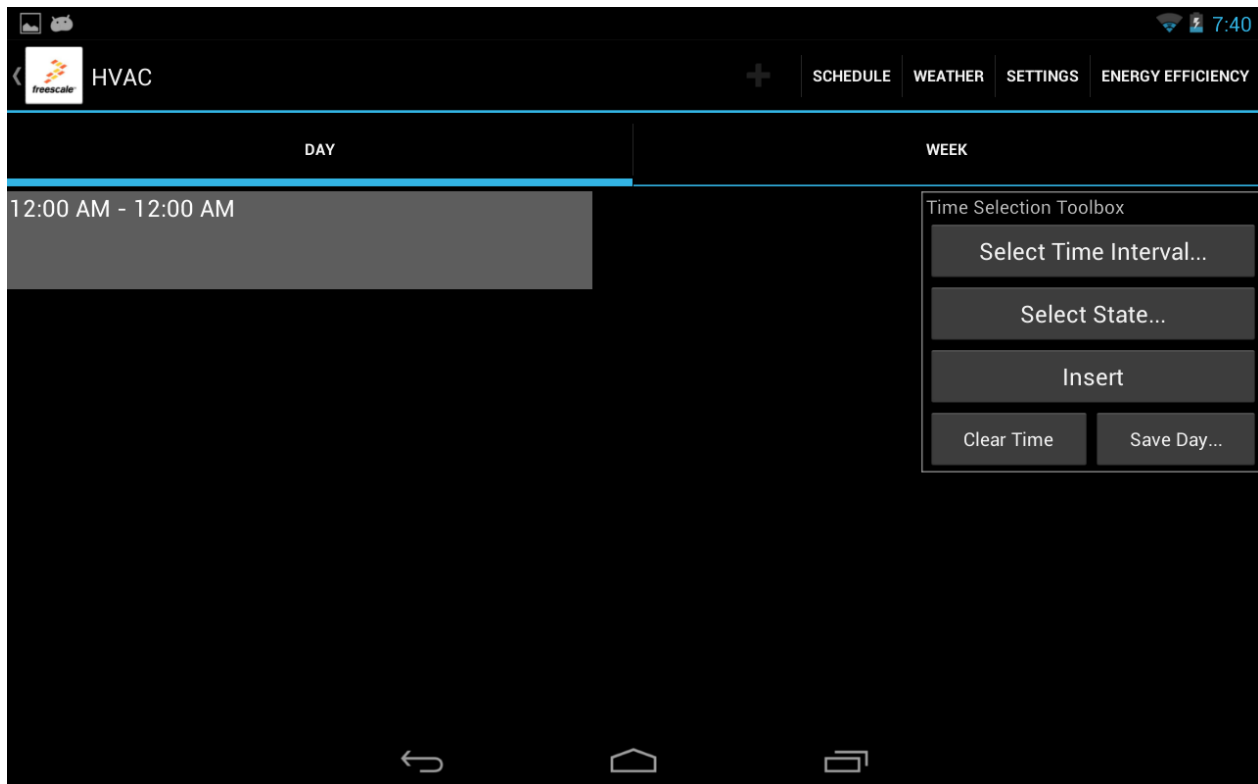
The scheduler is the interface used to program the HVAC. The view above is the first screen the user sees of the Scheduler component.
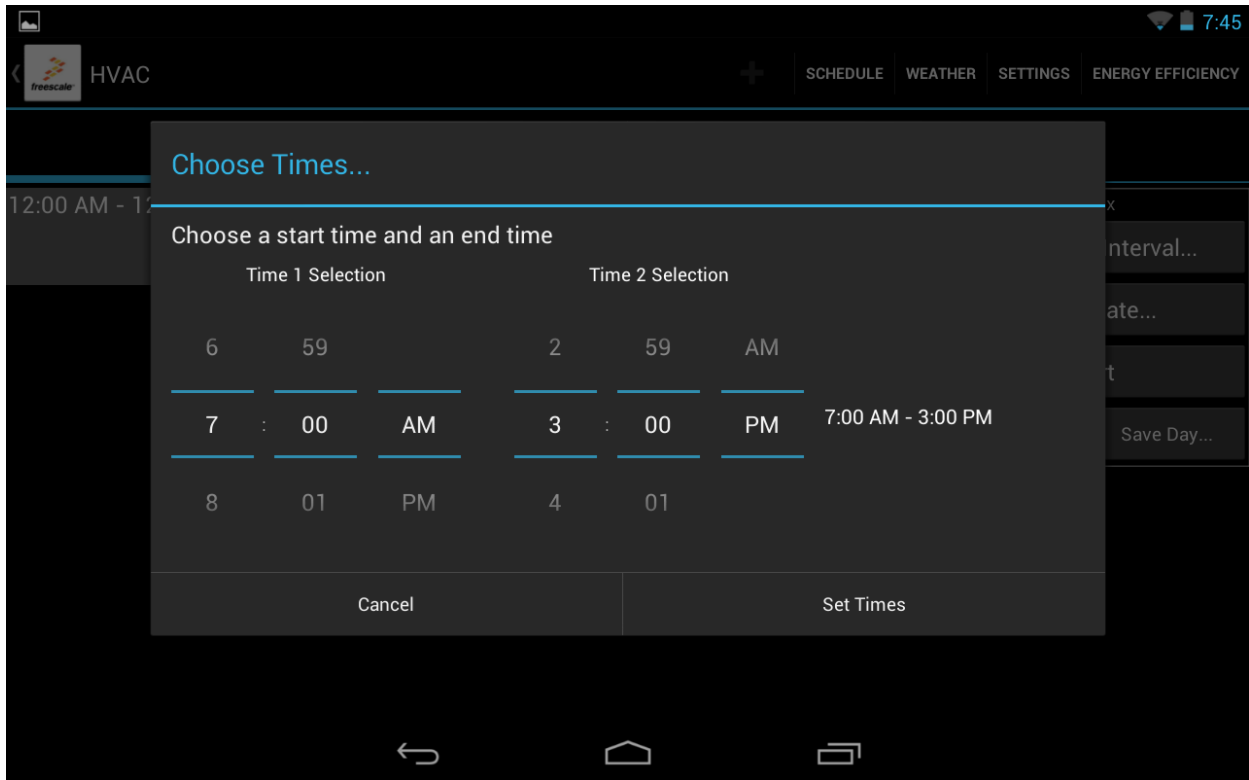
After the user has tapped "Set Time Interval..." the dialog allows them to choose two times that denote an inclusive time period.

On selection of the "Select State..." button, a dialog comes up prompting the user to select which state they would like to use. This state is then linked to the selected time interval.
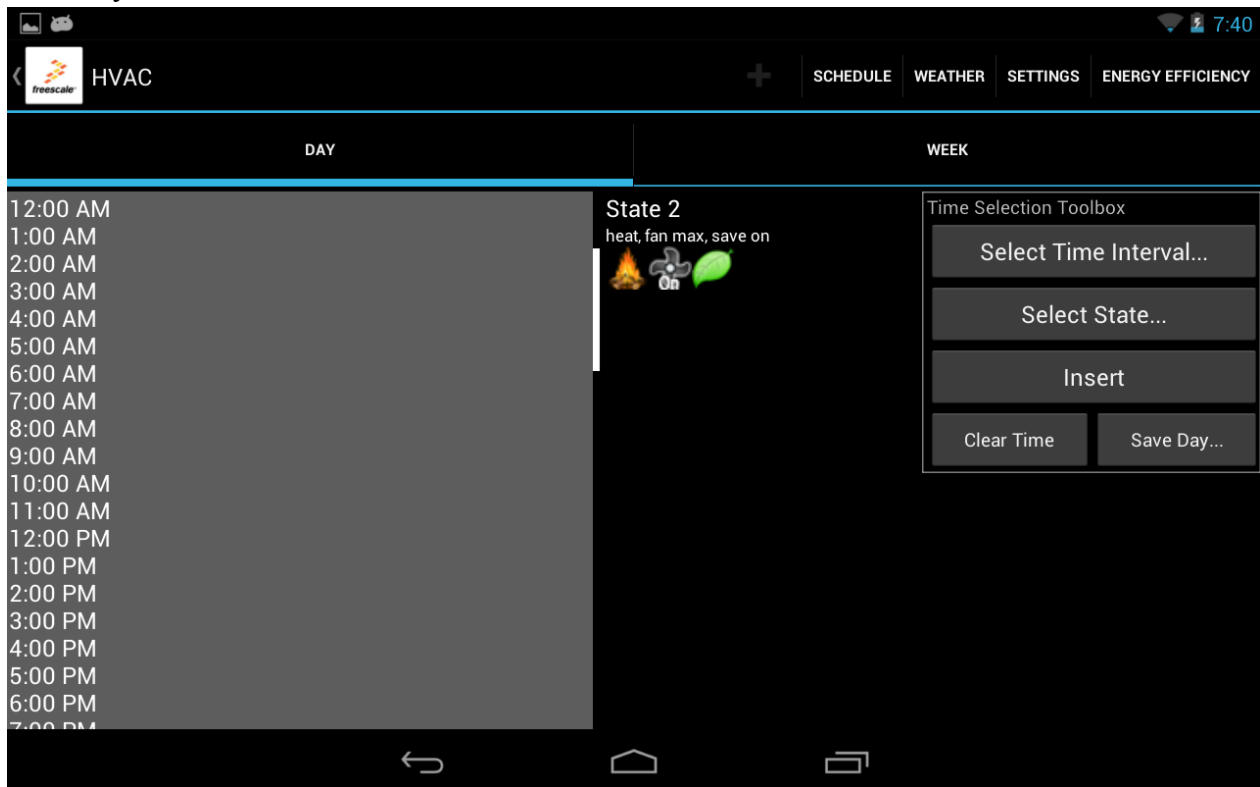
This is the scheduler screen after a time and state have been selected. Note the expanded time view and the state preview to the right of the gray area. When the user "Inserts" the preview, the preview shows up on the top right location in the gray area under the selected time.

Task Performed

This task was certainly the most challenging of the HVAC tasks, asking that the user set the schedule for a day by choosing times and selecting a system state in order to set a 24 hour cycle. Note: This feature was not completely implemented in the first round of testing.

Data

Minimum time for scheduling a day: 1 minute, 45 seconds
Average time for scheduling a day: 4 minutes, 10.5 seconds
Maximum time for scheduling a day: 7 minutes, 45 seconds

Feedback

Most users had never before programmed a thermostat, so the learning curve on this portion of the HVAC application was a bit steeper. Generally, after a period of a few minutes, the test

users figured out the workflow and were able to set the day. Feedback reflects this point, ranging from "I'm confused," before figuring out the system, to "That's not so bad," after exhibiting success.

A user noted, "I like being able to set different temperature settings for different times [of the day]."

Improvements

The biggest improvement the team can make is to finish implementing the functionality we desired. Even so, we received some feedback such as putting the two time pickers in the same dialog, and not attaching both to the main screen. We also will need to redesign or remove components that do not mesh with the final design, such as the white time interval indicator to the right of the gray area.

Energy Efficiency

The energy efficiency screen should allow user to view graphs that display their daily, weekly, monthly and yearly energy usage. However, during the time of testing, this module was nonfunctional.

Settings Menu
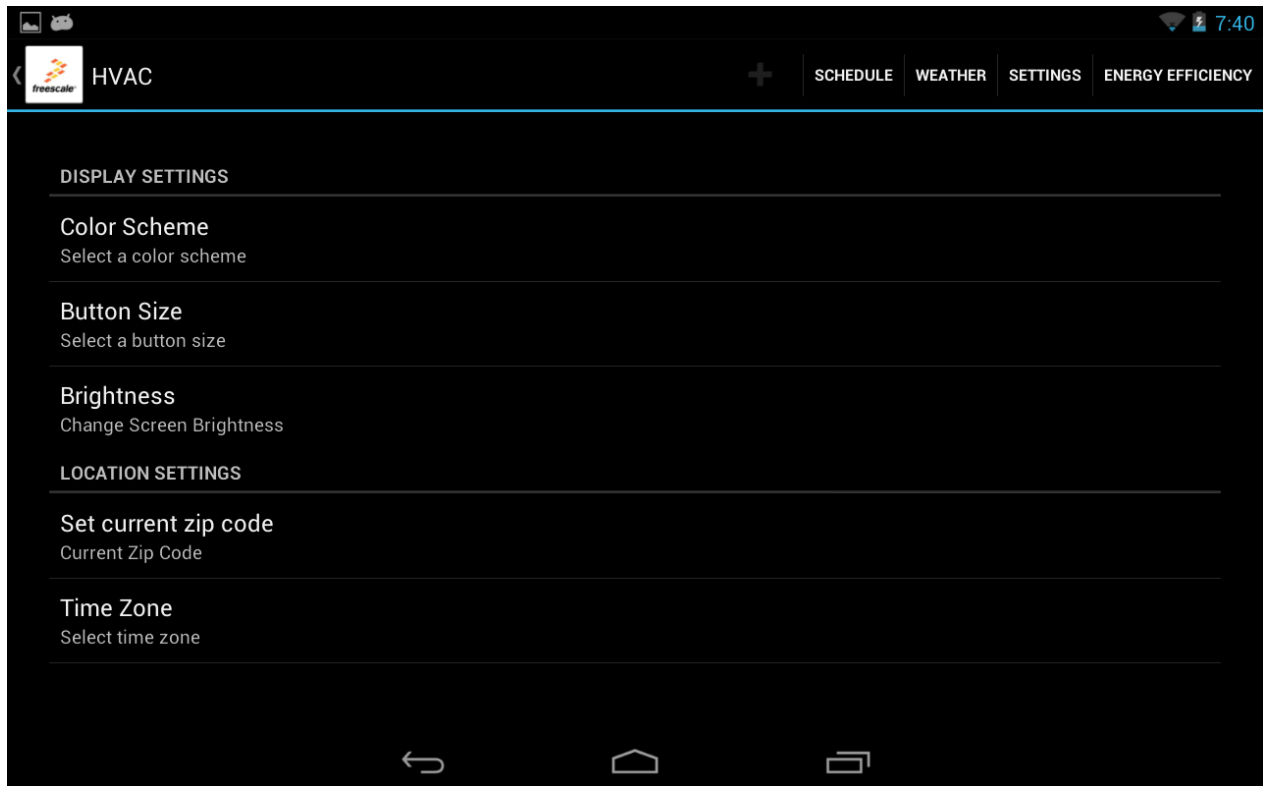
The settings screen allows users to change different settings for the HVAC device.

Task Performed

In the task associated with settings, the user was asked to change the current zip code to their hometown's zip code.

Data

Minimum time to change zip code: 10 seconds
Average time to change zip code: 29.25
Maximum time to change zip code: 1 minute

Feedback

"In the zipcode a number pad would be useful"

Improvements

Change the input keyboard to numeric keypad and highlight text to overwrite.

Task Performed

Finally, the user was asked to return to main screen and refresh the weather. This was to indicate that the zip code had indeed changed and new weather information had been downloaded.

Data

Minimum time: 2 sec
Average time: 15 sec
Maximum time: 30 sec

Feedback

It generally was not clear to users that they could click the weather graphic to refresh the weather on the home screen. Users ended up navigating to the Weather Forecast activity, which, for the purpose of the test, showed that the zip code was properly changed.

Improvements

Add a refresh button to front-page weather.

Overall Analysis

After finishing the testing and analyzing the results, we found that the prototypes were a good first step for intuitive touchscreen controls for appliances. Overall, users were able to complete tasks without much difficulty or confusion. We heard several test subjects say "[I] didn't need detailed directions to figure it out." when referring to the tasks they were instructed to carry out. The applications had features that the users believed the HVAC/thermostat and washing machine should. They also appreciated other non-essential features, such as the weather. While the testing did expose some areas for improvement, they were manageable. Indeed, some of the changes were implemented right away, based on user feedback. These included changes to the overall font size and button and screen labels, as well as modifications to make the modules to be fail-safe. In short, this period of testing gave us insight to users' responses to our prototype.

Graphics

General Image Specifications

Each project (HVAC, Washer) has a separate folder structure, each with a resources folder. All images in the projects are located in the resources folder. Each resources folder has a subdirectory categorized by image sizes, such as low density, high density, and extra high density. Each individual image is a Portable Network Graphics (.png) image with a transparent background. A summary of the project structure is below. The root folder of each project is called "ROOT."

General Project Structure

ROOT/res	General Resources folder
ROOT/res/drawable	Drawable Resources Defined for Android
ROOT/res/drawable-ldpi	Low Resolution Images
ROOT/res/drawable-mdpi	Medium Resolution Images
ROOT/res/drawable-hdpi	High Resolution Images
ROOT/res/drawable-xhdpi	Very High Resolution Images

HVAC Structure

File	Size (W x H) in Pixels
HVAC/res/drawable-ldpi/blank.png	25x25
HVAC/res/drawable-ldpi/campfire.png	25x25
HVAC/res/drawable-ldpi/fan_auto.png	25x25
HVAC/res/drawable-ldpi/fan_off.png	25x25
HVAC/res/drawable-ldpi/fan_on.png	25x25
HVAC/res/drawable-ldpi/ic_action_help.png	18x18

File	Size (W x H) in Pixels
HVAC/res/drawable-ldpi/ic_launcher.png	36x36
HVAC/res/drawable-ldpi/leaf.png	25x25
HVAC/res/drawable-ldpi/snowflake.png	25x27
HVAC/res/drawable-ldpi/temp_off.png	25x25
HVAC/res/drawable-ldpi/weather_clear.png	200x200
HVAC/res/drawable-ldpi/weather_cloudy.png	200x200
HVAC/res/drawable-ldpi/weather_partlycloudy.png	200x200
HVAC/res/drawable-ldpi/weather_rain.png	200x200
HVAC/res/drawable-ldpi/weather_showers.png	200x200
HVAC/res/drawable-ldpi/weather_snow.png	200x200
HVAC/res/drawable-ldpi/weather_storm.png	200x200
HVAC/res/drawable-xhdpi/decrease_arrow.png	150x66
HVAC/res/drawable-xhdpi/increase_arrow.png	150x66

(ROOT = HVAC)

Washer Structure

File	Size (W x H) in Pixels
Washer/res/drawable/ic_menu_search.png	64x64
Washer/res/drawable-xhpdi/dial.png	800x800
Washer/res/drawable-ldpi/weather_clear.png	200x200
Washer/res/drawable-ldpi/weather_cloudy.png	200x200
Washer/res/drawable-ldpi/weather_partlycloudy.png	200x200
Washer/res/drawable-ldpi/weather_rain.png	200x200
Washer/res/drawable-ldpi/weather_showers.png	200x200

Washer/res/drawable-ldpi/weather_snow.png	200x200
Washer/res/drawable-ldpi/weather_storm.png	200x200

(ROOT = Washer)

Application Installation

Application Download

https://github.com/downloads/broccolibird/Washer/Washer.apk

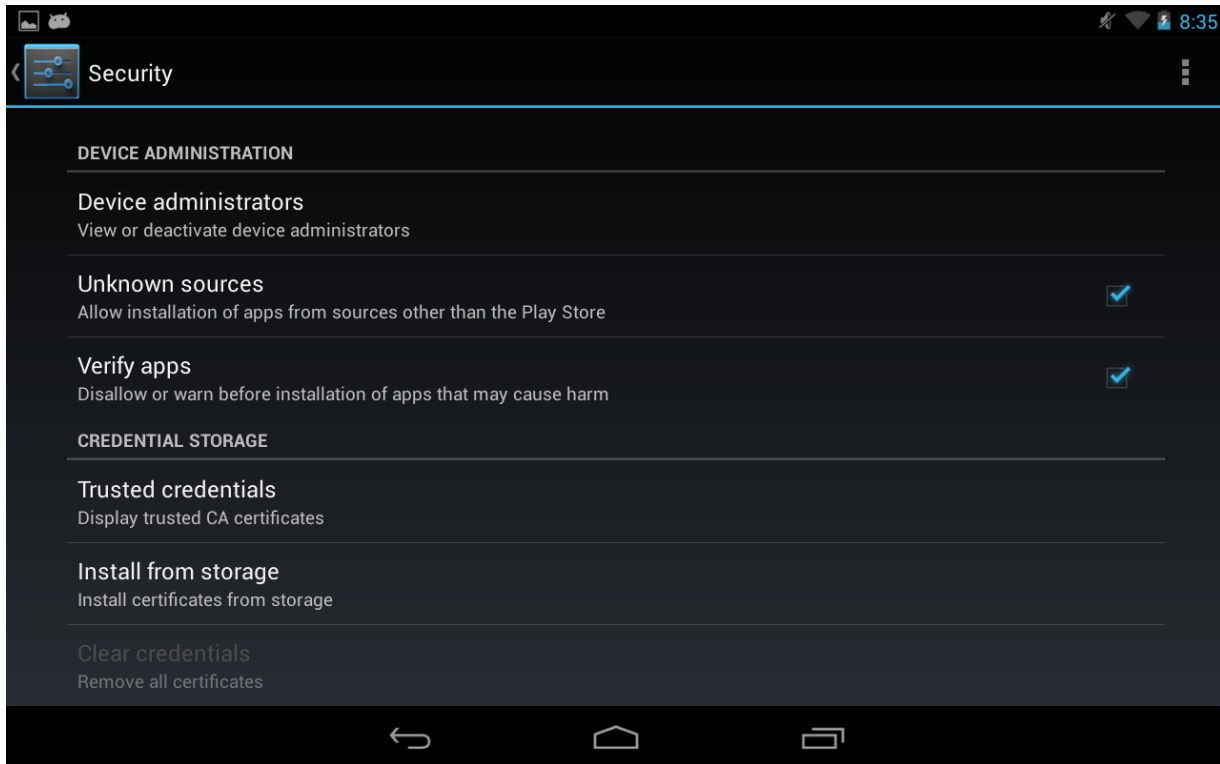https://github.com/downloads/broccolibird/HVAC/HVAC.apk

Install on Tablet

1. Enable installation from Unknown Sources
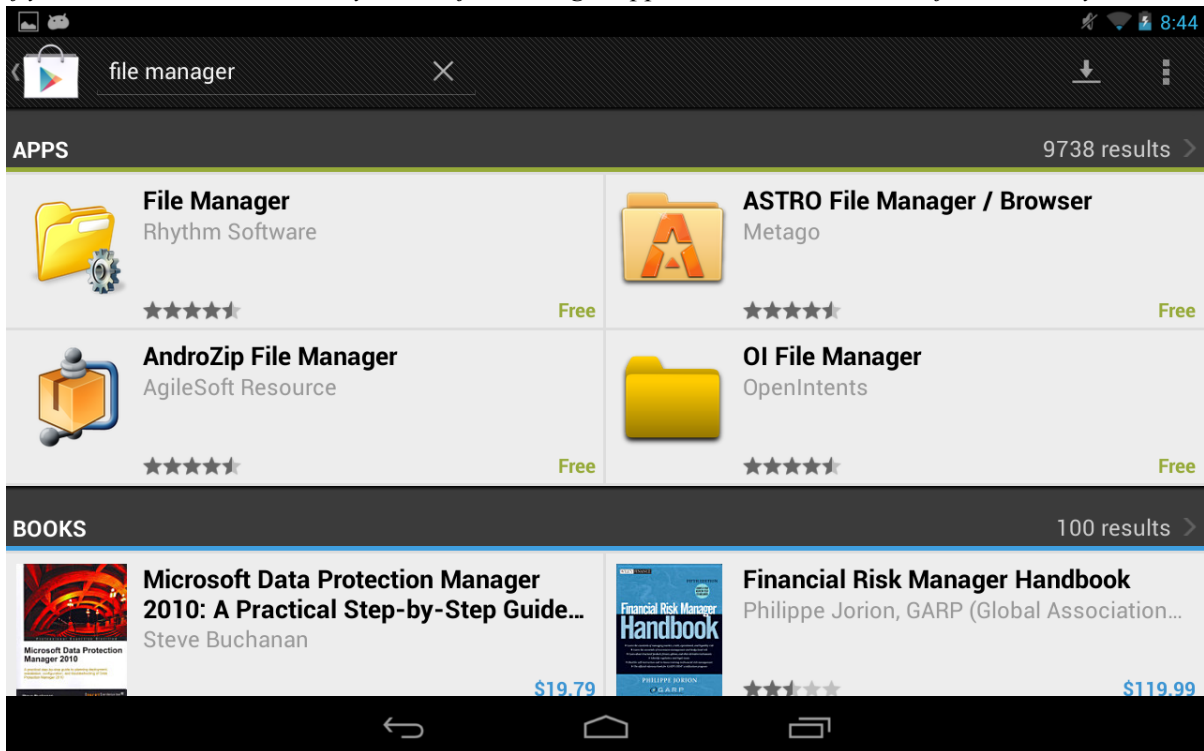 ● Open the settings on your device and select *Security*.
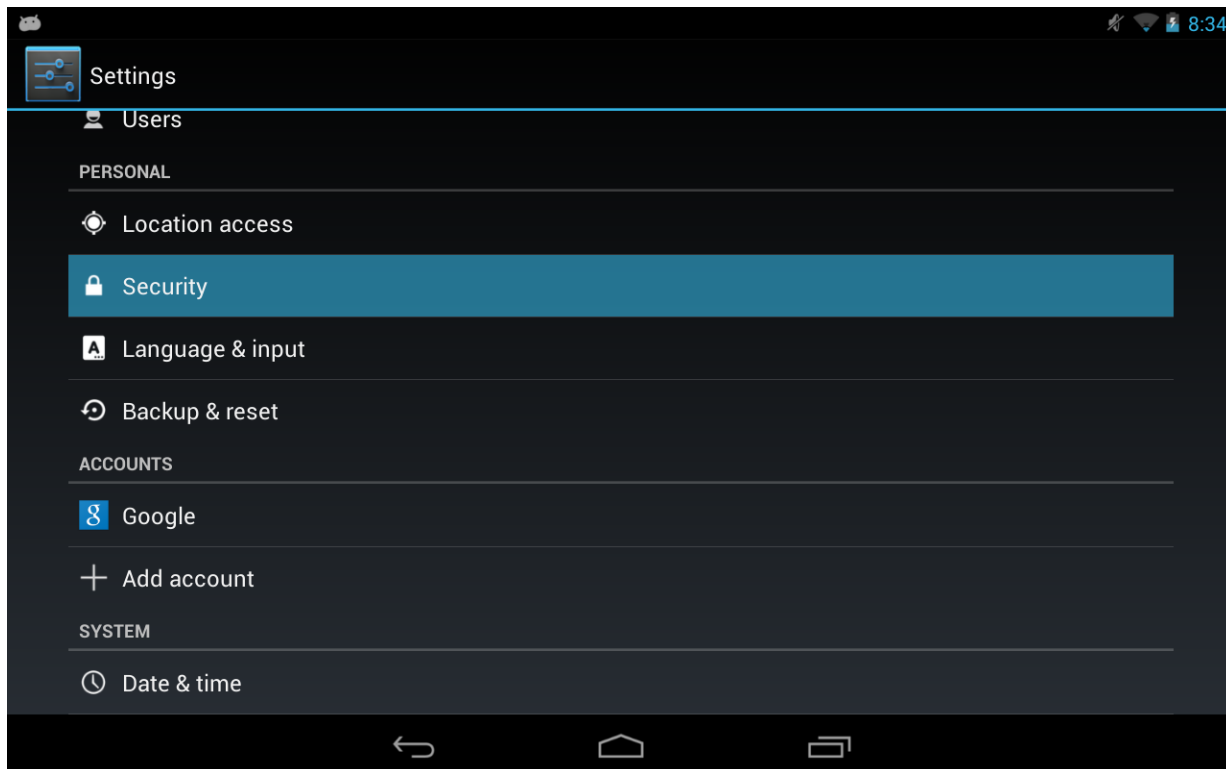
  ● Once in security, select the check mark next to *Unknown sources*. You will be prompted
    with a security warning, select OK.

- Your device is now ready to load and install the application.

2. Download File Manager

If your device does not already have a file manager application, download one from the Play Store.

● We chose to install a program called File Manager by Rhythm Software.
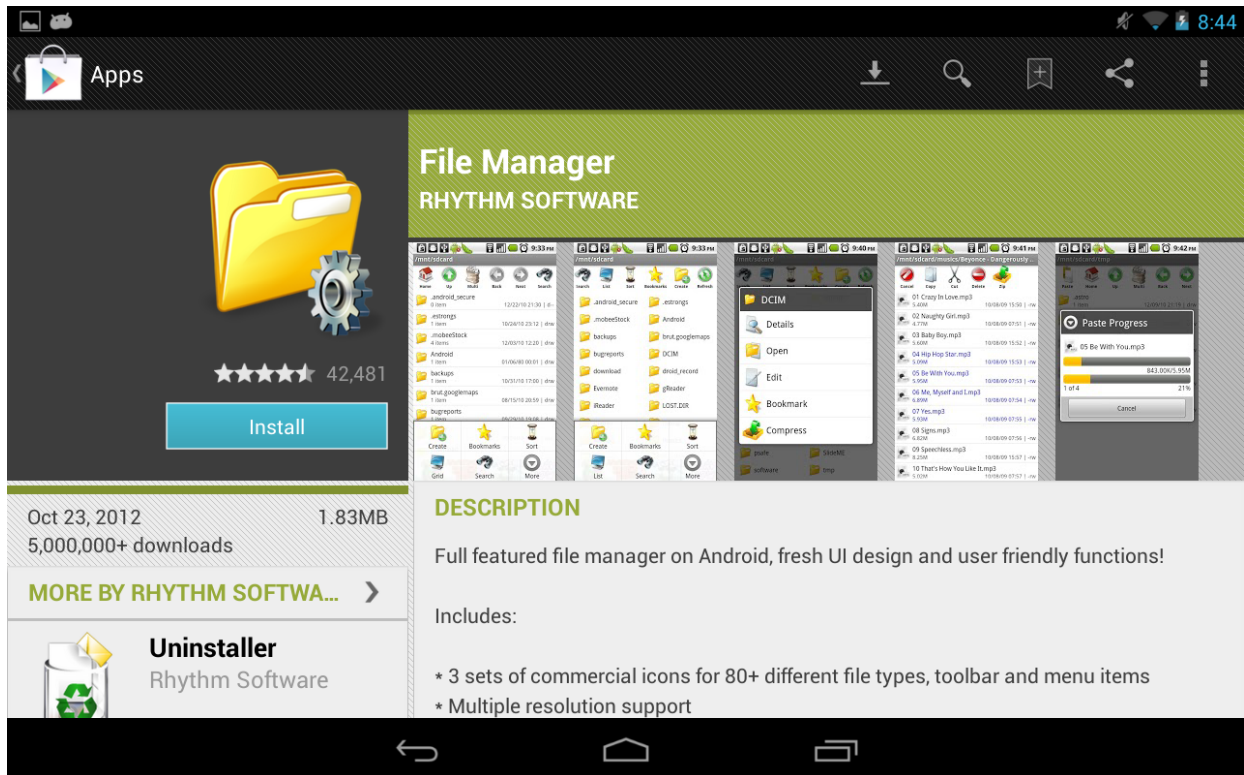

● Download and Install the file manager application.

3. Copy the APK File to the Device
● Connect the device to your computer using the USB cord.

● Open the device's files and navigate to the location you would like to store your APK file. (We used the DCIM folder, but you might choose the Download folder.)

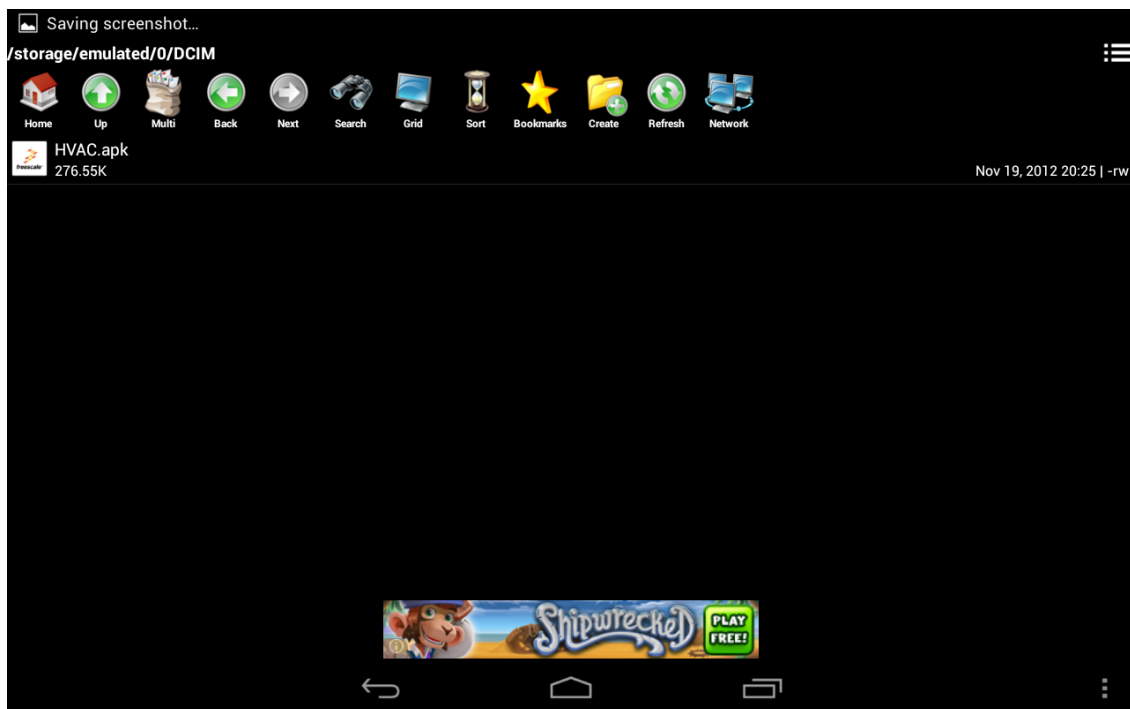● Copy the APK file from your file system to the device's file system.
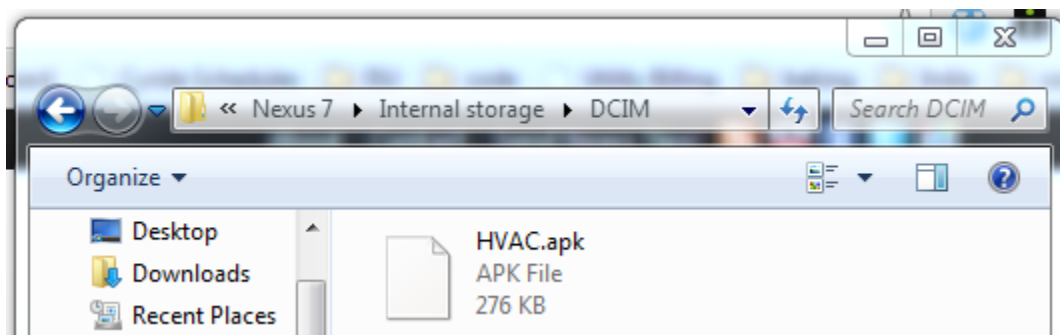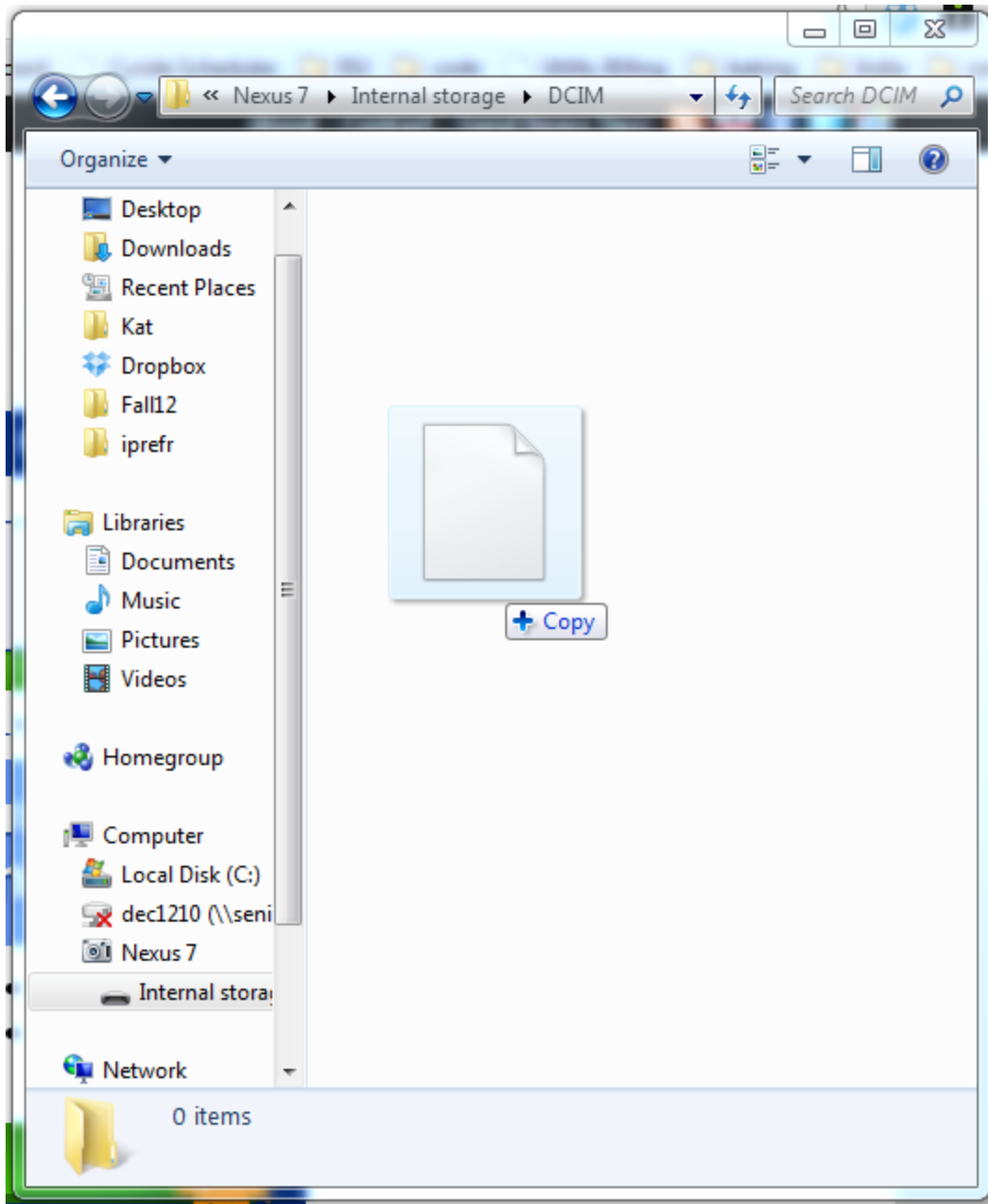
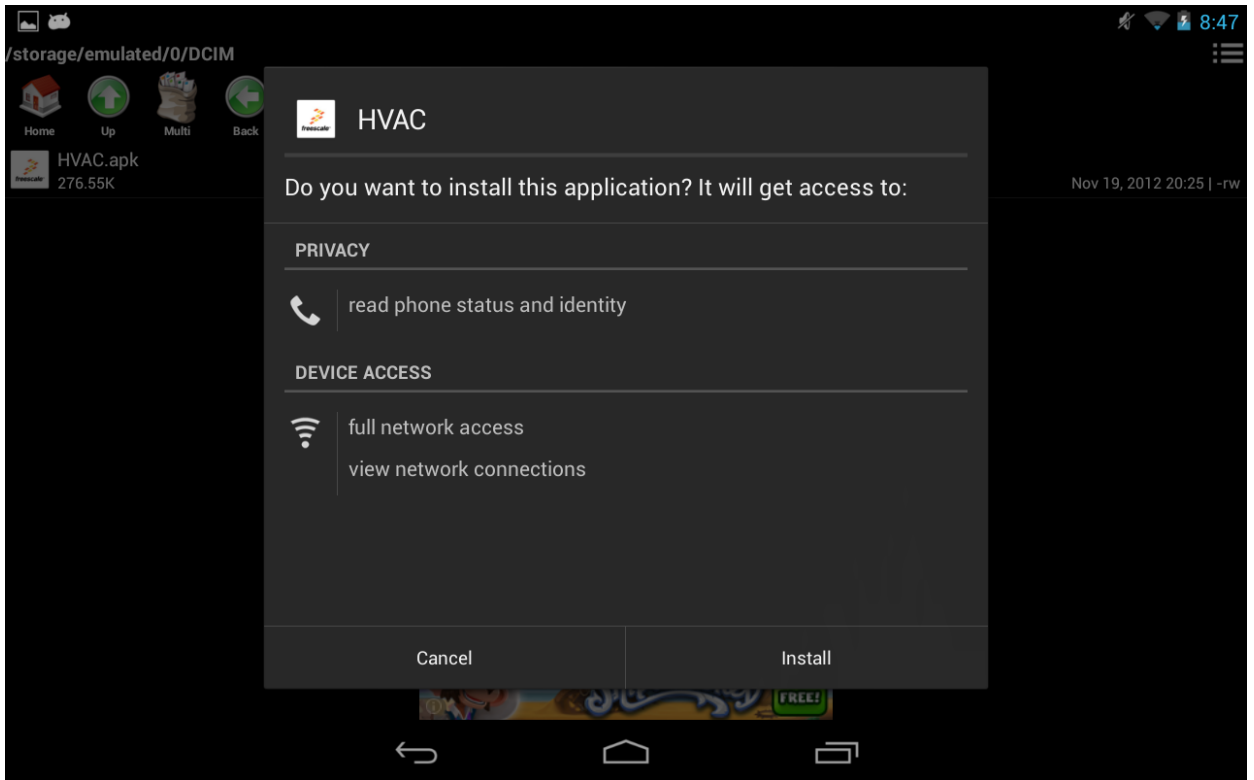## 4. Install the Application on the Device
- On the device, open the file manager application you downloaded.
- Navigate to the location of the APK File (in our case this will be the DCIM folder).
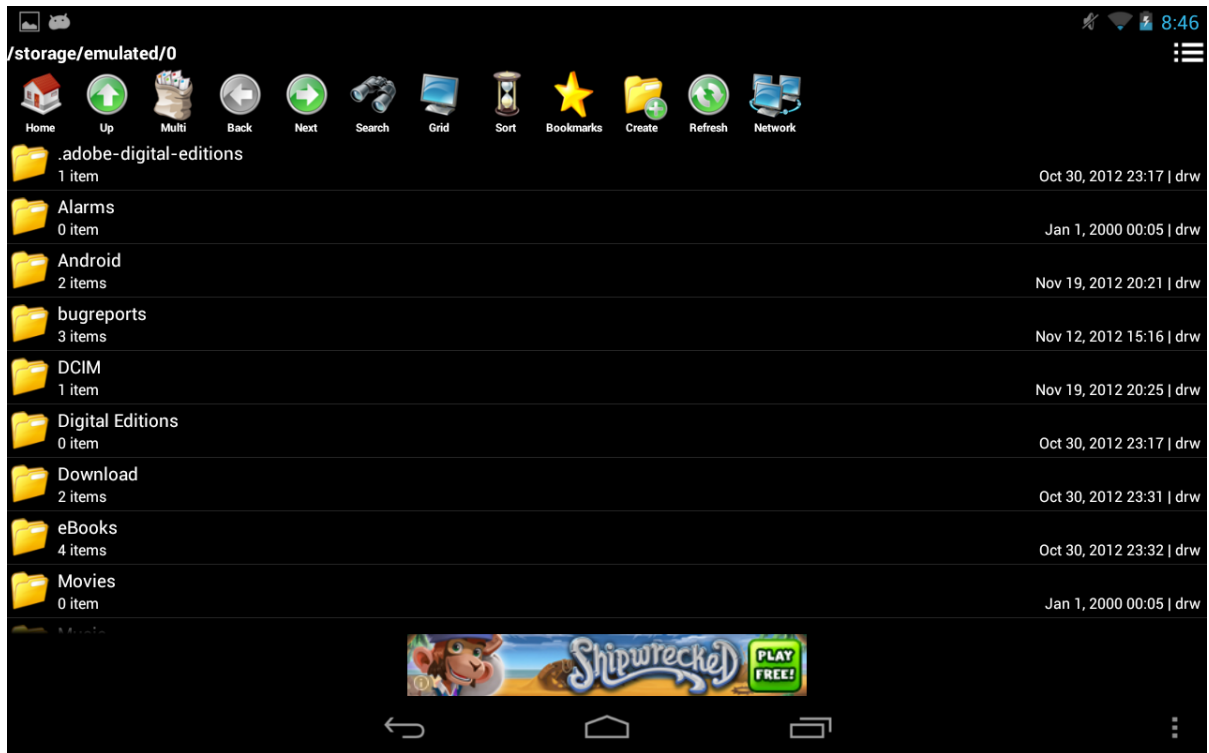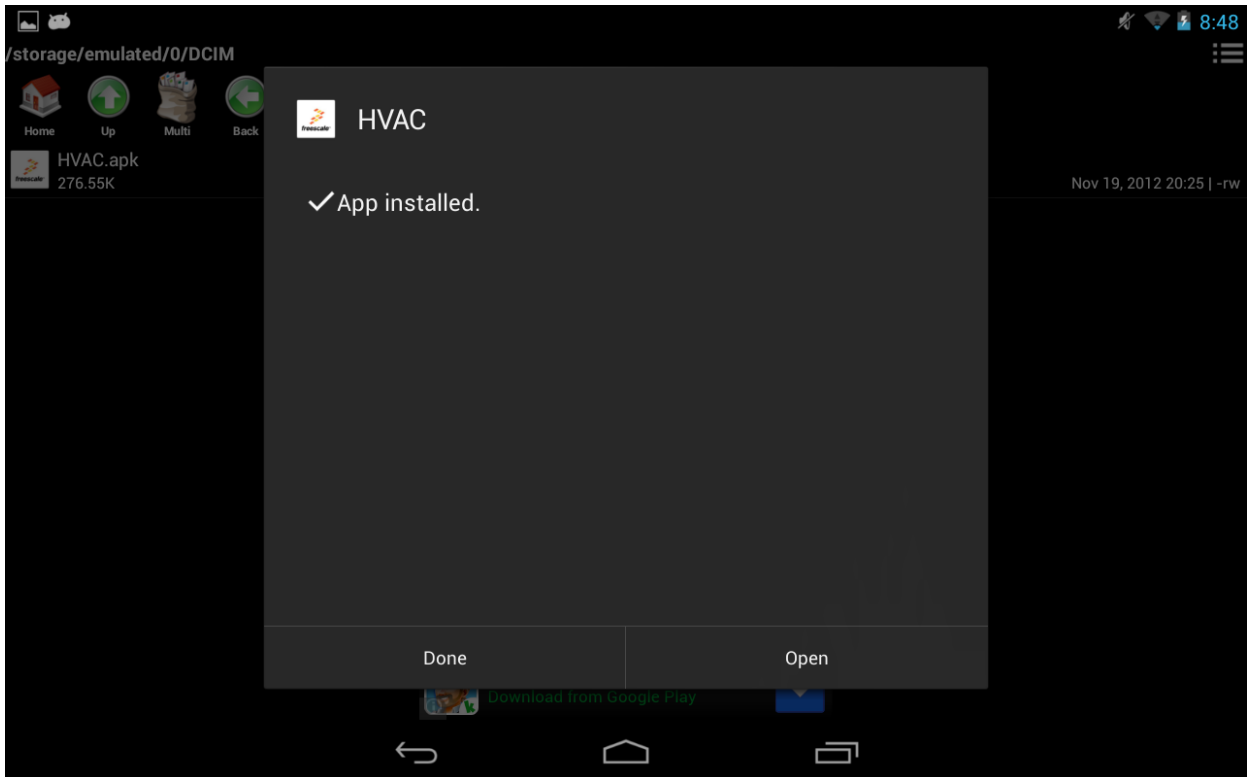

- Select the file

- The device will ask you if you would like to install the application, select Install.

- After the application is installed, you may choose to open it.

- You can also open the application by selecting the icon from the Apps Menu.