A Mobile Field Diary System for Infrastructure Construction Project Inspections

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ABSTRACT

We present our design and on-going implementation effort of a Mobile Field Diary System, to be used by infrastructure construction inspectors. The central goal of the project is to design a powerful mobile analysis and reporting tool for construction inspectors to use on the field, as they inspect and supervise activities performed on a daily basis by contractors and subcontractors of infrastructure construction projects. The development platform is any mobile telephone running the Android operating system. The project is being developed by a group of undergraduate students at the University of Florida, under our IPPD (Integrated Product and Process Design) program, a highly successsful University-Industry Cooperation program. Our project is sponsored by InfoTech, Inc. a Gainesville high-technology company. We describe the current status of the design and software/hardware that has been produced, and describe the educational program (IPPD) under which they have been developed.

Keywords: infrastructure construction, mobile application, Android

1. INTRODUCTION

The author's IPPD project [1] this year at the University of Florida consists developing a Mobile Field Diary System for our sponsor company, InfoTech, Inc. [2]. Info Tech is a leading provider of software solutions for the infrastructure construction management industry. Info Tech's products and services are used by dozens of US state transportation agencies, engineering firms, and contractors. The company's products range from web services to desktop applications, but Info Tech has not yet expanded to the mobile platform. There are potential advantages to utilizing mobile technology in the construction management industry, as inspectors and contractors are frequently on-site and therefore have limited access to a dedicated PC. To remedy this problem, Info Tech wishes to capitalize on the prevalence of mobile technology and create a field diary application for the Android [3] platform. This tool could be accessed by inspectors at any time, providing a more convenient method of reporting construction data. Mobile devices offer several additional benefits, such as the ability to take pictures, shoot videos, and record audio clips, all of which are potentially useful to construction inspectors. The Android platform offers a unique opportunity with its Open Accessory Protocol [4], which enables developers to create hardware devices which can interact with the phone or tablet. Such devices could be used to record temperature, humidity, and other relevant data on-site, providing inspectors with highly accurate measurements.

To capitalize on these opportunities, Info Tech initiated the Mobile Field Diary project. The primary objectives of the project are as follows:

- Design a field diary mobile application for construction inspectors
- Provide access to useful smartphone features, like the camera and GPS
- Develop a hardware accessory to automate certain measurements
- Integrate seamlessly with Info Tech's existing systems

To achieve these objectives, the project team has designed an Android application, the Mobile Field Diary, that allows inspectors to view, create, and modify daily reports from a smartphone. The application provides inspectors with easy access to the phone's built-in camera, effectively streamlining the process of taking photos on the job site. The application is compatible with the recently announced Android Open Accessory protocol. The team has developed a hardware accessory to monitor weather data on-site. This data can be transferred to the mobile app via a USB connection. Ultimately, the application will be integrated with Info Tech's existing systems through a software backend running on the company's servers. The phone will pull project data from the cloud and synchronize report data as it is entered. The application will keep a local copy of all relevant data as well, allowing the inspector to use the app even when there is no service available.

2. SYSTEM OVERVIEW

The Mobile Field Diary system is divided into three major components: the Mobile Field Diary application for Android, an external hardware accessory, and a server-based backend system.
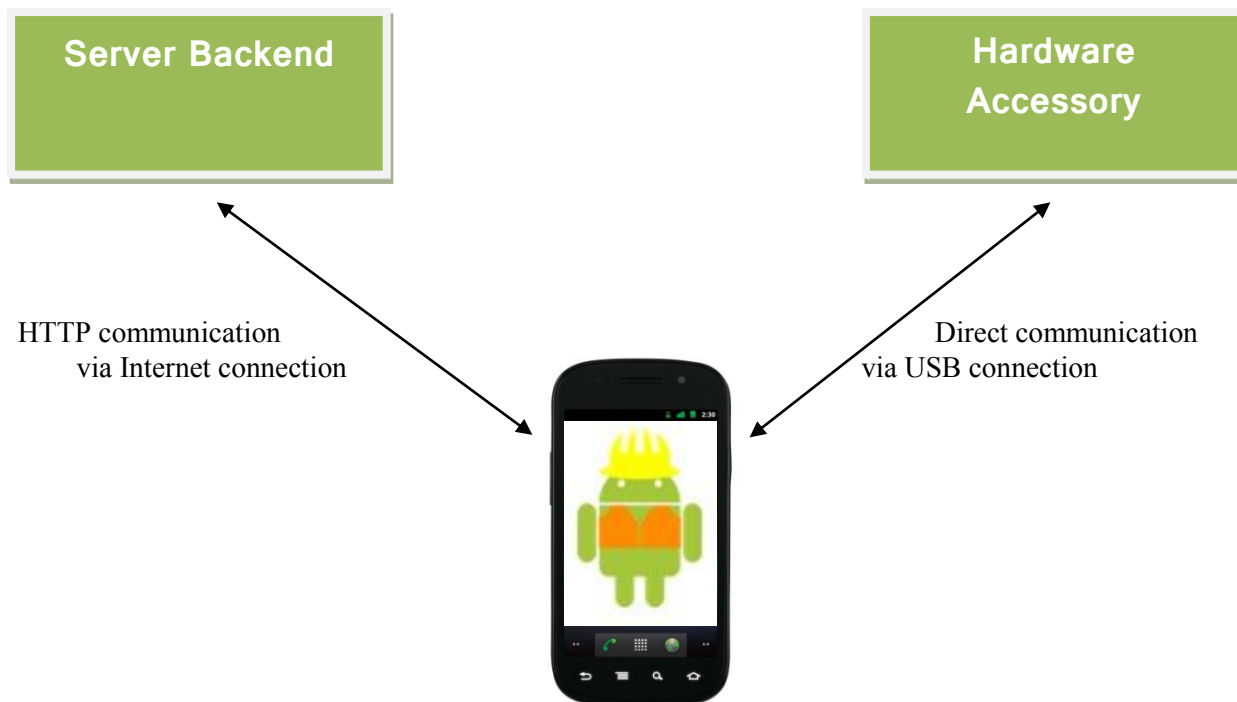

Figure 1 - System Architecture

Figure 1 shows the three primary components of the system. Their roles and interactions within the system are enumerated below.

- The Mobile Field Diary application (pictured above as the Android phone) forms the core of the system. It is the primary source of data input for the entire system, and it is the main component that the user interacts with. The application allows inspectors to record and store daily reports for construction projects. The application can communicate with the server backend by sending and receiving HTTP messages over a wireless internet connection. To communicate with the hardware accessory, however, the device must be wired via USB.

- The hardware accessory automates on-site temperature and humidity measurements, which are normally taken manually by an inspector. The device interacts with the application via Android's Open Accessory interface, which utilizes USB as its communication medium.

- The server backend complements and extends the functionality of the main application by providing real-time synchronization. In other words, project data stored on the server is also available to the mobile application. In addition, the application automatically uploads daily reports as they are recorded. This enables inspectors to access their reports from any other internet-enabled device.

By analyzing various examples of inspector reports, the team determined several commonalities and extracted a generic report model.
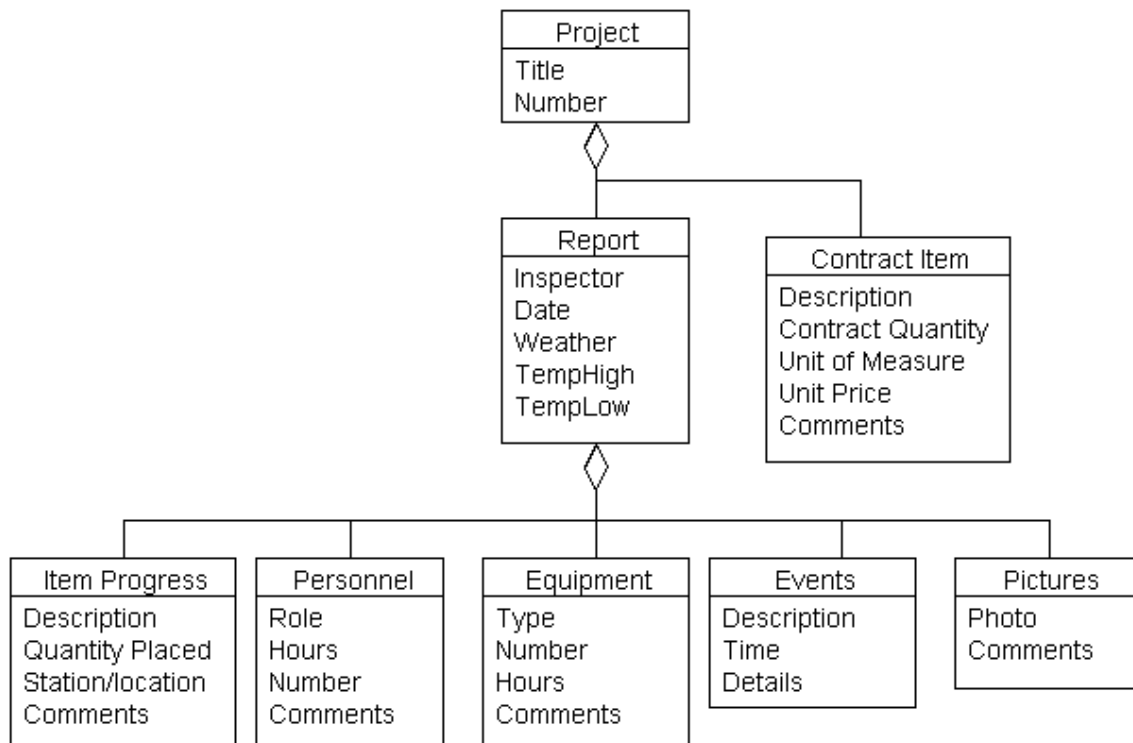

Figure 2 – Data Model

Figure 2 describes the hierarchical structure of project and report data. The top-level entity is the project, which contains a series of daily reports as well as a list of contract items. Each report is broken up into several sections: pictures, personnel, equipment, item progress, and events. Each entity and its associated subsections are explained below.

Projects

A project is the highest-level entity of the daily report system. It represents a real-world project, such as a road renovation or building construction project. Each project has a corresponding contract which contains details and specifications about the project. One of the main roles of the contract is to define what job items will be used throughout the life of the project. Job items include any required construction supplies as well as the associated labor. These items are represented in Figure 1 by the "Item" sub-entity of "Project". Part of an inspector's job is

to ensure that items arriving on the job site match what is listed in the contract. This and several other duties form the central subject of daily reports.

Contract Items

As explained above, contract items define what items (supplies and labor) will be consumed throughout the life of a project, and what quantity is expected. Below is a description of each attribute of the contract item entity.

- Description – a word or phrase describing the item, e.g. "Copper Pipe"
- Contract Quantity – the total quantity that will be used in the project
- Unit of Measure – the standard unit of quantity, e.g. "linear feet"
- Unit Price – the price paid per unit quantity
- Comments – any additional information the inspector wishes to add

Daily Report

The daily report is a deliverable produced by inspectors as they survey different aspects of a project on site.

- Inspector – the name of the inspector recording the report
- Date – the date that the report is taken
- Weather – a general description of weather conditions, e.g. "sunny, clear"
- High/Low Temperature – the highest/lowest temperatures recorded on site

Item Progress

As job items arrive on site and labor is performed, inspectors must acknowledge these events so they can later be compared to what is listed on the contract.

- Description – a word or phrase describing the item, e.g. "Copper Pipe"
- Quantity Placed – the total quantity that arrived on the job site
- Unit of Measure – the standard unit of quantity, e.g. "linear feet"
- Station/location – the site location where the item was used
- Comments – any additional information the inspector wishes to add

Personnel

Another aspect of a project that must be tracked is personnel on site. Inspectors must ensure that contractors are performing work in a manner that corresponds with what is listed in the contract.

- Role – the function of the personnel, e.g. "Painter"
- Hours – the number of hours the personnel were on site
- Number – the total number of people
- Comments – any other information the inspector finds relevant

Equipment

Equipment such as bulldozers and cranes must be tracked in a manner similar to personnel on site.

- Type – a description of the equipment, e.g. "backhoe"
- Number – the number of units present
- Hours – the total hours the equipment was active
- Comments – any other information the inspector finds relevant

Events

When exceptional events such as adverse weather conditions or accidents occur on the job site, the inspector must record them in the daily report.

- Description – brief details about the event, e.g. "minor flooding"
- Time – a time or range of time that the event occurred
- Details – any additional information the inspector wishes to add

Pictures

Inspectors often need to take photographs on the job site and attach them to reports. These pictures are often accompanied by comments from the inspector.

3. SOFTWARE DEVELOPMENT METHODOLOGY

After careful consideration during the early phases of the project, and considering the needs of the sponsor, we chose the scrum software development methodology [5,6]. In this methodology, a certain number of points (vaguely equivalent to man-hours) are allocated/budgeted to various activities begin carried out, as part of a "scrum sprint". A sprint is a planned short-term development effort to produce a working version of the software containing new features and/or functionality. During the academic year allocated to this project, we plan to carry out a total of 6 scrum sprints, each lasting 3 weeks. One of the most important and useful tools used in the scrum methodology is the burndown chart, which graphically displays two curves over time: the actual reduction of points remaining as the work progresses, and the ideal straight-line burn function. The graphical superimposition of these two curves is useful to detect, early, a project falling behind its schedule, or changes in programmer productivity, or simply tasks for which the amount of work was underestimated.
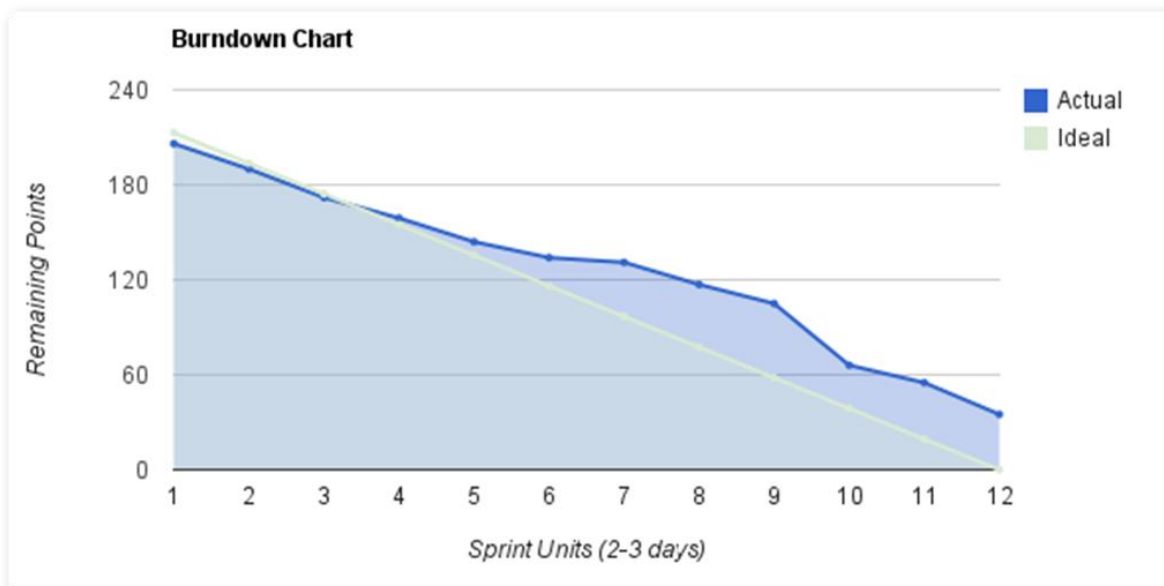

Figure 3 – A Sprint Burndown Chart

Figure 3 shows one of our actual burndown charts, after completing the sprint. The graph maps the estimated work remaining (in points) on the y-axis against sprint units on the x-axis. This particular sprint, which ended in December 2011, shows that progress remained steady for a majority of the sprint, but the team failed to account for Thanksgiving break, which spanned from November 22 to the 27th. This is clearly reflected in the chart by

sprint units 6 through 8, which mark the start and end of the break. The team learned from this, and has been bale to more effectively plan sprints since then.

4. **SOFTWARE ARCHITECTURE**

The Mobile Field Diary application is organized in a Model View Controller (MVC) architecture, in which the structure of the application is broken down into three main components:

- The *model*, which manages and manipulates data
- The *view*, which renders the user interface
- The *controller*, which receives user input and directs the model and view

The purpose of this architecture, as shown in Figure 4, is to isolate the user interface from the application logic, allowing the two components to be developed and tested separately.
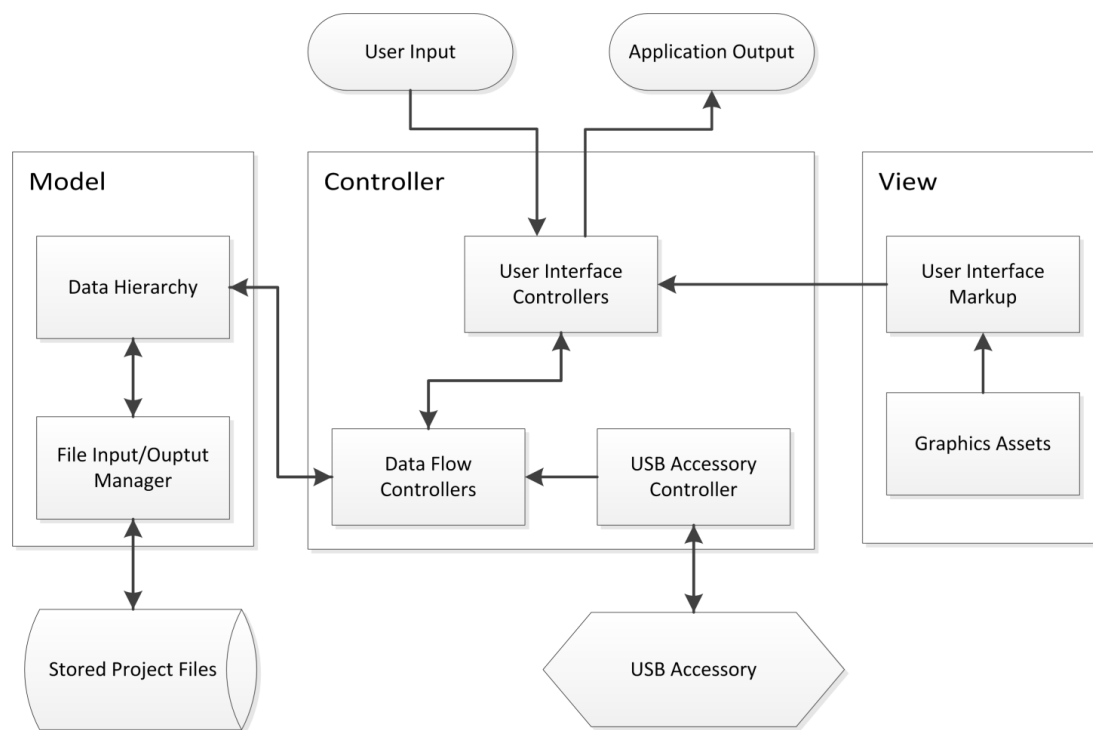
Figure 4 - Software Architecture

5. **GRAPHICAL USER INTERFACE**

In this section we show the various screenshots of the Mobile Field Diary's Graphical User Interface.
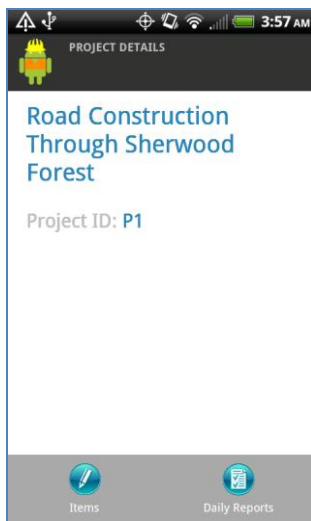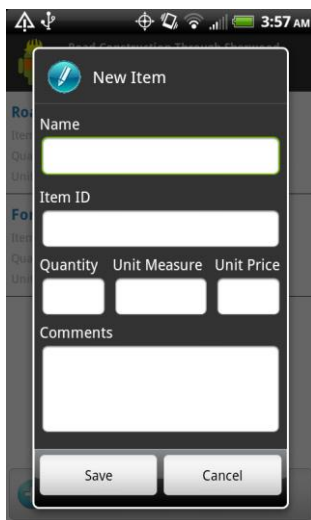
Main Screen
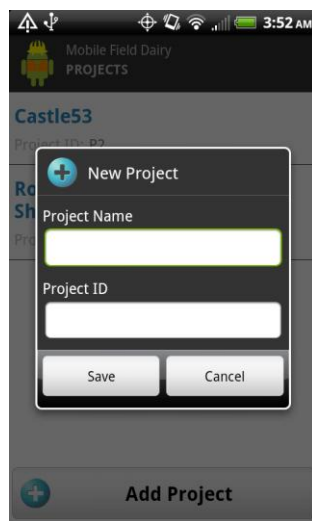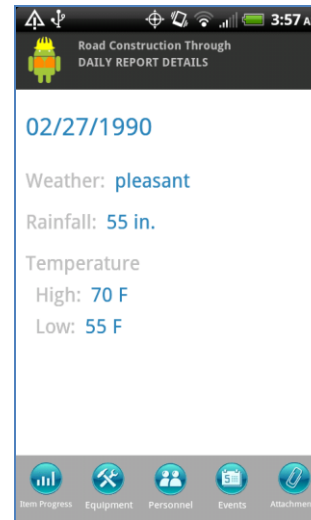

Adding a New Project
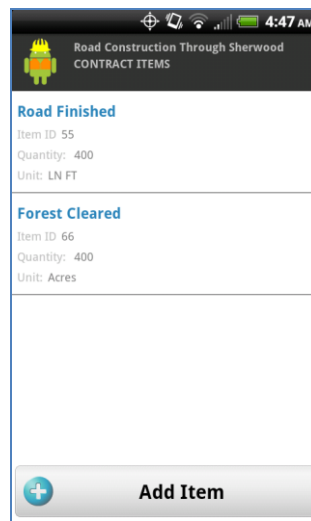
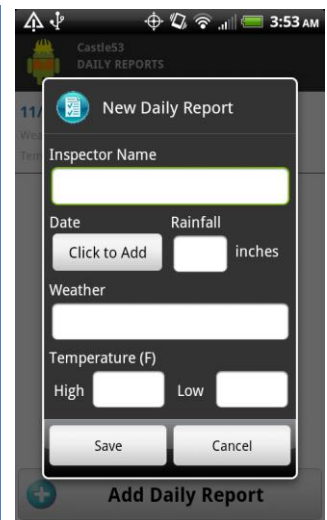Contract Items List
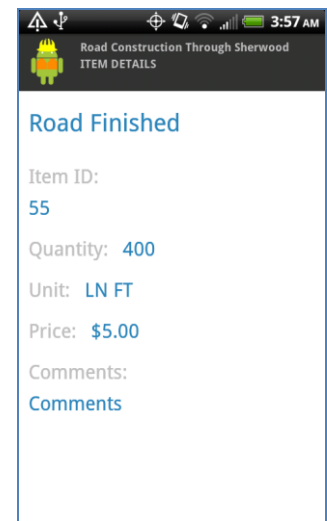
Items Details Screen
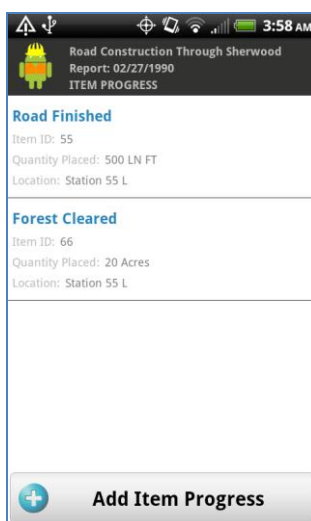

Adding a new item

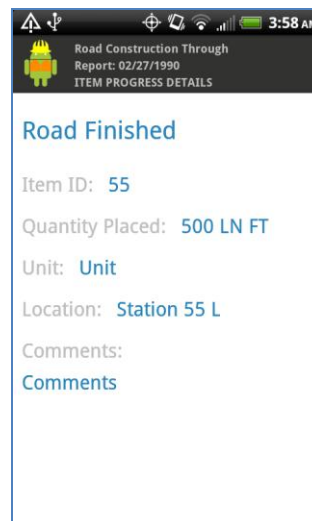
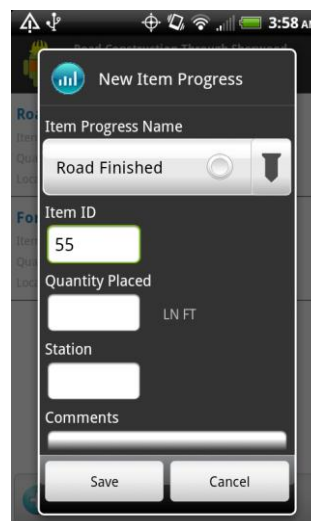Daily Reports List

Daily Report Details
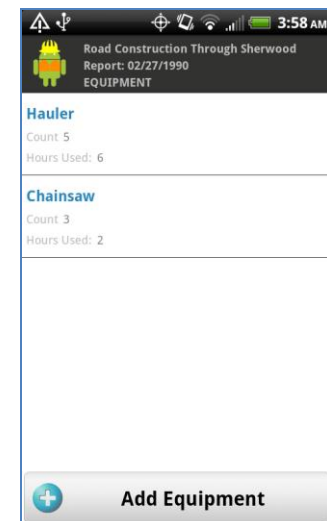

Add a New Daily Report

Item Progress List Screen

Item Progress Details

Add New Progress Item

Add Equipment

Equipment Information

Add New Equipment

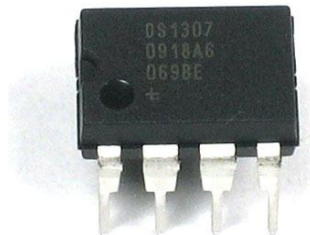Personnel List
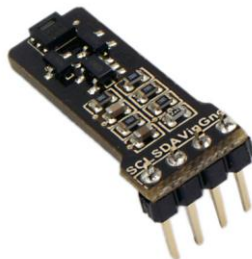

Personnel Details

Add New Personnel

Event List Screen

Event Details Screen

Add a New Event

6. **THE HARDWARE ACCESORY**

As part of this project, a hardware accesory has been designed and constructed, to detect temperature and humidity at a construction site, and transmit this data to the Android phone via a USB port.

As shown above, the hardware accesory consists of an Arduino MEGA ADK develeopment board [7], a SHT21 temperature/humidity sensor [8], a DS1307 clock chip mini-board [9], and a battery pack. These components have been asesembled and tested. The microcontroller state flow chart is shown in Figure 5.
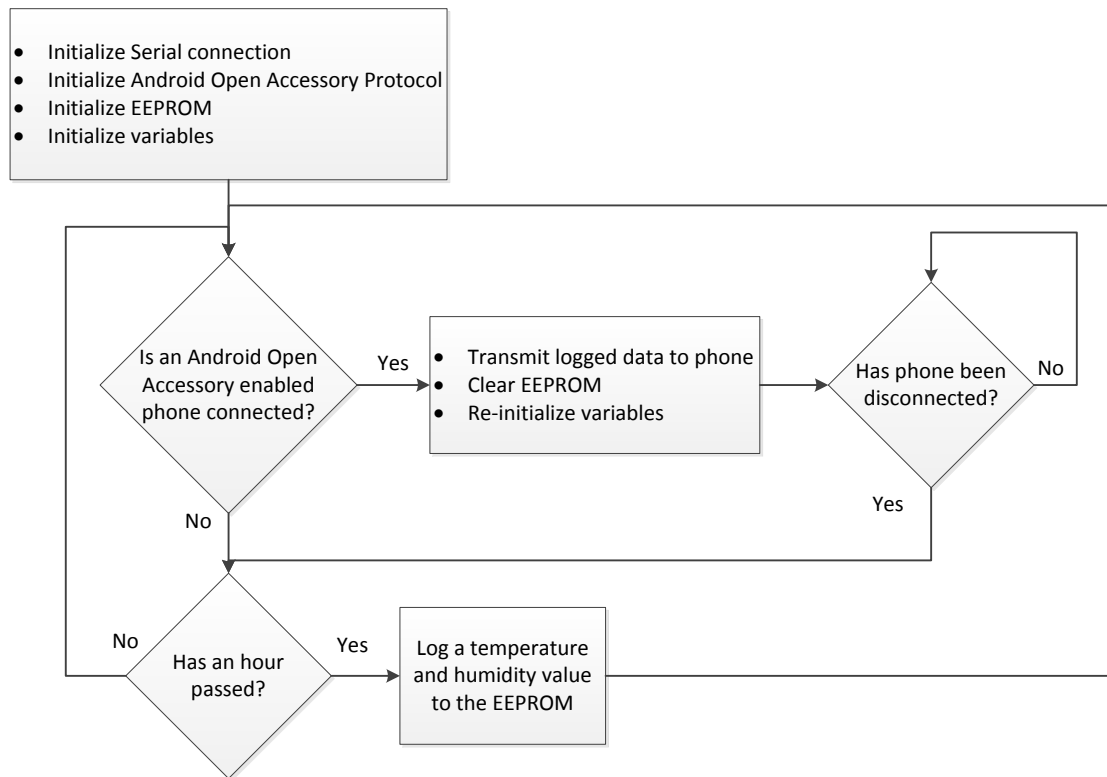

Figure 5 – Software State Flow Chart

7. STUDENT PARTICIPATION.

In this project we had six senior-level undergraduate students, four from Computer Engineering (software track), and two from Computer Engineering (hardware track). The author served as faculty coach, and Info Tech, Inc. appointed two liaison engineers. The students were all enrolled in the University of Florida College of Engineering's Integrated Product and Process Design (IPPD) program. In the IPPD program, an interdisciplinary group of senior-level students, of various engineering disciplines, engage in a product or process design project for an industrial sponsor, under the supervision of a faculty coach and liaison engineers from the sponsoring company. The students spend two semesters in this capstone design experience, designing and building authentic products for those industry sponsors. Participating students are seniors from the College of Business, and all Engineering disciplines. The projects, technical advice, and financial support are provided by the corporate sponsors. Teams and individuals are evaluated against defined project deliverables and lecture/workshop performance. Since 1994, over 1400 students from 12 disciplines have participated in 242 projects from 62 sponsors, which include companies such as NASA, Boeing, Dell Computer, Dow Chemical, DuPont, Energizer, Florida Power Corp., General Dynamics, Harris, Honeywell, IBM, Kimberley-Clark, Kraft Foods, Lockheed Martin, Motorola, Pratt & Whitney, Raytheon, Siemens, Southern Nuclear, Sunbeam, Texas Instruments, Tropicana, and the US Air Force.

8. CONCLUSIONS

We have described our design and on-going implementation effort of a Mobile Field Diary System, to be used by infrastructure construction inspectors. The project is well on its way to produce a powerful mobile analysis and reporting tool for construction inspectors to use on the field. The development platform is any mobile telephone running (a sufficiently recent version of) the Android operating system. A hardware accessro yhas been desgined, built and tested, to gather temperature and humidity readings on the field, and transmit them to the Android phone via a USB port. The project is being developed by a group of undergraduate students at the University of Florida, under our IPPD (Integrated Product and Process Design) program, a highly successsful University-Industry Cooperation program. Our project is sponsored by InfoTech, Inc. a Gainesville high-technology company.

REFERENCES

[1] http://www.ippd.ufl.edu/

[2] http://www.infotechfl.com/

[3] http://www.android.com/

[4] http://developer.android.com/guide/topics/usb/adk.html/

[5] http://en.wikipedia.org/wiki/Scrum_%28development%29/

[6] http://www.scrumalliance.org/learn_about_scrum/

[7] http://www.arduino.cc/

[8] www.sensirion.com/en/01_humidity_sensors/05_humidity_sensor_sht21/00_humidity_sensor_sht21.htm/

[9] http://www.futurlec.com/Mini_DS1307.shtml

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