UNITE: Smart, Connected, and Coordinated Maternal Care for Underserved Communities, Wearable Watch Application

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***Abstract*— Mothers in underserved communities with low socioeconomic status may not receive timely or quality maternal care while pregnant, which can lead to a decline in overall health of the mother and the unborn child. To respond to this problem, we are building a model, UNITE (UNderserved communITiEs), that is smart, connected, and coordinated. The project utilizes wearable technologies to continuously monitor important health data for expecting mothers to prevent preterm births. This project will bring together many disciplines, including technology, social sciences, nursing, as well as a nonprofit organization. The model is built to be scalable and portable across different ethnic communities. The UNITE project performs a controlled study using a community of underserved Orange County mothers together with non-profit agencies, hospitals, and local support organizations to evaluate the efficacy of this new community-enhanced self-management approach, and its impact on community building.**

***Keywords*— Wearables, wearable technology, prevention, watch, application, underserved, pregnant women**

I. Introduction

Mothers in underserved communities with low socioeconomic status may not receive timely or quality maternal care, which leads to a decline in overall health of the mother and the unborn child. There is currently a home visitation and group health education integrated program that is in place for at-risk women and families in underserved communities. There is currently research being done on wearable devices that monitor different parameters in different fields. Mothers in underserved communities with low socioeconomic status may not receive timely or quality maternal care while pregnant, which can lead to a decline in overall health of the mother and the unborn child. Pre-term births are particularly concerning within this population, as they are the most common cause of neonatal deaths.

Preterm births are not only dangerous to the baby, but to the mother as well. They are also more at risk for many other health complications, immediately and in the long-term. Some immediate complications include breathing problems, heart problems, brain problems, temperature control problems, gastrointestinal problems, blood problems, metabolism problems, and immune system problems. Some long-term complications include cerebral palsy, impaired learning, vision problems, hearing problems, dental problems, behavioral and psychological problems, and chronic health issues. Although the specific causes of preterm birth are not certain, certain lifestyle causes such as high stress, and lack of prenatal care, can increase the risk of preterm birth.

There have been past experiments performed on sleep monitoring in the research group. They used an Internet of Things (IoT) based long-term monitoring system to assess sleep quality. They analyzed this because lack of good sleep can lead to adverse pregnancy outcomes. One of the findings they found was that there was an increase in sleep abnormality at the end of pregnancy and postpartum.

II. Project Overview

A. Project Introduction

One program implementing the use of smart devices with expecting mothers is the UNITE Project I am going to introduce. The UNITE: Smart, Connected, and Coordinated Maternal Care for Underserved Communities project uses smart wearable technologies to ubiquitously track important health parameters, like activity, sleep, heart rate, and stress, to aid in the prevention of preterm births for underserved expecting pregnant mothers in Orange County (OC). There are many implications to preterm births and they are the most common cause of neonatal deaths, so tracking the current health of the mothers at all times will allow the mothers to receive more personalized, accurate maternal care.

The model is designed to be scalable and portable across diverse communities. A similar model is being experimented in the University of Turku, in Finland, with which we are also collaborating with. We are focusing more on underserved expecting mothers in the area of Orange County. It is also a partnership with other disciplines on the University of California Irvine campus (nursing, computing, education, social sciences) and non-profit organizations (MOMS of Orange County). Although currently piloted in only one county, the model is designed with the vision to expand to various communities. The project is envisioned to recruit twelve hundred women over the course of three years.

There are two wearable devices being tested with the project. The first is the Samsung Gear Sport Watch, which was utilized for this project considering several factors such as the built-in sensors, flexible strap, long battery life, and waterproofness. The second is the Oura Ring, which was chosen for its accuracy in sleep and activity detection. In this paper, the focus is on the application on the watch. All the sensor tracking technologies are already been built into the wearables, but we want to take some of the parameters that are essential in tracking of health and collect and analyze the data to personalize a recommendation system to the mothers. For example, the Gear Sport Watch can collect photoplethysmogram (PPG) and acceleration signals that help with understanding a person's health and stress rate.

To make sure the mothers get the proper care and recommendations during their pregnancy, this app will track their sleep, stress, activity, and heart rate. To analyze the data, the mothers have to send their data using WiFi through the watch app to a cloud server. When the data is sent to the server, it is deleted from the watch to save storage space on the watch. The cloud server is used to store the data remotely, to perform the health analysis, and to provide data visualization.

B. Background Information on the Sensor Data in the Samsung Gear Sport Watch

Tizen provides functions for managing sensors and receiving sensor data. The main features of the Sensor API include the sensor listener, sensor handle, and sensor types. The sensor listener can detect sensor and monitor their availability with the sensor listeners. The listeners receive registered sensor events and deliver the event data to apps at certain intervals. By creating a sensor listener, it allows monitoring of a devices internal sensor for changes. With the sensor handle, you can access the sensor hardware data, such as sensor name, sensor vendor, sensor type, resolution, sensing interval, and measuring type. Tizen has multiple sensors including the accelerometer, gyroscope, heart rate monitor sensors, pressure sensors, pedometer, sleep monitor, amongst many others. To use these functions, we need to include the <sensor.h> header file in the application.

To observe a specific sensor type, we can check its availability, a device can have multiple sensors, and you can create a listener handle upon the sensor handle.

To listen for sensor events, we defined a callback function and register it to the listener. If a callback is used to listen for different sensor types, it can check the sensor type.

Tizen can also support long-term data collection for some sensors, and that is what is being used for this project.

Certain data parameters can be queried.

The accelerometer measures the changes in the velocity of the device and measures data in three axes: x, y, z. It records acceleration in three directions. The output results in a timestamp and three axis values, and the units of the axis values are in meters per second squared. If the device is not moving, it has an acceleration of 1g in one of the three axis values.

The gravity sensor is derived from the acceleration sensor and show how the device is being rotated at the time.

The gyroscope measures the angular velocity of devices. It also has a timestamp and three axis values. Over long periods of time, the calculation becomes more incorrect as drift is being built up.

The heart rate monitor sensors use a specific light to calculate a heart rate value. The heart rate monitor (HRM) sensor measures the beats per minute of someone's heart rate.

The pressure sensor takes data from the surrounding atmospheric pressures of the device and records a value between 260 and 1260.

The pedometer tracks the user's steps and returns multiple values of data including the number of steps, number of walking steps, number of running steps, moving distance, calories burned, last speed, last stepping frequency, and last pedestrian state.

The sleep monitor tracks the effectiveness of one's sleep quality. Every minute, it tracks whether the user is sleeping or awake. The data that is shown is the timestamp and the user's sleep state. There are three sleep states built into the devices: SENSOR_SLEEP_STATE_UNKNOWN, SENSOR_SLEEP_STATE_WAKE, and SENSOR_SLEEP_STATE_SLEEP. In the watch app, 0 is the value for SENSOR_SLEEP_STATE_WAKE and 1 is the value for SENSOR_SLEEP_STATE_SLEEP.

In the following Literature Review section, several similar projects will be explored and explained in greater depth. In the Architecture section, a comprehensive overview of all the technical aspects of the UNITE project will be explained in detail. In the Watch Application section, there will explanation of the functions of the Samsung Gear Sport Watch in more detail. The paper is an overview of the entire project, which an emphasis on the watch application. In the Findings section, the progress and observations made to the watch application with be described, and in the conclusion, there will further details about the future direction as well as the limitations of the project.

III. Literature Review

Before this research project, the group has worked on finding the feasibility of smart wristbands for continuous monitoring during pregnancy. They explored the effects of sleep on a pregnant's mothers care. They collected continuous activity, sleep, and heart rate data from pregnant mothers. They measured the participants experience with the watches, as well as how long the participants wore the watches. The results they found with this research is that the application would be feasible, but the use of the smart wristbands after birth decreased after birth, as they were uncomfortable, viewed the data as unreliable, and were afraid of scratching their baby with the watch [1]-[2].

There is currently a Baby+ mobile application to support pregnant women in Pakistan. It helps women track their pregnancy and gives them relevant information. It was a valuable assistive tool to the women during their pregnancy, as the lifestyle of women in developing and developed countries are changing with technologies. They made their research-based app geared towards women in an urban, economically developing region in the world, as few mobile applications specific to helping pregnant mothers exist in the area. They tested the app with pregnant, educated women who had smartphones and have used mobile applications. The app was catered towards the diets of the Pakistan people, as what they eat during pregnancy is much different from women in more developed countries. The overall impressive of the app was viewed positively; many of the users were open to the idea of using the app to aid in their pregnancy. The most useful parts of the app were the daily tracking of the baby and tracking of their weight/food. On the app, information can be found in a much more systematic manner. A gynecologist mentioned that the app could help bring structure in the lives of people with the app [8].

The healthcare industry is facing significant sets of challenges because of lack of access, quality, and cost. There was previous research being done on a smart shirt. The shirt can measure one's heart rate, respiration rate, and body temperature using sensors that are built into the smart shirt. It can help the patient by being able to get their health monitored at home and would reduce the cost of healthcare [9].

At Sunway University College, there was research being conducted on first time pregnant mothers. They prototyped a mobile phone framework for pregnant mothers to check various factors such as due date, growth of fetus, complications, and drug and health alerting. They conducted preliminary interviews to find the feasibility of a mobile application as a tool for pregnant women. The result was positive, and many of the mothers were also interested in getting information about medication, due date, and diet, amongst other factors. Future work includes building upon the prototype that they came up with in Malaysia [5].

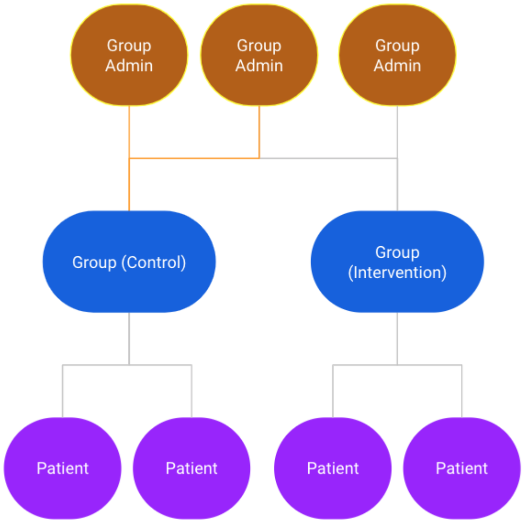
There is also research on whether wearable technology is being accepted in healthcare in general. The results that came out of this research was that medical device users are more interested in perceived expectancy, self-efficacy, effort expectancy, and perceived severity [4].

There is research that was conducted on smart health care the measures living conditions as well as health using sensors. This is important to immediately detect small abnormalities that usually go unnoticed in daily life settings. They developed a patch type wearable vital monitoring device with multiple sensors, a high performance processor and a dual mode Bluetooth transceiver that are integrated into a module. This research can also be expanded in various settings we be use in different scenarios as well [10].

With all this research, it shows that this topic is relevant and at the forefront of groundbreaking work.

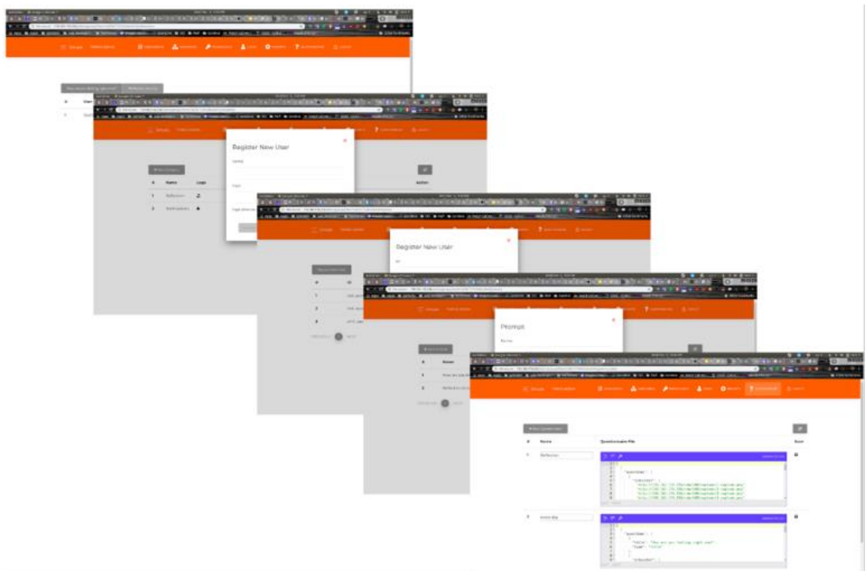
A. *Architecture*

Group admins are able to add and edit members and EMA (exponential moving average), view sensor data, process sensor data, and view EMA submission. The participants (patient) can receive EMA and use sensors. The group administrators are split into two groups, the group control or the group intervention, that will tend to two groups of patients.

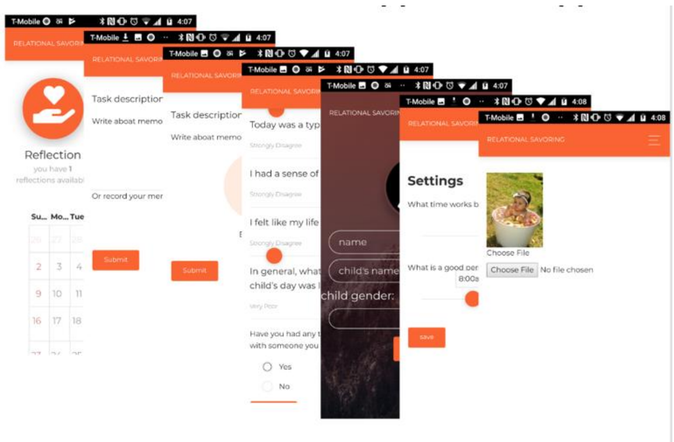


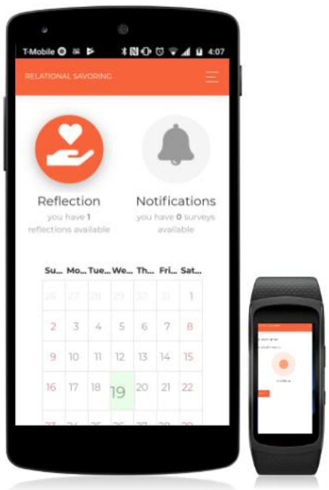
The technical side of the project includes many interfaces with the server. The server is split into three parts: the control, which does all of the processing, the database, which keeps all of the data, and tasks, which gets data from the Oura Server and extracts and saves the watch data. It directly communicates with the admin dashboard, which allows administrators to view and control EMAs and submission, view raw and processed data, and get custom reports and processing. The sensors, consisting of the Samsung Gear Sport Watch and Oura Ring, send data to server, and sync data from server, respectively. The phone app also interacts with the server and gets the EMA, has notifications, and has setting permissions. The specifics will be explained in detail below.

The first interface includes the Administrator Dashboard, where the administrators can get custom reports of the data, as well as view raw and processed data. There are the questionnaires that consist of a photo gallery and breathing exercise. The submissions and uploaded files can be seen, a user can make a new account, and there are prompts for notifications. The Dashboard can be used to monitoring of the patients.



Another interface of this project is a phone app, called the EMA App. There is a home screen, where users can see a general activity summary. On the app, users are able to create dynamic questionnaires, add and manage participants, and schedule notifications. It is available for both Android and iOS devices and is highly configurable. There are also questionnaires that have a photo gallery, breathing exercise, audio recording, sliders, checkbox, radio box, and text. There is a notification setting that the user can set. There is also the option of making the profile public or private.





The interface that was examined specifically in this research project were the wearables, especially the watch application. The Samsung Gear Sport Watch Application saves twelve minutes of raw data of activity (PPG, acceleration, gyroscope) every two hours. The sleep, sleep, calories, and other processed data is saved every twelve hours. The watch app will save up to seven days of data to the device, but will delete older data to prevent the storage from being full. The watch checks if there is WiFi connection, it then compresses and sends the data, and then it frees up the storage on the watch. The user credentials are already saved on the app. These functions are completed by running these five application/modules that were created previous to this research to run and gather all the information mentioned above.

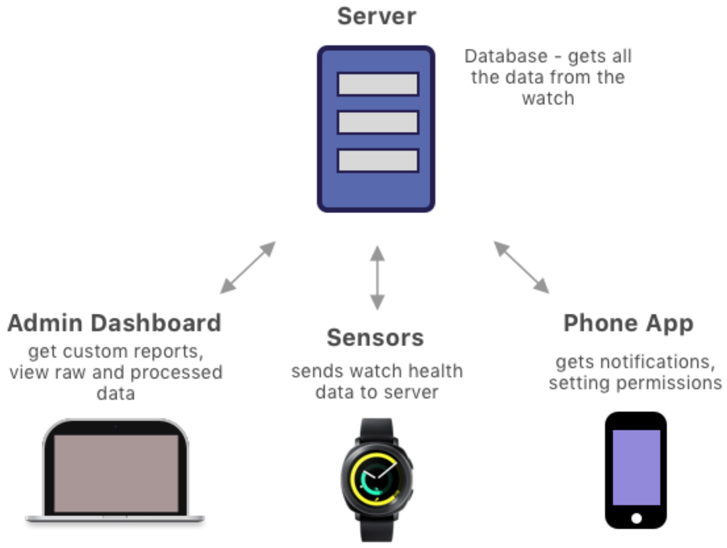
1. HRV Collection
2. Recording
3. Sleep Sensor Service
4. Alarm Service
5. WiFi App

One specific thing to note about these modules is that they must be run in the order above, for the functions in certain modules rely on previous modules to be run before during installation.

The Oura Ring authorizes UNITE through the app and dashboard. It downloads all the processes data every day. It is mainly used as a more accurate measurement of sleep effectiveness. It provides sleep HR, HRV (RMSSD), and sleep quality, as well as activity, MET for every minute and activity class every five minutes. Lastly, it also provides readiness every day with a restfulness score.

The server that is being used is a Flask RESTFul-API server, uses a NoSql MongoDB database, and has secured communication through SSL.

There are a total of four technical components that make up the UNITE project, as shown below.



B. Watch Application

The watch app consists of five modules: the Heart Rate Variability (HRV) Collection App, Recorder App, Sleep Detection App, an Alarm Service App, and WiFi Connection App. These apps were originally developed by the University of Turku research team and have to be installed into the watch in the order introduced above.

The HRV Collection file tracks collected PPG, heart rate, and activity to monitor the activity and stress levels of the mothers. The activity is monitored by the accelerometer gravity and gyroscope signals. The Recorder App records the pressure data that is sent in from the sensors. It takes all the activity data and writes it in the recorder file. The Sleep Detection App collects all the user sleep data from the watch. It collects the timestamp, gravity, gyroscope, accelerometer, pressure, heart rate, stress, and PPG data. It then writes all the data to the sleep detector file. The Alarm Service App continuously calls the data every so often. The app checks if the alarm is set, and sets the alarm. The WiFi App checks the WiFi connection state, zips the data folders, ands write and uploads the data to the cloud servers. It then deletes the data from the watch and pushes messages on the watch.
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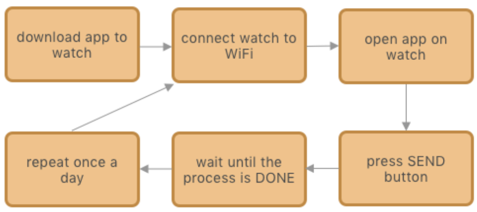

- The watch has built in sensors to track different preset parameters
- The watch can be used as a way for mothers to control their lives not only by directly monitoring the data, but also by getting feedback on some of the data sent to healthcare professionals

To run the app, the watch needs to be connected to WiFi. On Tizen Studio, the IDE used to code the code, run as a Tizen Native Application. Using the app, the mothers can send their health data to the cloud server once a day. After sending, the data will be removed from the watch, saving storage space on the watch.

C. Findings

1. Troubleshooting

First starting the project, there was a lot of troubleshooting involved with the watch and connection. In the first steps, installing Tizen Studio, an IDE made by Samsung for their Samsung wearable devices and downloading the appropriate (2.3.2) watch (wearable) SDK package was the first step. Looking through the various modules that were already created and seeing how they were

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all connected and created was an important second step. Since the data is sent through WiFi, both the machine that Tizen Studio is being run on and the wearable must be connected to be the same WiFi source.

The steps that were taken for the watch to pair with Tizen Studio were properly documented. One of the important last steps that was done was the installation of Samsung Smart Switch. The reason for needing this is still unclear, but it seems like having it downloaded on the machine will help connect the watch to Tizen Studio. To properly get the watch to connect with Tizen Studio, Samsung Smart Switch had to be installed to the machine, wearable packages from the package manager had to be installed, a certificate in the Certificate Manager had to be created, and Homebrew was downloaded. In this process, a Samsung account is needed, but a new account can be made if one does not have one.

The most difficult portion of the set up was creating the certificate. Since the certificate would often result in a signature error, it was difficult to solve the issue. After the certificate was successfully made, it was possible to run the modules on the watch and test the application on the watch.

2. Adding Headers

In some of the files that were generated from the application, the headers are not printed, so work was done to print the correct header labels on the files.

The headers on the Monitor and Detector Files are not showing, and work was done on printing out different functions in C to determine the header labels in those files. The sensor_get_type(), sensor_get_default_sensor(), and sensor_get_sensor_list() functions were printed to the log to see its output. In the Sleep Detection file in the example_sensor_callback() function, the lists that were outputted from the function were outputted in the log. The API of the sensors, which is explained in more depth above, built in the watch was referenced for the headers in the Pedometer File. This step was essential for the headers to show on the files.

```c
void
example_sensor_callback(sensor_h sensor, sensor_event_s *event, void *data)
{
    FILE * fp;
    sensor_type_e type = SENSOR_ALL;
    if ((sensor_get_type(sensor, &type) == SENSOR_ERROR_NONE) && type == SENSOR_HUMAN_SLEEP_DETECTOR) {
        updateFileName();
#ifdef DEBUG
    FILE * fp = fopen(logFileName,"a");
    fprintf(fp , "1");

    int printnum = sensor_get_type(sensor, type);
    fprintf(fp, printnum);

    int printnum2 = sensor_get_default_sensor(type, sensor);
    fprintf(fp, printnum2);

    fclose(fp);
#endif
```

```c
    if ((sensor_get_type(sensor, &type) == SENSOR_ERROR_NONE) && type == SENSOR_HUMAN_SLEEP_MONITOR) {

#ifdef DEBUG
    FILE * fp = fopen(logFileName,"a");
    fprintf(fp , "2");

    int printnum = sensor_get_type(sensor, type);
    fprintf(fp, printnum);

    int sensor_count;
    int** list;
    int printnum3 = sensor_get_sensor_list(type, &list, &sensor_count);
    for(int i=0; i<sensor_count; i++) {
        fprintf("%d", *list[i]);
    }

    fprintf(fp, printnum3);


    fclose(fp);
```

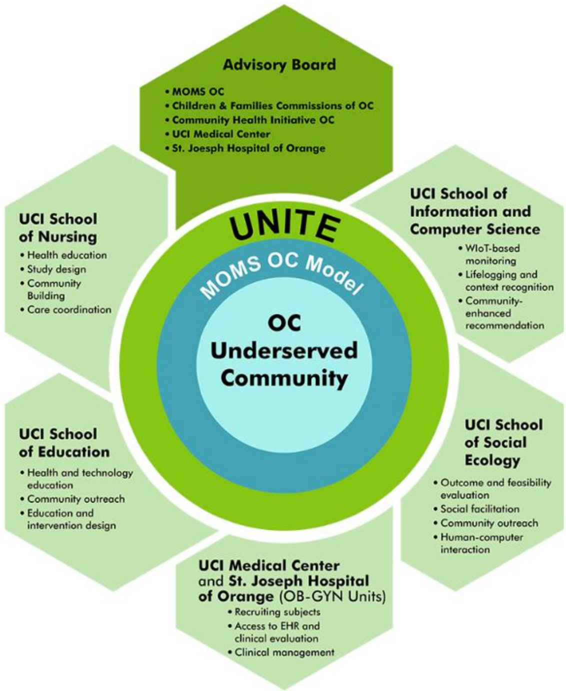
```c
void updateFileName(){
#ifdef DEBUG
    FILE * fp = fopen(logFileName,"a");
    fprintf(fp , "%s \t filenames updated \n", getCurrentTimeString());
    fclose(fp);
#endif
    setTimeForWakeupSensorFileName();
    sprintf(sleepDetectorFileName, sleepDetectorFile,time_file);
    sprintf(sleepMonitorFileName, sleepMonitorFile, time_file);
    FILE * fp = fopen(filename,"a");
        fprintf(fp , "stepNum\walkingNum\runningNum\movingDist\cal\lastSpeed\lastFreq\lastState\n"); // sophie-
    sprintf(pedometerFileName,  pedoFile, time_file);
}
```

3. Showing Alarm Service on WiFi App

Another task that was performed was attempting to show the alarm service on the WiFi Application. Showing this service was important so that users can see when the alarm service is called.

D. Connection with Other Departments

We are working with the UCI School of Nursing, who will be participating in the health education and take care of the coordination with the mothers.



IV. Conclusion

Some of the limitations of this project include that we are not assuming that the users of the app do not update the watch app. Different versions of the app do not display the data the same way, so there are complications in that area. Since the headers are not properly being shown, the updating of the watch will cause some bugs and problems that may not be immediately visible. Also, when the watch is at low battery, the services shut down on the app. This is an obstacle that will need to be fixed in later developments of the app. The data sent to the cloud server is also inconsistent. There are some current limitations on the project, but these limitations can be fixed with future continued research on the project.

In the future, we want to have a function that would allow the data to be transported through Bluetooth. It is currently being connected through WiFi, which is unreliable at times and also has very high power usage. It would be an additional app that would be much more energy efficient and have less connectivity issues. Power is an important part of this app, as if the app uses less battery, the watch would not need as much charging.

Furthermore, in some of the files that are written, there are some errors in calculation. In particular, in the Monitor file, the timestamps do not change in a particular time range since the times are not properly subtracted. This can be a problem with how the data is being viewed visually. Showing the alarm service in the WiFi app will also be continued in the future. Having a direct notification that would show when the WiFi is connected or disconnected, and therefore signal to the user if they need to connect to WiFi before sending the data.

In the future, we want to be able to run clinical trials with the mothers in Orange County, in partnership with OC MOMS. We are currently still testing its feasibility.

There is a need to have a specialized healthcare solutions to support the needs of a specific community. Although there are current limitations on our work, there has been significant progress made to help expecting mothers track their pregnancies and get the care that they need.

A. *Authors and Affiliations*

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