Hospital in Toilet

Abhipray Sahoo
Chenxin Fu
Christopher Buck
Evan Dougal
Jennifer Ding
Minyang Ma
EIIC 419 Final Report
Rice University
hospitalinatoilet@gmail.com

April 22, 2014
**Originality Statement**

All content in this paper is original, was not copied from any published or electronically reproduced source and is the sole work of the authors.

**Acknowledgments**

The team would like to thank Dr. Ashutosh Sabharwal, Dr. Ashok Veerarghavan and Mayank Kumar for supporting and guiding us on the project.
## Contents

1 Introduction 4

2 Product Definition 4

3 Hydration Assessment Metrics 4
   3.1 Specific Gravity 4
   3.2 Urine Color 5

4 Existing Competition 6
   4.1 Scanaflo by Scanadu 6
   4.2 mc10 Hydration Sensor 6

5 Feedback From Potential Customers 6

6 System Architecture 7
   6.1 Physical Setup 7
   6.2 Sensor system 8
   6.3 Data management 9
   6.4 Data interpretation 9

7 Current Status of Project 10

8 Future Plans 10
   8.1 Detect a Wider Range of Urine Information 10
   8.2 Improve User Experience For Mobile Application 10
1 Introduction

Urinalysis is a non-invasive medical tool that can provide valuable information on a wide range of health concerns. In addition to monitoring chronic and severe medical conditions such as diabetes and kidney failure, urine can be used to monitor general health and wellness by identifying different urine attributes such as pH, bacteria, and hormone levels. These can be used for detection of pregnancy and Urinary Tract Infections, among other conditions. However, at the present urinalysis is mostly limited to clinical settings.

2 Product Definition

Hospital in a Toilet is a urinalysis device that attaches to the side of a toilet. The device is designed in a modular fashion, allowing for customization of different sensors in the device sensor chamber based on each user’s health profile. Thus, HiT can provide personalized health monitoring based on the user’s needs. The HiT team has explored a variety of health metrics for our initial product development, and based on our observations decided to start by focusing on a hydration monitoring system.

Studies show that 70% of Americans are chronically dehydrated, and while hydration information is valuable for every person, we are focusing the development of our initial product for athlete use. For this target group, staying within ideal hydration levels before, during, and after an intensive workout or competition is essential for maintaining health and achieving peak performance. Athletes must aim to be in neither a dehydrated nor a hyperhydrated state, both of which can reduce physiological function and increase risk of a heat illness (Decker). This is especially important for athletes engaged in outdoor activities for a prolonged period of time such as marathon runners and football players.

3 Hydration Assessment Metrics

To obtain hydration level information, our team is utilizing two urine attributes: specific gravity and color. The HiT device uses a color sensor and differential pressure sensor to obtain this data, and combines the results of these two metrics to provide hydration level information and recommendations.

3.1 Specific Gravity

Urine specific gravity, the density of urine compared to water density, is utilized to measure how effectively the kidneys are diluting urine. This metric is commonly used in a clinical setting for determining hydration levels. According to National Collegiate Athletic Association (NCAA), it is the most practical, cost-efficient measurement of hydration status for athletes. For healthy adults, urine specific gravity generally ranges from 1.000 to 1.030 (Urine Specific Gravity).
A significant correlation can be seen between urine specific gravity and loss of body weight due to dehydration. Urine specific gravity has been proven to be a reliable and accurate metric for clinical standard hydration assessment.

3.2 Urine Color

Urine color is often used in recreational settings to determine hydration level, is best considered in comparison to each individuals relative normal color. Research has shown the correlation between urine color and other metrics that indicate a persons hydration level. For example, the figure above shows that there is a 0.77-0.96 correlation between urine color and urine specific gravity[4]. Additionally, studies have shown that a pale yellow color of urine indicates that a person is within 1% of euhydrated body mass. Although color may not have the precision of urine specific gravity, and depends on a variety of factors, when utilized in conjunction with other metrics and in comparison to a patients relative normal, it can be an inexpensive and reliable indicator of hydration [4].

The two metrics that we incorporated aim to provide hydration information for both clinical and non-clinical settings with a straightforward process that requires no additional usage of chemicals or dipsticks to improve the users ease of experience and reducing cost.
4 Existing Competition

There are two main competitors that provide similar features as the HiT device. Scanaflo performs urinalysis through the use of test strips and the mc10 sensor provides hydration information.

4.1 Scanaflo by Scanadu

Scanaflo by Scanadu is an upcoming product that involves a urine test kit that uses test strips combined with a smartphone camera to analyze levels of glucose, protein, leukocytes, nitrates, blood, bilirubin, urobilinogen, specific gravity, and pH in urine.

A smartphone app guides the user through the test procedure, processes the test results, stores them, and also explains them. [1] While Scanaflo provides a range of health information, it also requires consumers to repeatedly purchase test strips to continue testing. The estimated market price for Scanaflo is $150 (analogous to Scanadu product).

4.2 mc10 Hydration Sensor

The mc10 hydration sensor is a band-aid like adhesive skin patch that monitors hydration levels for athletes. It uses the skin’s bio-impedance (which changes with sweating) as an indicator of hydration. It also sends smartphone alerts that tell user when and how much to drink. [2] The mc10 hydration sensor also requires the users to repeatedly purchase the product for continuous monitoring. It also only provides information on users hydration status. Currently, the price for mc10 is about $10 per patch.

Our product has distinctive advantages compared to the two products above for the following reasons: single purchase, user-friendly design, and range of health information. With a one-time purchase, HiT can provide users daily information on a variety of health metrics. The cost of our product is estimated at $150 and can be repeatedly used. Users simply need to do an activity that they already do daily in order to receive health information, and the process and information display on the smartphone app is easy to use and understand.

5 Feedback From Potential Customers

Potential customers for Hospital in Toilet fall under two categories:

1. Health conscious adults; This includes adults who
   • Are looking for ways to improve their health and well being
   • Are willing to integrate the product in their daily lives
   • Will require no extra motivation other than visible benefits of the product

2. Adults prone to health conditions; This includes
   • Athletes especially those involved in intense activities such as marathons
   • Adults looking for convenient methods to manage health without major disruptions to their daily routine.
• Adults who have been forced out of necessity to look for solutions to their health problems

One of our first customers is likely to be the health conscious adult who is constantly looking for products that can improve his or her lifestyle. Most of these customers are tired of the thousands of apps available that have no real effect because they are not doing any diagnostics on the person themselves. Hospital in a Toilet is as personal as it gets, by monitoring a big indicator of health regularly - hydration level. By presenting this health information in a way that is conducive to this customer group, i.e., by presenting diagnostics and giving advice like Drink x amount of water to be hydrated for y activity, we are catering to the needs of the group better than most other products.

The biggest customers however will be athletes. Feedback from athletes at Rice shows that a hydration level indicator will be beneficial to their training and ultimately improve their performance. Hydration level information will be especially useful for marathon runners and new athletes who do not have adequate experience for controlling their hydration. Athletes performing outdoor sports tend to be dehydrated more easily than those performing indoors and will benefit most from our product. Overhydration also tends to happen to athletes and poses a big threat to their health. During intense performances athletes may consume more water than they need to. In this case overhydration will occur. Overhydration will lead to water-intoxication, which results in brain damage.

The health data history feature of our product is also valuable to our target customers, according to target customer feedback. A hydration level record history will be beneficial to athletes who need long-term tracking of their hydration level.

For adults who have actual health problems which requires regular monitoring for their hydration level, our product provides a convenient solution. For example, patients with kidney failure or stones can know their current health situation with ease as compared to sending urine samples to hospital labs. In short, patients can monitor their health status without major disruptions to their daily life.

6 System Architecture

6.1 Physical Setup

A preliminary model of the container of the device has been designed and fabricated using 3-D printing. The electronics sit in a small box adjacent to the urine collection cylinder. A large funnel collects the urine into the measurement cylinder. Urine in the collection cylinder is held by a servo controlled blocking mechanism. A small LED illuminates the collection chamber from the bottom, while the color sensor enters the collection chamber from the rear. Two pressure sensors enter the measurement chamber from the side. The entire device is held to the toilet via two arms.
6.2 Sensor system

The measurement system consists of a small urine collection device embedded in the user’s toilet. Urine enters the device through a funnel and is collected in a small measurement area. There, a color sensor measures the color of the urine. The color sensor is controlled by an arduino microcontroller. The color sensor communicates with the arduino via a serial connection.

Two gage pressure sensors are used to calculate the difference in pressure between two points in the column of liquid. The pressure between the two points in a column of a liquid is related by the height between the points, the area of the column, and the density of the liquid. Because the height between the points and the area of the column is fixed, these two pressure measurements give us a method of determining the liquid’s density, which is directly related to the specific gravity. The pressure sensors are both on a single SPI bus on which the Arduino is the master. The Arduino individually selects each of the sensors by manipulating the Slave Select line of each sensor, and then proceeds to clock data to receive the readings from the sensors. The pressure measurement is computed by converting the received bit stream into a pressure reading. This measurement is then converted to a measurement of specific gravity by finding the difference between the two pressure readings, given the other parameters of the fluid column and height difference between the pressure sensors.

Other sensors like pH, specific gravity, or absorption spectrum can be incorporated into this embedded device to provide additional functionality. Information from the sensors is then transmitted via bluetooth to the users smartphone. The arduino controls the bluetooth module using a serial connection.
6.3 Data management

The users smartphone receives the data and an application sends it to a modified open EMR server which is currently running on an Amazon EC2 server. The open EMR server has been extended with php scripts to store the urine information in a custom table within the database. Other sensor information can easily be added to the table. The smartphone application can also pull data from the server to show the user past hydration data. The server also supports querying for specific data, for example, all urine data between two dates.

6.4 Data interpretation

The smartphone app uses information from a urine color chart to provide hydration recommendations to the user based on the measured urine color. Currently the recommendations are based off of a linear model taken from the RGB values of a color chart. The RGB values from the color sensor are averaged and then compared with this linear model. Although this method provides a rough recommendation based on the users hydration, more research needs to be done to find a more accurate mapping between the color and the users hydration level. In the future more accurate recommendation data will be provided via a differential pressure sensor, which will calculate the specific gravity.

The app will also be able to show hydration trends to the user using information from the server. The team plans to use personal historical hydration data to provide smart recommendations which are tailored to the user.

The app will also support integration with existing social networks (facebook, twitter, instagram) to encourage use. The smartphone app uses information from a urine color chart to provide hydration recommendations to the user based on the measured urine color. Currently the recommendations are based off of a linear model taken from the RGB values of a color chart. The RGB values from the color sensor are averaged and then compared with this linear model. Although this method provides a rough recommendation based on the users hydration, more research needs to be done to find a more accurate mapping between the color and the users hydration level. In the future more accurate recommendation data will be provided via a differential pressure sensor, which will calculate the specific gravity.

The app is also be able to show hydration trends to the user using information from the server. The team plans to use personal historical hydration data to provide smart recommendations which are tailored to the user.
7 Current Status of Project

At the end of eleven weeks of work, the team has developed a functioning prototype of the entire system. This prototype controls a color sensor using an Arduino microcontroller, which communicates with the users Android smartphone via bluetooth. The user receives live recommendations from the smartphone app and can store hydration measurements as well as view previous hydration measurements.

Our hardware team has successfully integrated the color sensor and has now implemented two pressure sensors for measurement of specific gravity. The software team has developed the basic app with user interface, which displays and keeps track of urine color and give recommendation to users.

We also have taken part and placed in 3 competitions. We won fifth place at Rice Elevator Pitch, third place at Space Health Challenge, and first at Rice’s ECE Affiliates Day Presentation.

Additionally, we had an opportunity to meet with representatives from NASA’s Johnson Space Center and National Space Biomedical Research Institute, from which we received recommendations on possible plans for the future.

8 Future Plans

8.1 Detect a Wider Range of Urine Information

In the future, our team will expand the usability of the device to a wider range of urinalysis. Since the design of our device is modular, we can combine more sensors into our device to test for conditions such as diabetes, renal deflection, pregnancy, etc. Customers can choose the type of information they want to get from their urinalysis and we can incorporate the corresponding sensors into the system.

8.2 Improve User Experience For Mobile Application

Our mobile app team will develop smart recommendations to send out hydration alerts for users without the users opening the app. Recommendation system can be modified so that rehydration
reminders can be active throughout the day, not only when the user is using the hardware.

References


