UROP AY14/15 E234 Report

SOFTWARE SIDE: NON-INVASIVE CONTINUOUS GLUCOSE MONITORING SYSTEM

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Abstract

Non-invasive continuous glucose monitoring system requires 24/7 monitoring for diaphoresis and hypoglycemia in both Type 1 and 2 diabetes, to avoid the life threatening complications and amputation consequences. In this project, a new non-invasive glucose monitoring method is proposed, using peripheral skin temperature and sweat to check for diaphoresis. RF Technology (RF Chipset 5370) is used for on-the-go Wi-Fi access to access the glucose data measurements. Now with easy Cloud data storage, non-invasive glucose monitoring is one step closer to reality for diabetes mellitus on the go! Still under development, my portable device aims to harness technology to seamlessly and wirelessly link an Android app to Cloud data stream.

While other wearable technology, subcutaneous and epidermal glucose sensors are still being tested for calibration robustness, this small Wi-Fi portable device is a first step to finding a new cure. Poised to harness portable, wearable technologies among the technologically savvy, a small Wi-Fi portable device will be used to seamlessly link the glucose monitoring device to Cloud data stream.

1 Introduction

Monitoring the renowned diabetes mellitus has always been a world pressing problem due to its painful invasive glucose monitoring procedures and dire complications including heart disease, kidney failure and blindness. New non-invasive glucose monitoring technologies are still undergoing improvements and product tests before being distributed worldwide. This includes the nanotechnology biosensor and smart tattoos that use an affordable and easy fabrication process to harnesses an electrochemical transducer to measure the signal from a biological recognition reaction. Smart tattoos use colour change to detect low sugar levels with bromic acid and flurophores size. Drawbacks include the unreliability of nanotechnology smart tattoos in the long run, and toxic heavy metals used in the nanotechnology biosensor that render its in vivo usage harmful to humans.

Other methods that had their share of great market potential in glycemic control include the Near Infrared Spectroscopy non-invasive penetration, ultrasound above 20kHz, dielectric spectroscopy using electric dipole moment, and metabolic heat conformation to measure the peripheral body temperature to record the heat dissipated, perfusion (blood flow) and blood oxygenation levels. While subcutaneous and epidermal glucose sensors like CGMS System Gold Sensors are still being tested for calibration robustness to prove their consistent reliability, they are a first step to a new diabetes monitoring cure.

In this project, highly sensitive noninvasive glucose monitoring measurements and fast response time are achieved using the Honeywell temperature and humidity sensor that is also currently commercially implemented in diabetes products, to measure skin temperature and humidity levels. This gives a very good indication of cold sweat (diaphoresis), a symptom of dangerously low insulin in blood glucose levels.

As the sweat on diabetes patients' skin can create a conductive saline layer at the skin surface that changes the electrolyte balance, they have been utilized by minimally invasive CGM devices and noninvasive diabetic sensor companies in nano-electrodes to take measurement samples from even the most micro-vascularised areas of the upper and deep vascular plexus. This also provides an alternative form

of qualitative visual assessment of baseline calibration accuracy.

2 Creating an interactive database for transferring data from android application to social media platform Twitter and Cloud web server

Using a white breadboard and jumper wires, the digital setup below is soldered to a lightweight portable Honeywell HumidIcon™ Digital Humidity/Temperature Sensor: HIH-6130/6131 Series. This Honeywell microcontroller sensor measures the skin temperature and humidity accurately using 14-bit resolution.

Using this non-invasive approach, invasive diabetes controlling implantable devices are not needed, which can cause discomfort and painful injections. At present, the Honeywell sensor is also implemented in the Hypoband, a diabetes monitoring watch device distributed in Asia, including Singapore.

To enable self-timed automatic data measurements, python coding language is used to program the sensor to establish the link between the temperature and humidity sensor and Twitter, which posts the readings for online viewing. Then, the user has the option preference to transfer the same data to the portable Cloud web server for monitoring or sharing with the caregivers.

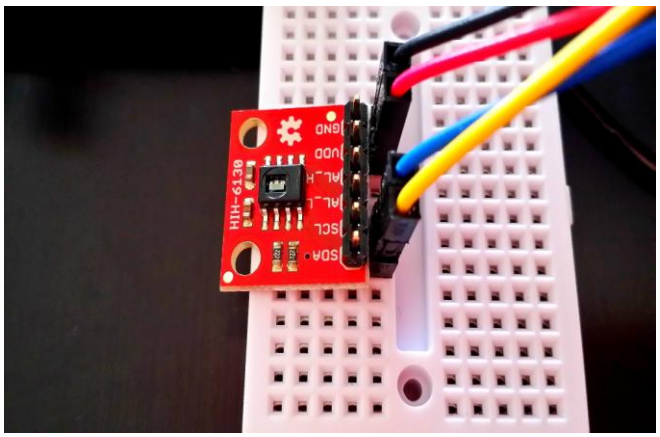


Figure 1: Linking up the Non-invasive Sensor

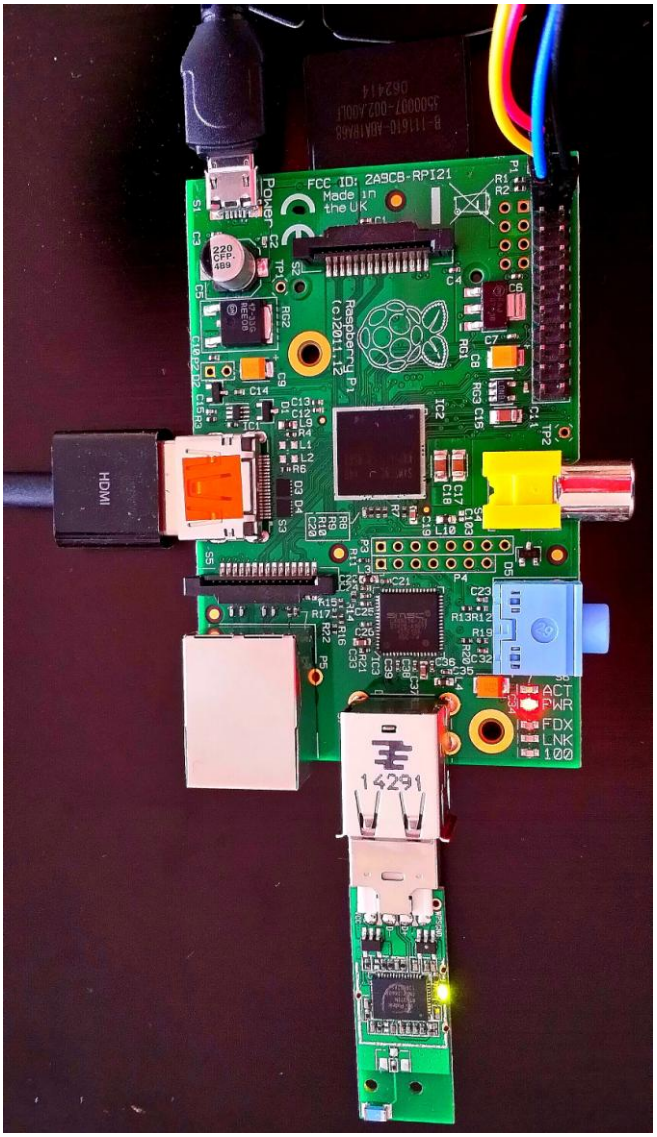


Figure 2: Wi-Fi Connectivity Setup, HDMI Inputs and Radiofrequency RF Chipset 5370

2.1 Figures and tables

date	diaphoresis_humidity	skin_temperature	time	timestamp
5-Mar	63%	25.4°C	13:36:09	2015-03-05T07:09:54.985Z
5-Mar	54%	27.3°C	13:35:09	2015-03-05T07:09:27.373Z
5-Mar	64%	30.6°C	13:34:08	2015-03-05T07:08:48.953Z
5-Mar	62%	30.4°C	13:32:58	2015-03-05T07:08:24.074Z
5-Mar	61%	31.0°C	13:18:11	2015-03-05T07:07:49.928Z
5-Mar	62%	30.9°C	13:17:10	2015-03-05T07:07:23.723Z
5-Mar	62%	30.8°C	13:16:10	2015-03-05T07:07:05.771Z
5-Mar	63%	30.7°C	13:15:09	2015-03-05T07:06:19.378Z
5-Mar	64%	30.6°C	13:14:09	2015-03-05T07:05:58.700Z
5-Mar	64%	30.5°C	13:13:08	2015-03-05T07:05:35.796Z
5-Mar	64%	30.3°C	13:12:07	2015-03-05T07:05:18.237Z
5-Mar	64%	30.1°C	13:11:07	2015-03-05T07:04:53.028Z
5-Mar	65%	29.9°C	13:10:06	2015-03-05T07:04:33.255Z
5-Mar	65%	29.8°C	13:09:06	2015-03-05T07:04:18.190Z
5-Mar	65%	29.8°C	13:08:05	2015-03-05T07:03:52.545Z
5-Mar	65%	29.8°C	13:07:05	2015-03-05T07:03:19.962Z
5-Mar	65%	29.7°C	13:06:04	2015-03-05T07:02:07.523Z
5-Mar	65%	29.7°C	13:05:04	2015-03-05T07:01:33.794Z
5-Mar	66%	29.7°C	13:04:03	2015-03-05T07:01:10.122Z
5-Mar	66%	29.6°C	13:03:03	2015-03-05T07:00:54.572Z
5-Mar	67%	29.0°C	13:00:56	2015-03-05T06:59:00.799Z
3-Mar	67%	29.0°C	13:00:56	2015-03-05T06:58:11.742Z
4-Feb	65%	29.3°C	4:39:54	2015-03-05T06:57:21.507Z
4-Feb	61%	30.2°C	4:38:54	2015-03-05T06:56:45.781Z
4-Feb	78%	32.2°C	4:37:53	2015-03-05T06:55:35.980Z
4-Feb	68%	28.3°C	4:36:52	2015-03-05T06:54:46.870Z
4-Feb	67%	28.3°C	4:35:52	2015-03-05T06:53:43.935Z
4-Feb	66%	28.6°C	4:34:49	2015-03-05T06:50:32.818Z

Table 1: Cloud data storage of non-invasive sensor measurements for diaphoresis humidity and skin surface temperature

2.2 Equations

The microcontroller sensor calculates the humidity and skin temperature using the equations below:

Humidity (%RH) = Humidity Output Count (214 - 1) x 100%

Equation 1: Humidity Conversion Function

Temperature (°C) = Temperature Output Count (214 - 1) x 165 - 40

Equation 2: Temperature Conversion Function (1)

3 Optimizing app system performance for maximizing battery life

In commercial on-the-go glucose android sensor devices, it is a growing necessity to conserve battery life to optimize the performance and lifespan of electronic devices. Such is an indispensable need, especially for diabetic patients who need constant data measurements.



Bluetooth Technology in Medtronic's Real Time Continuous Monitor, where Bluetooth can transmit and store 300 readings daily in internal memory to chart glucose level variations

4 Creating an android application for displaying the Bluetooth data from sensor to mobile device

This project uses the commercial Hypoband android app, which has several notable mobile phone communication functions like activating a local alarm beep for fast medical response, emergency call to 3 caregiver contacts and sending a user preset short sms to the diabetes caregiver, once the symptoms of severe hypoglycemia are detected.



Figure 3: Commercially tested Hypoband Diabetes Watch

5 Implementing machine learning algorithm using Raspberry Pi and Python Coding Language

The Raspberry Pi is a commercially economical, portable and viable solution that pairs a powerful processor into a small sized mini laptop with programming oriented platforms to mobile devices, using a wifi dongle port shown below instead of the usual wired networking, and also using RF chipset 5370.

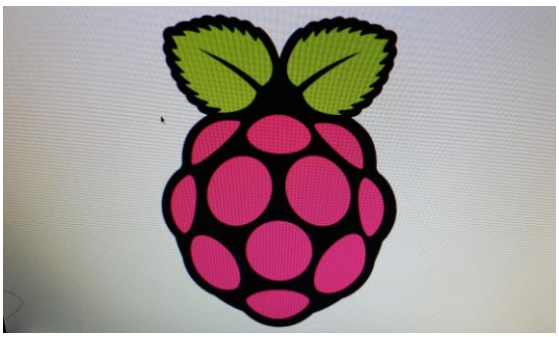


Figure 4: Raspberry Pi Monitor Screenshot

For high definition transmission of the data measurements, this project uses HDMI input cable (High-Definition Multimedia Interface) as a proprietary interface for transferring data from the microcontroller sensor to the user interface.

The Python coding script used for this project is as below:

a) Gluco_Tweet.py

```
from twython import Twython

APP_KEY='DSH3mWwy1k4C24kP1Yr5OILQ9'
APP_SECRET='16nZuyzzvE6jgQ3gVWrghP2kTvdYvJtVceQJ4xZvZfTUMmxyvz'
OAUTH_TOKEN='2999218784-c50vP9XPycA3iI05GfJC8wUe4KeY6fRO5qqm1WJ'
OAUTH_TOKEN_SECRET='mVhjIuknx10n3zD43NDuDCk7tVTmH7oTf8fWZG1pFlJGh'

twitter = Twython(APP_KEY,APP_SECRET,OAUTH_TOKEN,OAUTH_TOKEN_SECRET)
twitter.update_status(status='Testing out the new interface today. Stay tuned for sensor updates coming soon.')
```

b) Temp_Tweet.py

```
from twython import Twython
from smbus import SMBus
import time

# Twitter authentication
APP_KEY='DSH3mWwy1k4C24kP1Yr5OILQ9'
APP_SECRET='16nZuyzzvE6jgQ3gVWrghP2kTvdYvJtVceQJ4xZvZfTUMmxyvz'
OAUTH_TOKEN='2999218784-c50vP9XPycA3iI05GfJC8wUe4KeY6fRO5qqm1WJ'
OAUTH_TOKEN_SECRET='mVhjIuknx10n3zD43NDuDCk7tVTmH7oTf8fWZG1pFlJGh'

# Twython object
twitter = Twython(APP_KEY, APP_SECRET,OAUTH_TOKEN, OAUTH_TOKEN_SECRET)

# I2C globals
ADDR = 0x27
bus = SMBus (1)

# Special characters
```

```
deg = u'\N{DEGREE SIGN}'

# Main loop
while True:
        # Get the current system date and time
        datetime = time.strftime('%m/%d/%Y %H:%M:%S')

        # Read data from sensor
        bus.write_byte(ADDR, 0x00)
        ans = bus.read_i2c_block_data(ADDR, 0x00, 4)

        # Convert to human readable humidity
        humd = ((ans[0] & 0x3f) << 8) + ans[1]
        humd = humd * float('6.10e-3')
        humd = '{:.0f}'.format(humd)

        # Convert temperature to Celsius
        temp = (ans[2] << 8) + ans[3]
        temp = temp >>2
        temp = (temp * float('1.007e-2')) - 40.0
        temp = '{:.1f}'.format(temp)

        # Print data, time, temperature, and humidity
        print datetime
        print 'Skin Temperature: ' + str(temp) + deg + 'C'
        print 'Real-time Relative Humidity: ' + str(humd) + '%'
        print ''

        # Post to Twitter!
        msg = 'Automatic noninvasive glucose monitoring now reads ' + datetime + \
        '. Your skin temperature now is ' + str(temp) + \
        deg + 'C, & the relative humidity is ' + \
        str(humd) + '%.'
        twitter.update_status(status=msg)

        # Delay (in seconds) before next reading
        time.sleep(60)
```

6 3D Printing Prototype of Future Diabetes Mellitus Monitoring Recommendations



Figure 5: 3D Printing of a Diabetes 9INS Molecule

Currently, 3D Bioprinting of living body tissues and cells are now being advanced as a fresh new research interest to regenerate organs so that implantable devices like the glucose devices and pacemakers can be done away with in future as a much more noninvasive approach.

A notable mention is the world renowned NGM Biopharmaceuticals, Inc. that has created a new milestone into the research advancement of diabetes mellitus monitoring by leveraging on its world-class scientific expertise and proprietary insights into compelling human biology. Its Beta-cell Regeneration approach of insulin producing beta cells plays a well-recognized role in the pathogenesis of type 1 diabetes and type 2 diabetes.

Thus in the near future, the Beta-cell Regeneration may perhaps be envisioned to be made minimally invasive as possible, by using latest 3D Bioprinting technology of live cells.

In fact, another revolutionary biological development in the glucose monitoring industry is now spearheaded by Google, which has launched its latest project on using sensor in contact lens to detect the glucose levels in tears.

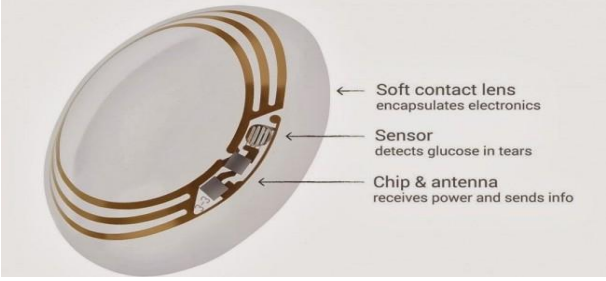


Figure 6: Google's non-invasive smart contact lens to monitor blood sugar levels

7 Conclusion

Despite the various new emerging non-invasive products in the diabetes realm, such continuous monitoring systems (CGMS) require stringent regulation tests.

In the pharmacies of Singapore context, self-monitoring blood glucose devices (SMBG) are more widely available as they are still the most accurate way of assessing the glucose levels at present, besides lower cost and easy usage. However, the potential of new noninvasive devices are not to be limited as they need fewer calibrations per day and are painless.

In conclusion, this project aims to harness Android, Cloud and Twitter technology to drive the portability and enhancement of future glucose monitoring calibration steps of NI-CGM devices.

8 References

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