SMART HEALTH TOILET

An Internet of Things Solution

APRIL, 2018

DOUGLAS BRENNAN
Student # n7326645

Tasks:

TASK 1: Problem Description

1.1 Problem Domain & IoT Solution

Since the invention of the internet, solutions have been adopted to solve inconvenience instances that existed in various industries. For example, the ability to shop for goods online and have them delivered to a home significantly increased convenience to the retail sector. Implementation of the internet eliminated the need for people to visit libraries and other research facilities to obtain knowledge for enquiry tasks. All media sources that were available at such facilities now have the potential to be accessed anywhere by a device that has access to the internet, i.e. a smart device.

The necessity for someone to visit a doctor each time to conduct a Rapid Urine Test (URT) is an example of an inconvenience issue that exists today that consists of sub-inconveniences. These include but are not exclusive to; travel and surgery costs, patient waiting periods, surgery opening hours and unavailability of personal health records. Unavailability of personal health records is an example of inefficient data collection management. This is because copies of the information are solely stored at the surgery and typically not shared with the patient.

The Smart Health Toilet is an Internet of Things solution equipped to solve these inconveniences by conducting routine Rapid Urine Tests and outputting the data to the user through the use of the Smart Health mobile application or website portal. A Rapid Urine Test is conducted by dipping a test strip with coloured fields into a urine sample, depending on the chemical balance of the urine the fields will change colour accordingly (Author, 2016). To routinely conduct these tests the IoT solution will implement an array of sensors to capture the necessary information and a microcontroller for data processing. Once processed the data is outputted and uploaded to the company's online database which is then stored with association to the users Smart Health profile.

1.2 Focal Problem & Stakeholders

The focal problem is recognised as 'the necessity to visit a doctor to conduct a Rapid Urine Test', in which the primary stakeholders existing are the patients and doctors. Secondary stakeholders exist although are too numerous to list individually, they are categorised as 'affected personnel'.

Patient:

The patient is the key stakeholder in the scenario for they are the most affected by the given problem, this is due to the likely inconveniences caused by the problem which are listed below;

- **Travel:**
    - Inconvenience: To conduct an RUT a patient must take a trip to the doctors.
    - IoT Solution: The patient can conduct the test from home
- **Associated Cost:**
    - Inconvenience: Each visit costs the patient an amount
    - IoT Solution: Each test consumes only 1 purchasable test strip
- **Waiting Periods:**
    - Inconvenience: Doctors surgeries often have waiting periods due to operating behind schedule
    - IoT Solution: There is no waiting period to use the Smart Health Toilet, unless it is occupied by another user
- **Opening Hours:**

    - Inconvenience: Doctors surgeries are open during normal business hours (8am – 5pm), thus causing patients to forego work commitments to conduct a test
    - IoT Solution: The user can choose when to undergo a test and how regularly tests are conducted
- **Health Records:**
    - Inconvenience: Records of visits and test results are handled by the surgery
    - IoT Solution: The test data is outputted for the user and stored in the company's cloud database with association to the user

Doctor:

The doctor is not the key stakeholder for they benefit from the focal problem, this is because patient visits are a major income source. The introduction of the IoT solution will decrease the income source for the surgeries due to those who use the solution no longer need to visit a surgery to conduct an RUT.

This is a negative aspect of the solution for the stakeholder, although a positive aspect is that health industry efficiency is increased due to doctors no longer being the primary conductors of Rapid Urine Tests. Efficiency is further improved regarding doctor-patient consultation times when seeing a patient who has adopted the IoT solution. This occurs when a solution user has been advised by Smart Health that their urine levels are abnormal, the user is then able to show their test results to the doctor and they are able to use the results to prescribe the patient with a remedy.

Affected Personnel:

Affected personnel is the category for the secondary stakeholders who are not directly affected by the focal problem. They are potentially influenced by the action of visiting a doctor's surgery to undergo a RUT. They include but are not limited to;

- Family
- Colleagues
- Friends
- Surgery Staff
- Bystanders

For example, person X is scheduled to visit a doctor surgery to undergo a RUT and needs to schedule time off work to do so. The colleagues of person X are affected by the visitation for person X will not be available for work related tasks during the visitation cycle.

This scenario is inherently similar with all other types of affected personnel, they are affected by the time off that person X will need to take to go for the test. The adoption of the IoT solution by person X means that the potential to affect personnel will drop to null for the adopter merely can do the test alone in the comfort of their home without the need to take time away from other activities to do so.

TASK 2: Solution Sensors

2.1 Solution Sensors & Components

For the Smart Health Toilet to sufficiently capture the required information a combination of various components and sensors are used, see the table below.

Part	Description	Stakeholder Need	Input	Processing	Output
Colour Sensor – Sick CS8	To detect RUT strip colour changes	User/Patient – Analyses test results	Light	Detects colour change and outputs colour result to microprocessor	Digital → Microprocessor
4x Strain Gage Button Load Cells - TE Connectivity Measurement Specialties FC2231-0000-0100-L	To detect when user sits on Smart Toilet	User/Patient – Knows when user has sat on Smart Toilet	Weight/Force	Analog to digital, microprocessor detects voltage, converts volts to weight	Analog → Microprocessor
Liquid Flow Meter - LG16 Liquid Flow Meter Series	To detect when urine flow begins and ends	User/Patient – Detects flow of urine	Liquid flow rate	Digital to digital– I2C-Bus	Binary → Microprocessor
Touch Screen Display - Newhaven Display Intl - NHD-4.3CTP-SHIELD-L-ND	To detect touch commands by user	User/Patient – Controls the Smart Health Toilet	Touch	Digital to digital – controller	Digital → Microprocessor

a) Colour Sensor (Sick, 2017)

- One (CS8-1) or four (CS8-4) colours can be saved
- 12.5 mm or 60 mm sensing distance
- Fast response time up to 85 µs
- High resolution colour
- Bar graph display shows the correlation of the colours
- Extremely precise light spot and high resolution
- Metal housing with two light exits (interchangeable)

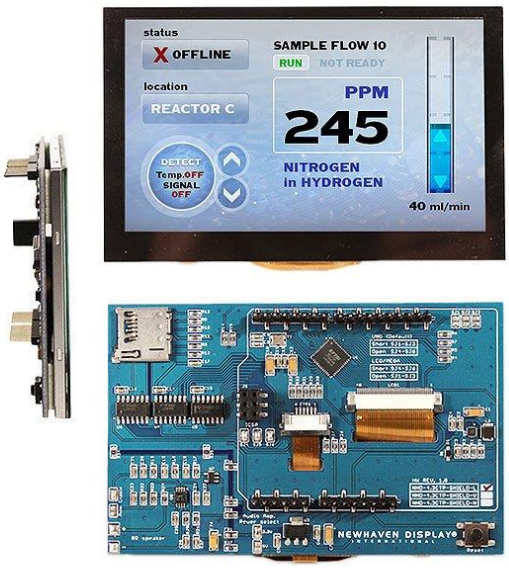
b) Strain Gage Button Load Cell (DigiKey, 2018)

- Small Size
- Low Noise
- Robust: High Over-Range Capability
- High Reliability
- Low Deflection
- Essentially Unlimited Cycle Life Expectancy
- Low Off Centre Errors
- Fast Response Time
- 10 to 100 pound Ranges
- Reverse Polarity Protected

c) Liquid Flow Meter (Sensirion, 2016)

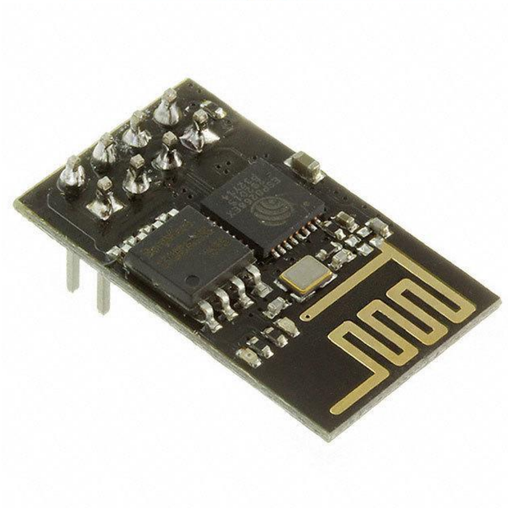
- Liquid flow rates up to 5000 µl/min
- Resolutions down to sub nl/min
- Totally non-invasive, pressures up to 200 bar
- Digital I²C interface or analog out 0-5 V

d) Touch Screen Display (Newhaven Display, 2018)



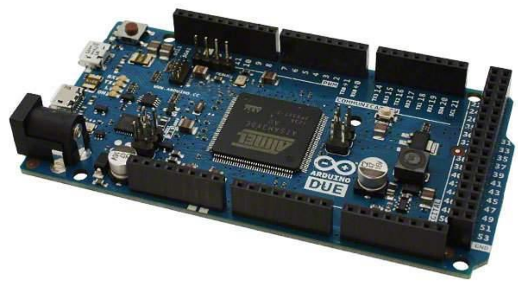
- 480xRGBx272 resolution, up to 262K colours
- Utilizes the FTDI FT801 Embedded Video Engine
- PWM backlight control
- Onboard audio power amplifier
- microSD card reader
- Built-in logic level shifting
- Assembled with NHD-4.3-480272EF-ATXL#-CTP
- Capacitive touch panel with controller
  - 5 point multi-touch input o Gesture input
  - Zoom In/Out
  - Swipe Up/Down/Left/Right

e) WiFi Card (SparkFun Electronics, 2013)

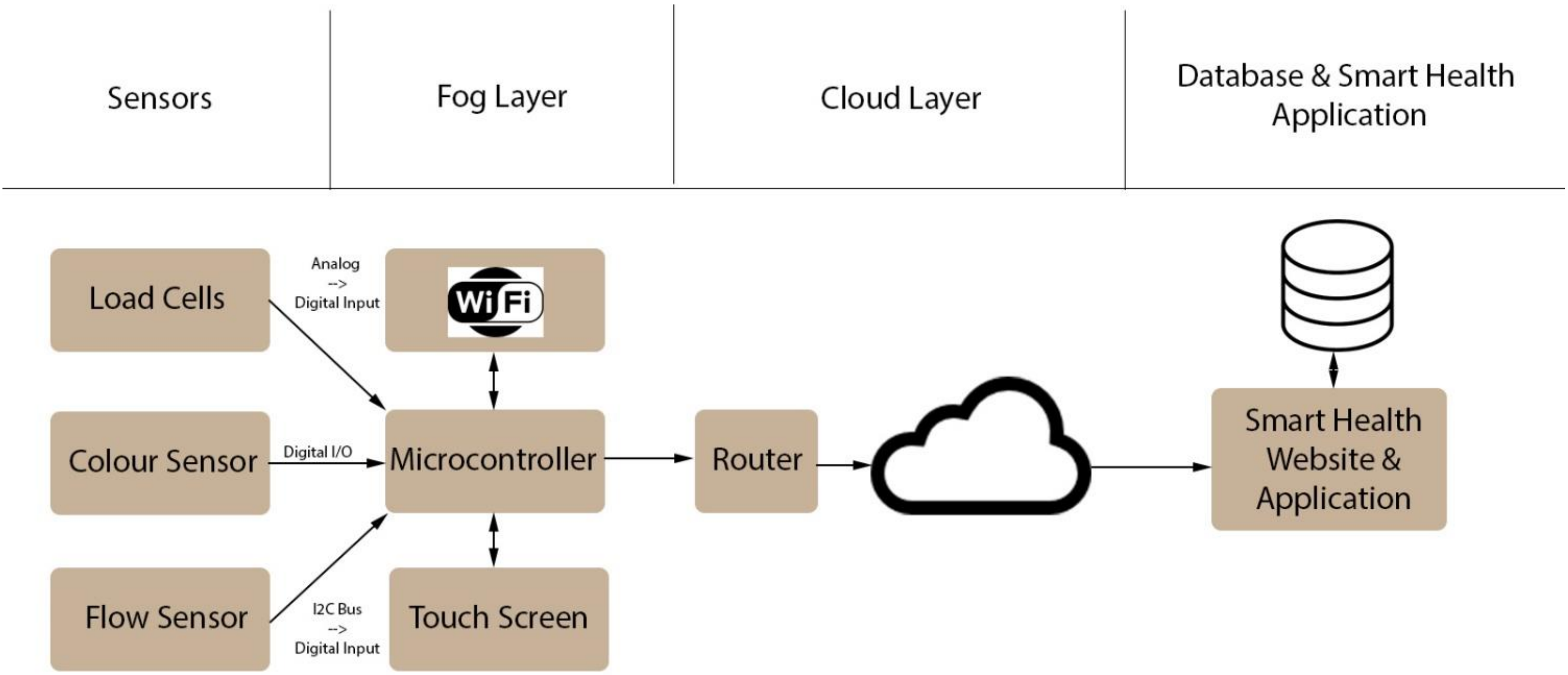


- 802.11 b/g/n protocol
- Wi-Fi Direct (P2P), soft-AP
- Integrated TCP/IP protocol stack
- Integrated TR switch, balun, LNA, power amplifier and matching network
- +19.5dBm output power in 802.11b mode
- Integrated temperature sensor
- Supports antenna diversity
- Integrated low power 32-bit CPU could be used as application processor
- Wake up and transmit packets in < 2ms
- Standby power consumption of < 1.0mW (DTIM3)

f) Microcontroller – Arduino Due (Arduino, 2017)
- 3.3v Operating Voltage
- 54 Digital I/O Pins
- 12 Analog Pins
- 130mA Total DC Output Current on all I/O lines
- 512kb Flash Memory
- 96KB SRAM
- 84MHz Clock Speed
- 36g Weight



TASK 3: Connectivity Diagram



3.1 Data Collection Process

The Smart Health Toilet data collection process begins when a user sits on the device. The four strain gage load cells transmit voltage to the microprocessor, this current awakens the Arduino Due's operating system from 'standby' mode to 'online'.

Once 'online' the status is displayed for the user on the touch screen. Via the touch screen the user is then asked if they would like to test their urine, if 'yes' the user chooses their matching user profile and the device advises when the user is able to begin urinating. The user is advised that they should only urinate for other substances such as faecal matter void the accuracy of the test (C. Rose, 2015).

The liquid flow meter detects the flow rate of the urine, once flow has initiated the information is passed to the microcontroller. To conduct a successful RUT a patients urine should be collected when it is mid-stream (Health Direct, 2016). To effectively capture this the microcontroller activates the toilets liquid seal once the flow has reached the mid-stream, this is calculated at 87mls given the mean adult flow being 263mls (Sheng-Mou Hsiao, 2013). Once the stream has reached the end of the mid-stream the seal is released, the urine is then held in a separate chamber for conduction of the RUT. The microprocessor calculates the end of the mid-stream by multiplying the flow rate by the time elapsed since the mid-stream was reached.

Once the mid-stream urine has flowed to the chamber a spindle with RUT strips attached is spun so that one of the strips is doused in the urine. Once doused the urine is disposed and the RUT can begin, the colour recognition sensor captures the colours of each colour field and returns the results back to the microprocessor for analysis. The microprocessor analyses the results against the colour database stored in the physical memory, from this the program assesses whether the chemical balance of each field on the strip is below or above the healthy norm. The assessment is stored locally, uploaded to Smart Health's website and stored further in the company's cloud database. Once uploaded these results can be accessed by the respected user when logged into the company's website or mobile phone application.

3.2 Test Frequency

The frequency of collecting data is set by the user, although the Smart Health Toilet User Manual is to suggest once per week to accurately monitor changes of urinary health. If the test shows an irregularity in the urine the manual advises to undergo the exam again the next day. If the tests show irregularities for 3 consecutive days, the manual advises to consult a health professional and show the results outputted by the IoT device.

3.4 Network Advantages

The Smart Health Toilet needs to connect to Smart Health's website and database to store its assessment data, to achieve optimum practicality and efficiency it has been equipped with WiFi network technology. The IoT solution is intended for instalment in home environments which typically each have an existing WiFi network. Homes have the potential to span large distances which is why other wireless network technologies that have limited range would not suit i.e. Bluetooth technology (Mahmoud Elkhodr, 2016). Larger span wireless network systems such as Zigbee and 6lowPAN would not be suitable for customers of the IoT device for they would need to install an additional network that would only be used for the Smart Health Toilet.

TASK 4: Fog Computing Analysis

4.1 Data Output

Once the IoT device has completed the analysis (see 3.1), the information is readily available for the user when they log on to Smart Health website or mobile application. The information displayed to the user is the chemical balance of each individual test field that exists on a Rapid Urine Test strip. From the information of the test the website will advise the user of the severity of the results and provide remedial steps for the user to take if required.

4.2 IoT Services Platform

If adoption of the Smart Health Toilet was widespread the need for a IoT Services Platform would be crucial for security, management and scalability. Implementing this platform would enable the automation of updates for each Smart Health Toilet that was connected to the network (Rayes, 2017). Automatic updates ensure the future of the device and accuracy of RUT's. A services platform provides key functions that keep IoT solutions up to date, ones that would be imperative for the given IOT solution are the Data Manager, Firmware Manager and Discovery and Registration. Without these functions a user would have to manually update the device and could risk false and outdated test results due to outdated firmware and protocols.

TASK 5: Security & Privacy

5.1 Security Measures

Security measures for the IoT solution are applied to ensure integrity and security of users Rapid Urine Test results. The long-term test results history is stored in the cloud domain which is the most likely domain for cyber-attack given the volume of data stored. To ensure the security of this domain the company's website and database need to be hosted by reputable cloud virtual machine providers such as Google and Amazon. The IoT system is designed for homes meaning the physical devices which are part of the fog domain are not in public locations, therefore data attacks on the fog layer would be difficult and rare. Access to the fog layer in a non-physical sense is only achievable by accessing it through the cloud domain, therefore security of the cloud domain is emphasised.

5.2 Potential Security Issues

As previously mentioned the Smart Health Toilet is predominantly susceptible to security issues in relation to the cloud domain. Although inaccuracy of data is at high risk in the home environment, this is because there is not an existing verification method when using the IoT device, the user simply selects which profile to conduct the test.

TASK 6: Conclusion

6.1 Value Proposition & Key User

The Smart Health Toilet is an Internet of Things project formulated to solve the 'necessity to visit a doctor to conduct a Rapid Urine Test', this was addressed as the focal problem. The device allows to the user to conduct RUT's in the comfort and privacy of their own home, the inconveniences solved (added value) were identified per stakeholder and addressed in full in section 3.1.

The key user of the IoT solution is recognised as a 'professional', these are customers who gain the most benefit from the adoption of a Smart Health Toilet. This is because solution adoption eliminates the necessity to take time away from a 'professional environment' to conduct a RUT. As stated in 3.1 the benefits or inconveniences solved by the solution are categorised by the following;

- Travel
- Associated Costs
- Waiting Periods
- Opening Hours
- Health Records

6.2 Future Solution Iterations

If successfully adopted, the Smart Health Toilet's future iteration's will aim to improve and extend the convenience and functionalities of the IoT solution. Such an improvement would be the introduction of Urinalysis and Urine Culture testing. These are elaborate tests which are usually conducted in hospitals or advanced surgeries (Author, 2016).

Urinalysis is conducted by observing the blood features of urine using microscope technology. “Urinalysis is used to find the cause of – or monitor – urinary tract infections, bleeding in the urinary system, or kidney or liver disease. It can also be used for diabetes, some diseases of the blood, and bladder stones” (Author, 2016).

Urine Culture testing is conducted to analyse the germ content of urine by using ‘mid-stream’ samples and storing them in an incubator for one to two days, the incubation process allows the bacteria or fungi to grow (Author, 2016).

In addition to more elaborate testing, greater data security measures would be installed into future iterations of the Smart Health Toilet. An example of this would be recognition software to detect the current user, this would eliminate the data conflict issue explained in 5.2.

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