SMART HEALTH TOILET

CONCEPTUAL DESIGN

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Contents

Executive Summary:

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'. The device allows the user to conduct Rapid Urine Tests (RUT's) in the comfort and privacy of their own home.

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.

1 - PACT Analysis

According to (UKEssays, 2015), "PACT analysis is defined as a user requirement document that is used for a more detailed design brief. This analysis is a way of reflecting about people, activities, content and lastly technology (PACT Analysis)."

People: To correctly address the 'People' aspect of the analysis the physical, psychological and social characteristics are assessed. With context to the Smart Health Toilet the following abilities are required to use the IoT solution;

- Physical Abilities:
    - Urination – ability to pass urine
    - Healthy Vision – ability to see touch screen interface
    - Touch – ability to interact with touch screen interface
    - Movement – ability to navigate to device instalment location
- Psychological Abilities:
    - Age – ability to use the device (cognitive ability) (recommended age of use 10-90 years old)
    - Read: ability to read and interpret displayed information
- Social Abilities: Not applicable for it is designed for private use

Activities: Th 'Activities' portion of the PACT analysis assesses how the activity of using the IoT solution is performed, why it is performed and what can be done to improve the activity? (Trulock, Unknown).

- How is it performed: With reference to my previous paper 'Smart Health Toilet' (Douglas, 2018), the IoT solution functions when a user wishes to urinate. The user is presented with a choice to conduct a rapid urine test or not on the integrated touch-screen. If yes is selected the user urinates and the device assesses their urine for abnormalities, the device then uploads the test results to their respective Smart Health profile.
- Why is it performed: The device is used to eliminate the need to visit a doctor to conduct a RUT (Douglas, 2018).
- Activity Improvement: The fundamental flaw in the activity is the touch-screen and its' potential exposure to harmful bacteria. Notifying the user to wash their hands before using the touch-screen is not an effective method of reducing the transfer of such bacteria, the onus is on the user to adhere to these recommendations. A potential

solution to this issue is to apply replaceable translucent ant-bacterial films to the surface of the touch-screen to minimalize the spread of harmful bacteria.

Context: The 'Context' element of the PACT analysis assesses the environment of the activity (Trulock, Unknown). The following categories are used to detail this assessment;

- Physical Environments: This environment is recognised as the users' location of instalment of the IoT solution, which is a restroom. This is a private environment typically exposed to harmful bacteria.
- Social Environment: Not applicable for a restroom is typically a private setting.
- Organisational Context: Not applicable for use of the device is individual.
- Activity Circumstances: The activity is performed in the privacy and comfort of the consumers home, the time and pressure constraints are relevant to the users' life schedule, which is impracticable to measure successfully.
- Activity Support: The intention is to provide the user with an instruction manual that comes with the device, it is also intended to provide video tutorials on how to use the device on a media platform like YouTube.

Technologies: This section describes the technical functionality of the device and how future iterations could update the solution (Trulock, Unknown).

- Technical Functionalities: Gathered from Smart Health Toilet (Douglas, 2018).

- Input:
    - Data input: is collected when the user selects their profile, chooses to conduct RUT and urinates into the Smart Health Toilet.
    - Commands: are activated when the user interacts with the touch screen and sensors, the information is processed by the onboard microprocessor.
    - Security: There are currently no security measures incorporated to authenticate the user when using this touch-screen, this flaw has been documented in the Smart Health Toilet report.
- Output:
    - Touch-Screen: The information outputted to the touch-screen is limited, it provides the user with options to conduct a RUT and to select a profile. Once a profile has been selected it will out a message confirming that a specific user profile has been chosen.
    - Smart Health Profile: Results of the RUT are displayed under the users Smart Health Profile (available online), these results update the user of their health based off their urine. Note: These results should as a complete health-check for not all ailments are measured by a rapid urine test.
- Communications:
    - Sensors: The Smart Health Toilet consists of a multitude of sensors (Figure 1), their connections are explained in depth (Figure 2) in the Smart Health Toilet paper. The below are excerpts from that report showing these connections.
    - Microprocessor: "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." Refer to the connectivity diagram (Figure 2) for this routing.

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

Figure 1 - Sensors

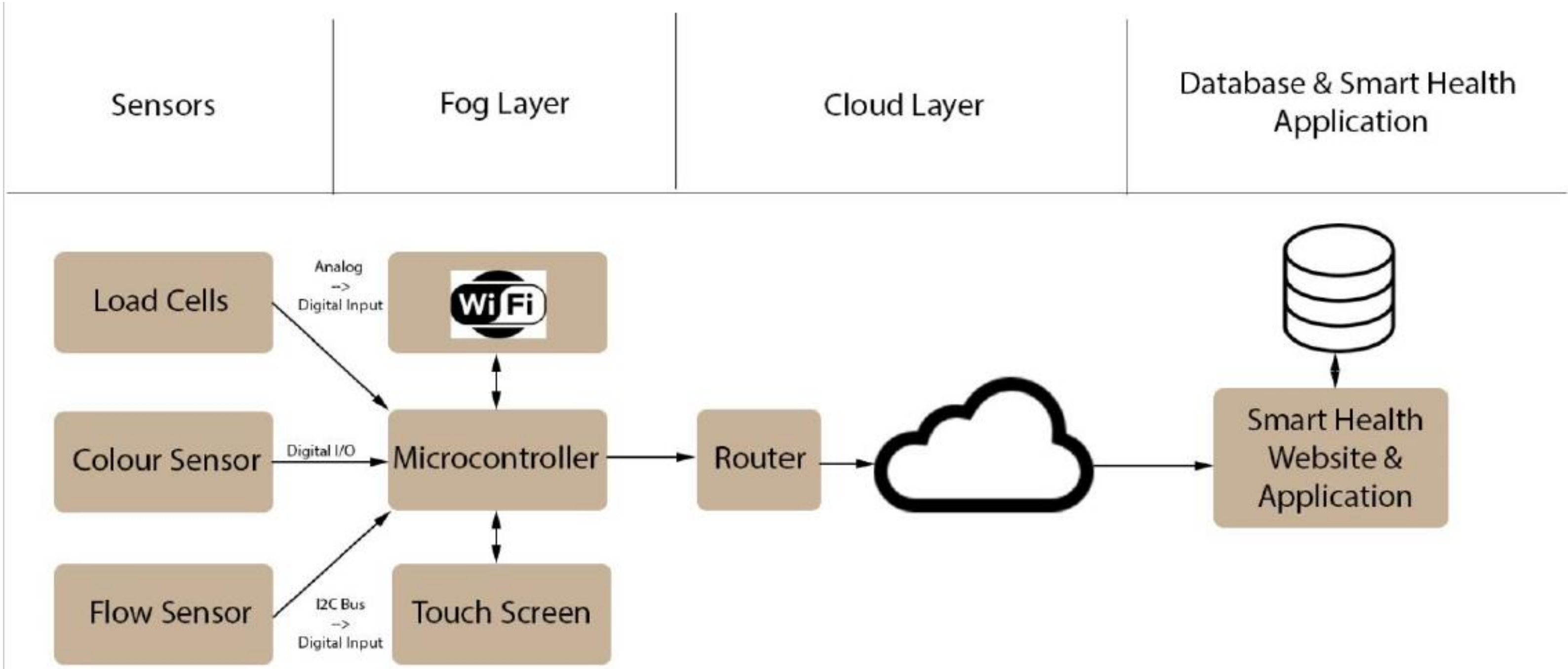


Figure 2 – Connectivity Diagram

- Security: Referencing the Smart Health Toilet report (Douglas, 2018), "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."

2 - Problem Space Scenarios & Use Cases

Problem Space: In the Smart Health Toilet report the focal problem is recognised as 'the necessity to visit a doctor to conduct a Rapid Urine Test'.

Solution: The implementation of the Smart Health toilet allows people to conduct RUT's in the privacy and comfort of their own home. Thus, eliminating the need to visit a doctor to conduct such an exam.

Key Stakeholder: Referencing the Smart Health Toilet report (Douglas, 2018), "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"

Given the above information the following table describes these inconveniences and details the use cases to solve these problem space instances;

Problem Space	Scenario	Use Case
Travel	"I think there's something wrong, it hurts to urinate. I need to go to the doctors to get my urine analysed, although I don't own a car and GP is 5km away."	"Thankfully I can do a check to see if there are any abnormalities with my urine by using the Smart Health Toilet. This means I won't need to travel."
Associated Costs	"I think there's something wrong, it hurts to urinate. I need to go to the doctors to get my urine analysed, although I'm a student and cannot afford to visit a doctor."	"Thankfully I can do a check to see if there are any abnormalities with my urine by using the Smart Health Toilet. The cost of replacing the RUT test strips is minimal compared to the cost of visiting my GP"
Waiting Periods	"I think there's something wrong, it hurts to urinate. I need to go to the doctors to get my urine analysed, although I just checked and there are no availabilities left at the surgery."	"Thankfully I can do a check to see if there are any abnormalities with my urine by using the Smart Health Toilet. There are no waiting times unless someone is using the restroom."
Opening Hours	"I think there's something wrong, it hurts to urinate. I need to go to the doctors to get my urine analysed, although it's 1am in the morning and it doesn't feel serious enough to go to the hospital."	"Thankfully I can do a check to see if there are any abnormalities with my urine by using the Smart Health Toilet. I can conduct the test in the comfort of my own home."
Test Results	"My GP has all my results of prior RUT's stored at the surgery and I have no access to these records."	"Since I started using the Smart Health Toilet I can see exactly when I had abnormalities with my urine and know what was wrong."

Figure 3 – Problem Space Scenarios & Use Cases

3 - Information Architecture Flow

The below table shows how the information from the sensors are processed by the microprocessor, then transmitted to the Smart Health cloud database.

Elements & Processing (Information Architecture Flow)
Hardware Elements (Fog Layer): - Load-Cell (Sensor): Outputs voltage to microprocessor, utilises the Arduino Due's 12 analogue pins. - Liquid Flow Meter (Sensor): Outputs to microprocessor via I2C-Bus (Digital Signal) - Colour Sensor (Sensor): Utilises microprocessors digital I/O pins. - Touch-Screen (Sensor): Utilises microprocessors digital I/O pins. - Arduino Due (Microprocessor): Receives inputs from sensors and processes data - WiFi Transmitter (WiFi Card): Enables microprocessor to connect to cloud Connections (Between Fog, Cloud & Application Layers): - Fog ←→ Cloud ←→ Application: The microprocessor connects to the cloud and internet services utilising the WIFI transmitter. Transmission Control Protocol (TCP) and Internet Protocol (IP) are used to transmit the data outputted by the microcontroller to the cloud and beyond safely and securely (Gerwig, 2017). The information is parsed and uploaded by connecting to Smart Health's online MySQL database, the program uses encrypted admin credentials to log into the server so that the data can added. Processing: (referencing section 3.1 of the Smart Health Toilet report (Douglas, 2018)) "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 Student Name: Douglas Brennan Student # n7326645 Smart Health Toilet April 2018 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."

Figure 4 – Information Architecture Flow

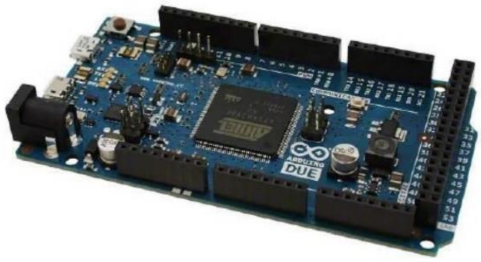
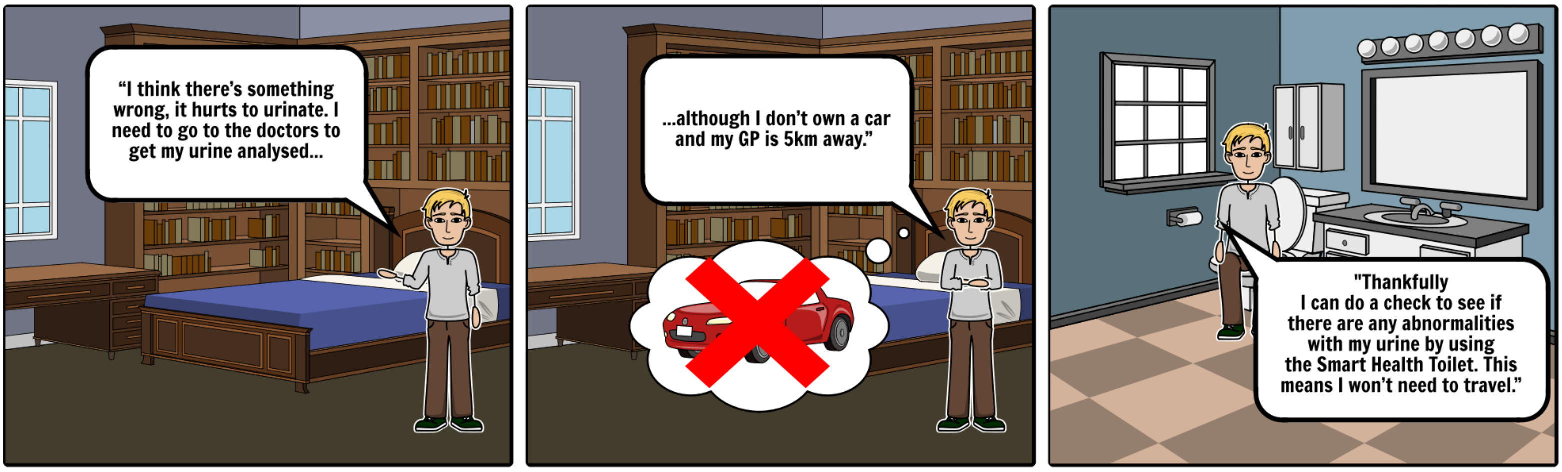
Software Information	
Microprocessor (Fog)	(Google or Amazon) Server (Cloud & Application)
	
<u>Software Functions</u> - Recognises analogue voltage from load-cells to wake up 'Main' program - Records selections made using touch-screen (digital input) - Recognises digital input from liquid flow sensor, runs methods to operate liquid seal and spindle - Activates colour recognition sensor using digital I/O pins - Calculates health scores for each test strip field and stores results in local database -Transmits results via TCP/IP connection available through WIFI - Connects to Smart Health's database using encrypted credentials	<u>Software Functions</u> - Receives transmission from Smart Health Devices using login credentials - Stores transmitted results to local database - Hosts Smart Health Website - Transmits updates back to Smart Health systems using the IoT solutions such as Data Manager, Firmware Manager, Discovery and Registration.

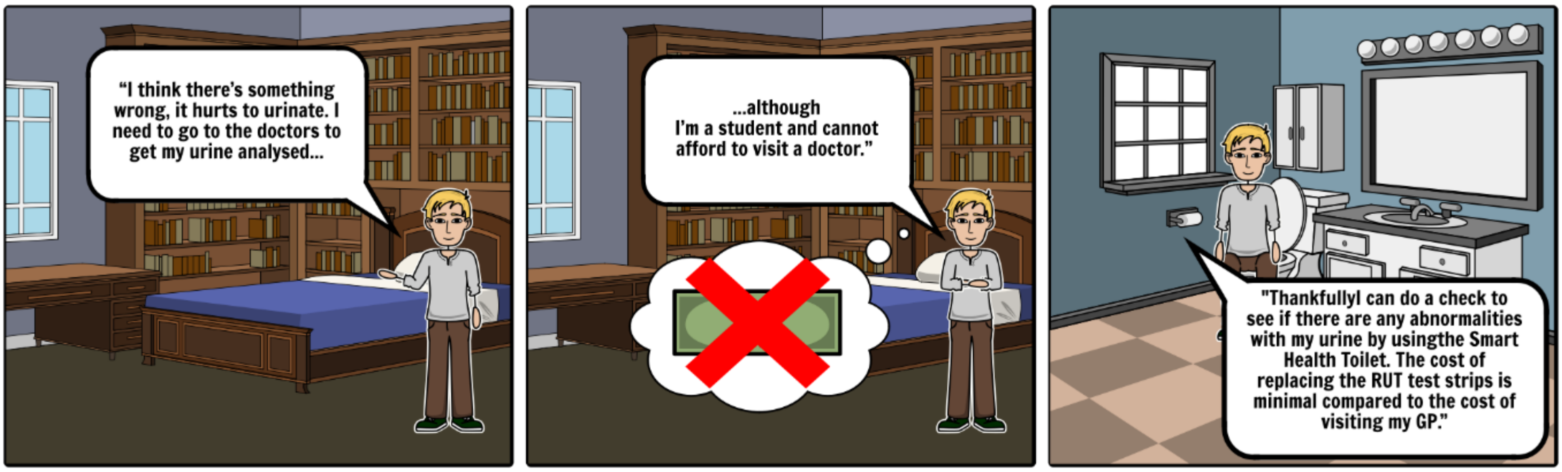
Figure 5 – Software Architecture

4 - Storyboards



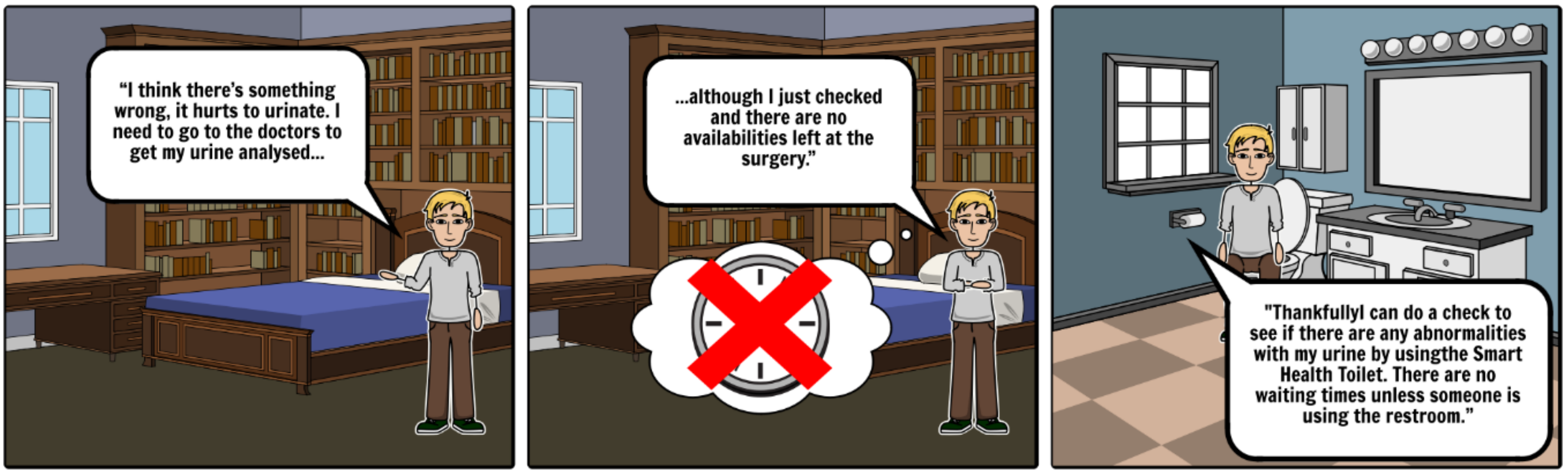
Create your own at Storyboard That

Figure 6 – Travel Use Case



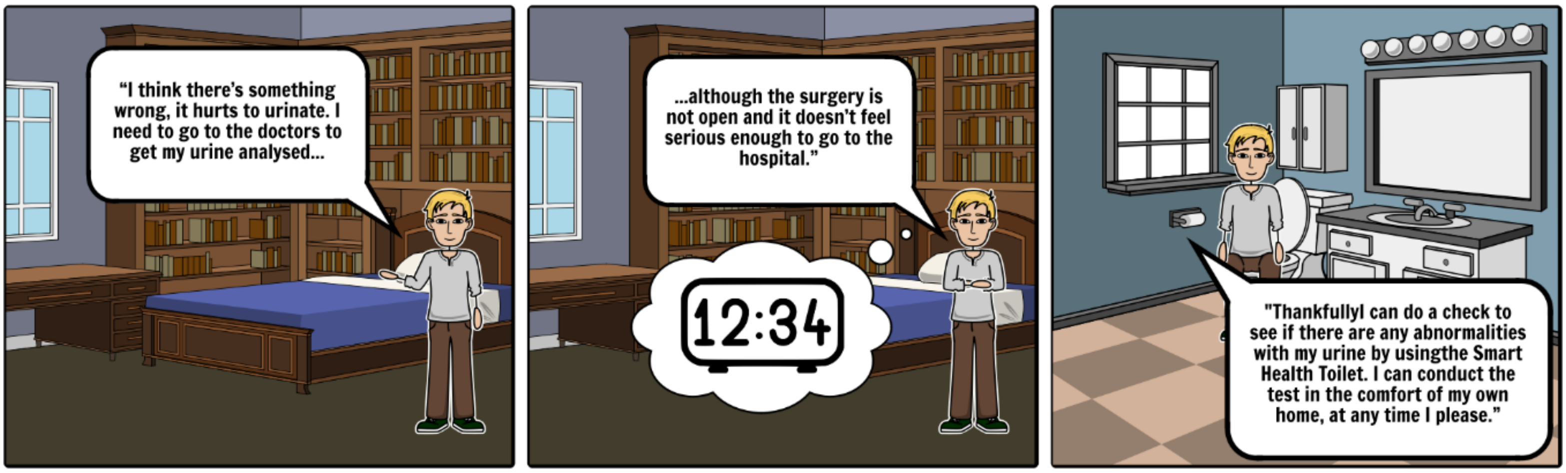
Create your own at Storyboard That

Figure 7 – Associated Costs Use Case



Create your own at Storyboard That

Figure 8 - Waiting Period Use Case



Create your own at Storyboard That

Figure 9 – Opening Hours Use Case

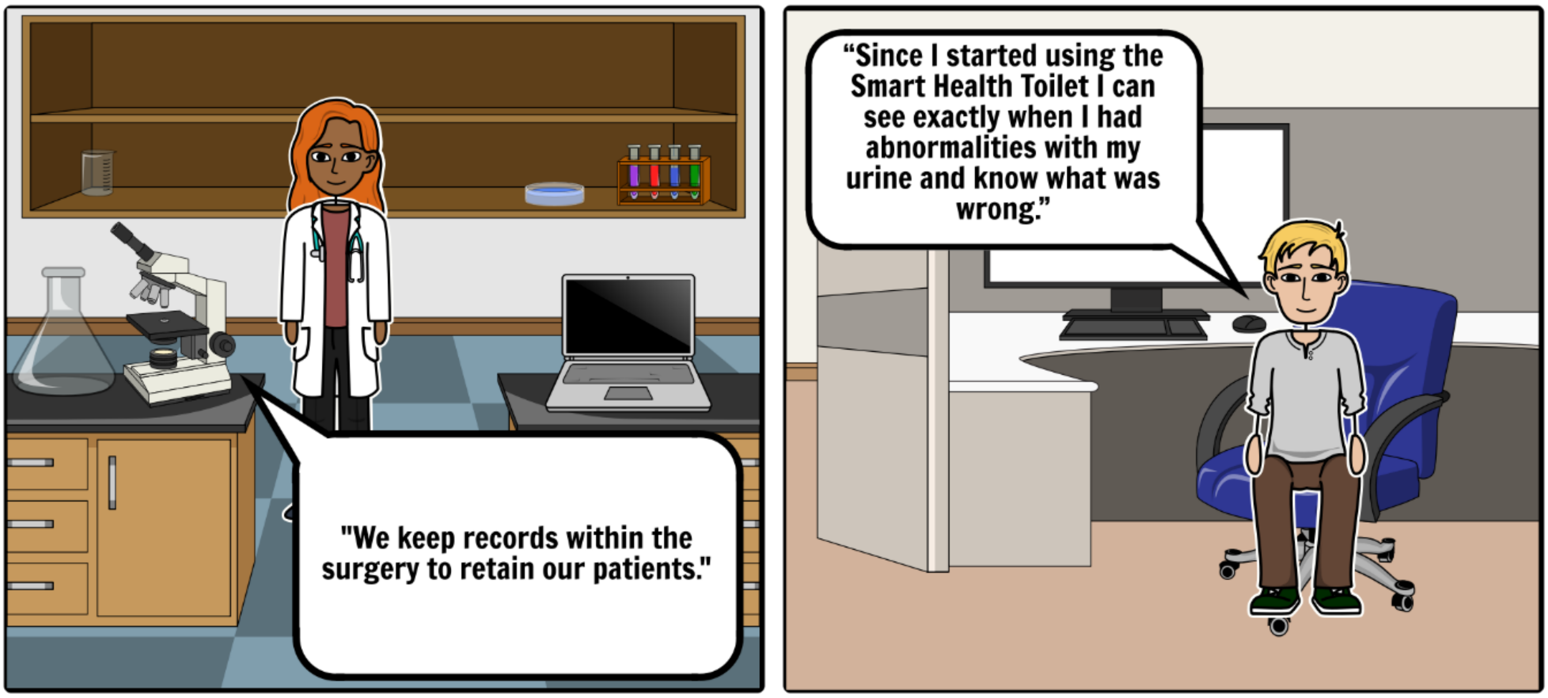


Figure 10 – Test Results Use Case

5 - Conclusion

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'. The device allows the user to conduct Rapid Urine Tests (RUT's) in the comfort and privacy of their own home.

This report has detailed in depth a deeper analysis of the device. Section 1 assessed the IoT solution through use of a PACT analysis which investigates the people, activities, content and technologies surrounding the project (UKEssays, 2015). The second section addressed was problem space scenario and use cases, this reiterated the problem space defined in assignment 1 as 'the necessity to visit a doctor to conduct a Rapid Urine Test'. Based off this use case scenarios were formulated that show the different instances when the problem space can occur. Section 3 described how the Smart Health Toilets' produced data flows between the fog and cloud layer. A software architecture diagram shows functions which occur on each layer to process this data effectively. Then section 4 uses the use cases from section 2 to visually show existences when the problem scenario can occur.

The potential factors which could limit the success of the device are ideated as the following;

- Cost: the estimated 'shelf' price of a Smart Health Toilet is estimated to be between $1,000 to $3,000 Australian Dollars. This could be seen as a luxury item and not worth the money considering a GP will conduct the test for roughly $50. The attractiveness of the IoT solution is therefore marketed towards 'professionals', which was outlined in section 2 as the key stakeholder, due to the assumption that professionals are busy and require convenience solutions.
- Computational Limits: The limitations of the device is that it only currently conducts a Rapid Urine Test. This was addressed in the first paper (Douglas, 2018), "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.”

The Smart Health Toilet is a potentially revolutionary innovation which could drastically improve the efficiency and convenience of conducting urine analysis. I am seriously thinking of patenting the idea for it is novel and I think it has potential to become a commercial item which ‘professionals’ would purchase. If I had the capital I would consider invest in the production of a prototype.

6 – Video

The video presentation for the Smart Health Toilet is viewable using this link.
https://youtu.be/wDHjDjk8f5E

7 - Bibliography

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