UNSW SYDNEY

COMP6733 - IoT Design Studio
Project Proposal

Hand washing quality monitoring with sensorTag

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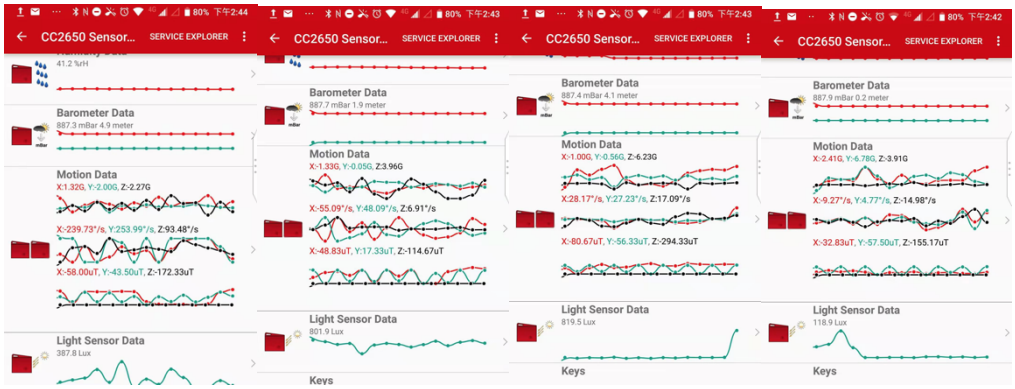
Background & Introduction

Nowadays, in medical institutions such as hospitals and clinics, in the food businesses of restaurants, grocery stores and food processing industries, the hand hygiene compliance of the works is very important. Hand hygiene is critical to achieve universal health coverage as it is a practical and evidence-based approach with demonstrated impact on quality of care and patient safety across all levels of the health system. According to WHO count, about 10% patients get an infection while receiving care, more than 50% of surgical site infections can be antibiotic-resistant, and effective hand hygiene reduces health care-associated infections by at least 30%. Also, one study about the food industries is that food contaminations by food workers are responsible for about 89% of the food borne illness outbreaks.
Washing hands correctly is a most important part of hand hygiene compliance, but not all the relevant works can wash hand on time and ensure the quality of hand washing. So, reminding workers to wash their hands when necessary with a high quality is extremely important for ensuring hand hygiene requirement. And it is also very important to provide a personal washing hand activities feedback to the users.
Hence, we decided to development a product which can notice users to washing hand, check their hand washing quality, teaching user how to do a high-quality hand washing, also, collecting these data and generate a report show to users about these washing hand activities during a period. In this project, we present HandyTag, a smart watch based on Sensor tag which can achieve the above requirement.

Aim

1. Detect the hand washing quality
2. Store the most recent hand washing records
3. Display the hand washing quality data through an Android application
4. Instructs users to properly wash their hands

We're going to use accelerometer, gyroscope to get the data These sensors are embedded in the sensor tag and can monitor the action of user hands. Different actions will generate different patterns of feedback, and we can transform and filter the data to build a database to identify different hand washing patterns. ROTATE, X, Y, Z response for accelerometer and gyroscope.

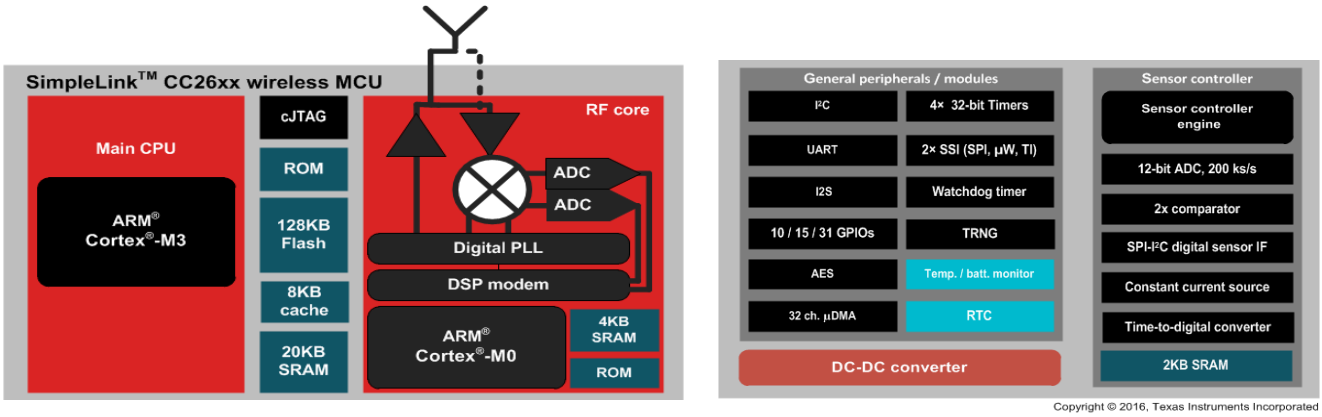


Final demo:
In the final presentation, we will connect our sensortag with android, score and instruct users to wash their hands correctly through a regular and unconventional hand washing and show the recent hand washing quality and times.

Platform Introduction

- Sensortag introduction:
    - SensorTag, which includes 10 sensors like light, digital microphone, magnetic sensor, humidity, pressure, accelerometer, gyroscope, magnetometer, object temperature, and ambient temperature, is a programmable IoT device in a small overall size.

  In this project, we mainly utilize the gyroscope, accelerometer and CC2650, which in charge of the wireless communication. Thus, there are some description about in the following part
- Wireless communication module introduction:
    - The CC2650 device is a wireless MCU targeting Bluetooth, ZigBee® and 6LoWPAN, and ZigBee RF4CE remote control applications.
    - Below is a diagram describing its overall structure:



- MPU9250 introduction:
    - MPU-9250 is a chip containing one 3-axis gyroscope, a 3-axis accelerometer and one 3-axis digital compass.

By utilizing these two sensors, we should be able to track hand motion and below is one sample model of data collected from some research papers:

ViBand: High-Fidelity Bio-Acoustic Sensing Using Commodity Smartwatch Accelerometers

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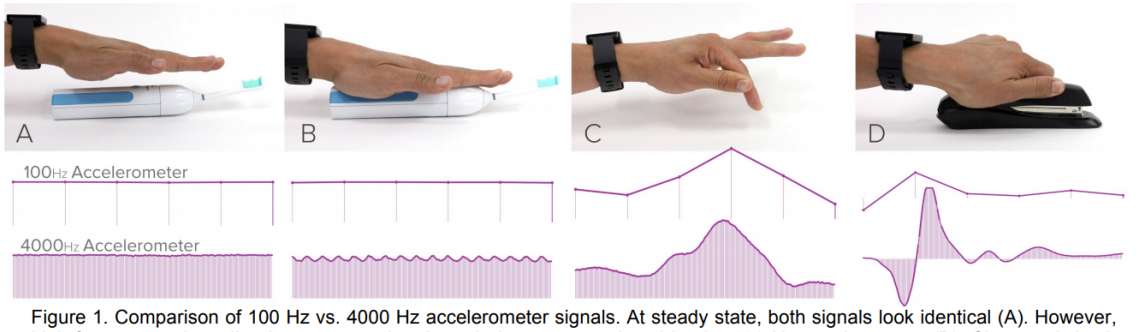
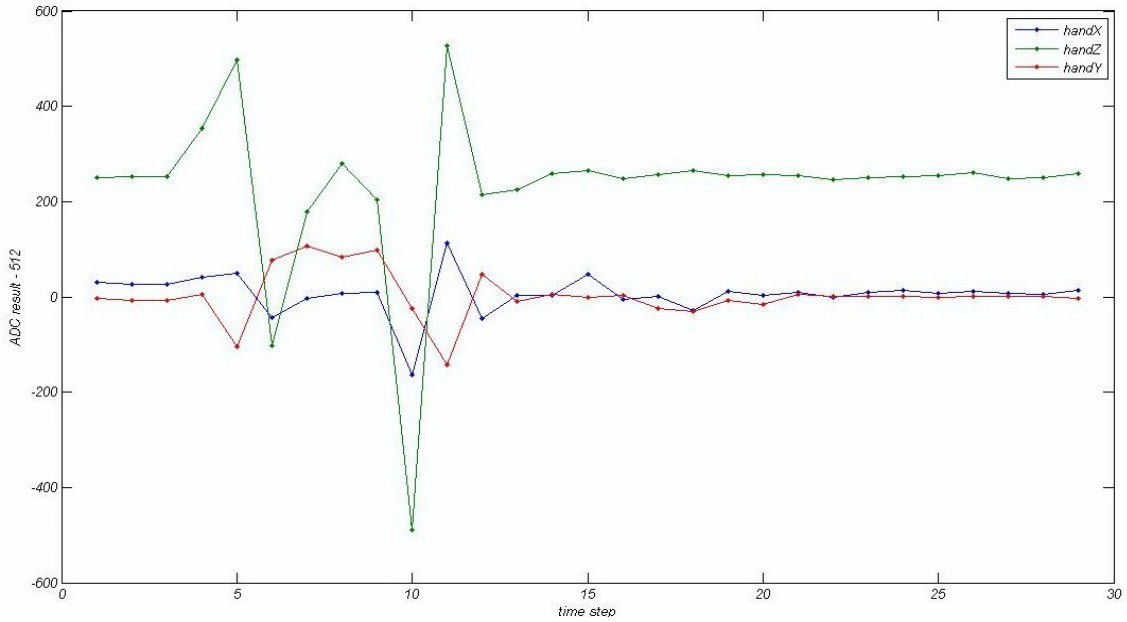


Figure 1. Comparison of 100 Hz vs. 4000 Hz accelerometer signals. At steady state, both signals look identical (A). However, high frequency micro-vibrations propagating through the arm are missed by the 100 Hz accelerometer (B). Characteristic vibrations can come from oscillating objects (B), hand gestures (C) and the operation of mechanical objects (D).

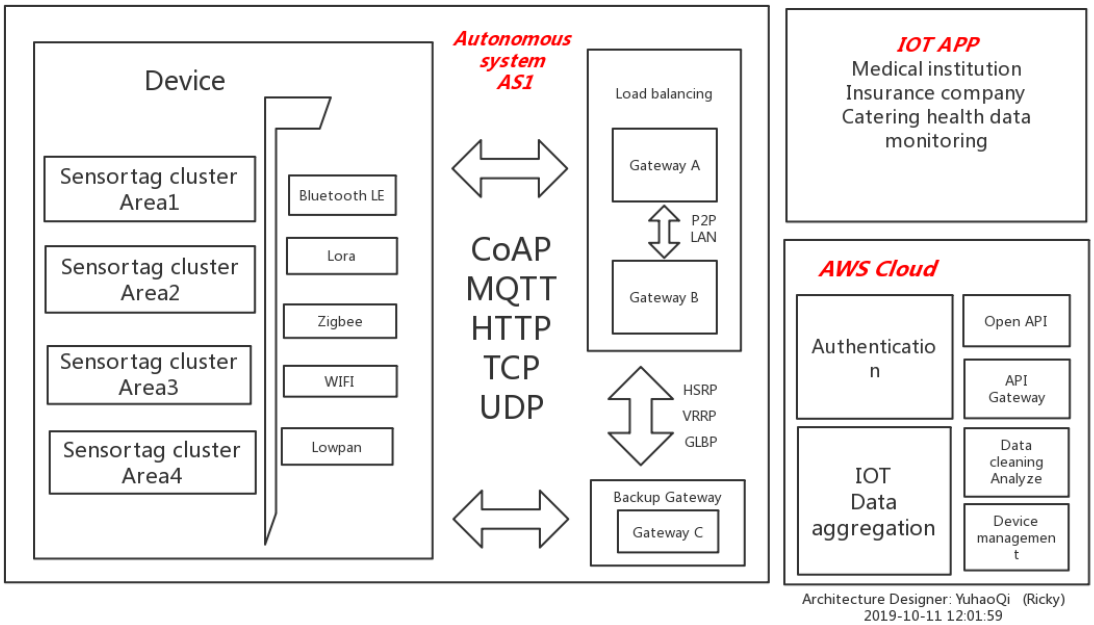
- By utilizing similar data as below collected with sensortags, we should be able to modelling hand washing gestures.



Project Architecture

For the design of the architecture, we will make our architecture accommodate as many IOT devices as possible, and maintain high scalability, high availability, and high security, as well as high performance

Architecture diagram:



Scalability:

This architecture can accept 1000-10000 sensors through the different Autonomous System. Each Autonomous System can include 200~1000 Sensortag through different Sensortag cluster Area. The cluster of sensors can connect to the gateway through the low power wireless protocol. (For example: each hospital would be act as an Autonomous System. If there are 10 hospital, the number of AS would be 10. Inside the hospital, we can treat each floor as an Sensortag cluster Area.) For AWS central connection points, we can extend our service resources by deploying multiple servers on AWS.
This has many advantages:
1. Deployment on demand (server can be added when more nodes join in the future)
2. Cost savings (we can save money by hanging up the server when the traffic is low)

Availability & Security:

As the feature of sensortag is low power consumption, it is in a sleep state during normal times. Once an event is activated, it will start to consume network resources and generate traffic. Once most sensortags are activated at the same time, a lot of network resources will be consumed, so we designed a load balancing gateway. These gateways can share resources and distribute network traffic over cable, through peer-to-peer or other protocols. Based on risk management, in order to prevent the main gateway from losing functions due to intensive resources, we designed an alternate gateway to mitigate the network environment. These gateways can be automatically switched through some redundant gateway protocols (eg. HSRP, VRRP, GLBP). For gateway and server connections, we use IPSEC to connect the AWS server gateway to the Autonomous System. Its functions include data encryption, access control, source address authentication, data integrity checking and preventing replay attacks.

Performance:

The gateway connects to AWS cloud server through ISP network. When the secret key authentication is successful, the cloud server store the data in mongoDB. Because IOT devices generate a lot of data, we need to do a lot of inserts, and Nosql is better suited to this kind of data store than relational databases. After the data is cleaned and analyzed, it will be stored in the back-end database, some authorized companies and institution can use our application, such as hospitals and insurance companies, which can pay service fees to access our data on a regular basis. Since we have little requirement on the timeliness of data, we can accept 10-60s transmission delay, which will not affect the user experience and the functional integrity of the system. In our project, due to time constraints, we plan to collect and analyze data from sensors, establish a database of hand-washing gestures through machine learning, and display data through a wireless protocol connected to an android gateway

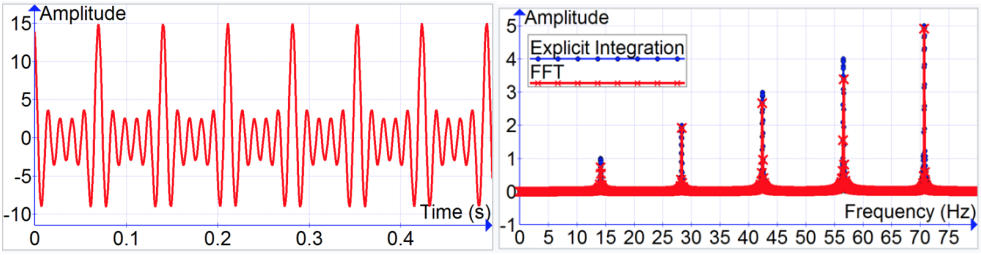
Implementation details:

1.Hand washing scoring algorithm
We will monitor the entire hand-washing process and score the final hand-washing quality in frequency based on the number and duration of matching postures during the process
2.Sensor data acquisition algorithm development
We will build a set of code for data collection, data packaging and segmentation

based on time, sending for further analysis on sensortag through Bluetooth low energy.

3.Data is filtering and cleaning & transforming

We may use fast Fourier transform (FFT) to convert time-segmented data into frequency-domain data for more intuitive data analysis, and we may also perform some additional data filtering and cleaning



After the FFT, the data is easy to read.

4.Using machine learning build hand gesture fingerprint database

We'll use machine learning to learn different gestures to build a fingerprint database, which is expected to be done in python on a personal computer, and then we'll import the database into the device to identify specific gestures. And coding on sensortag or android to recognize a match between the start behavior and the end behavior

5.Monitor startup action identification

In practical application, we will set a time threshold to activate the monitoring. If the user has been using high frequency actions for a period of time, the monitoring will be started, or the identification will be started according to the front action buffer. The user will press the hand sanitizer before washing hands, and then turn the faucet before washing hands

6.Android phone application logic and interface development

We'll develop an android app to show the quality of your hand washing and make Suggestions, show recent records and maybe do some additional logical processing

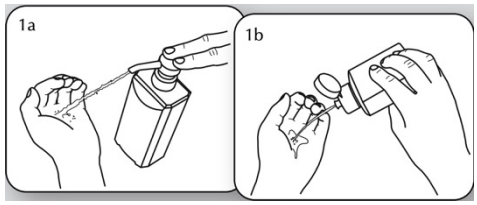
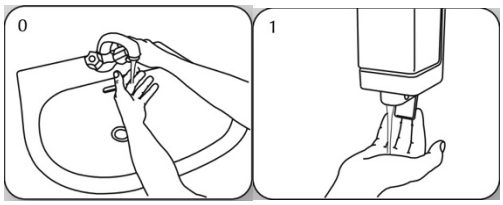
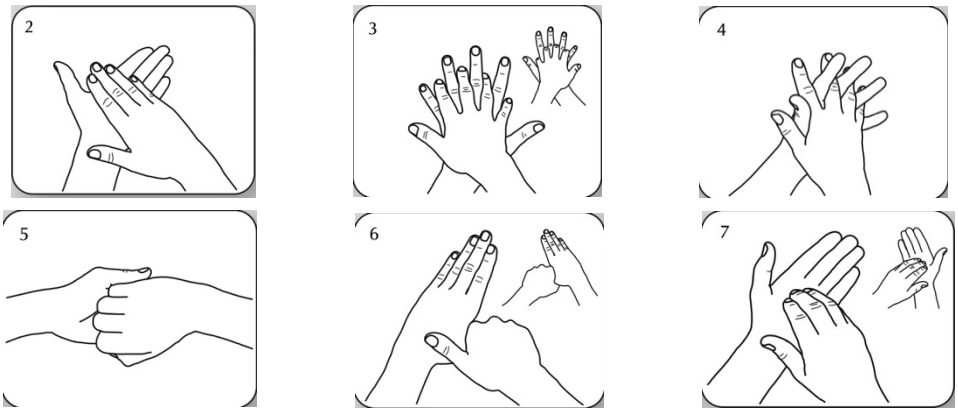
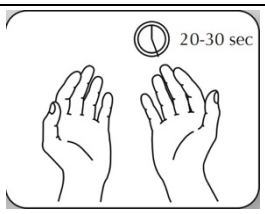
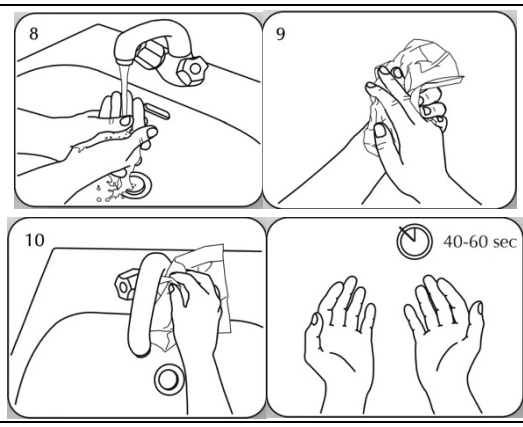
7.Build connection

We prefer to use BLE for connection, because BLE has three definitions of class that can control power, class1 can establish a stable connection of 100 meters in the case of obstacles, and a stable connection of 300 meters in the case of obstacles. In addition, bluetooth is very common and well documented.

Hand Hygiene Technique and Qualify Define

We have two kinds of washing method, with Alcohol-Based Formulation, and

with Soap and Water, the main washing steps is the same for them, only the beginning and the end steps is not the same, but we may not focus on this party during this project. But we will introduce it which is provided by the WHO.
Two kinds of mthods:

With Alcohol-Based Formulation	With Soap and Water
	
	
	

In this project main party and it will focus on the steps 2 to 7:

Steps No.	Actions
2	Rub hands palm to palm
3a	Right palm over left dorsum with interlaced fingers
3b	Left palm over right dorsum with interlaced fingers
4	Palm to palm with fingers interlaced
5	Backs of fingers to opposing palms with fingers interlocked
6a	Rotational rubbing of left thumb clasped in right palm
6b	Rotational rubbing of right thumb clasped in

*** for step 3,6,7 sub steps a and b can be changed.
*** each steps need 10S to achieve high quality

No action	~ 2S
Low	2 ~ 5S
Mid	5 ~ 8S
High	8 ~ S

*** final qualification marked by Harmonic

	left palm	Mean
7a	Rotational rubbing, backwards and forwards with clasped fingers of right hand in left palm	
7b	Rotational rubbing, backwards and forwards with clasped fingers of left hand in left palm	

For steps 1, we decided to use it as the beginning action of the hand washing monitor and may not have the quality score for it. It is an indispensable step before washing, and there is no specific quality requirement. For the last step, we may not think about the action which turn off the faucet, we just think about the hand drying for 20S.

Project Plan and Risks

Project plan

Code organization: GitHub

Weekly face-to-face meeting time: 9am to 12pm, Thursday weekly

Online contact: 24*7

Detailed plan:

- Week4: Project research. This including what exactly the problems are, what solutions are available, which one should we choose.
- Week5: Machine learning research. This include which framework should we use and how to implement in our project. Though some lab practices may mention it, there still may be heaps of extra works we should conduct. In addition, the preliminary report will also be conducting.
- Project milestone one: A machine learning framework was chosen and the preliminary report done; hard deadline for milestone one: 20 Oct. 2019
- Week6: Implementing six handwashing gesture models and identifying them. This requires multiple tests and data collection so delay may be expected to week 8 at most.
- Week7: Implementing the detection of beginning and termination of handwashing actions automatically.
- Week8: Discussing current progress and preparing the intermediate report and final presentation.
- Project milestone two: handwashing gesture models are built, auto detection done and intermediate report done; hard deadline for

milestone two: 10 Nov. 2019

- Week9: Android app development starts
- Week10: Comprehensive tests for the whole procedure, bug fixing and final report preparation.
- Week4——week10: unit tests for each module once development has done
- Project milestone three: a set of prototype product featuring our expected functions is done and available for presentation and final report is done;
  hard deadline for milestone three: 24 Nov. 2019

Sprint schedule:

COMP6733 Project schedule

activity	planned starting week	planned duration week(s)	current finish percentage	week time 4	5	6	7	8	9	10
Project research	4	1	100%							
machine learning research	5	maximum 2	30%							
handwashing gesture modelling	6	1								
handwashing auto detecting	7	maximum 2								
intermediate report	8	1								
android app development	9	1								
unit testing for each module	4	10	10%							
comprehensive testing, bug fix, final report and presenattion preparation	10	1								

legend:
- planned week
- passed week(s)
- current week
- finished week
- excceed week(s)

potential risks:

number	risks	migration
1	Some sensors in sensortags doesn't work	Keep in touch with tutors once faulty sensortags found and apply for replacement
2	team members with limited machine learning background	Self, group learning and discussing regularly to help each group member understand better about this topic
3	Limited working period	Well orgainzed project timetable and in time response to help team members work efficiently
4	Server-side data breach due to	Internal and external

	vulnerabilities	inspection to minimie any possible security risks
5	Limited handwashing action data	Invite as much people to join in our tests to get as much as handwashing data with their permission

Reference:

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2.https://www.invensense.com/products/motion-tracking/9-axis/mpu-9250/

3.https://www.ti.com/data-sheets/diagram.tsp?genericPartNumber=CC2650&diagramId=SWRS158B

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5.https://people.ece.cornell.edu/land/courses/ece4760/FinalProjects/s2010/ky237_zy49/ky237_zy49/index.html

6.https://dl.acm.org/citation.cfm?id=2984582

7.https://zh.wikipedia.org/wiki/%E5%BF%AB%E9%80%9F%E5%82%85%E9%87%8C%E5%8F%B6%E5%8F%98%E6%8D%A2

8. M. Ross and J. Guzewich. Evaluation of risks related to microbiological contamination of ready-to-eat food by food preparation workers and the effectiveness of interventions to minimize those risks. FDA White Paper, FDA, CFSAN, 1999.

9. Liu L, Johnson HL, Cousens S, Perin J, Scott S, Lawn JE, Rudan I, Campbell H, Cibulskis R, Li M, Mathers C, Black RE; Child Health Epidemiology Reference Group of WHO and UNICEF. Global, regional, and national causes of child mortality: an updated systematic analysis for 2010 with time trends since 2000.external icon Lancet. 2012 Jun 9;379(9832):2151-61.

10. https://www.who.int/

11. HTTPS://biocote.com/hand-wasing

Contribution:

In this submission, members in charge of below port

Nan Li, z5182060

Doc design, Backgroud & Introduction, Hand Hygiene technique and qualification define

Yuhao Qi, z5189309

Aim, Project Architecture, Implementation details

Jeremy HE, z5142853

Project Plan and Risks, Platform Introduction