Proposal for displaying discomfort information on the road targeting to the users of wheelchairs

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Abstract Japan is entering into the age of decreasing birthrate and aging population. The numbers of users of wheelchairs is increasing and it is important to navigate users to identify the comfort level of the surface profile of the road. Also recently GPS (Global positioning system) sensors, acceleration sensors and gyro sensors and so on have been widely used and embedded in smartphones. People can correct many kinds of data from smartphone sensors and can share as knowledge using network. This article is addressing on the alert system to the users of wheelchairs who can sense the surface profile of road than any other people. We are proposing the alert system which has analyzed from discomfort point on the road using a three-axis acceleration sensor and a GPS sensor of smartphone to minimize the cost. Each user has different discomfort level. So we have proposed mapping solution of indicating each user's discomfort point on the road using interactive method on the smartphone to minimize the risk of the impact of the surface profile of the road.

Keywords: probe information system, navigation system for wheelchairs, smartphone, wheelchairs, discomfort level

1 INTRODUCTION

Japan is entering into the age of decreasing birthrate and aging population. Users of wheelchairs will be increasing. People cannot imagine how wheelchair uses are always facing discomfort because of the road condition. Even on the flat road, because of sensitivity of the wheelchairs, users feel discomfort level from the surface of the road. Typical wheelchairs are using tube less front wheel with small diameter. Major size is 7 inches. This is because front wheel is in charge of changing direction for wheelchairs [1]. That is the reason wheelchairs are so sensitive on the surface condition of the road surface. A solid tire with small diameter senses the difference of the surface of the road very much.

Visualization of the discomfort level of the surface of the road helps to navigate the users of wheelchairs to avoid discomfort course of the road. Discomfort level of the vibration on the wheelchair is mainly related to speed of the wheelchairs and weight of the user with the condition of the surface of the road. Sharp slopes also can be dangerous to the users of wheelchairs to control the speed of the wheelchairs. When users slow down just before the bad condition of the road, discomfort level can be mitigated. In case of the outdoor course, we can use GPS sensors on the smartphones to detect position on the road. On the same road, if the sidewalk is wide enough, it may be different condition even on the same road. It requires to detect 1m level of preciseness on the detected data of GPS sensors of smartphones.

There are so many types of wheelchairs in the market. Nowadays electric-powered wheelchairs are evolving and are becoming popular. But those are still expensive and not for many People. Major type in Schools and hospitals and department stores are human-assisted models. Those models are prepared whenever required people visited the site, site owners can provide moving ability. Use case of those types of wheelchairs are the people who are not familiar to the place are using and are trying road at the first time. We have picked up such a model for the experiments to certify the ability of our proposed system.

A sensor's technology on the smartphone is becoming popular because of the widespread use of MEMS (Micro Electric Mechanical System) technology. After the year of 2000, MEMS technology have used as many variety of sensors' Technologies like acceleration sensors on the automotive to detect crash for air back and gyro sensors to guide drivers for safety drives and protecting the hand vibration when pushing button of digital camera and so on. Many researchers are working on the advanced studies in this field of mobile sensing. Such mobile sensing are using the embedded technology with moving objects like cars, bikes, bicycles, humans. And also the number of users of smartphone is increasing dramatically and people can use many kinds of sensors like acceleration sensors and gyro sensors for logging data long period of time to gather information on the circumstances and can share the information within the people who knows the importance of such data. People can develop cost effective and convenient system using smartphones and a sensors' technology embedded in them. This paper is addressing three-axis acceleration sensors and GPS sensors on the smartphone to detect bad condition of the road with discomfort level of vibration on the wheelchairs.

Our study proposes a method for detecting bad condition of the surface level of the road which causes discomfort level of vibration to the humans. We have used human interactive input method to calculate each person's threshold of the discomfort level of the road. It is based on each person's discomfort level of the vibration from the input of each user and indicates potential discomfort positon on the road.

2 RELATED WORKS

There is three related works on navigation to the users of wheelchairs. One navigator has created on smartphone, and the other works are getting log from the commercial level three-axis accelerometers.

2.1 Indoor and outdoor navigation system for disabled

At the year of 2012, headed group by WATTANAVARANGKUL NATTAPOB have created the navigation system based on the static information like stairway and precipitous slope. Smartphone has been used to get the value from a direction sensor and communicate using Bluetooth to a wheel speed sensor. But it is not based on the condition like sharp drop in road level (Figure 1), or the sidewalk road under construction (Figure 2) or the surface of the old pavement on the road (Figure 3). Old pavement on the road causes discomfort level to the users of wheelchairs. That is why it cannot detect the discomfort level of the surface of the road [2].


Figure 1.Sharp drop in the level of the road


Figure 2. Sidewalk which is under construction


Figure 3. The old pavement on the sidewalk

2.2 Unevenness evaluation of sidewalk pavement with vibration acceleration of wheel chair

In the study at the year 2004 by headed group by Miyoshi OKAMURA, they have proved that surface of the sidewalk with paver tile like Figure 5 causes unsatisfied vibration even bad effect physically to the human body. And also it has proven that accelerometer’s value is proportional to speed. They found that type of surface like Figure 4 can be used by the users of wheelchairs during only 1 hour per day otherwise it causes side-effects. Similar type of sidewalk road can be seen like Figure 5 [3] [4] [5].

The facts they have found are as below.

1) Dominant frequency of the response of the acceleration value on the vibration of the wheelchair is almost same as integral multiplication of the space size between the joints.

2) Acceleration value is proportional to the speed of the wheelchair and acceleration value of vertical direction is most remarkable.

3) When the weight of the user becomes lighter, level of the vibration becomes larger.

4) Evaluate the comfort level of the vibration on the wheelchair by using the measurement of vibration acceleration value.

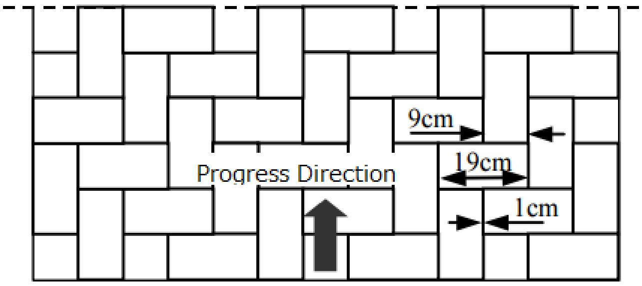

Figure 4. Surface condition on the sidewalk with paver tile and direction of movement


Figure 5. Sidewalk with paver tile

2.3 Spatiotemporal Life-Log Mining of Wheelchair Driving for Visualizing Accessibility of Roads

In the year 2013, headed group by Yusuke Iwasawa have tested using three-axis accelerometers to capture the surface condition of the road to show the results of classification and to visualize the results of tough/smooth surface detection. It can demonstrated as Figure 6.

But they were not using smartphone-based accelerometers and their objectives are to visualize accessibility of the road. They were not targeting the comfort level of the surface of the road [6] [7].

They have also studied on the comfort level of the users on the wheelchairs based on the value of VAL (Vibration Acceleration Level) theoretically. But we thought it needs human interaction to realize the potential discomfort level which is depending on the each user's sensibility.

2.4 Summary of related works

In Table 1, it show the advantages and disadvantages of the related works mentioned in this section.

The first work did not sense the surface on the road to detect the discomfort level of the vibration. Second work shows damage on vibration. But Second work and third work are using exclusive tools of accelerometers only measuring on this purpose and third work is targeting on the road not people's discomfort level.

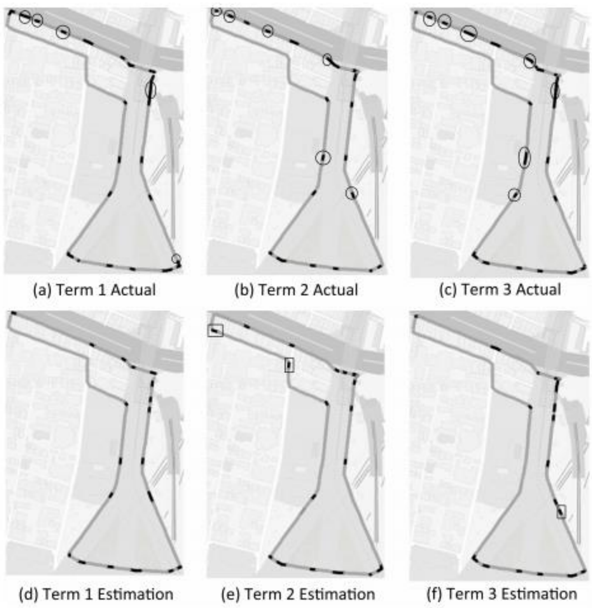

Figure 6. Comparison between actual status of ground surface and estimated status.

Table 1. Advantage and disadvantage of related works

	Concerning the surface condition on the road	Using Acceleration sensor on the smartphone
2.1. Navigation	No	No
2.2 Evaluation	Yes	No
2.3 Visualization	Yes	No

Because of such reasons, we propose a method of solving problem such as introductory cost and sensing the individual discomfort level of the surface of the road by smartphone sensors in this paper. The proposed method can proactively display the potential discomfort point of the road after user setup automatically the threshold value of the acceleration caused by the surface condition on the road.

3 PROPOSED METHOD

In this section, we explain a method of our proposing system how to approach to solve the existing problems in related works and the purpose of this study.

3.1 Purpose and approach

The related works have problems such as introductory cost, and not addressing the discomfort level of each individual level of the surface of the road.

Our proposed system is using a three-axis accelerometer and a GPS sensor on the smartphone to gather information at reasonable cost and using interactive method to address on human discomfort level of the surface of the road and its positioning through a GPS sensor. And also because discomfort levels are depending on the feeling of the people, it can address individual discomfort level of the value on Vibration.

This study aims to collect the acceleration values of the discomfort points of the road and to show the bad conditional points of the sidewalk which can be potential discomfort points for the users of the wheelchair on the map. Final target of this study is to create navigation system to avoid the discomfort point of the road in the future.

3.2 An overview of the proposed system

Proposed system consists of four parts as Figure 7.It is important to implement interactive input method to identify each person's discomfort level historically. First module is Data collection module on the smartphone which can collect the sensed data from three-axis accelerometers and GPS sensors on the smartphone. And second module is Data Process module on Server which can calculate the discomfort threshold value based on the gathered data. Third module is Data store module on Server receiving data from smartphone. Fourth module is Data display module in the smartphone which can show existing potential point of discomfort level on the road which is exceeding the level of each person's discomfort level into the map of smartphone.

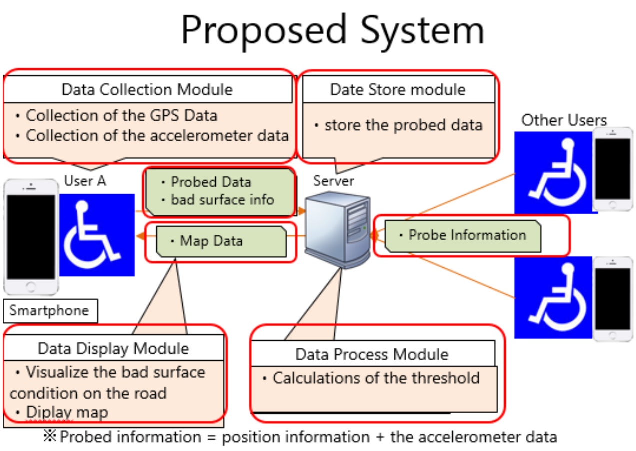

Figure 7. Proposed System

3.3 Visualizing the discomfort point of the road

In this section, we describe how our proposed method can visualize the discomfort points of the road in the system. Acceleration values of the Smartphone can be measured like Figure 8. From the timing of inputting the unique ID into the system, proposed system will store and calculate threshold of the discomfort levels of the users of the wheelchairs.

3.3.1. Start moving

We use iPhone4 as our smartphone which has fixed on the left arm of the wheelchairs to get the information. Data collection will start soon after user enter unique ID into the smartphone on the screen of Figure 9. Data gathering will continue during 60 seconds. Every 60 seconds, data will be sending to Server with the sets of the records of Table 2.

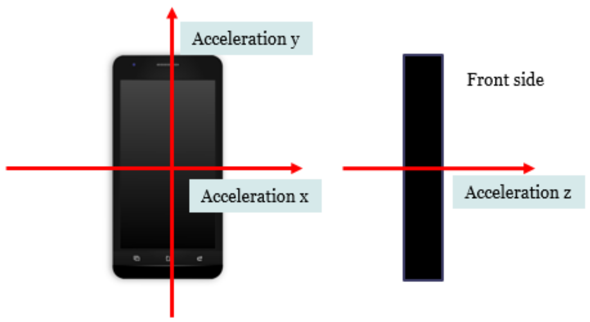

Figure 8.Acceleration value of Smartphone

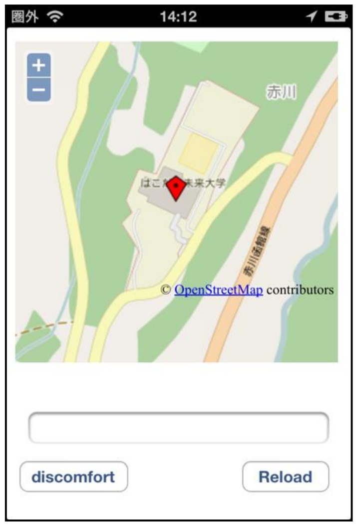

Figure 9. Data Collection User Interface on the smartphone

Table 2. Sending record to the server

UserID	ID of each user
Latitude	Value from GPS
Longitude	Value from GPS
Acceleration Y	Value from Accelerometer

3.3.2 Data collection

Data will be collecting in the smartphone every 1 second to have the value of latitude / longitude from a GPS sensor and the maximum/minimum acceleration y value from the three-axis accelerometer.

And user will push the discomfort button on the screen of the smartphone in case he feels discomfort level of vibration. If it is the first time to track discomfort level, that value will be stored in the DB accordingly as user's threshold value of Min/Max like Figure 10.

If the case is not the first time, it will be stored after calculating average value between the current value and historical value like Figure 11.

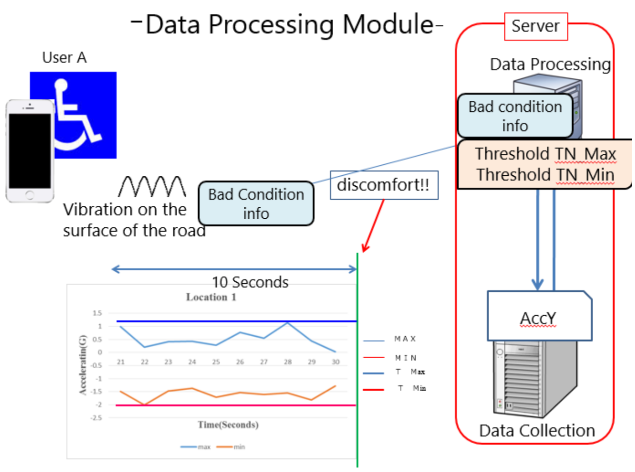

Figure 10. Data collection module in case of no data in DB

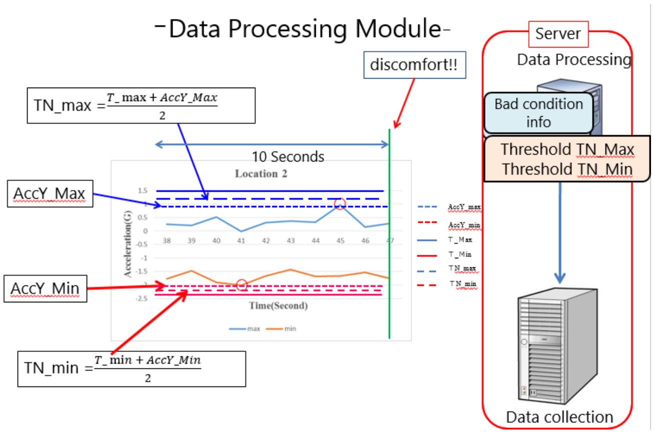

Figure 11. Data collection module with historical data

Values are stored like Table 3 to identify each user's discomfort profile on the DB.

Table 3. Stored record in the DB

UserID	ID of each user
Latitude	Value from GPS
Longitude	Value from GPS
Acceleration Y	Value from Accelerometer
Threshold max	Max threshold value of each user
Threshold min	Min threshold valu of each user
Comfort	information that feels discomfort

3.3.3 Data Display

After system records the value to DB, such probe information will be displayed on the screen of smartphone like Figure12. Every person's potential discomfort points can be seen on the map, if the person's threshold values are under the other person's threshold values. We have used OpenStreetMapAPI for our display API.

4 EXPERIMENTS AND DISCUSSIONS

In this section, we explain about preliminary experiments before creating proposed method and simulation we have done for confirming the effectiveness of the proposed method. And discuss about the results and concerning points.

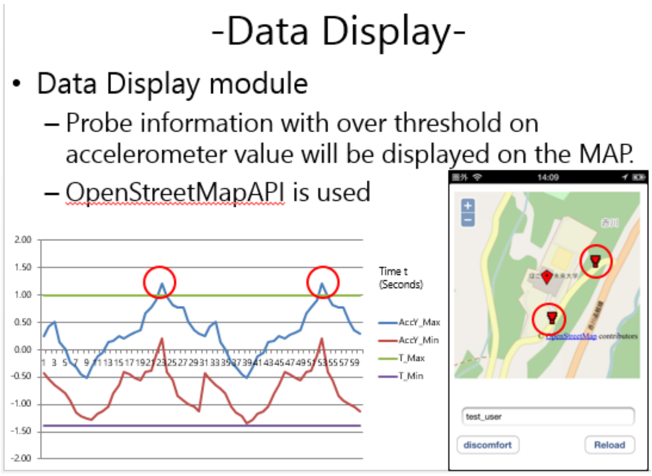

Figure12. Data display on smartphone

4.1 Preliminary experiment

Before creating proposed method, we have done the preliminary experiments to learn about the relationship between vibration on the wheelchairs and real condition of the surface of the road. We could find that the front tube-less tire is sensitive to the difference of the level of the surface on the road. For the assessment of the accuracy level to sense the surface profile of the road with vibration which can cause the discomfort level of the wheelchair users, we have tested as below.

(1) On the left arm of the wheelchair, we fixed on the smartphone. And collect data from the application of HASCLogger like Figure 13 on the testing board like Figure 14 with different in space between the several bars with the height of 2mm/4mm as Experiment 1.

(2) We have used major type of the wheelchair with front tire with 7inch, rear tire with 24 inch in diameter.

(3) We have used 4 patterns of difference of pattern of the testing board with 4mm/2mm height.

(4) Our test operated on each patterns 5 times with 5 persons. (4 patterns x 2 heights x 5 times x 5 persons = 200 times).

(5) Test subjects are 5 students with different weight (55kg, 58kg, 64kg, 65kg, 73kg)

(6) We have done walking tests from front door of the university to bus stop like Figure 18 as Experiment 2. With 5 persons round-trip.

In the Experiment 1, we have tested in the room how smartphone fixed on the left side arm of the wheelchair can detect the vibration from the surface of the road. Testing board on the floor has designed to be picked up the vibration from the ground by front tube-less tire of wheelchair. Testing board has been designed like Figure 14 to see how smartphone's accelerometer can detect the surface profile exactly from the value of the acceleration y from the vibration of the wheelchair. From the initial raw data, it cannot be distinguish exactly the signal from the surface of the road like Figure 15.

Figure 13. Experimental environment

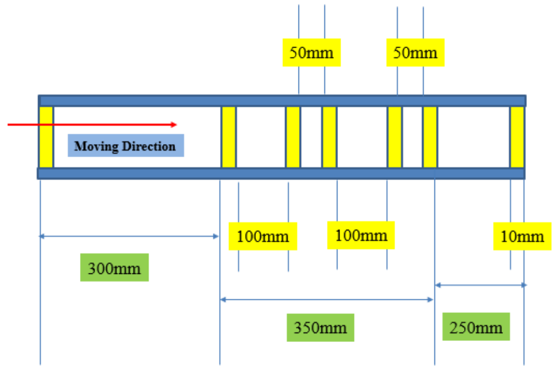

Figure 14. Example testing board with difference of the level

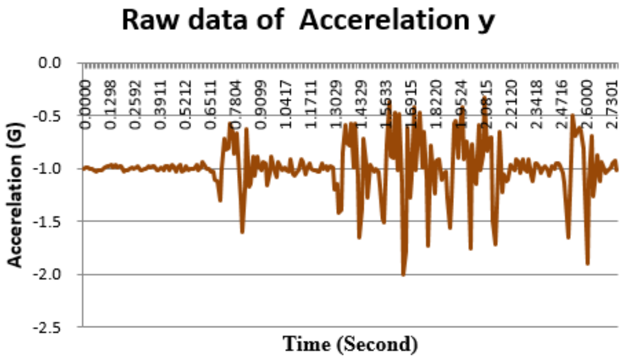

Figure 15. Raw data of Acceleration y

We have found that values of the accelerometer can be filtered noises by using 4 periods of moving average. In case of the raw data of acceleration related to the Figure 14 could be plotted like Figure 15.Many noises could be seen on the chart of the Acceleration. After using 4 periods of Moving Average value, Noise can be eliminated dramatically as Figure 16. Simplified graph can be seen as Figure 17. Out of 200 times test, almost 100% we could get exact difference of the level of the test board from the acceleration sensor of smartphone.

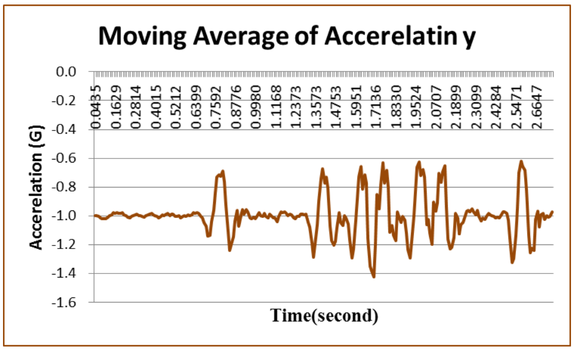

Figure 16. Moving Average of Acceleration y

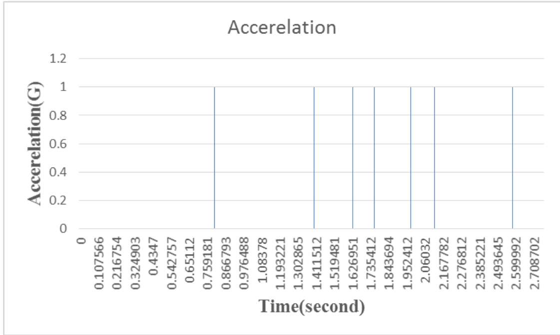

Figure 17. Simplified graph

In the experiment 2, testers have ride on the wheelchair at road of the outside of University. Wheelchairs with smartphone could gather the information of acceleration values and GPS values from the entrance to Bus-stop on the road like Figure 18. To figure out the real moving status like hearing the user's voice and seeing surface status of the road like smooth or rough or bumpy or so, test team took movie on the different smartphone by chasing testers behind the user of the wheelchair. Simulation

We have done the simulation on the data of which has gathered from the preliminary experiment 2 how proposed method can show the effectiveness.

4.2 Result of the simulation

From the entrance of the university to the bus-stop, we have got the logging Data on GPS and acceleration sensor value from the smartphone. Based on the assumption that user could feel three discomfort points such as after 27seconds and 45 seconds and 57 seconds from the starting point of the entrance of the university. In the chart on the Figure 19, Location 1 is after 27 seconds, Location 2 is after 45 seconds, and Location 3 is after 57 seconds. We could simulate the moving result using our proposed system to show discomfort point of the road on the map like Figure 19.

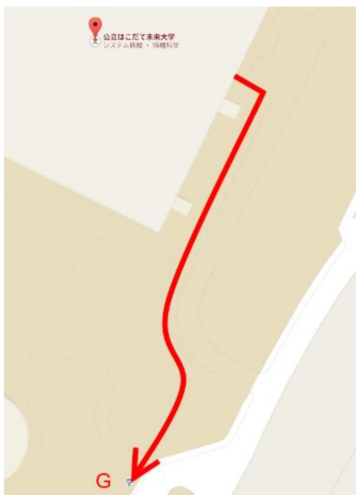

Figure 18. Experimental road from entrance to bus stop

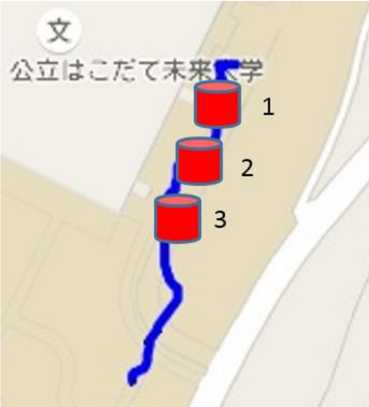

Figure 19 Experimental road from entrance to bus stop

These series of points have recognized as bumpy sidewalk like Figure 20 by seeing tracking movie on the smartphone.

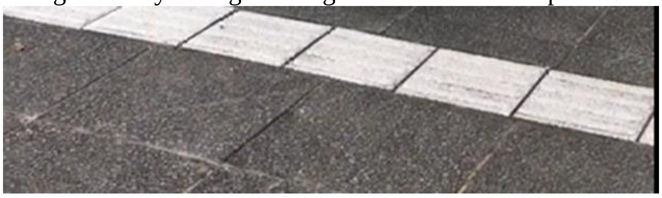

Figure 20. Bumpy sidewalk

And also from gathered log data from the wheelchair, min/max data of acceleration can be plotted on the chart. First case is location 1 as Figure 21, second case is Location 2 as Figure 22, and third case is Location 3 as Figure 23. From these chart, it can pick up the man/mix value as threshold value of this person's discomfort level of the vibration on the wheelchair.

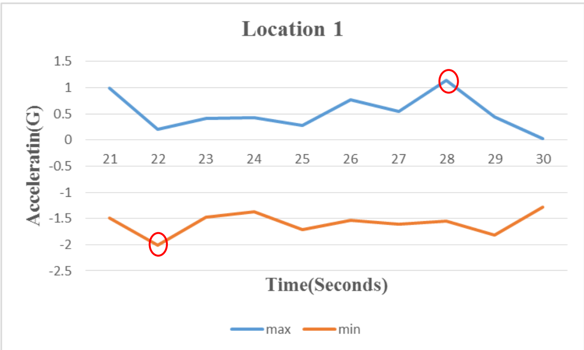

Figure 21. MAN/MIN value of Location 1

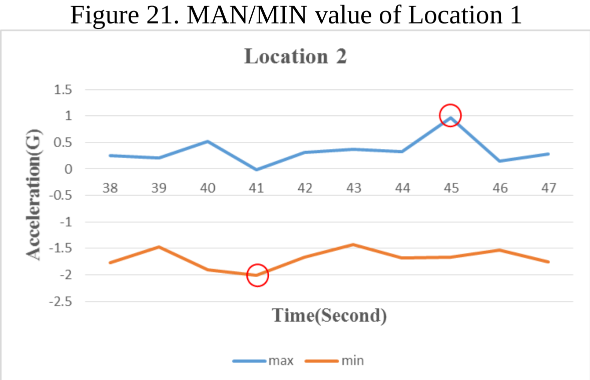

Figure 22. MAX/MIN value of Location 2

Figure 23. MAX/MIN value of Location 3

Smartphone stored accelerometer y values like Table 3.User could detect the discomfort level of the surface of the road on the smartphones' screen.

4.3 Discussion of experimental results

In this section, we discuss the experiment results.

We could show our proposed method how discomfort point can be visible to every user of wheelchairs. But there is two concerning points in the experiment data.

First point is related to speed of the wheelchair. If the wheelchair stops, vibration becomes nothing. The vibration levels of the wheelchairs are proportional to the speed of the wheelchair according to Okamura [3] [4] [5]. Too much speed causes unexpected sensitivity to the user of the wheelchair. There is law in Japan that wheelchair should run under the speed of 6km per hour which is equivalent to 1.667 meters per second. Because that acceleration values of Y are proportional to the speed of wheelchairs, when wheelchairs' speed are exceeding the value of 6km per hour, it can sense much bigger value of the acceleration value Y unexpectedly even the surface of the road is not bumpy. It can cause misleading alert to the users of wheelchairs. Points of discomfort should be plotted only when the speed of the wheelchairs are not exceeding the limit of the speed of the law. We should consider about that.

Second point is about the saturation value in minimum value. Because of the gravity, value of acceleration y is starting at the value of -1(G). Value of minimum is saturated on the value of -2(G) which is the minimum boarder value of smartphone. It is more suitable to use maximum value to identify the discomfort level of the surface of the road.

Table 3 Assumed stored value as threshold min/max

	Real Value		Threshold (after calcultion)	
	Acc Y min (G)	Acc Y max (G)	Acc Y min (G)	Acc Y max (G)
Location1	−2.0084475	1.14548875	−2.0084475	1.14548875
Location2	−2.007637	0.96374525	−2.00804225	1.054617
Location3	−1.79909875	1.038414	−1.9035705	1.0465155

5 CONCLUTION

There is existing problems in related works in the navigation to the users of wheelchairs. Points are reasonable cost for sensing acceleration data with GPS data and consideration about each person's discomfort level of the value of acceleration. We have proposed to visualize discomfort level of surface information on the road to the map on the smartphone. Every trigger has initiated by each user of wheelchairs. So wheelchair users can be helped by using this system. We have done the two pattern of experiment. First experiment was for basic experiment of which to find the effective way to track vibration of the wheelchairs on the road. Second experiment was for simulation on our proposal system how this system can display the discomfort point on the map.

After two experiments we have got the fact as follows.

1) We could understand that smartphone can use for the effective logging tool to identify discomfort levels of the sidewalk together with human interaction.

2) We have found that 4 periods of moving average can filter the noise of the signal from vibration of the wheelchairs.

3) Combination with GPS sensors and acceleration sensors can be effective to point out the discomfort point of the road.

4) After we get the each person's threshold, People can see the potential discomfort point of the road in the historical DB for their alert of the bumping state.

For the future work, we need to evaluate on the real road to get result on this method not by simulation. And to create navigation system to evaluate effectiveness of this method. And also to become more realistic navigation, we need to consider the slope identification by gyro sensors and scalability of servers and collectiveness of the probed data.

We have used GPS sensors on the smartphone. There is some possibility existing 10m of error range on GPS data in smartphone. So we should find the technology of sensitivity which can detect road 1 or road 2 exactly on the Figure 24.

Figure 24. Two sidewalks besides the road

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