Design and Development of Google Glass-Based Campus Navigation System

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***Abstract*—This paper investigates the feasibility of a Google Glass-based campus navigation system for both indoor and outdoor areas. The Indoor Positioning System (IPS) of the proposed system utilizes the magnetic positioning technology of IndoorAtlas Maps™ API which depends on structure's magnetic field fluctuations or geomagnetic fingerprints. The outdoor navigation mechanism simply consists of a map displayed within the Google Glass app with an augmented routing path leading to the set destination, while the indoor navigation interface displays a blue dot indicator of the current position on top of the augmented map with minimum spanning tree route. Furthermore, a data logging feature is incorporated for logging the movements of the user through the use of QR coded checkpoints for outdoor location monitoring and indoor-to-outdoor navigation transitions. The proposed system was tested in De La Salle University (DLSU) - Manila Campus, where 30 participants (15 DLSU and 15 Non-DLSU) were invited to utilize the proposed system navigating from an entry point to a set destination. The proposed Google Glass-based navigation system was found to have an average error of 1.77 meters (indoor) and around 77% of the users who utilized the application responded with a positive feedback. However, Google glass' limited battery life and high cost are among the barriers to adaptation. These results could provide empirical evidence supporting the feasibility of Google glass-based navigation deployment in other public areas, e.g. malls, government buildings, hospitals, etc.**

***Index Terms*—Geomagnetic Fingerprinting; Google Glass; Head-up displays (HUDs); Indoor Positioning System (IPS); Indoor Positioning; IndoorAtlas Maps™; Magnetic Positioning.**

I. INTRODUCTION

Recently, wearable computers and head-up displays (HUDs) are gaining popularity with an idea of providing computing capability while establishing a wearable interface that helps the user pay attention to the real world as opposed to retreating from it [1]. Figure 1 shows the basic design of the Google Glass which includes common components found in a smartphone device, i.e. central processing unit (CPU), camera, global positioning system (GPS), speakers, microphone, etc. [2]. Among its main goals is to minimize interaction with the hands of the user to maximize the melding of the physical and the digital world.

Over the past few years, Google glass has seen many applications. Google glass has clear utility in the clinical setting, i.e. surgery [3][4], assistive device for people with parkinson's [5], remote chest X-ray interpretation [6], surgical education [7], vital signs monitoring [8], patient monitoring [9], etc. Google glass also has applications in robotics, i.e. remote control of a mobile robot [10]. The glass has also found its way into the classroom for helping in teachers' management task [11] and student interaction [12]. Finally, the glass can also be applied to navigation systems where wearable device was perceived to be more accurate [13].

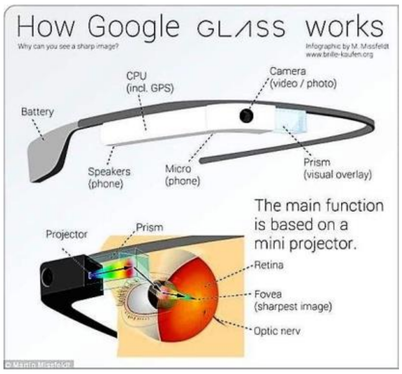

Figure 1: Basic design of Google Glass [2]

In general, Google glass-based navigation systems are more commonly applied outdoors, as demoed for activities like walking, biking, and driving [14]. However, in this study, we also integrate indoor navigation where the technical challenge involves signal scattering, non-line-of-sight conditions, high attenuation and physical obstructions. Figure 2 shows the conceptual diagram of the campus navigation system which features the campus map of DLSU at the bottom, in which, the person wearing the Google Glass standing on the map wishes to go to Lambda building (the position with the star marker as seen on the map). In the proposed system, the user should first choose their desired location on the Google Glass before the glass displays the navigation routes to help the person reach the destination.

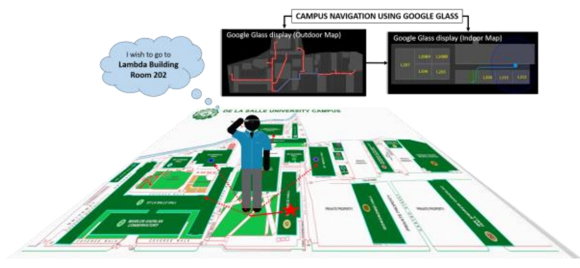

Figure 2: Conceptual Diagram of the Google Glass-based Campus Navigation System

When the user is traveling outdoors, the glass will display an outdoor routing path leading the person to the destination building. Various checkpoints in the form of QR code posters are also spread along the outdoor path to aid in monitoring and indoor/outdoor transitions. When the user has entered the target building, proposed system will display an indoor routing path leading to the room of choice, along with a blue dot indicating the current location of the user.

II. THEORETICAL CONSIDERATION

A. Indoor Positioning System

A positioning system is a mechanism that helps determine the location of a specific object in space [15]. It utilizes signals such as WiFi, Bluetooth [16], GPS signals [17] and/or geomagnetic signals [18] in order to get the location of the user. Several devices are provided with these sensors so that they are able to detect these parameters. Since GPS is generally not effective for indoor use, IPS mainly uses either WiFi, Bluetooth [16] or geomagnetic fields [19] for indoor positioning. IndoorAtlas is an indoor positioning system that uses geo-magnetic technology [19]. It is an existing and commercialized mobile application which utilizes built-in magnetic sensor of the smartphone to measure the magnetic field inside a building. The geomagnetic fingerprints allow the IndoorAtlas application to detect which area or which floor the device is in.

B. Image Processing: QR Code

Quick Response (QR) codes are two-dimensional images that can perform multiple services (e.g. be redirected to a website, access information at high speed, access multimedia such as videos or images or personal contact information) once they are scanned by a device with a camera and image processing capabilities [20]. The QR code can contain several chunks of information and data can be extracted when scanned by a device [21].

As shown in Figure 3, we made use of the QR codes as checkpoints for the different campus entrance/exit areas that have low to no internet connectivity. Another reason for the implementation of the QR code is that the physical location of the testing site; which is in the middle of a dense urban environment with multiple tall buildings where it would be extremely difficult to acquire GPS data with pinpoint accuracy. For the Google Glass to be able to scan QR codes, the Zebra Crossing (ZXing) API [22] was utilized.

Figure 3: Sample QR code placed at Bldg. Lambda Entrance

C. Likert Scale

The Likert Scale concept was utilized to evaluate the participant feedback form in testing the efficiency of the application. This scale is commonly used for questionnaires, especially for survey researches. The respondents answering this type of questionnaire would have to specify their rate or level of agreement to a question or statement in the questionnaire. The most common Likert-scale is the five-point Likert item. Five ordered response levels are usually used for Likert items. This includes item choices such as the following: Strongly disagree, Disagree, Neither agree nor disagree, Agree and Strongly Agree [23].

D. Google Glass

The Google Glass is a device that attempts to put the functionality of a smartphone into a pair of glasses and project its contents into a glass display directly into the user's field of vision within a single eye. In this study, the Google Glass was chosen as the application's platform because of its minimal heads-up display, lightweight, and its efficient portrayal of information [24]. The Google Glass can also display visual information similar a typical handheld smartphone [25]. Table 1 tabulates the specification of the Google glass utilized in this study.

Table 1
Google Glass Specifications

	Specifications
Camera	5-megapixel camera, capable of 720p video recording
Storage	16 GB memory with Google cloud storage
Connectivity	Bluetooth and WiFi
Battery	570mAh lithium-polymer battery
Charger	Micro USB and charger (outlet or PC charging)
Processor	Texas Instruments OMAP 4430 SoC 1.2GHz Dual (ARMv7)
Compatibility	Android 4.0.3 (Ice Cream Sandwich or higher)
	Motion Process Library (MPL) Accelerometer
	MPL Gyroscope
	MPL Magnetic Field
	MPL Orientation
	MPL Rotation Vector
	MPL Linear Acceleration
Sensors	MPL Gravity
	LTR-506ALS Light Sensor
	Rotation Vector Sensor
	Gravity Sensor
	Linear Acceleration Sensor
	Orientation Sensor
	Corrected Gyroscope Sensor

III. DESIGN CONSIDERATIONS

A. Block Diagrams

Figure 4 shows the design process of the proposed campus navigation system. The process starts with creation of the indoor and outdoor maps. Then, coding the indoor and outdoor map display simultaneously and creating a QR code for logging purposes. Finally, the indoor maps were utilized for positioning and input routing.

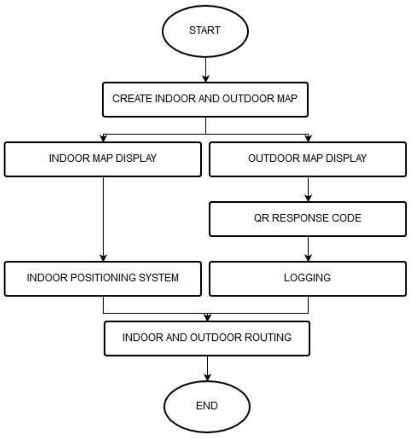

Figure 4: Design Process Flow Chart

Figure 5 displays the overall block diagram of the proposed system. From the magnetometer and location sensors of the Android-powered smartphone, the data were sent to the IndoorAtlas API and Google Maps API, respectively, for precise indoor geo-location. The IndoorAtlas API produced the indoor positioning data, while the Google Maps API produced the geo-location data. These data, which are considered map identifiers, each have unique Identification codes pulled from the IndoorAtlas and the Google Maps servers and were fed into the user positioning algorithm. The Google Glass camera took images of the QR codes and these were processed using the ZXing QR Code Scanner API. The desired endpoint was obtained through user input by using the Google Glass GUI. The resulting data of the Positioning Algorithm, QR Algorithm and Desired End Point were inputted to the Routing Algorithm for the computation of the routing path from starting point to destination. Finally, the computed Routing Path as well as the current position of the user were displayed on the maps that were fed to the Google Glass display.

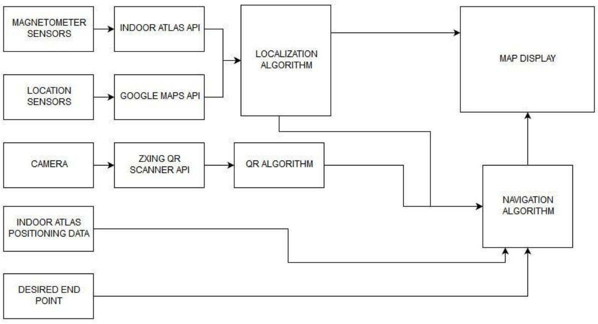

Figure 5: Overall System Block Diagram

B. Graphical User Interface (GUI) and System Design

The GUI of the Google Glass was displayed for the user to be able to input data, such as the desired locations, or to be able to scan the QR codes. Figure6 shows the User-System Swim Lane diagram of the proposed system. The developed Google Glass application initially displays a menu after the user has initialized interaction by tapping the touchpad of the Glass. The Main Menu contains two options: Display Map and Navigate. The Display Map option displays only the map of user's current location. The Navigate option opens a directory where the user must select their intended destination. The navigation directory is a list of buildings and areas of the campus where the users could choose from. Once the user has inputted their preference, the system prompts for a QR code scan. After the QR code is scanned, data is then logged and the user is informed of their current location, and their intended location. The QR code helps the system identify the initial location of the user. After the user has scanned the nearest QR code, the system begins computing the routing path using the navigation algorithm. After the routing path has been computed, the Outdoor segment of the navigation is displayed on the Google Glass. When the user has reached the intended building, the application will then prompt another QR code scan to transition into the Indoor portion of the navigation. The scanned QR data is then logged into the Google Glass. When the user has reached their final destination, they will return to the main menu and will be able to select a new destination if desired.

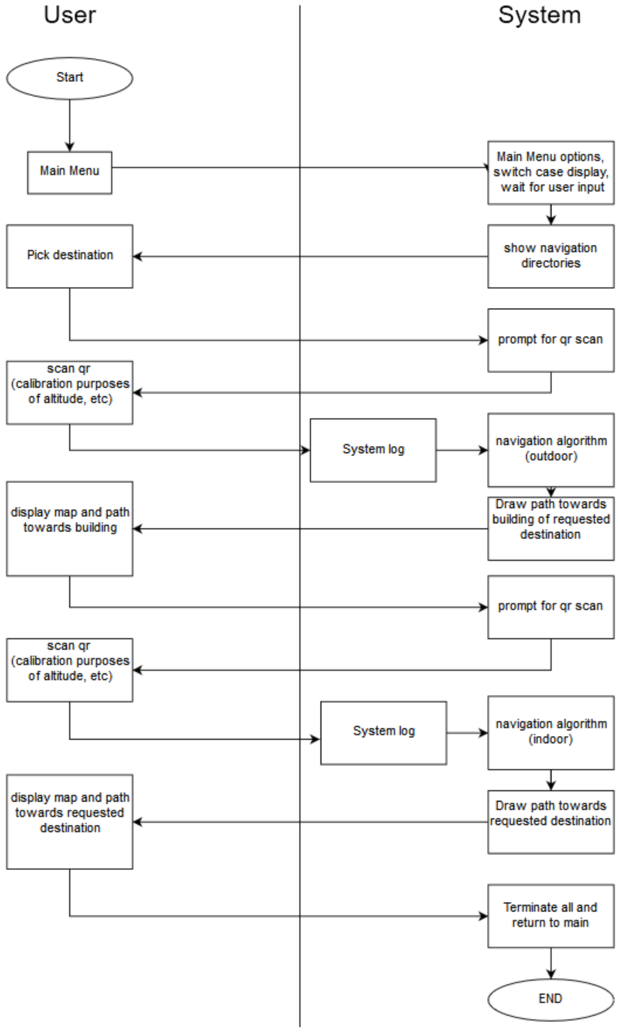

Figure 6: Proposed User System Swim Lane Diagram

C. Layout of the Buildings

Each floor plans were converted into digital files. These converted floor plans were intended to be an accurate representation of the real life location; scaling are based on the blueprints provided by the DLSU Office of the Associate Vice Chancellor for Facilities Management. The scale is 1 meter is to 15 pixels to be able to represent the size of the building correctly when resized in the IndoorAtlas cloud server.

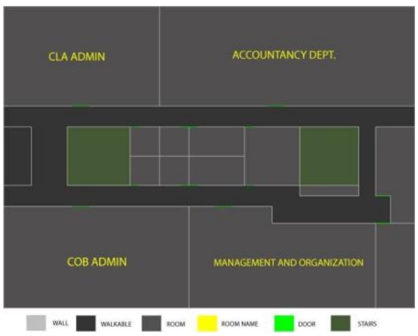

Figure 7: Sample digitized floor plan

Each layer and color of the floor plan represented a layer that differentiated the walls, doors, rooms and walkable path. Each floor plan consists of 7 layers as seen in Figure 7: out of bounds, walkable path, rooms, stairs, walls, doors, and the room name. The digitized map must be able to match the physical location of the area, if the creation of the digital map to reflect the physical location was not as close as possible, it could potentially result in the whole system being inaccurate.

D. Indoor Positioning: IndoorAtlas

The Indoor Positioning module was comprised of two submodules: the IndoorAtlas Application, and the Routing Application which was developed by the group. Since the IndoorAtlas Application only goes as far as to provide assistance for indoor positioning and geomagnetic fingerprinting for its clients, the group has further developed an application to incorporate routing with the aid of the IndoorAtlas application by using the recorded geomagnetic fingerprint data stored in the IndoorAtlas cloud server under the account of the group. Each floor was magnetically mapped by the group, attempting to encompass all the walkable areas in the magnetic mapping, in order to be able to send as much data as possible to the IndoorAtlas cloud servers.

According to the step-by-step guide of the IndoorAtlas application manual, in setting up Indoor Atlas, pre-made architectural floor plans should be available since it is a major part in the use of the application. When the application was booted up, it would have asked for login credentials. Once signed in, the group was greeted with an interface similar to Google Maps since IndoorAtlas makes use of the Google Map Application Programming Interface (API). In this case, the group has located and focused on the area where De La Salle University is located geographically. The map of the area as seen in the IndoorAtlas application with the aid of the Google Maps API is shown in Figure 8

Figure 8: Google Maps of the De La Salle University campus as viewed from IndoorAtlas Application

IV. Methodology

A. Precision Testing

The first testing assesses the accuracy of the indoor navigation of the Google Glass application around the campus. In order for the group to gain an accurate estimation of error discrepancies, the group performed five runs on selected floors of each building. On each floor checkpoints were marked beforehand with a minimum of 2 checkpoints depending on the size of the floor plan. These checkpoints would serve as a guide for each run. Once a run is commenced, the tester must reach the checkpoint and then compare and check if the marked checkpoint was also reached by the blue dot indicator in the Google Glass application. The tester would then take a screenshot of the current position shown in the Google Glass application and then move on to the next checkpoint and follow the same procedure until the last checkpoint is reached. Once the five runs on the current floor have been achieved, the tester would move to the next floor and repeat the same procedures previously mentioned. These checkpoints are placed near pillars and at the center of intersections in order to reduce the errors due to the techniques used in the creation of the maps. In this trial, six (6) check points were used as reference points for data. Screenshots were taken every time the user was at a designated checkpoint in the real world. the steps taken in order to evaluate and compare data for the precision plot are the following: each screenshot was collated and was overlain in order to display the gathered data in one screenshot; checkpoints are then marked on the overlain map; the pixel-to-meter ratio is then measured using tools physically and digitally; the distance between the center of the blue dot (digital representation of current location of the user) and the center of the checkpoint is then measured using geometry; calculate the error using Eq. 1; finally, the values calculated from step 5 will then be input into a table and then averaged in order to get more informative data. In this example, there were a total of five (5) data gathering runs conducted. The resulting image is seen on Figure 9. Some possible reasons for error discrepancies in the application might be due to various magnetic deviations in the data of IndoorAtlas.

$$\frac{Actual(meters)}{Display(pixel)} = \frac{x}{DisplayedError(pixel)} \quad (1)$$

B. Feedback from Test Participants

The second testing involved 15 DLSU participants and 15 non-DLSU participants who helped test the usability of the navigation of the Google Glass application. Each participant was asked to navigate two different areas. After the navigation process, the participants were asked to complete a feedback form regarding their experience with the Google Glass App whether the tool helped them locate the desired destination or not. The feedback form also asked for personal comments regarding the comfort and ease-of-use of the Google Glass. Feedback questions were included to determine responses and comments of the participants with regards to the application. The feedback questions were designed to follow the Likert-type ratings which include response choice ratings such as 1 for Strongly Disagree, 2 for Disagree, 3 for Neutral, 4 for Agree and 5 for Strongly Agree. To plot and analyze the results of the Likert-type feedback form, the group used the Diverging Stacked Bar Chart. According to published paper Plotting Likert and Other Rating Scales [21], the diverging stacked bar chart is the recommended method for presenting rated scale results.

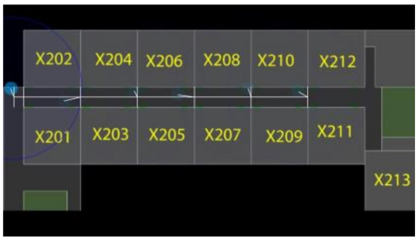

Figure 9: Distance between center of blue dot and reference point marked

V. Data and Results

A. System Battery Usage Results

As shown in Figure 10, indoor and outdoor usage (with different resources) has slightly different effect on the battery span of the Google Glass. The blue plot displays the battery drain graph of the Google Glass when it was displaying the outdoor map, while the orange plot displays the battery drain graph of the Google Glass when it was displaying the indoor map. The battery of the Google Glass drained faster when navigating indoors since it uses more functionality such as internet connectivity, built-in sensors, among others. This usage characterization also shows that the Google Glass battery is easily drained and must be used sparingly in regards to navigation. The outdoor map displays averages of 1% battery drain per minute while the indoor map averages a 2% battery drain per minute.

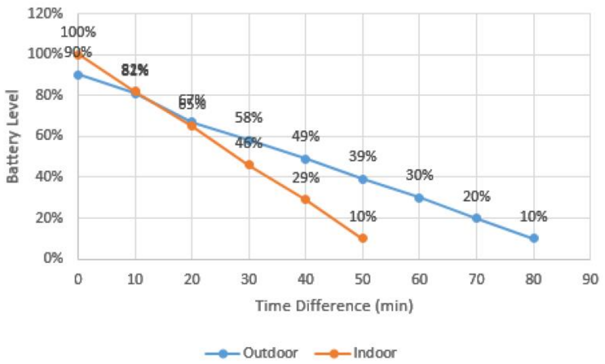

Figure 10: Proposed Google Glass Based Campus Navigation Application Battery Usage

B. Precision Test Results

Figure 11 displays an example of the checkpoints of a floor in the Xi building. Each building that was tested had similar checkpoints along the halls of each floor that was mapped.

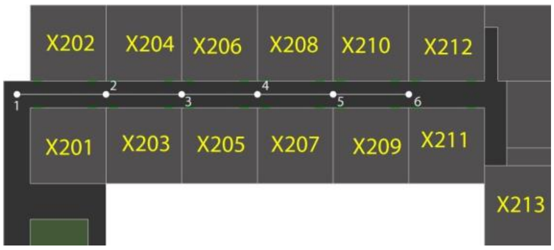

Figure 11: Sample Checkpoints for Precision evaluation (Xi Second Floor Checkpoints)

Table 2 represents the precision test results of various buildings in the campus. The error discrepancy of the application versus the physical world was measured five times per checkpoint.

Table 2
Precision Test Data

Bldg. Code	Floor No.	Checkpoint	Average error (m)	Ave. Error per Bldg. (m)
Alpha	1	1	1.39	1.77
		2	2.01	
		3	1.52	
	2	1	0.62	
		2	3.17	
		3	1.92	
Beta	1	1	0.82	1.00
		2	1.05	
		3	0.7	
		4	1.05	
Delta	2	1	0.85	2.05
		2	0.6	
		3	1.17	
		4	1.76	
	3	1	1.59	
		2	3.54	
		3	1.78	
		4	2.18	
		5	2.13	
	4	1	1.32	
		2	1.67	
		3	1.08	
		4	2.52	
		5	2.71	
Heta	2	1	3.18	1.99
		2	0.95	
		3	1.83	
Iota	2	1	2.19	1.93
		2	1.67	
		3	2.78	
		4	1.52	
		5	1.51	
Lambda	1	1	2.15	1.81
		2	2.3	
		3	1.56	
		4	2.54	
	2	1	1.13	
		2	1.41	
		3	1.84	
		4	1.56	
		5	1.82	
Mu	1	1	1.64	1.96
		2	1.51	
		3	1.62	
	2	1	2.14	
		2	2.03	
		3	2.55	
		4	2.23	
Omicron	1	1	2	1.79
		2	2.45	
		3	0.93	
Rho	8	1	0.99	1.61
		2	1.46	
		3	1.49	
		4	1.95	
		5	1.51	
	9	1	1.81	
		2	2.2	
		3	1.26	
		4	0.97	
		5	1.26	
		6	2.77	
Theta	2	1	2.32	1.61
		2	1.43	
		3	1.07	
Xi	1	1	1.42	1.88
		2	3.89	
	2	1	1.64	

Bldg. Code	Floor No.	Checkpoint	Average error (m)	Ave. Error per Bldg. (m)
		2	1.13	
		3	1.57	
		4	1.92	
		5	1.53	
		6	1.96	
Zeta	1	1	1.16	1.84
		2	2.94	
		3	3.28	
		4	2.89	
		5	3.08	
		6	1.28	
		7	1.83	
		8	2.13	
		9	0.67	
		10	1.24	
		11	1.12	
	2	1	2.29	
		2	1.37	
		3	1.55	
		4	1.26	
		5	1.34	
		Overall Error	1.77 m	

Since the system relies heavily on internet connection, it is important to note that the number of users of the readily available campus Wi-Fi affects how much data could be retrieved. Mobile data can be used if Wi-Fi is not available or is performing poorly. Figure 12 shows the error rate of the Wi-Fi and mobile data connections during the test run. The positioning error rate varies from less than 1 meter up to 7 meters depending on the Wi-Fi and mobile data connectivity. According to these results, for the device to have an accurate indoor positioning, it should have a reliable internet connection of at least 200 kbps. 5 meters is the maximum acceptable error for when the blue dot indicator deviates from the real location, the system yielded 98% accuracy (49 out of 50 test runs each) when used with either Wi-Fi or mobile data connection. The overall average error in meters that the proposed system yielded is 1.77m (Table 2).

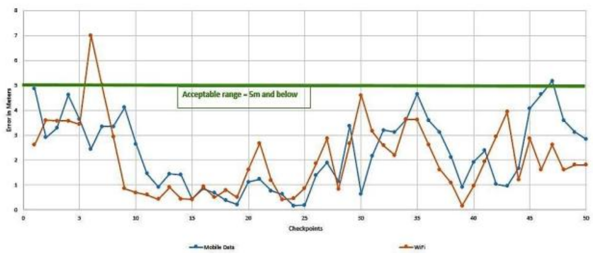

Figure 12: Test run with WiFi vs. Mobile data connectivity error rate

C. Sample Test Run

Figure 13 shows the test run navigation of a group member who wished to travel to Xi building room 204. These images were taken from the feeds of the Google Glass as displayed on the prism. The first two side-by-side images show the group member, Kevin, wearing the Google Glass, and the main menu of the application. The third image shows the chosen location of the user. The fourth image shows the initial QR code scanning of the user from his starting point (North Gate) for the outdoor navigation which the user has scanned using the Google Glass. The fifth image shows the outdoor navigational blue path leading to Xi building. After following the outdoor navigation, the user then scanned the indoor QR code for the Xi Building as seen on the sixth image. After the user entered the building, the Google Glass sensors immediately picked up the geomagnetic fingerprint of the indoor environment and displayed the closest match (pulled from the IndoorAtlas cloud server) which was the 1st floor of Xi building. The blue dot is the indoor positioning indicator of the user; then, as seen on the seventh image, the user was asked to follow the blue line which lead to the staircase. Upon reaching the second floor, as seen on the eight image, the Google Glass once again read, compared and displayed the closest geomagnetic fingerprint match to the IndoorAtlas cloud server and pulled out the 2nd floor of Xi building. A path is again displayed for the user to follow leading to the chosen destination which is X204. Upon reaching the destination, the application terminates by going back to the main menu.

D. Feedback Form Results

Figure 14 and 15 display the summary of the feedback forms. Using a Likert-type rating, the group analyzed the feedback data of the respondents using a diverging bar chart graphical representation. The questions at the leftmost side refer to the questions on the feedback forms answered by the participants. The legends of the charts can be seen at the bottom of the figures. The broken gray line at the middle of the charts aim to divide the more positive answers (blue bars) from the more negative answers (red bars). The numbers in black above each bar refer to the specific number of participants (out of 15 for each set) who have answered that particular option. All in all, as seen in both figures 14 and 15, majority of the respondents gave a more positive feedback regarding the overall usage of the campus navigation integrated in the Google Glass.

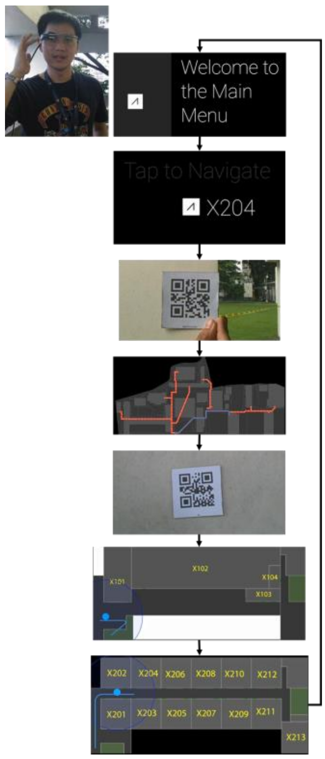

Figure 13: Test Run Navigation to X204 as seen on the Google Glass Display

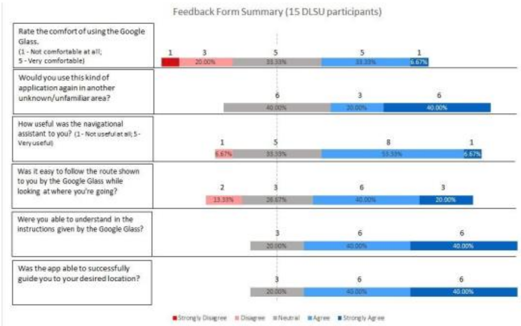

Figure 14: DLSU Feedback Form Summary

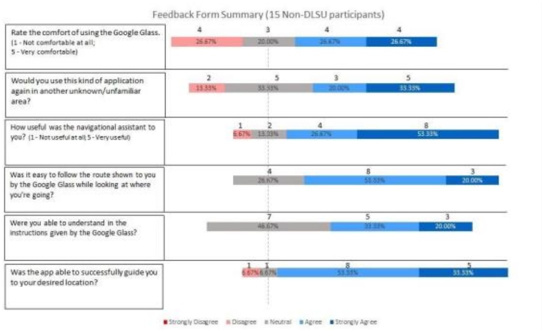

Figure 15: Non-DLSU Feedback Form Summary

VI. CONCLUSION

In this paper, we explored the feasibility of utilizing Google Glass for aiding new students, professors, personnel and visitors in indoor/outdoor campus navigation. The proposed system incurs an average error of about 1.77 m (indoor) which is acceptable for the problem of locating unknown offices or rooms within the campus. The proposed application utilizes the IndoorAtlas API which detects the indoor location and altitude levels of the user by using sensors to read the geomagnetic fingerprints of the area. The precision test of the system yielded a 98% accuracy (with 49 out of 50 test runs) when utilized with either WiFi or mobile data connection. Finally, for the participants who were invited to test the functionality of the system, 77% of the DLSU respondents and 79% of the non-DLSU respondents gave a more positive feedback.

Future research includes the investigation of optimal path considering not only the distance but also some external factors such as student room-to-room rush hour, real-time student traffic or the presence of unpleasant weather conditions. Furthermore, a fully automatic outdoor-to-indoor (vice versa) transition mechanism, instead of relying on QR code should be explored..

REFERENCES

[1] T. Starner, "Project glass: An extension of the self". IEEE Pervasive Computing, 12(2), pp. 14-16, 2013.

[2] M. Missfeldt, "Google glass infographic: How google glass works," Retrieved from http://www.brillen-sehhilfen.de/en/googleglass/, February 2013.

[3] O.J. Muensterer, M. Lacher, C. Zoeller, M. Bronstein, and J. Kübler. Google Glass in pediatric surgery: an exploratory study. International journal of surgery, 12(4), pp.281-289, 2014.

[4] J.Y.C. Chang, L.Y. Tsui, K.S.K. Yeung, S.W.Y. Yip and G.K.K. Leung. Surgical vision: Google Glass and surgery. Surgical innovation, 23(4), pp.422-426, 2016.

[5] R. McNaney, J. Vines, D. Roggen, M. Balaam, P. Zhang, I. Poliakov, and P. Olivier. Exploring the acceptability of google glass as an everyday assistive device for people with parkinson's. In Proceedings of the 32nd annual ACM conference on Human factors in computing systems (pp. 2551-2554). ACM, 2014.

[6] E. Spaedy, G.E. Christakopoulos, M.N.J. Tarar, G. Christopoulos, B.V. Rangan, M. Roesle, C.D. Ochoa, W. Yarbrough, S. Banerjee, and E.S. Brilakis. Accuracy of remote chest X-ray interpretation using Google Glass technology. International journal of cardiology, 219, pp.38-40, 2016.

[7] Z.E. Brewer, H.C. Fann, W.D. Ogden, T.A. Burdon, and A.Y. Sheikh. Inheriting the learner's view: a Google Glass-based wearable computing platform for improving surgical trainee performance. Journal of surgical education, 73(4), pp.682-688, 2016.

[8] C.A. Liebert, M.A. Zayed, O. Aalami, J. Tran, and J.N. Lau. Novel use of Google Glass for procedural wireless vital sign monitoring. Surgical innovation, 23(4), pp.366-373, 2016.

[9] T.F. Drake- Brockman, A. Datta, and B.S. Ungern- Sternberg. Patient monitoring with Google Glass: a pilot study of a novel monitoring technology. Pediatric Anesthesia, 26(5), pp.539-546, 2016.

[10] Y. Song, X. Wen, W. Li and G. Chen. Google Glass-Based Remote Control of a Mobile Robot. Proc. SPIE 9838, Sensors and Systems for Space Applications, 2016.

[11] M. Silva, D. Freitas, E. Neto, C. Lins, V. Teichrieb, and J.M. Teixeira.Glassist: using augmented reality on Google Glass as an aid to classroom management. In Virtual and Augmented Reality (SVR), 2014 XVI Symposium on (pp. 37-44). IEEE.

[12] M. Ebner, H. Mühlburger, and M. Ebner. Google Glass in Face-to-face Lectures-Prototype and First Experiences. iJIM, 10(1), pp.27-34, 2016.

[13] U. Rehman, and S. Cao. Augmented-Reality-Based Indoor Navigation: A Comparative Analysis of Handheld Devices Versus Google Glass. IEEE Transactions on Human-Machine Systems, 47(1), pp.140-151, 2017.

[14] C. Burns, "Google Glass navigation expansion demoed: walking, driving, biking" Aug 2013.

[15] A. Ghose, A. Pal, A. Choudhury, V. Chandel, C. Bhaumik, and T.Chattopadhyay, "Indoor positioning system," Feb. 5 2015, uS Patent App. 14/450,890.

[16] S. Aparicio, J. Perez, A. M. Bernardos, and J. R. Casar, "A fusion method based on bluetooth and wlan technologies for indoor location," in Multisensor Fusion and Integration for Intelligent Systems, 2008. MFI 2008. IEEE International Conference on, Aug 2008, pp. 487–491.

[17] R. Eshenbach, "Gps receiver using a radio signal for improving time to first fix," Sep. 2 1997, uS Patent 5,663,735. [Online]. Available: https://www.google.com/patents/US5663735 [Online]. Available: https://www.google.com/patents/ US20150039226.

[18] S.-E. Kim, Y. Kim, J. Yoon, and E. S. Kim, "Indoor positioning system using geomagnetic anomalies for smartphones," in Indoor Positioning and Indoor Navigation (IPIN), 2012 International Conference on, Nov 2012, pp. 1–5.

[19] IndoorAtlas, "Ambient magnetic field-based indoor location technology: Bringing the compass to the next level," IndoorAtlas Ltd, 2012.

[20] N. T. Lombardo, A. Morrow, and J. Le Ber, "Rethinking mobile delivery: using quick response codes to access information at the point of need," Medical reference services quarterly, vol. 31, no. 1, pp. 14–24, 2012.

[21] J. Rouillard, "Contextual qr codes," in Computing in the Global Information Technology, 2008. ICCGI '08. The Third International MultiConference on, July 2008, pp. 50–55.

[22] ZXing, "Official zxing ("zebra crossing") project home," Retrieved from: https://github.com/zxing/zxing, 2016.

[23] B. Robbins and R. M. Heiberger, "Plotting likert and other rating scales," in Proceedings of the 2011 Joint Statistical Meeting, 2011, pp. 1058–1066.

[24] R. Iwanaj, T. Nitta, K. Ishikawa, M. Yanagisawa and N. Togawa, "Indoor navigation based on real-time direction information generation using wearable glasses," 2016 IEEE International Conference on Consumer Electronics-Asia (ICCE-Asia), Seoul, 2016, pp. 1-4. doi: 10.1109/ICCE-Asia.2016.7804754

[25] Shi Cao, Umair Rehman,. "Augmented Reality-Based Indoor Navigation Using Google Glass as a Wearable Head-Mounted Display", 2015.