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Context-Aware Based Alert System for People with Hearing Impairments

[1]Maythem K. Abbas and [2]Bie Tong
[1]Department of Computer and Information Sciences, Universiti Teknologi Petronas, Perak, Malaysia
[2]School of Computing, Asia Pacific University of Innovation and Tecnology,
Kuala Lumpur, Malysia

Abstract: People with Hearing Impairments (PHIs) face challenges every day in identifying sounds like a visitor pressing the doorbell. The traditional doorbell uses an audio signal to notify people. However, it may not be able to notify PHIs because PHIs are very insensitive to sound. Due to the lack of help from support services, PHIs may not have normal daily lives. Therefore, it is necessary to propose an efficient doorbell solution in helping PHIs to be notified and the intangible benefit for PHIs is that it will reduce their dependency on their families in their daily lives. The proposed context-aware alert system would notify PHIs by using visual communication signals and tactile cues instead audio signals. Compared with the existing solution, the face recognition feature was added into the proposed system design and the system has become smart enough to know when the visitor's image has to be snapped and how to reduce the transmission time of the image. In addition what is context aware and how the context aware feature will benefit the system design will also be discussed. On the other hand, the intangible benefit of this research would be helping PHIs by reducing their dependency on others and building their self-confidence.

Key words: Context aware, face recognition, alert system, people with hearing impairments, PHIs, intangible benefit

INTRODUCTION

Currently, there are over 5% of the world's population living a life with hearing loss (WHO., 2016). In this project, the abbreviation "PHIs" was used to denote those people with hearing impairments, deaf, old age and anyone who is extremely insensitive to sound.

With insufficient services, PHIs live a life full of inconvenience. For example, the traditional doorbell is not able to alert PHIs because they cannot be notified by audio signals. The existing Internet-of-things based alert system can help them to be notified when a visitor presses the doorbell (Kumari *et al*., 2015). However, the photo duplication and long transmission time of the image in the existing system will cause a poor user experience.

The proposed solution aims to notify the PHI with visual signals and tactile cues in addition, the system will recognise the visitor and avoid taking photos of the same person repeatedly, reduce the transmission time of the image by adding a context aware feature and maximise the use of those devices which the PHI already has.

Literature review: The existing alert system is an IoT based wireless alert system (Kumari *et al*., 2015). It is installed on the front door and connected with the doorbell. The whole system is based on the rasp berry pi and the system also contains a camera, wireless GSM and bluetooth. It has the ability to keep an uninterrupted connection with those people's wearable devices via. bluetooth and could also send an SMS to those people's mobile phones through the wireless GSM.

Similar face recognition approach, the name of the face recognition system is called the 'Aarhus face recognition algorithm' (Letupe, 2013) and it was created by Kevin Letupe in 2013. It uses the Law of cosines to recognise a person.

MATERIALS AND METHODS

The proposed system is able to minimise the studying cost for the user and visitor by adding the context aware feature. It avoids making the visitor learn how to snap the picture and how to send the message. The only thing that the visitor needs to do is press the doorbell (the doorbell button can be an image displayed on a screen). The experience for the visitor is almost as simple as pressing the traditional doorbell. The developed Context-aware model (Perera *et al*., 2014) will minimise the studying cost for the user also. For example, the level of

Corresponding Author: Maythem K. Abbas, Department of Computer and Information Sciences, Universiti Teknologi Petronas, Perak, Malaysia

the context awareness will define how smart the system should be whether the system should be executed fully automatically. Context acquisition will define how to get the context data should it be calculated or sensed. Context modelling will specify how to store those context data then the context reasoning will determine what the system should do after the analysis of the context data.

The flow chart of the proposed system: The existing system (Kumari *et al*., 2015) takes a visitor's image every time when the visitor presses the doorbell, even if the visitor's picture had already been stored in the database of the system.

The proposed system has the ability to distinguish between first time visitors and second time visitors. The system will compare the visitor's face with an existing database of the people who had previously. If the visitor is not a first-time visitor (the database has a copy of their image) accordingly, the system will recognise the visitor and not take a photo of the visitor again to save as a new visitor. Otherwise, the system will take the photo of the visitor and save it in the database for future use.

The flow chart of the proposed system has been shown in Fig. 1. The proposed system takes the picture of the first-time visitors and stores the data in the database. Then when the visitor comes to visit again, the system will detect the face of the visitor, extract the features of their faces and finally, identify whether the visitor had visited before or not. If he/she has the system will not snap the image of the visitor again. It will just notify the PHI of who has come over for a visit and then retrieve the picture of the visitor in the database of the PHI's phone.

Face recognition: Face recognition is a technology based on a person's facial feature information. According to Zhao *et al*. (2003), the face recognition statement can be formulated as follows:

> "Given still or video images of a scene, identify or verify one or more persons in the scene using a stored database of faces"

The face recognition system contains three procedures, they are face detection, face extraction and face recognition as shown in Fig. 2.

In the proposed system, face detection and face extraction can be done by 'Google Mobile Vision' API and 'Google Vision Face' API (GTC., 2016). The (x, y) position of the landmark where (0, 0) is the upper-left corner of the image will be returned once the face is detected.

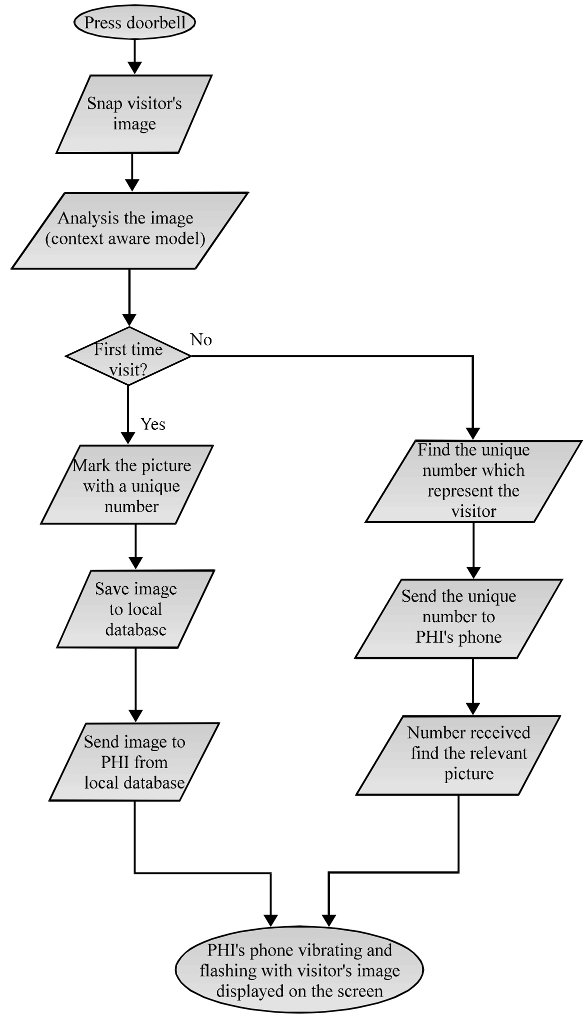

Fig. 1: The flow chart of the proposed system

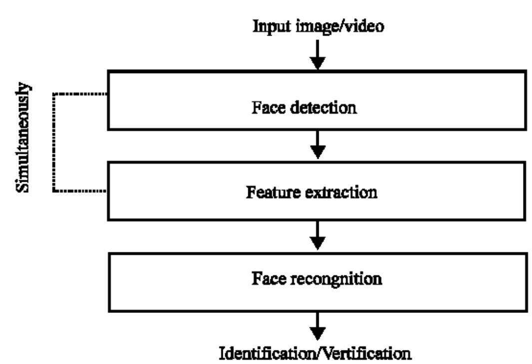

Fig. 2: Three procedures of face recognition (Zhao *et al*., 2003)

The similar face recognition approach 'Aarhus' discussed in related research. There are three landmarks on the face will be used in 'Aarhus' the position of two eyes and the position of the mouth.

Table 1: Description of landmarks

Numbers	Name of the landmark	Description of the landmark
1	Left-eye	The center of the subject's left eye cavity
2	RighteEye	The center of the subject's right eye cavity
3	Left-cheek	The midpoint between the subject's left mouth corner and the outer corner of the subject's left eye
4	Nose-base	The midpoint between the subject's nostrils where the nose meets the face
5	Right-cheek	The midpoint between the subject's right mouth corner and the outer corner of the subject's right eye
6	Left-mouth	The subject's left mouth corner where the lips meet
7	Bottom-mouth	The center of the subject's bottom lip
8	Right-mouth	The subject's right mouth corner where the lips meet

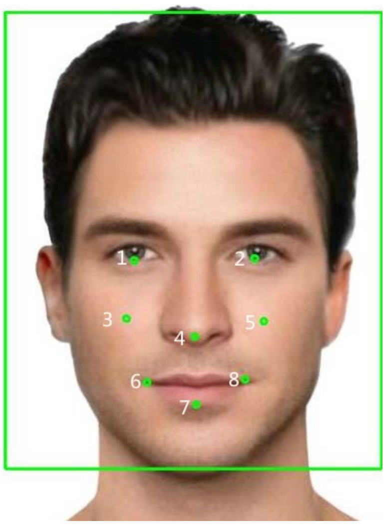

Fig. 3: The 8 landmarks needed

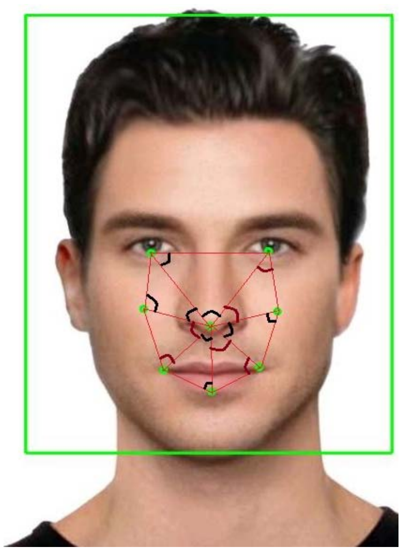

Fig. 4: The 7 triangles formed by 8 landmarks

Triangles can be formed by those 8 landmarks: In the proposed system, the number of the landmarks used for face recognition will be increase to 8. Those 8 landmarks are shown in Fig. 3 and its description is shown in Table 1. Based on those 8 landmarks there are 7 triangles can be formed shown in Fig. 4.

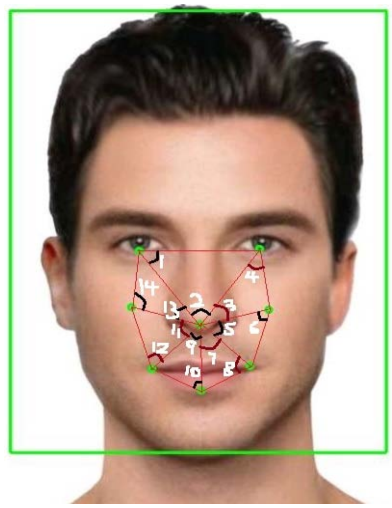

Fig. 5: The 14 angles will be calculated

Every sides of the triangle: Once, the position of two points are given, the distance between two points in a coordinate system can be calculated by the following equation shown in Eq. 1:

$$AB = \sqrt{(x_A - x_B)^2 + (y_A - y_B)^2} \quad (1)$$

Based on Eq. 1, all the sides of each triangle shown in Fig. 4 can be calculated. Once, the three sides of a triangle are given, the cosine value of any angle can be calculated by the Law of cosine shown in Eq. 2:

$$\cos(C) = \frac{a^2 + b^2 - c^2}{2ab} \quad (2)$$

Therefore, the cosine value from cosine1 to cosine 14 (14 angles shown in Fig. 5) can be calculated.

Face matching: By comparing those 14 cosine values of each angle to determine if those two sets value come from a same person.

Context-aware feature in the proposed system: Before explaining the concept of context-aware, let's look at DIKW pyramid (Rowley, 2007), the DIKW hierarchy is

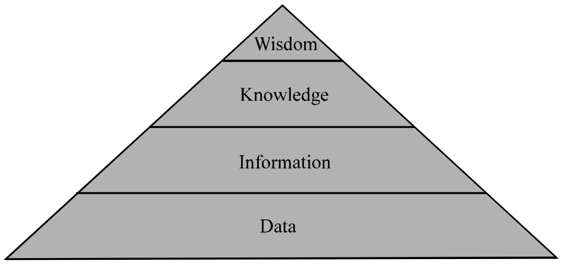

Fig. 6: DIKW pyramid

shown in Fig. 6. Raw data around us can be collected by different sensors. Those raw data can be analyzed as information to identify the patterns and trends which would turn information into knowledge. Ultimately, wisdom can be derived from that knowledge.

> "A system is context-aware if it uses context to provide relevant information and/or services to the user where relevancy depends on the user's task (Abowd *et al*., 1999)"

The level of context awareness can be either personalization, passive context awareness or active context awareness (Barkhuus and Dey, 2003). The main purpose of setting up the level of context awareness is to determine how many times the user must interact with the system. In this project, it means what kind of interaction the user should do before the system alert PHI that visitor is front of the door.

At the beginning, the passive context awareness was used to provide more functions. For example, the system can give the option to the visitor if they want to put their name attached with their image, so when, the second time the visitor comes over, their face picture will be displayed automatically on the screen with their name on and easy to be classified by the system.

Whatever the functions that the system provides to the visitors, it involves lots of interaction with the system from the visitor's side and the PHI side. However for untrained visitors, it takes a long time to get used with the doorbell system if the system offers too many options or functions to the visitor. Therefore, active context awareness was chosen which will allow the system to continuously monitor the visitor's face and snap the visitor's face image, analyzing autonomously and send the result to PHI's device.

Context acquisition: It is easy to be confused in this project about what is context data. For example, most of the people may consider the visitor's image as context data. First of all in our project, the visitor's image will be collected by the camera. However, the original image of the visitor it is not context data because it cannot be used for context reasoning directly which means the system won't be able to recognize the visitor just by the visitor's image. The system will extract the landmarks from the visitor's image then the position of each landmark will go through the face recognition algorithm. The values of each angle in different triangles are considered as context data. Because this context data is not auto-detected or collected by virtual sensors, it is derived by the face recognition algorithm (calculated). Therefore in our project, the context acquisition is 'Derive'.

Context reasoning (Perera *et al*., 2014): The context data should go through context reasoning process after the context data derived. Active context awareness means the system will execute the task automatically and this feature is mainly based on and depends on the result from context reasoning.

'Rules usually structure in an IF-THEN-ELSE format, it is simplest and most straightforward methods of reasoning. In our project, the value of angles will be stored in the SQLite database for the first visitor come and visit. Who ever come and press the doorbell, the value of angles will go through context reasoning. The process of context reasoning can be roughly explained as the following sentences.

IF the values of the angles from the new visitor are as same as a record which stored in SQLite database (face recognition). Then, this visitor will be considered not first time visit, the unique ID of the visitor will be sent to PHI. Else the visitor's image will be snapped and send to PHI with a unique ID.

Experimental work: In real scenario, the doorbell has to be pressed by the visitor then the image of the visitor will be analyzed by the system and relevant information will be sent PHI. Finally, once their phone received the data from doorbell, PHI will be notified by vibration of the phone and the flash blinking on the phone.

Experimental setup

Environment and tools: Here, is the list of environmental tools needed for developing the proposed system:

- Integrated development environment, Android studio 2.2.3
- Testing phone model, Google Nexus 6 and Google Nexus 5
- Network connection: Wireless network(Wi-Fi)
- Database: SQLite (Worldwide, 2017)

Platform and testing devices: To test the developed system, the following items are required:

Table 2: Test cases

TC#	Test cases	Expected result
No.1	Visitor press the doorbell at the first time	The system should snap the visitor's image, the unique ID of this visitor and image will be sent to PHI side The phone will vibrate, the flash will blinking, and the image will be displayed at PHI side
No.2	visitor press the doorbell at the second time	The unique ID of this visitor will be sent to PHI side with The phone will vibrate, the flash will blinking and the image will be displayed at PHI side

- Internet connection, Wireless network Wi-Fi
- Mobile operating system, the proposed system will be running on android platform. Now the latest version of android is android 7.0 which is also called Android 7.0 Nougat (DigitaGlobe, 2016).
- IDE, the system is running on the android platform, so that, android studio was chosen as the IDE for this project
- Testing devices, Google Nexus-6 research as the doorbell and interacts with the visitor and Google Nexus-5 research as the device which notifies PHI

System permission needed: The proposed system is running on Android platform, therefore there are two permissions needed for the system those are Algorithm 1.

Algorithm 1; Android permission request code:

```
<uses-permission android: name = "android. permission.CAMERA"/>
<uses-permission android: name = "android. permission.INTERNET"/>
```

Size of the image: As shown in Algorithm 2, the camera preview size was set as 240*380 Pixels.

Algorithm 2; Android image resolution setting code:

mCamera Source = new Camera Source Builder (context. detctor)

- set requested preview size (240, 380)
- set facing (Camera Source. CAMERA-Facing-Front)
- set requested Fps (30.0f)
- build ()

Experimental scenario: Our face recognition algorithm is based on the position of landmarks. This type of face recognition algorithm highly depends on facial land marks. The accuracy rate is subjected to several aspects such as visitor smile or not facing the camera while the system taking the picture.

The developed system will be set up as the doorbell on the front door and invite 5 people as our test audience (the visitor). Every visitor will be asked to have no facial expressions and face the camera while testing and the test audience press the doorbell. At the first time, the system should be able to snap the visitor's image, stored the context data (cosine value of each angles) to database, assign a unique ID to this visitor and then send the image with the unique ID to the other test device. When the second time the same visitor comes and press the doorbell, the system should be able to recognize the visitor, then looking for the unique ID of this visitor assigned by the system before from local database, the system will send the unique ID to the other test device. The test cases of the system are shown in Table 2.

The first permission is the camera access permission which permits the system to use the vision hardware of the testing device. The second permission is the Internet access permission which allows the system to transfer data on the internet. Both of the android permission request code are shown in Algorithm 1.

Results were recorded: There were several types of data that needed to be recorded besides the results of the test cases. The other types of data helped in analysing the performance of the system.

The cosine values of the different angles of the same person. For each face there were 14 angles calculated and each of the values was represented by a parameter which was types twice. A possible cosine value of the angle was between 0 and 1 and it could have looked like this, 0.8131275276135674. For testing purposes, all of the values were displayed in the android studio. This helped us in determining how many decimal places should be used in the angle comparisons.

Whether the image displayed on the PHI's mobile phone (Google nexus 5) was from the local database or transferred from the doorbell. No matter if the system could recognise the visitor or not, the image of the visitor was displayed on the PHI's mobile phone anyway, for testing purposes. The system checked whether the image was from the local database (SQLite data base) or from the Google Nexus 6 (doorbell). This was accomplished by printing out the information whether the doorbell (Google Nexus 6) found any face match or no matching face was found in the android studio. This helped us in analysing the success rate of the face recognition.

Image size and transmission time of the image. The developed system aims to reduce the transmission time of the image, so that, the visitor does not have to wait for a long time for the response by the PHI. Therefore, the image size was displayed in the android studio and the transmission time of the image was be calculated and recorded.

RESULTS AND DISCUSSION

The first batch of tests showed that the system was not able to recognise the visitor at the second time. No matter how many times the same person pressed the doorbell, the system was still not able to recognise the visitor. The same person was asked to press the doorbell six times and all the cosine values of the same person were recorded. Six sets of data were recorded as shown in Table 3.

At first, it was believed that only if all the values of the angles were exactly the same, it could be regarded as the same person. For example, the cosine value of angle1 when the visitor visited for the first time had to equal the value of angle 1 when the visitor visited for the second time. All the cosine values of the angels from the same person have been shown in Table 3, however when we look at the results, none of each single piece of data is exactly the same as any other one.

If all of the decimal digits were kept and compared for the different angles, the precision range would have been too high and the system would not have been able to recognise the visitors if they had come before which means that the system may not have been able to recognise anyone. On the contrary, if only the first decimals were used to compare the different cosine value of the angles, the system might have regarded different visitors as the same person. Because all of the values were from the same person when analysing the results shown in Table 3, it was noticed that for the same angles, the first two decimal places were basically the same. The first 4 angles were picked up and a list of its first two decimal places has been presented in Table 4.

According to Table 4, the first two decimal places which were from the same angle were basically the same except for the third record in the value of angle 2. In addition by looking at the first two decimal places from different angles for example, the first two decimal digits of angle 1 were '94' then they were '82' of angle 2 '88' of angle 3 and so on. So, two decimal places for each angle were considered therefore in the face recognition algorithm, two different angle1's were regarded as the same if their first two decimal places were the same.

There were 5 people who took this test and each of the 5 people pressed the doorbell which was displayed on the screen by Google Nexus-6 and the testing device Google Nexus-5 worked as in the PHI's side to notify the PHI that a visitor is in front of their house. All the results have been shown in Table 5. Here are the findings according to Table 5.

Table 3: The Cosine values for the same person's facial landmarks angles for six experiments

	The cosion value for the same person's facial landmark					
Angle #	1st try	2nd try	3rd try	4th try	5th try	6th try
1	0.9442447420026289	0.9491096537605782	0.9442317240766819	0.9400086022568210	0.9429221946217272	0.9453709225047882
2	0.8263487159628947	0.8232580914414143	0.8290028921316951	0.8317540930172648	0.8269008656427103	0.8588888550465133
3	0.8821984445899151	0.8825733881088309	0.8839629982473993	0.8818620491748750	0.8810219923648400	0.8837130512438154
4	0.9011228725221136	0.9005966325411988	0.8987984271108583	0.8973529298443575	0.9007048021126273	0.8974798511257296
5	0.9075006753805460	0.9085804666947459	0.9078642839393195	0.9046009986559939	0.9058178294966966	0.9069322688232350
6	0.8777745848556628	0.8788758051460337	0.8770446799616109	0.8787148351633371	0.8784730908725835	0.8777198433632770
7	0.9132441662144773	0.9149218568928524	0.9126468869055389	0.9096114445104722	0.9118947952367761	0.9120880962993670
8	0.8531665420995307	0.8517322421600855	0.8521680424304833	0.8542660627698051	0.8546995598624582	0.8530014713943436
9	0.8932201595019398	0.8928796375343150	0.8909721679793629	0.8890968750024542	0.8923457978867733	0.8902430280160694
10	0.8370548023791096	0.8334792568844180	0.8369154752254730	0.8405643273989615	0.8379956292554791	0.8366337005454679
11	0.8481424894721209	0.8447894408051412	0.8451866381967075	0.8476965064511812	0.8488268821531257	0.8445343354900411
12	0.8564610194088633	0.8580022832943226	0.8592089277971863	0.8620566786262907	0.8582122127706232	0.8606417280902617
13	0.8359053445265926	0.8343960815656758	0.8330821906715410	0.8391276512827417	0.8383394564400052	0.8348953589845500
14	0.8768602310891603	0.8754244741198609	0.8800313362535435	0.8775718717004356	0.8754266390158760	0.8783399637487866

Table 4: The first two decimal places of each angle

#. Press doorbell	Values of angle 1 (cos)	Values of angle 2 (cos)	Values of angle 3 (cos)
1st time press	0.94	0.82 0.88	
	42447420026289	63487159628947	21984445899515
2nd time press	0.94	0.82 0.88	
	91096537605782	32580914414143	25733881088309
3rd time press	0.94	0.82 0.88	
	42317240766819	90028921316951	39629982473993
4th time press	0.94	0.82 0.88	
	0008602256821	17540930172648	1862049174875
5th time press	0.94	0.82 0.88	
	29221946217272	69008656427103	102199236484
6th time press	0.94	0.82 0.88	
	53709225047882	88888550465133	37130512438154

Table 5: Test results

Test person	Test 1 cases	Test 2 cases	Image size (kB)	Transmission time per image	Face recognition
P1	PHI's Device vibrated	PHI's device vibrated	36.322	Immediate	Recognised
P2	with flash blinking	flash blinking and visitor's	33.607	Immediate	Recognised
P3		picture shown in screen	39.605	Immediate	Recognised
P4			43.646	Immediate	Recognised
P5	The Image was displayed on screen	The log of the doorbell android device shows that the visitor's image was matched in its local database (SQLite)	39.605/36.61	Immediate	Failed

Fig. 7: Angle possibilities for face recognition

Transmission time of the image: The resolution of each image was 240×380, the sizes of the image have been shown in Table 5. The range of the image size was from 33.607-43.646 kB. The duration from the face being detected to the face's picture being displayed on the PHI's phone was recorded. However, every time the duration was recorded, the image had been immediately displayed on the screen.

After analysing the results, it was found that there were two main reasons why the image transferring was very fast. One was because the internet speed was fast enough secondly, the size of the image was very small, this will also benefit the system in image transferring and image encoding and decoding.

According to the tests results shown in Table 5, there were 5 people who took this test. The system could recognise 4 out of the 5 visitors. Currently, the accuracy rate of our developed system is 80%. However, the accuracy rate might be changed with more and more people taking the test.

Visual communication signals and tactile cues: During the test, Google Nexus 5 vibrated with the flash blinking and the image was displayed on the screen, the visual communication signals and tactile cues were successfully delivered to the PHI (Fig. 7).

CONCLUSION

The developed system is user-friendly and able to notify PHIs with visual signals and tactile cues and can also reduce the transmission time of the image by adding a context aware feature into the alert system. After analysing the cosine values of the same person, it was found that the first 2 decimal places of each cosine value of different angles were the most important for face matching (compared with 'Aarhus face recognition'). Based on this conclusion, the system is able to recognise the visitors by capturing the visitor's images, extracting landmarks and analysing the context data.

LIMITATIONS

The system is able to notify PHIs regardless of how the visitor behaves. However, the face recognition accuracy rate greatly depends on how the visitor behaves. When the visitor was standing statically in front of the doorbell without any facial expressions. In a real scenario, the visitor may have different facial expressions depending on their mood or sometimes they may not be facing the camera directly. Those factors may lead the system to fail in face recognition.

RECOMMENDATIONS

The developed system has its own limitations which can be overcome by the recommendations of some enhancements to the project in this study. The first limitation is the self-learning of the system itself. After discussing and analysing the limitations of the system in the conclusion and findings it will improve the performance of the developed system in recognising the same person regardless of how they face the camera and even with different facial expressions if the system allows the PHI or the visitor to classify the visitor's image by themselves. For example, 'visitor A' had visited twice already but the system did not recognise the 'visitor' at the second time of visiting. When the PHI sees the picture and realises those two visitors are actually the same person then the PHI can classify those two pictures into one record of the same person or after the system has snapped the visitor's image it will allow the visitor to put his/her name on the photo, just like when one person has two mobile phone numbers. Therefore if a visitor's facial data can be matched with any of the records of 'visitor A', the system will consider this visitor as 'visitor A' like the different angles shown in Fig. 7, this person may have 9 sets of context data and even if this visitor is not facing the camera, perfectly, the proposed system would still be able to recognise this visitor.

REFERENCES

Abowd, G.D., A.K. Dey, P.J. Brown, N. Davies, M. Smith and P. Steggles, 1999. Towards a better understanding of context and context-awareness. Proceedings of the 1st International Symposium on Handheld and Ubiquitous Computing, September 27-29, 1999, Karlsruhe, Germany, pp: 304-307.

Barkhuus, L. and A. Dey, 2003. Is context-aware computing taking control away from the user? Three levels of interactivity examined. Proceedings of the 5th International Conference on Ubiquitous Computing (UBICOMP), October 12-15, 2003, Springer, Berlin, Germany, ISBN:978-3-540-20301-8, pp: 149-156.

DigitalGlobe, 2016. Android 7.0 nougat made for you with more ways to make android your own, android nougat is our sweetest release yet. DigitalGlobe, Westminster, Colorado, USA. https://www. android. com/versions/nougat-7-0/

GTC., 2014. Mobile vision. Google Technology Company, Mountain View, California, USA. https://developers. google.com/vision/

Kumari, P., P. Goel and S.R.N. Reddy, 2015. PiCam: IoT based wireless alert system for deaf and hard of hearing. Proceedings of the 2015 International Conference on Advanced Computing and Communications (ADCOM), September 18-20, 2015, IEEE, Chennai, India, ISBN:978-1-4673-9777-3, pp: 39-44.

Landmark Worldwide, 2017. Google APIs for android Google developers. Landmark Worldwide, San Francisco, California, USA.

Letupe, K., 2013. Android Application for Face Recognition. Aarhus University, Aarhus, Denmark,.

Perera, C., A. Zaslavsky, P. Christen and D. Georgakopoulos, 2014. Context aware computing for the internet of things: A survey. IEEE. Commun. Surv. Tutorials, 16: 414-454.

Perera, C., A. Zaslavsky, P. Christen and D. Georgakopoulos, 2014. Context aware computing for the internet of things: A survey. IEEE. Commun. Surv. Tutorials, 16: 414-454.

Rowley J., 2007. The wisdom hierarchy: Representations of the DIKW hierarchy. J. Inf. Sci., 33: 163-180.

WHO., 2016. World report on disability. World Health Organization, Geneva, Switzerland. http://www. who.int/disabilities/world_report/2011/report/en/

Zhao, W., R. Chellappa, P.J. Phillips and A. Rosenfeld, 2003. Face recognition: A literature survey. ACM. Comput. Surv. CSUR., 35: 399-458.