Design and Development of Interactive Mirror for Aware Home

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Abstract— **This paper describes the design, development and deployment of an "Interactive Mirror", an artifact augmented with intelligence to demonstrate personalized services for enhanced comfort. The mirror aims at recognizing the user based on image processing techniques and provides personalized services like emotion recognition, health progress representation, event reminder and mirror usage time. The prototype of the interactive mirror was deployed in laboratory environment and the user's feedbacks were obtained. The face recognition and emotion recognition algorithms were tested and the results are discussed.**

Keywords - Ubiquitous Computing; Interactive mirror; Face Recognition; Emotion Recognition; Smart Artifact.

I. INTRODUCTION

Ubiquitous computing, with wirelessly connected embedded devices that are being used in day–to–day activities, is changing and improving our quality of life. Based on ubiquitous computing and communication technologies, many devices/products are emerging to make users comfortable. We daily look at the mirror and interact with it psychologically to find out how we look and how our attire is. Generally everyone spends some time to select a suitable outfit for the day during mirror usage. The interactive mirror is a development effort to augment the mirror with embedded intelligence for offering enhanced features such as face recognition, facial expression analysis, health progress reporting and selection of appropriate dress for the day. The 'Interactive mirror' is formulated as follows

Interactive Mirror = Mirror + Sensors + Database + Intelligence + Display

The Interactive Mirror comprises of a dielectric coated mirror mounted over a LCD Display, a camera for capturing the user's image, load sensors for measuring user's weight, Radio-frequency identification (RFID) reader and RFID tags for identifying the garment worn by the user. The mirror gets the inputs from all these sensors, processes it and provides output by displaying text and graphics as well as audio output.

Our contributions are as follows: 1) Conceptualization, design and development of interactive mirror that provides personalized services based on biometric identification of the user. 2) Facial feature extraction for emotion recognition 3) Training face recognition and emotion recognition algorithm with the database images created by us 4) Test results of face recognition and emotion recognition algorithm in the deployed environment.

The paper is organized as follows. Section 2 comprises of our comments about the related work, Section 3 details about the engineering of interactive mirror, Section 4 gives an overview of our proposed system and different modules involved in it, Section 5 presents the results obtained, and finally, Section 6 concludes the work.

II. RELATED WORK

Few investigations have been done in this area. By keeping the mirror usage in mind, certain efforts have been done to add the technologies in the mirror to do multiple tasks parallel at a time. How it will be if the mirror is talking to us. This concept has been realized in [2] using speech processing techniques. The mirror interacts with the user through verbal commands, functions like a good friend, listens to user's question and responds them, provides relaxation and consolation. It is essential to do the tasks parallel in our daily activities to save our time. Philips laboratory has come out with such a mirror [3] to assist the users in saving their time. One can watch news reports, TV channels, weather reports, etc., while brushing in bathroom. The bathroom lighting comprises of 50 light sources of different kind. Various light sources have been used which generates light of different color and temperature.

A mirror [4] makes use of behavioral data in order to provide its user with continuous visual feedback on their behavior in a natural manner. It tells you how you will look after 5 years.

An augmented setup [5] has been demonstrated targeting card game application. The system captures the image of the surrounding, detects multiple objects on it and provides augmented display on a LCD screen mounted on a table.

A digital mirror that detects tracks and model the human face and expression on a computer screen is demonstrated in [6]. The system uses robust multiple face detector and tracker based on active infrared (IR) illumination, and developed a physics based face model to generate realistic graphics output, and tested the integration of both modules using an eye-contact application, that randomly changes facial expressions.

Our system assists in leading a healthier life by measuring and providing health progress of basic health parameters, in addition to face recognition and facial expression analysis. The system also attempts to keep track

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of the garments used over a period of time and suggest an appropriate dress for a particular day. Even though the system is designed for user without any disabilities, visually impaired people might find it more useful.

III. ENGINEERING OF INTERACTIVE MIRROR

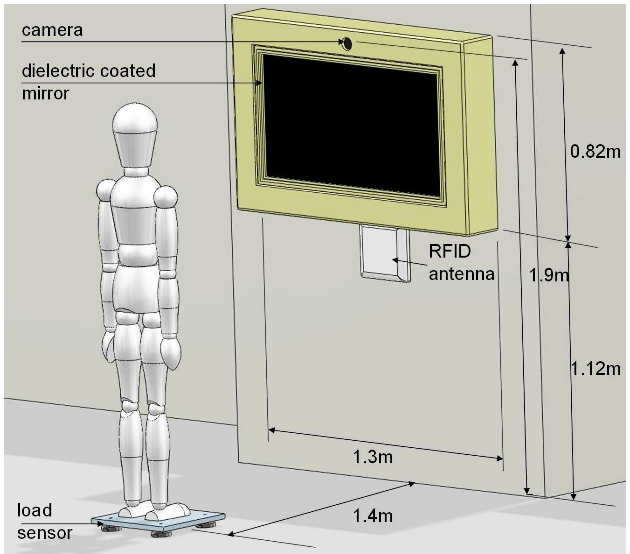

Figure 1. Engineering of Interactive Mirror

The dielectric coated mirror of thickness ¼” is mounted over the LCD display, so that the entire panel acts both as a mirror and display. When the display is ON, the dielectric glass will be transparent and when display is OFF, it will act as a normal mirror. A Creative web camera having VGA resolution and frame rate of 30fps is mounted on the top of the panel for capturing the images. The camera will be on sleep mode and triggered by the application for capturing mode when the user starts using the mirror. A weight measuring platform is formed with four load sensors from Loadstar. Each load sensor can carry weight up to 50lb, resulting in the maximum weight of the platform is 200lb. The weighing platform and the camera are mounted at suitable distance so that the entire face image should be covered by the camera Field of View (FOV). The distance between the weighing platform and the camera is kept constant to avoid scaling changes in the face image. The entire application has to be ported on atom processor which is placed inside the top frame of the panel. The omni directional, circular polarized Poynting UHF RFID antenna having 7dbi gain is positioned under the panel to detect the RFID tag attached in the garments. The antenna is connected to the SIRIT Infinity 510 RFID reader that is placed inside the wooden frame. The entire setup is shown in Figure 1.

IV. SYSTEM OVERVIEW

The system encompasses of several modules to implement the services shown in Figure 2. The modules are described as follows.

A. *Face Recognition*

The steps involved in face recognition module are shown in Figure 3. The image captured by the camera needs to be preprocessed in order to enhance the contrast. Generally, an image is a collection of pixels. The pixel value refers to the intensity. To improve the image contrast, the intensity value is analyzed from top left pixel to bottom right pixel. The intensity value which occurred frequently is distributed over the entire image using histogram equalization technique.

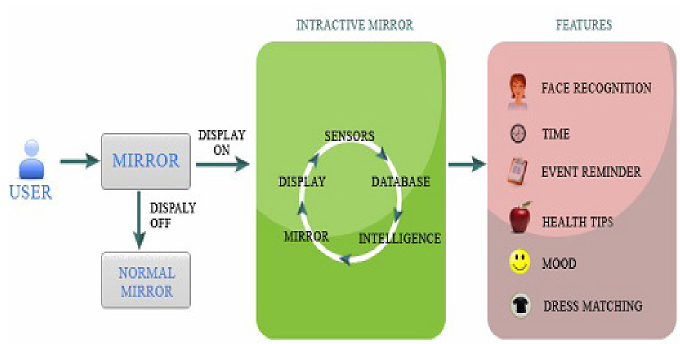

Figure 2. Services of Interactive Mirror.

The first step of face recognition is face detection. The process of finding faces in an image is called as face detection. Processing an image, pixel by pixel is a time consuming process. The methods available for face detection and face recognition are surveyed and compared in [7]. The system is using Viola and Jones algorithm [1] for face detection. It processes the image based on haar-like features and not pixels. The image is scanned from top left to bottom right using a window. The scan looks for the presence of haar-like features. The scan window is passed through a chain of filters called as classifiers. The classifiers are all trained with both face and non face images. The window which passes through all the classifiers are classified as “face” and if a window is rejected by any of the classifiers in the chain is classified as “Non-Face”.

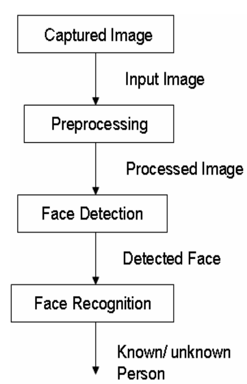

Figure 3. Steps involved in Face Recogntiion module.

The second step is to recognize whose face is this? The detected face image is to be cropped and resized for further processing. Many algorithms exist for face recognition

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technique [13]. The face recognition technique using geometric approach and template matching have been compared in [12]. "EigenFace" Recognition method is used here [8][9][10] taking advantage of the actuality that the faces images will be frontal and upright while the user uses the mirror. This method works on training basis. The algorithm includes projecting the images over a lower dimensional space and finding the distances between them.

The face images of the users are captured and stored in a face database after processing shown in Figure 4. The algorithm needs to be trained with these standard face database images.

Figure 4. Face DataBase Images.

As said earlier, processing an image pixel by pixel is a time consuming process. For example, an image of size 100 * 100 is said to be a 10000 dimensional image. Hence, in order to reduce the dimension, principal component analysis (PCA) technique has been used. The Eigenvalues and Eigenvectors for all the images are calculated and projected over a lower dimension space.

Then the distance between the input image and all the training images in the projected space needs to be calculated using "Euclidean Distance" method. The Euclidean distance between two point's p1(x1, y1) and p2(x2, y2) is given by (1),

$$d = \sqrt{((x2 - x1)^2 - (y2 - y1)^2} \qquad (1)$$

Based on the distance measured, the input image is recognized. If the input face is a known face, the user is authorized, otherwise the user is unauthorized. OpenCV, an image processing library developed by Intel Corporation has been used for image processing algorithms.

B. *Emotion Recognition*

Generally, a person's emotional state is very important, since it has effect for whole day. Human Computer interaction by understanding the human's emotion is a recent research topic. Interactive mirror detects the user's emotions based on their facial expressions while the user is interacting with the mirror. There exist various methods to recognize the user's emotion. However, the system infers the emotions from the facial expressions as it get the input as face image. Facial expressions can be recognized from the facial features as per the steps shown in Figure 5. Facial features are the spatial position of the features and its displacements.

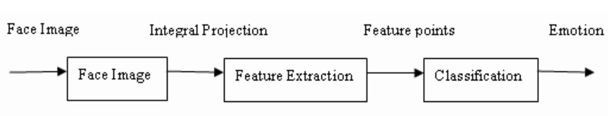

Figure 5. Steps inviolved in Emotion Recognition Module.

The following assumptions have been made 1) Constant lighting and illumination 2) Front Face image 3) No scaling variations.

The mouth features best describes the emotion of a person. Hence, mouth features like mouth width and height have been taken into consideration. Eyes also play a vital role in finding the emotion of the person. Thus eye features like eye width and eye height have also been extracted. The facial expression database images for happy, surprise and sad are shown in Figures 6, 7 and 8, respectively.

Figure 6. Happy Expression Database Images.

Figure 7. Surprise Expression Database Images.

Figure 8. Sad Expression Database Images.

Integral Projection method is used to extract facial features [11][14]. This method is affected by the external conditions like illumination changes, and skin color.

1) Mouth Feature Extraction:

In order to extract the mouth features, the search region has to limited by segmenting the mouth part alone from the face image. There exist three approaches [11] to extract the face features (i) based on luminance, chrominance, facial geometry and symmetry [12] (ii) template matching [15] (iii) PCA. Facial geometry approach is being used in our application. The steps involved in extracting the mouth features are shown in Figure 9. As per the face geometry, the mouth region is segmented from the face image. The segmented image is preprocessed to improve its contrast and converted to binary image using image thersholding. The threshold value is selected dynamically by the algorithm as per the image brightness. The unwanted blobs as shown in Figure 10a) occurred because of illumination variation along the face region is eliminated using blob removal technique. The blob removed image is shown in Figure 10b). A minimum blob size and the connectivity of the pixels are analyzed to say whether the blob belong to mouth region or not. By applying the integral projection method on binary

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image, the exact position of the mouth corners and top point is located.

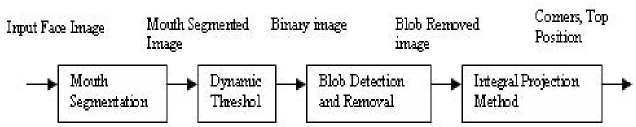

Figure 9. Steps involved in Mouth Feature Extraction

Let I(x, y) be a gray value of an image.
The Horizontal integral projection [11] of the image m x n is defined as

$$H(y) = \sum_{y=0}^{n} I(x, y) \quad (2)$$

The Vertical integral projection of the image is defined as

$$V(x) = \sum_{x=0}^{m} I(x, y) \quad (3)$$

a) b)

Figure 10. a) Binary Image b) Blob removed Image

where m = no of rows and n = no of columns.

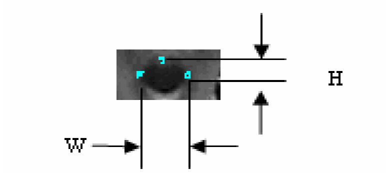

Figure 11. Mouth Feature Points.

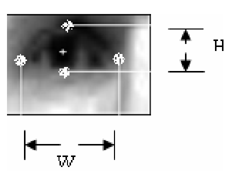

Figure 12. Eye Feature Points

The minimum value observed in the horizontal projection curve is the centre line of the upper and lower lip. Scan along the line both left and right to locate the corners. In vertical projection, the minimum value is the centre line of the mouth and scanning from top to bottom locates the top and bottom point of the mouth respectively. The mouth width is obtained from the two corner points and mouth height is obtained from the top point and the centre point of the mouth centre line shown in Figure 11.

2) Eye Feature Extraction:

As like mouth image segmentation, the same steps are followed for eye feature extraction also. The left and right eye region is separated from the face image as per the face geometry. The integral projection method is applied to locate the feature points as shown in Figure 12. The eye width and height is calculated from the featured points extracted. The minimum value in both the projection curve denotes the iris centre point.

3) k-NN Classifiaction Algorithm:

There exist various classification algorithms [18] suitable for facial expression recognition; the system make use of k-NN classifier. Similar works using k-NN classifier are available at [17]. It is one of the simplest machine learning algorithms. An object is classified by the majority vote of its neighbors. K is a constant denotes the no of neighbors. The value k should not be too small and not too large. The different k values are used for testing the accuracy of our algorithm and the results were discussed in section IV. The classification algorithm is trained with the extracted mouth feature values for classifying emotions like happy, surprise, sad and normal.

C. Health Progress Representation

The basic health parameters like weight, height, BMI and BMR are measured and saved in the health database. The values measured are saved in the health database along with the date and time of measurement. The health database is secured so that only the authorized person can have access after proper authentication.

The weighting platform mounted in front of the mirror starts giving the weight output when the user stands over it. The height information is obtained from the database currently; later the system will be integrated with the ultrasonic sensor to obtain height information of the user. Based on the weight and height information, the parameters like Body Mass Index (BMI) and Basal Metabolic Rate (BMR) have been calculated using the following formulas shown in equation 4 and 5/6 respectively.

$$BMI = (Weight) / (Height)^2 \quad (4)$$

Weight in Kilograms and Height in meter.
For Women,

$$BMR = 655 + (4.35 x Weight) + (4.7 x Height) - (4.7 x Age) Kcal / day \quad (5)$$

For Men,

$$BMR = 66 + (6.23 x Weight) + (12.7 x Height) - (6.8 x Age) Kcal / day \quad (6)$$

Weight in pounds, height in inches and age in years.

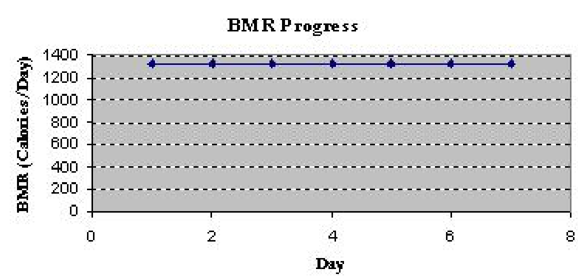

Figure 13. BMR Progress Representation.

BMI determines a person’s weight according to his height and BMR is the measure of number of calories burned by the body when he/she is at rest. This helps in determining how much calories he need to intake inorder to maintain an energy balance and balanced diet condition.

Both of these parameters are important to measure and monitor to ensure that the person is healthy. The measured BMI value is analyzed for the conditions such as normal, overweight and underweight.

Drastic weight change over a short time period is the main symptom of identifying certain major diseases in human body. Hence the parameters measured have to be analyzed to monitor the change over a certain time period. Therefore the measured values are retrieved from the database and represented graphically to the user inorder to analyze any drastic change has occurred or not. For example, the BMR progress is shown in Figure 13. Similarly, the progress in weight and BMI are also analyzed and displayed to the user. The weight measurement accuracy depends on the accuracy of load sensor.

D. Event Reminder

In this busy world, it's normal to forget certain things like bill payments, birthdays, and important dates etc., hence, there is a need to have reminders to remind all those things. Interactive mirror will do for us. It reminds the important dates in the calendars, birthday, bill payments, tour date, etc.

The user has to enter the details which they want to be reminded using a GUI. When the user is using the mirror, the system will check for reminders against him/her at that particular time. If so, it will remind and also send a message to a hand held device of the user

E. Garment Description and Suggesstion

This feature is proposed to be implemented. The system makes use of RFID technology to identify the garment worn. The RFID tags are attached to the garments. The tag is flexible, water and heat resistant.

When a tag comes into the antenna coverage area, the reader detects the tag. Once the tag id detected by the reader, the details like when it was purchased, where purchased, price, color, material, how many times worn etc are retrieved from the database and displayed to the user. The suitable dress for the particular day is suggested by the mirror according to the presence of events like marriage function, birthday party, etc.

In textile application, the mirror can suggest a suitable dress color based on the skin tone of the user. The first step is to segment the skin color pixels from the captured face image. Next, the skin color pixels are analyzed with a certain predefined values to find the skin tone of the user.

RGB color space is used for skin color segmentation. The face image captured by the camera is scanned pixel by pixel from top left to bottom right. The pixels values are analyzed to classify whether the pixel belongs to skin color or not.

The following condition is used for classification.

A RGB pixel is classified as a skin color pixel, if the following condition is satisfied, the pixel is said to be skin color pixel.

$$R > 95 \;\&\&\; G > 40 \;\&\&\; B > 20 \;\&\&\; (\max\{R,G,B\} - \min\{R,G,B\}) > 15 \;\&\&\; |R-G| > 15 \;\&\&\; R > G \;\&\&\; R > B$$

Else the pixel doesn't belong to skin color.

Once the skin color regions are segmented, the values are analyzed and based on the values and the dress color availability with the particular user, a suitable dress is suggested for the particular day.

F. Mirror Usage Time

Interactive mirror sense the amount of time an individual uses the system and signals them if they are using for a long time. Based on the face recognition, the user's profile is unlocked and their school/office is checked. It tells how much time is remaining for them to get ready. If they have enough time to get ready then make up tips will be provided.

The weight measuring platform is used to find out the mirror usage time. The weight over the platform is monitored continuously. When anyone starts using the mirror, the weight will go up. That gives the start time. When the user leaves the load sensor platform, the weight will gradually decrease and then goes to zero and that time gives the end time. The time difference gives the mirror usage time.

Figure 14. Deployment of Interactive Mirror in Ubicomp Laboratory.

The demo illustration of all these features in the interactive mirror is represented in Figure 14.

V. RESULTS

A. Face Recognition Algorithm Accuracy in Deployed Environment

The face detection algorithm had been tested with CMU face database. The false detection percentage and missing face rate were found to be 7.56 and 9.18, respectively. For example, the background partition glass image (non-facial image) shown in Figure 16 was detected as face image by the face detection algorithm.

Assume that the face images were frontal face images with no scaling variations taken under constant illumination. The users were asked to look at the camera and no other restrictions for them. There was no special experimental setup for capturing face image like dedicated light settings, user positioning with respect to camera, user's viewing angle on a particular object, etc. This created a real life testing environment. Therefore our database images are not strictly front face images. The face images may be tilted, pose varied, with/without expressions, etc., but not with much

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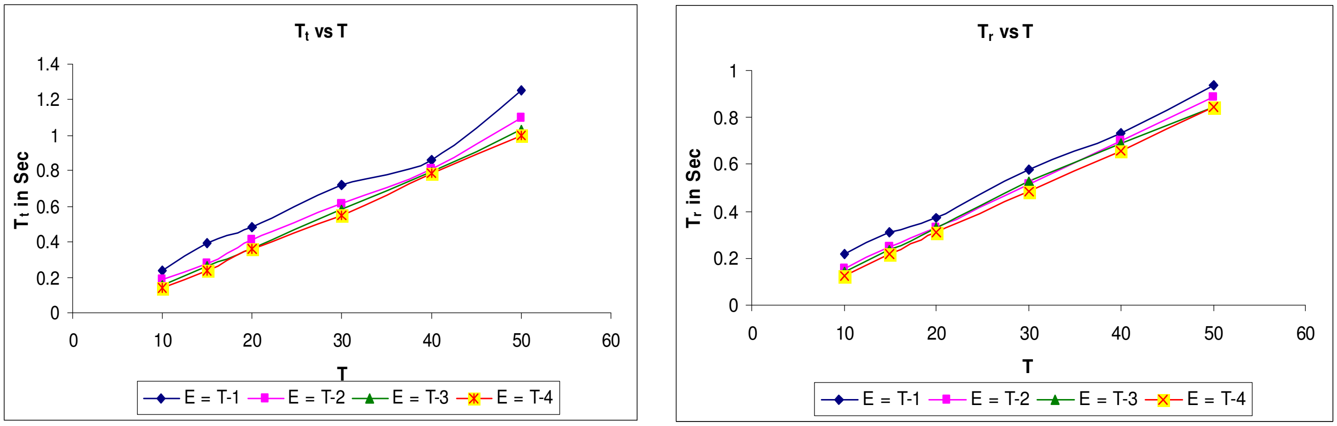

a) b)

Figure 15. Training time and Recognition time versus number of training images for different Eigenvalues a)Training time b)Recognition time.

variation. The training set consists of 42 images of 9 different subjects. The test set consists of known faces, unknown faces and non face images (false positives). Mahalanobis distance [19] method is better to use than the euclidean distance method. Inorder to recognize the unknown images and non face images, a proper threshold values have to be set for the distance calculation. These threshold values have to be calculated by experimentation for the chosen training set. Two different cases were considered for recognition. The one was to recognize the test image based on the first match alone and other based on the majority of first 3 matches. The accuracy of the algorithm for these two cases is listed in Table I. The role of number of eigenvalues (E) used in determining the algorithm accuracy was tested. It is noted that the accuracy decreases with number of Eigenvalues.

Among the two cases, the accuracy was found to be better in the case of considering the first match alone for recognition.

TABLE I. ALGORITHM ACCURACY FOR DIFFERENT NUMBER OF EIGENVALUES

Case	E = 41	E = 40	E = 39	E = 38	E = 37
First Match alone	91	77	72	71	68
Majority of first three matches	53	39	27	36	23

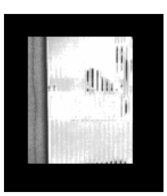

Figure 16. False Positive Image

The false positive result shown in Figure 16 had been eliminated out in face recognition algorithm as “Non face” image by setting up the proper threshold value.

B. *Face Recogntiion Algorithm Processing Time*

The training time (T_t) and recognition time (T_r) of the algorithm were obtained for different number of training images (T) and E. The results are represented in Figure 15a) and b). It was observed that both training time and recognition time increase with respect to number of training images. More number of training images leads to larger face space which in turn increases the training and recognition time. However the training time doesn’t affect the application much since the training has to be done only once at the initial stage. Later recognition process alone will run repeatedly.

The role of number of eigenvalues used in determining the algorithm processing time was also examined and presented. It was observed that the fewer number of Eigenface reduces the training and recognition time.

For achieving better accuracy, we were using maximum number of Eigenvalues.

C. *Emotion Recognition Algorithm Accuracy*

The Emotion recognition algorithm had been tested with our database images. The algorithm was trained with the mouth features like mouth width, mouth height, and left mouth corner to top point distance and right mouth corner to top point distance. The algorithm was tested with Yale facial expression database for different number of nearest neighbors (K). The results are presented in Table II. The algorithm was capable enough to recognize the happy expression when compared to other expressions. The extracted eye features has to be also included in the classification algorithm to improve the algorithm accuracy. The algorithm has to be tested in the deployed environment.

TABLE II. EMOTION RECOGNITION ALGORITHM ACCURACY

K	Happy	Surprise	Normal	Sad
3	93.33	53.33	66.66	33.33
6	100	60	46.6	26.66

TABLE III. USER'S FEEDBACK ON INTERACTIVE MIRROR SERVICES

	Face Recognition		**Emotion Recognition**		**Health Progress Representation**		**Event Reminder**		**Mirror Usage Time**	
	Rating	**Comments**	**Rating**	**Comments**	**Rating**	**Comments**	**Rating**	**Comments**	**Rating**	**Comments**
User 1	4	No comments	3	Should be Improved	4	No comments	5	No comments	4	
User 2	3	Sometimes the algorithm has reported as unknwon face, eventhough the information is already in database.	4	More emotions can be added to the database	4	No comments	4	How to input events to the system? Can we have some interaction where the suer can give inputs as well?	4	No comments
User 3	3	Sometimes good	3	Sometimes good	4	Good	1	Am not using yet	5	Good
User 4	3	Almost 60% it is Giving correct result	3	Same comments here also	1	Not at all watching, you may make it colorful and attractive	1	Didn't use till now, so don't know its capability	2	Not very sure how much it is getting reduced
User 5	3	Good only the environment is similar to training. Sometimes recognizing wrongly	3	Sometimes showing wrongly	4	Good	1	I haven't used it yet	5	Good
User 6	4	Mostly recognizing correctly. Problem arises only when lighting varies	2	Difficult part	5	Good		NA	5	Good
User 7	3	Still need complex algorithm of two or more algorithms running parallel for recognition	4	Eye and nose can also be considered in addition to lips for mood recognition	2	Instead of plain graph, info-graphics can be used		NA	3	No comments

D. *Weight Measurement Accuracy*

The weight measurement accuracy depends on the load sensor accuracy. The load sensor accuracy was tested with standard weights. The percentage error for various loads on a 50lb load sensor is shown in Figure 17.

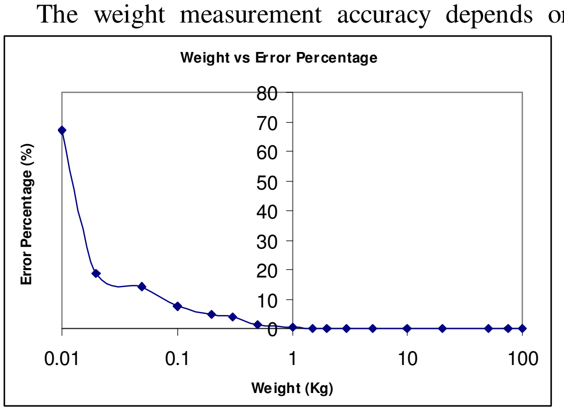

Figure 17. Weight versus error percentage.

The test results conclude the following 1) The error percentage is very high at 10grams, gets decreased up to 100g and finally very low and got stabilized after 1 Kg. 2) The load sensors should be loaded with maximum capacity to reduce the error percentage.

The rest of the features like mirror usage time and event reminder were found to be useful.

E. *User Evaluation of the System*

The system is deployed in our UBICOMP laboratory. The feedback has been obtained from the users (age group 24 to 32) for the services such as face recognition, emotion recognition, health progress representation, event reminder

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and mirror usage time and listed in Table III. The rating has been done from 5 to 1 based on comfort/convenience level achieved in each service where 5 is the highest rate represents more comfortable and 1 represents not at all comfortable. The suggestions for improvements are being analyzed and suitable modifications will be carried out in the future development work.

VI. CONCLUSION AND FUTURE WORK

The Interactive Mirror system has been designed developed and deployed in our Ubiquitous computing laboratory. The features are all personalized using face recognition technique. The health parameter measurement and analysis help the user in leading a healthier life. The computation time and accuracy of the face recognition algorithm have been analyzed and discussed. The accuracy of emotion recognition algorithm is tested and results are presented. The system is targeted towards smart home application. It can be also used in Beauty Parlors, Textile Shops, and Hotels with some modifications in the offered features. The new user is trained automatically by the system when they use first time.

The system can be made much more useful to the users by adding more functionality like integrating light settings, speech processing, etc. The accuracy of the emotion recognition algorithm can be improved by including the extracted eye feature. The system can be deployed in real life home settings and feedback from wider set of users could be obtained for further enhancement of the system.

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