



Formal Specifications for Automated Face Recognition System using Z notations: Motivation towards Formal Methods

F. EJAZ, I. AHMED, N. I. CHAUDHRY, N. J. RAJPER*

Department of Information Technology, University of the Punjab, Gujranwala Campus. Gujranwala, Pakistan

Received 11thOctober 2017 and Revised 12thJuly 2018

Abstract: Use of Computer based systems is becoming our need with each passing day. Automated face recognition system is used in face matching in driving license, passport, and mug shot and in criminal suspects. From few decades, lot of progress has made in face recognition system. One of the major issues in automated facial recognition system is its computational complexity. Major problem in development phase of the computationally complex systems is to define user requirements accurately and precisely. Formal methods are a solution to this problem. Formal methods use mathematical notations and sets theory to articulate system specifications according to the customer needs. This paper includes formal specifications of automated face recognition system using Z notation.

Keywords: Formal Methods, Z-Language, face recognition system, Eigen face, face Book

1. INTRODUCTION

Researchers have made incredible progresses in automated face recognition systems over the last few years; this system is used to match faces in driver license, passport and mug shot with nearly great precision. Moreover, this system is also used by the US investigation agencies for illicit suspects. However, there are some issues which leave the automated face recognition speechless e.g. differences in age, pretence, look etc. (Klontz 2013) Because of clear reasons, face recognition machine based cannot exceed human facial recognition system. There is a continuing part for upgrading incase of optimal or proficiency recognition consequences. Computational complexity is the one of the big problem of facial recognition. The problem of motivated for enlarged database even applying state of the art machines. For real time applications, automated face recognition (AFR) is computationally ill and complex posed reason that requests to be tackled. High resolution image increases the computation intricacy and visualize large characteristic vectors to be managed. Another problem in this context is that extraordinary dimensionality hampers the grouping and later conclusion creation procedure for recognition. With every passing day computer based systems are becoming our ultimate need. They are increasingly used in communications, transportation, economic markets, health-concern systems, safety, and security systems as well as in education too. With the proficient design and great complexity of these systems, developing understanding about their requirements is extremely

challenging. These challenges necessitate the acceptance of suitable engineering schemes and manners, and have induced the utilization of formal methods to define requirements in software engineering (Farahbod, *et al.*, 2014). In the development time of the software system the ultimate goal of the requirements specification is to articulate the user's needs plainly and correctly (Goel, *et al.*, 2010) The foremost problem of modeling any system is how to guarantee that the practical performance of the system gratify with the equivalent functional requirements of the system (Khan and Ahmad, 2012). Formal methods are used to solve this problem. Formal methods are imperative for identifying accurate requirements of the system, paying attention to the uniformity and totality of the system (Christophe 2012) One of the formal specification languages is Z. it is a set of the rules for modeling the software systems requirements. It is most widely used formal language (Mona.2013) Z has the foundation of mathematical concepts for formal specifications and usually used for the requirements specifications and refinement of safety critical and complex systems (Michael *et al.*, 2003). For the correctness of a system, formal methods and languages are mathematical representations and techniques that are described to be built by mathematical evidence. Submission of formal techniques eliminates a large uncertainty and allows the designers to hold stable, objective and exact understanding of a system. An application of formal methods is rigid and asks for complete knowledge of mathematic. That's why formal techniques are not

appropriate for all form of system. While the development life cycle comprises the specifications, design, validation of the design, execution of the design, and the checking of the applications. This induced the development of formal techniques for all these phases. (Hazem *et al.*, 2005). Formal techniques are suitable for which specific set of applications named industrial critical application (occasionally named mission critical). As some traffic regulation systems, wafer steppers, medical systems and electronic payment systems. Failures may cause serious consequences for this type of system. A lot of disappointments can be reduced with the support of usage of formal methods and languages (VanSanten, *et al.*, 2002), Formal techniques can also help to define the formal aspects of the modeling methods (Bork 2015). Formal techniques basically contain 1. mathematical framework, 2. formal specification languages and 3. supporting tools. The Formal techniques are used in identifying software. In formal specification language, formal semantics and syntax are encompassed. A formal syntax, in specification, clearly defines the syntactic binding of a linguistic while, a formal semantics discuss the mathematical importance of entire language composition (VanSanten, *et al.*, 2002), Specification is to create specific report of the software what to develop and how it will be achieved. Ordinary understanding of the idea of the application, specification is a scientific agreement among user and programmer. The programmer procedures the specification to direct its creation; customer uses it to direct purpose of the software. Sub specification can be smashed from complex specifications, each portion tells a sub component of the system, that portion handed to other programmers, with the intention that a programmer at one stage turns into a client at another (Jim. *et al.*, 2009) Mathematical framework and support enables calculation just like calculation in natural mathematics. Theoretically, such a structure accomplishment to take out authentication. For the precise, only one can currently complete manually confirmation. Manual verification requires a solid background in formal analysis and logics also, because it is comparatively difficult. In practice, mostly for prototypes of manufacturing systems, the system beneath attention will be big early to be proved manually. At that time, supporting tools are critical. Supporting tool areas from co-operative managerial tools that check confirmation phases and keep track of proof responsibilities, to completely automatic tools, which set evidences themselves? The latter provide with amenities for automatic verification. In each phase of SDLC the formal methods and languages are applied i.e. specifications, verification, designing implementation. The usability of formal specification languages for the development industry can't be denied.

Dilemma of technology shift, which is habitually proposed since a key reason for the worry between industry and research, is not utterly a crisis for formal methods. Innovative Technologies made in other fields of computer science as well lean to be taken on gradually in industry however for the matter of formal methods, yet circumstances look worse owing to the following reasons:

Automatic Support

Role of Formal Methods in Software process
Formal methods are assuring completeness and accuracy in safety critical systems (Darren,2010) automated Face recognition system is one of the complex and ill posed system so in this paper this system is modeled using formal methods.

2. RELATED WORK

Face recognition system basically depends on either 3D or 2D images, to carry out there are different processes. The preliminary stair is the face recognition. This includes the withdrawal of a face image from a large image or scene or video sequences. The following method is for face position, which includes positioning the face image with aids exact and certain coordinate system consequences. These processes can be achieved by different key tasks such as model and illustration of facial surfaces (Amberg *et al.*, 2008) (Wang *et al.*, 2007). In disciplined way, it aims to decrease the computational difficulty and help to rise the good performance in the face recognition part; Secondly, extraction of 3D facial characteristics. Characteristics extraction contains a set of feature points related with the key facial characteristics, mouth, nose and eyes. Now the most common techniques for facial feature extraction are point facial profiles, clouds and surface curvature based features etc. (Wang, *et al.*,2001). Thirdly, methodology and algorithm used for 2D or 3D facial surface records in quick way. Our study purpose is to cover state-of-the-art 3D face recognition methods, containing the ideas, methodologies, technical background and concepts. More explicitly, there are some problems we shall discuss in the study: Discover the current face recognition systems interact with expressions and related researchers as well as the present state-of-the-art in this part; Investigate the difficulties in present face recognition systems; Detect the difficulties in the 3D face recognition, i.e. in the presence of expression face recognizing; Suggest related methods to improve it in the progress of well-organized 3D face recognition manage with expressions; Investigate the properties of our earlier curvature-based method (Han 2009) in face recognition underneath expression variations. (Lu *et al.*, 2006) match 2.5D facial images in the existence of appearance differences and pose variations to a kept 3D face model with impartial expression by correcting the two forms of expression-

specific, deformable models and expression generic, created from a minor number of subjects to a provide check image which is framed as a minimization of a price function. Fundamentally, drawing a deformable model to a specified test image contains two transformations, non-rigid and rigid transformation. Therefore, the price function is designed by rotation matrix and conversion vector for rigid transformation, and a set of hefts. (Li *et al.*, 2009), (Yin, *et al.*, 2006) used low level arithmetical features to form sparse representation models ranked and collected by the feature ranking and pooling pattern in order to attain suitable recognition percentage. Their attained percentage of recognition was 94%. Facial feature extraction is important in face-related applications (Fatimah, 2009). (Xia *et al.*, 2012) presented the major face recognition methods in the existence of expression variations were constructed on a co-relation learning model which develop a non-neutral model through a neutral model in order to compare non-neutral faces with a neutral face. There were two chief benefits of their suggested method: coaching the interaction between neutral and expressions provide the flexibility of spreading the feature sets; using the slightest feature set removed from the facial arrangement info and the outline data clearly to characterize face models.

In the above figure, five different shape features have been described in face recognition system having different categories. Shape (a) is the sketch of contour shape features that define the face origins, i.e. contour shape of eyes, eyebrows, mouth and nose. In second category, shape (b) shows localization of twelve landmarks while shape (c) is labeled of distance-based features. Shape (d) is the illustration of two distances whereas shape (e) is for contour shape feature set. The most eminent cataloguing techniques aimed at face recognition are those of Eigen face and fisher face (Vijayshree and Wagh 1997). (Vijayshree *et al.*, 2012) suggested a generalized form of the fisher face process

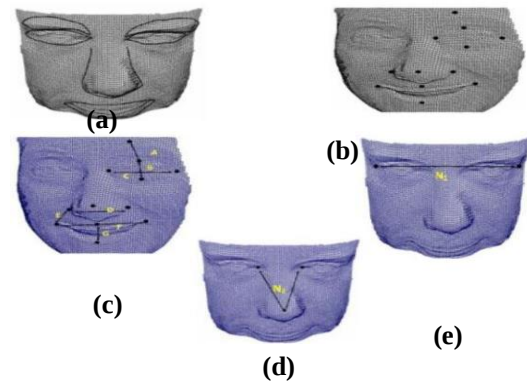


Fig. A.1: Illustrations of shape features Illustrations of shape features



Fig.C.1: Fuzzy Fisher Faces for face recognition system

for face recognition with refined info about class association of the dual labeled faces (patterns) that are shown in the following (**Fig. C.1**). In (Marijita 2012), using the Principal Component Analysis (PCA) face recognition system algorithm was executed. This algorithm was dependent on an Eigen face methodology which represented a PCA process in which a trifling set of important characteristics are applied to define the dissimilarities among face images.

Fuzzy Fisher Faces for face recognition system.

(DewiAgushinta *et al.*, 2012) have used biometric technology in recognition and identifying human body

components. This technology recognizes human's unique and fixed body parts, such as face, eyes and fingerprints. They developed a system that describes face components by defining the distance of face components (i.e.: nose, mouth, the eyes) and further facial components. This procedure handled on a frontal single still image to acquire the components. Area between components are resolved by identifying the based skin color, picking to normalize face region, and extracting eyes, nose, and mouth.

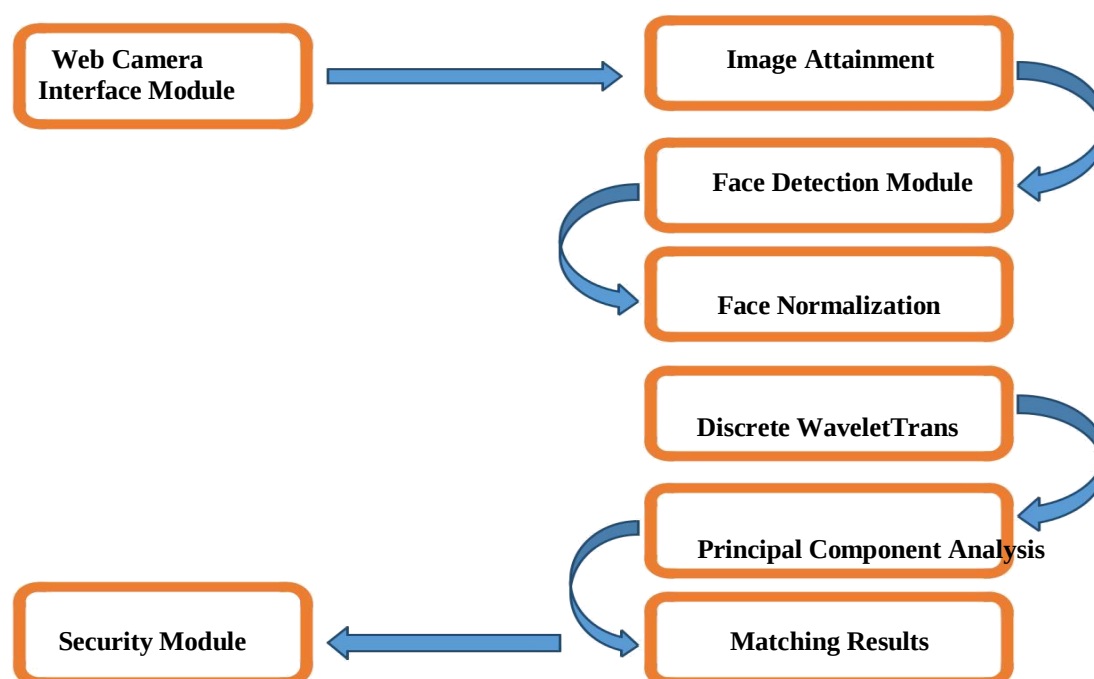


Fig: C.2 model of Facebook face Recognition system

Proposed Methodology

We have proposed a case study approach by giving formal specifications for face recognition system by using Z – Language. We also have shown the work flow of automated recognition system going to be implemented. And at the end, we have discussed the result of this face recognition system by using Z-Notations.

System's Specification:

The Attainment Module

The attainment module is the starting point of the face recognition mechanism. The user is requested to submit a face image to the face recognition system by using different devices. The module can request a face image from different milieus that can excerpt from already saved database like images, Scanned files or videos or through live reconnaissance camera.

Face Detection Module

After the attainment of image, face detection segments the face area from the background. The detected face may require to be tracked using a face tracking module. Resizing is important in appearance based method because it operate on fixed size windows. For correct deviations in imaging parameters and illumination, normalization of pixel helps correctly. For intensity normalization operation normalization, mean values, illumination correction and histogram equalization are included. Image size is resized into constant dimensions 112 x 92 pixels because it operates on fixed size windows that are support 112 x 92 pixels.

Discrete Wavelet Transform Module

DWT did not create stable basis, somewhat it creates design factors. Wavelets are the small waves with zero mean and unit energy. Underneath

compatibility limitation their contraction and dilation along with translations establish the Hilbert space. Mallet works on development of wavelet execution by filter that envisages perfect rebuilding.

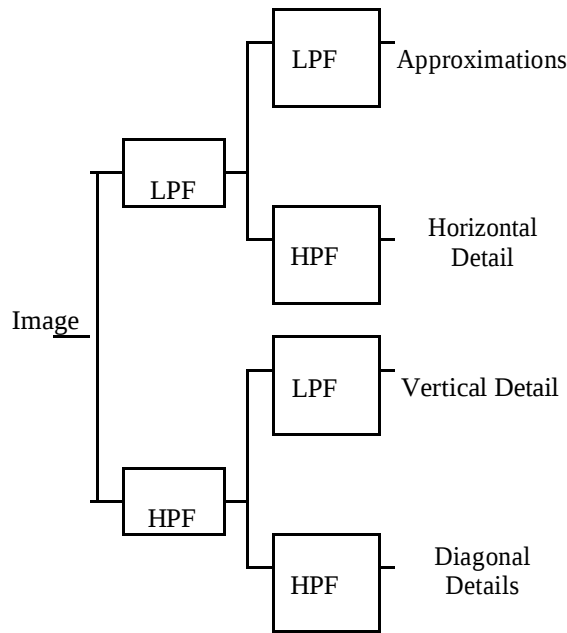


Fig. 2-2: Wavelet Decomposition Filter

Measurement as magic amounts that tolerate by the wavelet design limitations. Discrete Wavelet implies on image in horizontal direction. Devastation by two situations of Haar is applied in each direction to keep over all energy. The image is decomposed into its approximations labeled as LL group, vertical details called as HL band, horizontal details called as LH band and diagonal detail called as HH band where the letter L signifies low rate and H signifies high rate. Fig. 2.2 illustrate decomposition of image by using wavelet filter

Principle Component Analysis

High dimensionality is the critical problem in the exploration of multidimensional. Principle Component Analysis is a dimensionality reduction method which depends on removing the required number of principal components of the multidimensional records. The first principal component of PCA is the sequential mixture of the unique dimensions that contain the high inconsistency; the n th principal component is the sequential mixture of the extreme inconsistency, the $(n-1)$ first principal component is subject to being orthogonal. To achieve an ideal representation of second order digit of input image that reduce the remaking mistakes in least square sense. While PCA has limitations like large computational burden and weak discriminatory authority, still it is a mixture of procedure is predicted to compensate it by DWT dimensionality reduction module.

Principle Component Analysis is a process of finding arrangements in the records and to show it in a means to signify the similarities and differences. Meanwhile in high magnitude it is tough to examine hence, for suitable examination PCA is applied to decrease the magnitude of the records. It produces an ordinary face and denotes all other faces as the entirety and variance of this ordinary face and all other Eigen-faces. PCA working on two dimensional data, so first stage is transformation of grey scale image from RGB image. Then it composes all standards pixel in a row, therefore n th pictures will create a matrix of $n \times n$ dimensions. Each dimension average from each and every rows and subtract from that average. Therefore, a data set is created whose mean is 0(zero).

$$ImagesMatrix = \begin{pmatrix} ImageVec1 \\ ImageVec2 \\ \vdots \\ ImageVec20 \end{pmatrix}$$

First row of image is the representation of matrix components; the next image represents the next row, and so on. The intensity values of the image in the direction, perhaps a one grey scale value. The large matrix therefore obtained is presented below:

Covariance Matrixes

Eigen vectors which are created from the covariance matrix; we take original information in term of Eigen which is suitable for facial recognition. So the original images were the faces of people, there was a problem, when new image is given, whose face in original set? We start off with new image which is not one of training image. Computer calculates the variance between the fresh image and the original images along the new axes taken from the PCA examination, but not along the original axes. For face recognition these axes are much efficient, because the PCA analysis present the original images in the form of the similarities between axes.

The PCA examination has recognized the arithmetical forms in the data. Eigen values and Eigen vectors are measured, when we have the covariance matrix. Then in face space these vectors are projected. PCA for face recognition is to show the large 1-D vector of pixels created from 2-D facial image into the solid principal components of the Feature space named as Eigen space projection. Eigen space is measured by finding the Eigen vectors of the covariance matrix resulting from a set of facial images (vector).

Feature Extraction

In order to catch the main features that are probable to be used for ordering, the distributed face image is extended to the face extraction unit. In another context, this unit is answerable for creating a feature vector that is well abundant to denote the face image.

Match Module

Face recognition is the final module of the proposed face recognition in which image is taken as input for test. Inputted image is pre-processed at first and subsequently it is annihilating with similar value of down scale causes as applied in exercising module. After that image transformed into a dimension of $L \times I$ with a column vector. In identical way, the Euclidean space of this vector with individual column of sub-space collected throughout training of the model is attained and at the end a variance matrix of dimension $L \times T$ has been gotten. LSE is measured and next matching with an indicated threshold yields the consequence as recognized face, not recognized face or even not a face image.

Formal Modeling of automated Face Recognition System



Fig. 1: FACEBOOK Schema

In the following section we will presents the Z specifications of automated face recognition system. In this research paper we named this system as “FaceBook”. Later on this paper we will use this name in creation of Z-schemas.

Illustration of Fig. 1:

The box shown in Fig. 1 is known as schema. Schema in Z language contains schema name, declarations and constraints.

Schema Name:

In Fig. 1 schema name is Face Book.

Declaration Part:

In declaration part we have declared one variable of known faces and one function that is face book. Illustration of declared variable and function is given below.

Known_faces: Set of face images stored insystem’s database known as FACEBOOK
 known_faces = {image1, image2, image3}

Facebook: This is function named as FaceBookhaving two arguments NAME and face images. We can write this function in c/c++ like void facebook (NAME, faceimage);

facebook = { Aslam $\square$ image1, Ali $\square$ image2, Arshia $\square$ image3 }

Constraints Part:

In this section we have added constraint for known faces variable. so all known faces should belong to

FaceBook domain. Means these faces should already exists in the system’s database.

Following is the initial level schema:

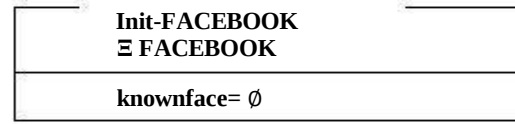


Fig. 2: Init-FACEBOOK schema

In Fig. 2 we have created schema named Init-FACEBOOK. In this schema we are going to initializing only face book.

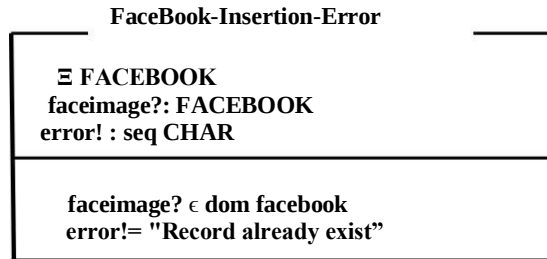


Fig. 3: Face Book-Insertion-Errorschema

In the automated face recognition module there should be a module by which user will be able to add new user’s image in the FACEBOOK database.

So in Fig. 3 we have created the schema named FaceBook-Insertion-Error in this schema we will handles “scenario” when user’s image is already available in the FACEBOOK database and someone want to store that image again. So in constraints section there is a check that will show that if face image is already exists in FaceBook then system will throw an error that is “Record already exist”.

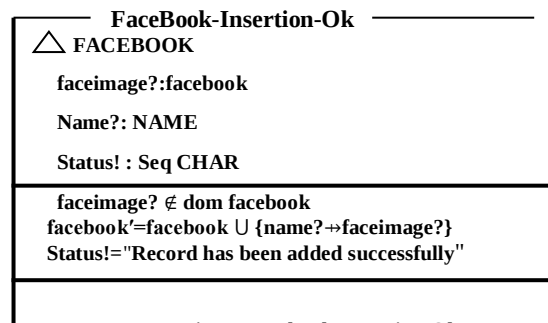


Fig. 4: Facebook-Insertion-Ok

In Fig. 4 we have created a schema named FaceBook-Insertion-Ok. In this schema we are handling the scenario when user will be able to successfully add new face image in FaceBook database. So in declaration section we have created 3 variables face images, name, status. “?” sign indicates that this schema will ask user to input image and name and “!” sign indicates output symbol. So status variable will display the output of that

schema. In constraints section we have added first constraint regarding face image that is newly inputted image should not belong to existing FaceBook's record. After that FaceBook value will be updated with newly entered record. In last line, Status variable will display a status that is "Record has been added successfully".

FaceBook-Insertion schema

So far we have handled two possible scenarios for new record insertion in automated FaceBook recognition system. So on record insertion system will show output either with error or ok state. So in Fig. 5 we have created schema.

FaceBook-Insertion
FaceBook-Insertion-Ok V FaceBook-Insertion-Error

Fig. 5: FaceBook-Insertion schema

FaceBook-Insertion in which we are defining that either FaceBook-Insertion-Ok or FaceBook-Insertion-Error schema will be activated.

FaceBook-Lookup-Error $\exists$ FACEBOOK faceimage?: FACEBOOK error! : seq CHAR
faceimage? $\notin$ dom facebook error!= "No record found"

Fig. 6: FaceBook-Lookup-Error

In face recognition system there should be functionality by which user's image will be detected by system. For this functionality we have created FaceBook-Lookup schema that will display the results of inputted FaceBook image. This schema has also two states either inputted image will exist in system or not. So in Fig. 6 we have created schema "FaceBook-Lookup-Error". This schema will display an error message if image that you want to search from existing FaceBook database store have no record.

FaceBook-Lookup-Ok $\exists$ FACEBOOK faceimage?: FACEBOOK Name?: NAME
faceimage? $\in$ dom facebook name!=facebook(faceimage?)

Fig. 7: FaceBook-Lookup-Ok

In Fig. 7 we have created schema named as "FaceBook-Lookup-Ok", this schema will display the name of image that you want to explore from database. User will input image via camera and system will detect that if image is exist in system already then display name of user's whose image was inputted.

FaceBook-Lookup
FaceBook-Lookup-Ok V FaceBook-LookupError

Fig. 8: FaceBook-Lookup

So in (Fig. 8) we have been created FaceBook-Lookup schema which will display either lookup error

or show the Lookup results that is lookup is ok, name of the images that inserted into the system.

FaceBook-Deletion-Ok ΔFACEBOOK faceimage?: FACEBOOK Status! : seq CHAR
faceimage? $\in$ dom facebook facebook '=' {faceimage?} $\Leftarrow$ facebook Status!= "Record has been deleted"

Fig. 9: FaceBook-Deletion-Ok

In automated face recognition system there should be a module by which user will be able to delete any existing record. So for this purpose we have created schema in Fig. 9 named "FaceBook-Deletion-Ok". This schema will successfully delete the already inputted image. For deletion operation inputted image should exist in FACEBOOK database.

FaceBook-Deletion
FaceBook-Deletion-Ok V FaceBook-Lookup-Error

Fig. 10: FaceBook-Deletion

So in FaceBook-Deletion schema there will be two states either inputted image will exist in system or not. So we can use FaceBook-Lookup-Error schema for verification that either inputted image exists in system or not. In Fig. 10 we have created schema "FaceBook-Deletion" in which either user will be in FaceBook-Deletion-Ok state or in FaceBook-Lookup-Error. So far we have created possible schemas for automated face image recognition system. We have created schemas for insertion, deletion and search operations by using Z notations. We have created formal specifications using Z notations so that this system will be able to handle all possible scenarios before development stage.

3. CONCLUSION

Computer based systems are becoming ultimate need of every field of life e.g. they are included in health, transportation, communication, economic markets, safety, security and education. With the great complexity and skilful design of these systems understanding of user requirements of these systems is a great challenge. The eventual goal during the development phase of the software system is to develop understanding about the user needs of the system. This goal leads to the adaptation of some engineering schemes that have been used in development phase to define requirements plainly and consistently. Formal method is one of these engineering schemes. Z notation is one of the techniques of formal methods that use the mathematical techniques to define the requirements. Because of the computational complexity of automated face recognition system, Z notation is used for its formal specification

REFERENCES:

- Amberg, B., R. Knothe and T. Vetter, (2008) "Expression Invariant 3D Face Recognition with a Morphable Model," Face Recognition in the Presence of Expressions 329 IEEE International Conference on Automatic Face and Gesture Recognition, 1-6
- Belumeurej, P. N., P. Hespanha D. J Kriegman (1997) "Eigenfaces vs. fisherfaces: recognition using class specific Linear pattern Analysis and Machine Intelligence, 19(7)711-720.
- Bakri, S. H., H. Harun, A. Alzoubi, and R. Ibrahim, (2013) "The formal Specification for the Inventory System Using Z Language," no. 064, 419–425.
- Bork, D., K. Engineering, H. Fill, and K. Engineering, (2014) "Formal Aspects of Enterprise Modeling Methods : A Comparison Framework," 3400–3409.
- Darren C., M. Whalen, C. Rapids (2010) "Software Model Checking for Avionics Systems IEEE/AIAA 27th Digital Avionic System conference 5.D.5-1 – 5.D.5-8.
- Fatimah, K., N. Khalid and A. Lili, (2009) "3D Face Recognition Using Multiple Features for Local Depth Information," International Journal of Computer Science and Network Security, Vol. 9, No. 1, 27-32.
- Farahbod, R., V. Gervasi, and U. Glässer, (2014) "Executable formal specifications of complex distributed systems with Core ASM," *Science of Computer Programming*, vol. 79, 23–38, .
- Goel, S. (2010) "Specifying Safety and Critical Real-Time Systems in Z," 596–602.
- Hazem EI-Gendy, (2005) "Using Formal Methods: Importance and Experience", International Journal on Computing Methods in Science and Engineering, Vol. 5, 235 – 247.
- Han, X., and I. Palmer (2009) "Method Characterizing 3D Faces Using Gaussian Curvature," Chinese Conference on Pattern Recognition, Nanjing, 528-532.
- Jean-Christophe D. and C. Ponsard (2012) "Industrial deployment of advanced system engineering methods for high productivity and dependability", Project Deploy Guide, vol. 2, 1 – 42.
- Joachim K. and H. Sahm (2010) "Automated Formal Method Verifies Highly-Configurable HW/SW Interface", SDC Source, 1 – 7.
- Klontz J. C. and A. K. Jain, (2013) "A Case Study of Automated Face Recognition : The Boston Marathon Bombings Suspects," no. November, 91–94.
- Krishna, A. S. Vilkomir, and A. Ghose, (2000) "a case study of combining framework and the z notation" 1–9.
- Lu X. and A. K. Jain, (2006) "Deformation Modeling for Robust 3D Face Matching," IEEE Computer Society Conference on Computer Vision and Pattern Recognition, Vol. 2, 1377-1383. doi:10.1109/CVPR..96
- Li, X., T. JIA and H. Zhang, (2009) "Expression-Insensitive 3D Face Recognition Using Sparse Representation," IEEE Conference on Computer Vision and Pattern Recognition, 2575-2582.
- Michael W., D. Cofer, S. Miller, B. H. Krogh and W. Storm (2007) "Integration of Formal Analysis into a Model-Based Software Development Process", International Conference on Formal Methods for industrial critical systems, pp 68 – 84.
- Mona B., A. Malik, M. Dave, (2013) "Formal Methods: Benefits, Challenges an Future Direction", Journal of Global Research in Computer Science, Vol. 4, 21 - 25.
- Marijita (2012) "Face Recognition Using Eigenface Approach ", Serbian Journal of electrical Engineering, Vol 9, No. 1, 121 – 130.
- Turk, M., A. Pentland, (1991) "Face recognition using eigenfaces", I Proceeding of IEEE Conference on Computer Vision and Pattern Recognition, Maui, HI, USA, June 1991, 586–591. (second Paper M. Turk and A. Pentland, "Eigenfaces for recognition", I J. Cogn. Neurosci., vol. 13, No. 1, 71–86.
- Vijayshree M. and A. Wagh, (2012) "Improved Fisher Face Approach for Human Recognition System using Facial Biometrics", International Journal of Information and Communication Technology Research, Vol. 2. 2Pp.
- Van, R. A. (2006) "Formal specification and analysis of industrial systems", EJC, Vol. 2, 115 – 130.
- Wang, Y., G. Pan and Z. Wu, (2007) "3D Face Recognition in the Presence of Expression: A Guidance-Based Constraint Deformation Approach," IEEE Conference on Computer Vision and Pattern Recognition, 1180-1187. doi:10.1109/CVPR..383277
- Wang, Y., and Y. Ho, (1202) "Facial Appearance Detection and Face Recognition from 2D and 3D Images," Pattern Recognition Letters, Vol. 23, 101-191.
- Xia H., M. H. Yap and I. Palmer, (2012) "Face Recognition in the presence of Expressions" Journal of Software Engineering and Applications, 5, 321 - 329
- Yin, L. J., X. Z. Wei, Y. Sun, J. Wang and M. J. Rosato, (2006) "A 3D Facial Expression Database for Facial Behavior Re- search," International Conference on Automatic Face and Gesture Recognition, Southampton, 2-6 211-216