Received: February 8, 2018

International Journal of
Intelligent Engineering & Systems

http://www.inass.org/

Adaptive Skin Colour Modelling for Hand and Face Segmentation

Shailendra Chandrakumar Badwaik[1]* **Shashikant Dnyandev Lokhande[1]**

[1]Sinhgad College of Engineering,
Department of Electronics and Telecommunication Engineering,
Savitribai Phule Pune University, Pune, India
* Corresponding author's Email: shailendra.sppu@gmail.com

Abstract: A real-time skin colour segmentation is a prime concern in posture/hand gesture based sign language recognition. The developed novel method separate posture/hand gesture without any marker on any background by taking into account foreground skin colour. The proposed algorithm, segmenting dynamic posture/hand gesture done in front of the camera or from images or video database. The values of YCgCr are determined in real time and form YCgCr adaptive bound. These bound values are used to segment foreground skin colour from skin / non-skin colour background. The algorithm deployed on the embedded image processing hardware platform and any skin colour/tone it can adapt and used further to segment face/ hand gestures. The proposed adaptive skin colour algorithm accuracy for standard Ali Yawar Jung video dataset of ISL hand gestures is 92.64% and visually when two different signers performed same gestures the average accuracy is 91.82%.

Keywords: Skin colour model, Hand gesture, $YCgCr$, ASCM.

1. Introduction

Skin colour segmentation plays a prudent role in a broad range of image processing applications like gesture/posture detection and analysis, face detection and tracking, human-computer interface (HCI) system, content-based image retrieval (CBIR) systems, etc. Many researchers use skin colour segmentation approach as it involves less computation than the other segmentation methods.
Kakumanu, P., S. Makrogiannis, and N. Bourbakis in [1] explores the details of different skin colour in three different ways: first, different colour spaces used for skin modelling and detection. Second, different skin colour modelling and classification. Third, use skin-colour dynamic adaptation techniques[2, 3] for dynamically varying illumination and environmental conditions.

Skin colour modelling is done based on colour space like: Basic Colour Spaces [3] (RGB, normalised RGB, CIE–XYZ) [4], Perceptual colour spaces [5, 6] (HSI, HSV, HSL, TSL), Orthogonal colour spaces [1] (YCbCr, YIQ, YUV, YES) perceptually uniform colour spaces [2, 3, 7, 8] (CIE-Lab and CIE-Luv) and Hybrid colour spaces [3, 9]. On the other hand skin-colour classifications [5] done using Explicit skin-color space thresholding [10] , Histogram model with Naïve Bayes classifier, Gaussian classifier : Single Gaussian models (SGM) [11], Gaussian mixture models (GMM) [12] , Elliptical boundary model [13], Multi-layer perceptron (MLP) classifier [14], Self-organizing map (SOM) classifier [15], Maximum entropy classifier [16], Bayesian network (BN) classifier [7]. Each Skin colour modelling and classification method has its own merits and demerits. These methods play a prudent role in hand segmentation and recognition. In this paper $YCgCr$ skin colour based adaptive skin segmentation model designed and used to identify Indian Sign Language (ISL) gestures in real time.

Hierarchy of Skin colour modelling is as shown in Fig. 1 as follows. The hierarchy of Skin colour classifiers classification is as shown in Fig. 2.

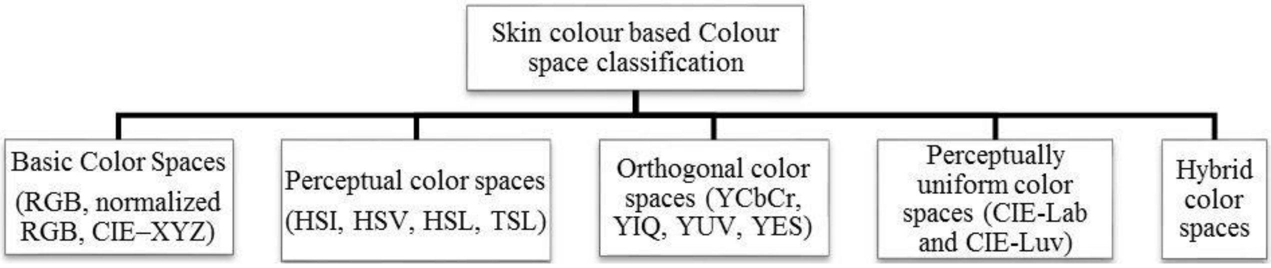


Figure. 1 Skin colour modelling based on colour space classification

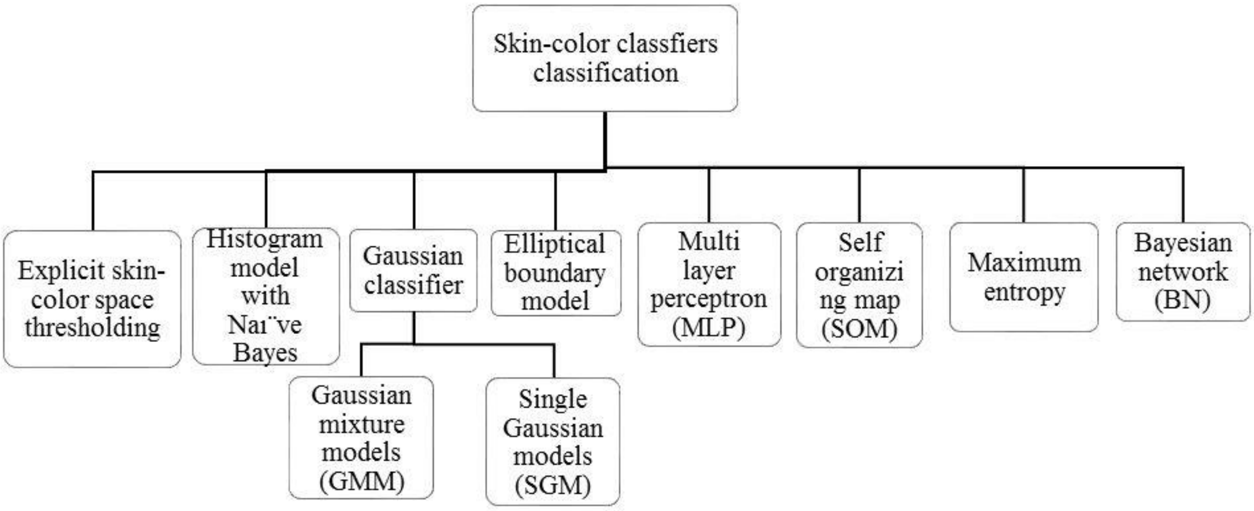


Figure. 2 Skin colour classifiers classification

The listed classifications are not limited to gesture recognition. Various researchers used sensors, clour gloves, markers, skin colour spaces and classification techniques for gesture recognition by creating fixed bounds or threshold values for $RGB, HSI, HSV, YCgCr$ *etc.* These bounds or threshold values may work in specific conditions. Certainly, these fixed bounds or thresholds restricts real-time gesture recognition. This key issue addressed in proposed work. The main focus of this paper is for adaptive varying skin colour/tone modelling and detection for hand / face gesture(s) / posture(s) segmentation and detection. The proposed algorithm detects signer's variations in skin colours/ tones of Hand/ face gesture(s) / posture(s) which are done in front of camera for segmenting skin colour hand / face for gesture(s) / posture(s). The adaptive skin colour/tone model generates specific bounds for Y, Cg and Cr in real time further these are used for segmenting skin colour Hand/ face gesture(s) / posture(s).

Researchers have suggested various schemes/methods for skin colour segmentation which works for specific bounded values of skin colour/tone. Problems of fixed $YCgCr$ bound analysed as:

- Varying skin tone gives different bounds for skin segmentation
- In INDIA itself skin tone varies drastically for different states
- Unable to segment dark skin clour of African, Caucasian and Hispanic people
- Colour Histogram analysis indicate the presence of black colour in such skin tone
- Colour Histogram analysis generally gives skin tone as Red and Yellow colour

It indicates $YCgCr$ model need to be adaptive an innovative technique is developed to detects signer's variations in skin colours/ tones of Hand/ face gesture(s) / posture(s) done in real time.

The present invention deals with recognition of hand gestured performed in front of the camera by separating signers skin colour region of interest mainly hand/face. Thus this technique generates adaptive skin colour/tone bounds of Y, Cg and Cr segments out hand/face from the human body for gesture/posture recognition. The algorithm is designed and deployed on image processing embedded platform.

This main contribution of this paper tackles several other features which are:

[1] For hand segmentation from posture proposed method does not require a sensor, marker, glove, etc.

Received: February 8, 2018

[2] Real-time recognising any signer's skin colour/tone.
[3] Separate palm from hand, face from the body in any background including skin colour/tone.

The core logic designed is in the form of functions tailored for image segmentation. Hence, the algorithm works for different backgrounds and varying signer's skin colour/tone. The proposed method will help hard in listening people to communicate seamlessly with normal human beings without using marker, sensor, glove, etc. kind of restrictions.

The proposed method gives better results regarding skin colour segmentation and we modified fixed thresholding $RGB\ to\ YCgCr$ conversation into adaptive skin colour model (ASCM) for efficient skin colour segmentation process. ASCM based three crops from signers forehand and backhand helped in identifying Indian Sign Language (ISL) hand gestures near to face of the signer, beneath the face of the signer, in front of the face of signer etc. Our proposed method also supports, visually selecting and recognising the single and both hand gestures and eliminate signers face. The first section introduces different skin colour model and overview of related work. The second section describes our Proposed Methodology for adaptive skin colour model. Experimental results with the suitable figures described in the third section for ISL hand gesture recognition using proposed ASCM skin colour segmentation method. This method gives a region of interest (ROI), i.e. palm from signers posture. These ROI objects used for features extraction; these further used for designing feature vector bounds and ISL hand gesture recognition. The fourth section gives conclusion and future work.

2. Adaptive skin colour modelling (ASCM)

Gesture recognition pertains to recognising different signer's skin colour/tone meaningful expressions of motion by a human, involving hands, arms, face, head and body. It is crucial in designing an intelligent and efficient human-computer interface. Gestures are used to convey the information and interact with the environment by any human being.

2.1 Analysing skin colour by colour histogram

Skin colour analysis is done using the colour histogram and shown in Figs. 1, 2, 3 and 4. The face of women shown in Fig. 3 is same except left side face is with makeup, and right side face in this figure is without makeup. The forehead skin sample showed besides the face. Colour histogram analysis of forehead skin sample used for building adaptive skin colour model. The colour histogram indicates makeup face with red, yellow and white colour bar chart, on the other hand, it differentiates without makeup face by indicating only red colour in a bar chart.

The skin colour across the globe is drastically varying which is analysed by the colour histogram. The faces indicated in Fig. 4 are African countries which are dark in colour. The same analysis is carried out by colour histogram for left side woman face by indicating red and black bar chart. In right side face of man indicates red and black bar chart but its level is different than left side woman face in Fig. 4. The presence of black colour indicates it is dark skin colour. For the dark skin colour, the colour histogram shows the intensity of black bar. The earlier face in Fig. 3 is white skin woman face; colour histogram indicates the absence of a black bar. The light intensity plays a vital role in deciding black colour presence. The white skin faces shown in Fig. 5 is captured by keeping light source on the left side of the face; hence half of the face on the left side is brighter than right half of face. The shadow of nose reflects the right side of the face which in turn makes right half of face dark in colour. The colour histogram analysis for forehead skin sample of white skin man shown in Fig. 5 indicates presence of black bar along with red colour. In this case, light distributed unevenly on the face.

Fig. 6 indicates white skin woman face. Colour histogram analysis for the left side white woman forehead skin sample shows the presence of red colour by a bar chart.

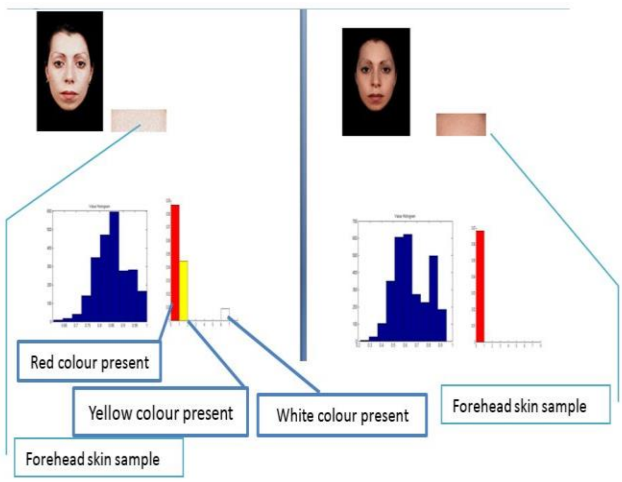


Figure. 3 Colour histogram analysis of skin colour tone with the presence of red and yellow colour for the same signer in different light conditions

 DOI: 10.22266/ijies2018.1031.08

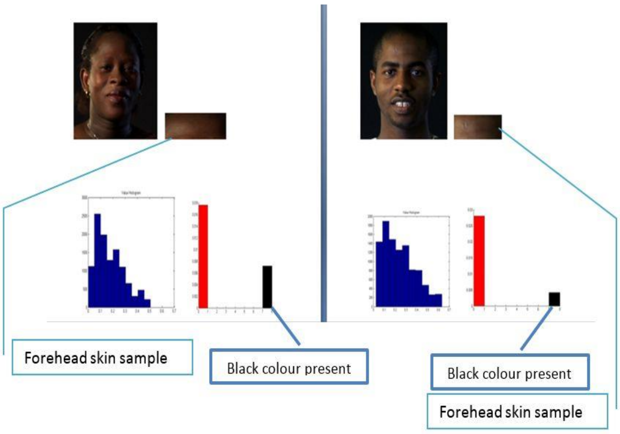


Figure. 4 Colour histogram analysis of skin colour tone with the presence of red and black colour.

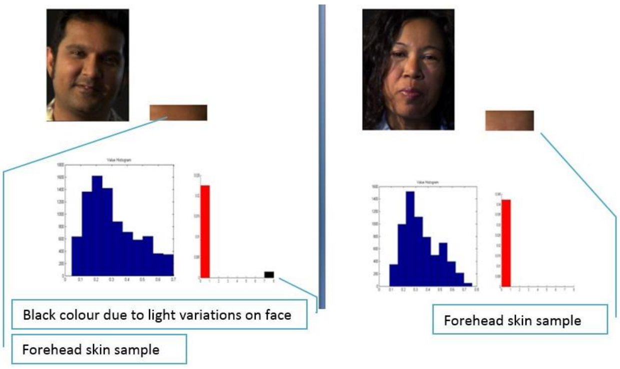


Figure. 5 Colour histogram analysis of skin colour tone with the presence of red and black colour.

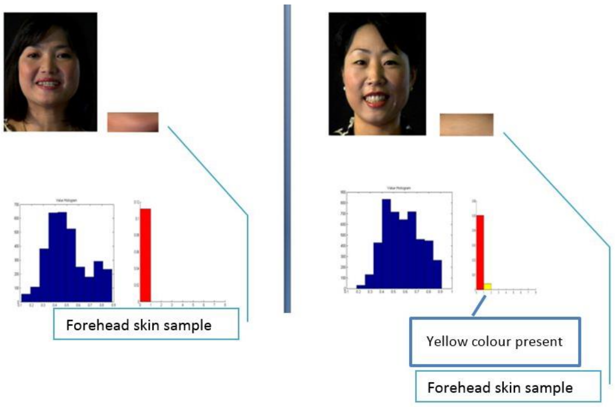


Figure. 6 Colour histogram analysis of skin colour tone with the presence of red and yellow colour.

The colour histogram analysis for right-hand side white women forehead skin sample shows the presence of red and yellow colour by a bar chart. The persons having white skin colour across the world is varying, its analysis made by the colour histogram.

2.2 Analysing $YCgCr$ Values of Skin Colour

The experiments are carried out for two different signers. The 13 megapixel HD camera is used to capture the signer's face and hand image. These images are processed to find $YcgCr$ values for facial, skin and hand. Equations for RGB to $YCgCr$ conversion mentioned in [17] are used to compute $YcgCr$ values. At three different places like the forehead, face and nose the face image is randomly cropped. The user can take any three crops of skin. Tables 1, 2 and 3 have five rows and ten columns. The first crop yields the values of a second row. Similarly, second and third crop gives values of the third and fourth row respectively. The most minimum and most maximum value of Y, Cg and Cr are computed. The last row of Table 1 shows three crops, the most minimum value Y_{min} is 18.535, and the most maximum, Y_{max} is 151.494. Similarly Cg_{min}, Cg_{max} and Cr_{min}, Cr_{max} values determined in Tables 1, 2, and 3. The average values Y, Cr and Cr are computed using the minimum and maximum values of Y, Cr and Cr. In Table 1 Y_{avg} is 85.014 determined by taking an average of Y_{min} and Y_{max}value. Similarly, Cg_{min}, Cg_{max}, Cr_{min}, and Cr_{max} values are used to determine Cg_{avg} and Cr_{avg}.

2.3 Designing an adaptive skin colour model

For taking three crops and find Y, Cg and Cr value the frame number 14 considered. This frame should consist skin colour part. The earlier frames skipped as signer gets enough time to bring bare hand in front of the camera. The RGB image captured by camera need light compensation. It is done using Eqs. (1) to (4). For taking three crops and find Y, Cg and Cr value the frame number 14 considered. This frame

$$F(r_m, g_m, b_m) = \sum_{i=1}^{m} \sum_{j=1}^{n} \begin{bmatrix} \left(r_m + I(i,j,r)\right) \times \\ \left(g_m + I(i,j,g)\right) \times \\ \left(b_m + I(i,j,b)\right) \end{bmatrix} \quad (1)$$

Where, the frame $F(r_m, g_m, b_m)$, is the outcome of input image components of red, green and blue colour planes as $I(i,j,r), I(i,j,g)$ and $I(i,j,b)$.

$$r_{(i,j)} = \frac{r_m}{m \times n}; g_{(i,j)} = \frac{g_m}{m \times n}; b_{(i,j)} = \frac{b_m}{m \times n} \quad (2)$$

The average of RGB objects are computed like red as $r(i,j)$, green as $g(i,j)$ and blue as $b(i,j)$.

$$k = \frac{r(i,j) + g(i,j) + b(i,j)}{3} \quad (3)$$

Table 1. Variations in $YCgCr$ values for skin colour/tone of Libyan Signer's Face

Y_{min}	Y_{max}	Cg_{min}	Cg_{max}	Cr_{min}	Cr_{max}	Y_{avg}	Cg_{avg}	Cr_{avg}
41.087	104.639	121.473	126.197	125.386	137.520	--	--	--
18.535	151.494	119.611	126.849	128.664	145.722	--	--	--
34.831	85.509	119.717	126.545	127.143	138.777	--	--	--
18.535	151.494	119.611	126.849	125.386	145.722	85.014	123.230	135.554

Table 2. Variations in $YCgCr$ values for skin colour/tone of Cameroon Signer's Face

Y_{min}	Y_{max}	Cg_{min}	Cg_{max}	Cr_{min}	Cr_{max}	Y_{avg}	Cg_{avg}	Cr_{avg}
50.326	111.208	119.581	123.443	132.310	141.830	--	--	--
19.595	137.990	115.342	124.594	131.657	151.850	--	--	--
33.973	82.074	116.100	123.836	133.117	147.529	--	--	--
19.595	137.990	115.342	124.594	131.657	151.850	78.792	119.968	141.753

Table 3. Variations in $YCgCr$ values for skin colour/tone of Libyan Signer's Hand

Y_{min}	Y_{max}	Cg_{min}	Cg_{max}	Cr_{min}	Cr_{max}	Y_{avg}	Cg_{avg}	Cr_{avg}
56.879	99.826	127.712	131.406	119.380	129.910	--	--	--
35.508	74.142	125.699	130.075	123.465	131.882	--	--	--
29.608	104.522	125.850	133.133	117.173	130.635	--	--	--
29.608	104.522	125.699	133.133	117.173	131.882	67.065	129.416	124.527

The average of all three planes red, green and blue is computed using Eq. (3).

$$L(i,j)=\sum_{i=1}^{m}\sum_{j=1}^{n}\left[\left(\frac{frame(r).k}{r_{(i,j)}}\right)\times\left(\frac{frame(g).k}{g_{(i,j)}}\right)\times\left(\frac{frame(b).k}{b_{(i,j)}}\right)\right] \quad (4)$$

Where $\mathscr{L}(i,j)$ is a light compensated image.

The transformation of RGB to $YCgCr$ done as discussed in[17]. To make system adaptive, $YCgCr$ to binary conversion is done using Eq. (5) is designed as follows

$$\sum_{i=1}^{m}\sum_{j=1}^{n}\mathcal{P}(i,j)=\begin{cases}1\ ;[\mathrm{I}(i,j,1)\geq Y_{avg}\ \ \&\ Cg_{min}\geq \mathrm{I}(i,j,2)\leq Cg_{max}\ \ \&\ Cr_{min}\geq \mathrm{I}(i,j,3)\leq Cr_{max}] \\ 0\ ;\ \text{otherwise}\end{cases} \quad (5)$$

Where Y_{avg} , Cg_{min}, Cg_{max}, Cr_{min} and Cr_{max} are computed as follows

$$Y_{min}=\min_{1\leq k\leq 3}\sum_{i=1}^{m}\sum_{j=1}^{n}C_k(i,j) \quad (6)$$

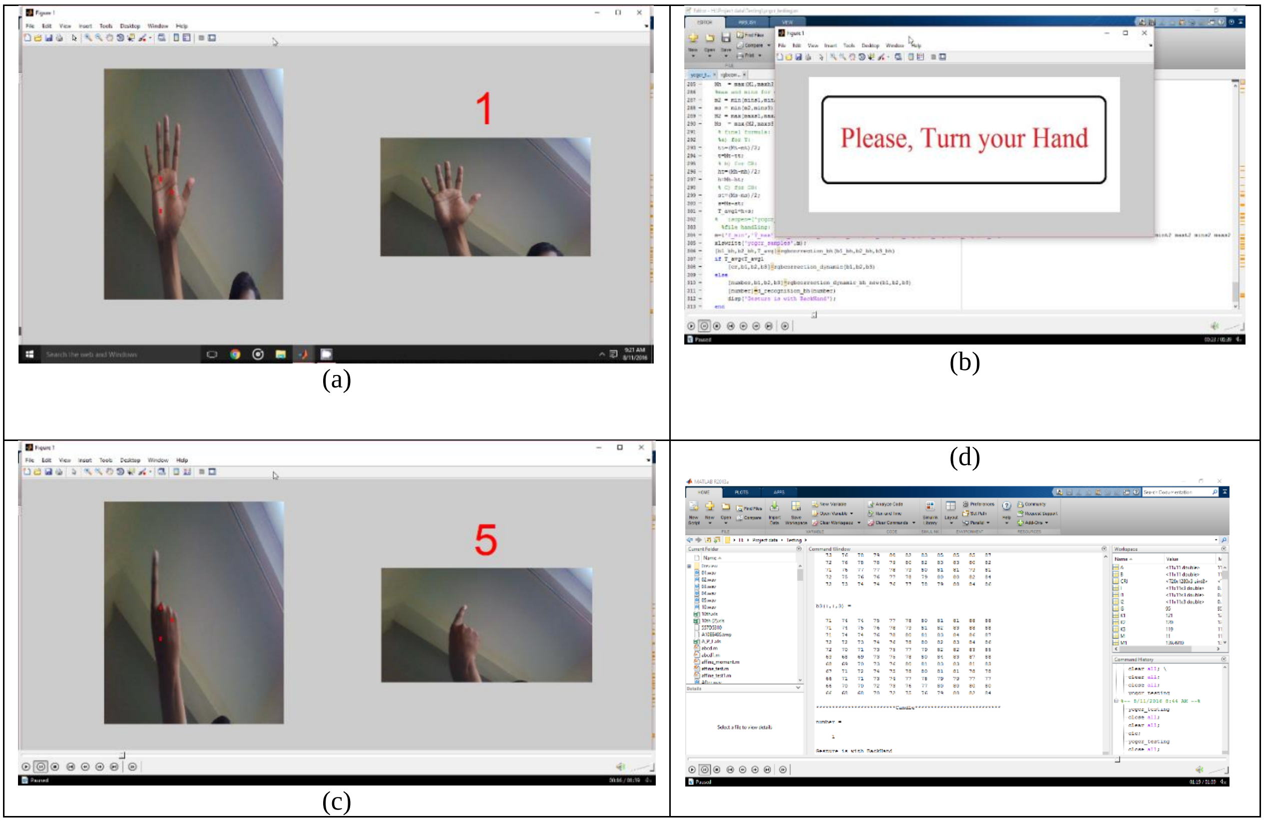
$$Y_{max}=\max_{1\leq k\leq 3}\sum_{i=1}^{m}\sum_{j=1}^{n}C_k(i,j) \quad (7)$$

$$Cg_{min}=\min_{1\leq k\leq 3}\sum_{i=1}^{m}\sum_{j=1}^{n}C_k(i,j) \quad (8)$$

$$Cg_{max}=\max_{1\leq k\leq 3}\sum_{i=1}^{m}\sum_{j=1}^{n}C_k(i,j) \quad (9)$$

$$Cr_{min}=\min_{1\leq k\leq 3}\sum_{i=1}^{m}\sum_{j=1}^{n}C_k(i,j) \quad (10)$$

Received: February 8, 2018



(a) (b) (c) (d)

Figure. 7 Skin colour modelling: (a) ASCM for forehand skin colour processing, (b) Indication to user, (c) ASCM for backhand skin colour processing, and (d) Crop samples for ISL Recognized hand gesture 'Candle'

Table 4. Forehand and backhand $YCgCr$ values for ISL gesture 'one and 'candle'

Forehand $YCgCr$ Values									
Y_{min}	Y_{max}	Cg_{min}	Cg_{max}	Cr_{min}	Cr_{max}	Y_{avg}	Cg_{avg}	Cr_{avg}	T_{avg}
115.53	142.31	123.55	127.82	130.40	135.03	0.00	0.00	0.00	0.00
138.13	151.78	125.06	128.92	127.92	132.54	0.00	0.00	0.00	0.00
127.55	143.71	122.28	124.99	132.97	137.52	133.66	125.60	132.72	258.32
Backhand $YCgCr$ Values									
Y_{min}	Y_{max}	Cg_{min}	Cg_{max}	Cr_{min}	Cr_{max}	Y_{avg}	Cg_{avg}	Cr_{avg}	T_{avg}
107.15	138.83	126.74	130.50	125.99	131.79	0.00	0.00	0.00	0.00
135.57	156.18	129.76	129.11	130.38	131.79	0.00	0.00	0.00	0.00
134.33	154.46	126.17	128.94	128.62	135.07	131.66	128.33	130.53	258.86

$$Cr_{max} = \max_{1 \le k \le 3} \sum_{i=1}^{m} \sum_{j=1}^{n} C_k(i,j) \qquad (11)$$

The Algorithm for Adaptive skin colour/tone determination

Step1 From face/hand RGB image take three different skin colour crop of as $C_k(i,j)$ for $k = 1,2,3$.

Step 2 Sort row wise and column wise pixels of each crop using Eqs. (6) to (11) to obtain values of Y_{avg} , Cg_{min}, Cg_{max}, Cr_{min} and Cr_{max}

Step 3 Find Most Minimum and the Most Maximum Pixel value for Y from Step 2

Step 4 Compute: $Y_{avg} = (Y_{max} + Y_{min})/2$

Step 5 Find Most Minimum and Most Maximum Pixel Value of Cg from Step 2

Step 6 Compute: $Cg_{avg} = (Cg_{max} + Cg_{min})/2$

Step 7 Find Most Minimum and Most Maximum Pixel Value of Cr from Step 2

Step 8 Compute: $Cr_{avg} = (Cr_{max} + Cr_{min})/2$

Step 9 Set bound as
$[I(i,j,1) > Y_{avg}$ & $Cg_{min} > I(i,j,2) < Cg_{max}$ & $Cr_{min} > I(i,j,3) < Cr_{max}]$

3. Results and discussion

The binary segmented hand gestures from a posture of signer are segmented using Eq. (5). The above algorithm is used to segment hand gestures from standard Indian Sign Language (ISL) video database. The results of ten different ISL tabulated in Table 4. The database selected to segment gesture made by single hand, both hand, hand moving toward the face, hand moving away from the face, hand aside from the face, both hand overlap / mixed, etc. The proposed algorithm based the novel mathematical model improves the signers palm and face segmentation results compared to the work mentioned in [18, 19]. Above mathematical model designs the ASCM and based on that each three crops extracts total 11 X 11 matrix elements of the complete input image to get signers skin colour components. The design is as shown in Fig. 7 (a) where three red colour squares indicate the crop position to hold skin colour. In this signer need to hold his forehand/backhand such a way that skin colour covers these three squares. The system designed in such a manner that user gets enough time to place his/her hand on 3 cropping squares. A 10 down to 0 counter is imitated on the screen to overlap hand/skin portion in front of 3 squares. The image009.jpg, i.e. 9^{th} frame used for forehand processing. Further user gets a message on the screen to turn his/hand; the system is going to extract skin components of backhand. It illustrated in Fig. 7 (b). This time 5 down to 0 counts imitated, and the signer is supposed to overlap his backhand skin colour. The frame image_bh004.jpg, i.e. frame 14th (frames elapsed in case of forehand are 10 plus the next frames elapsed in the case for backhand are 4) used for backhand skin colour extraction. The Fig. 7 (c) illustrate it. ASCM based forehand and backhand YCgCr values indicated in Table 4. The segmented binary hand gestures as shown in the last column of Table 5 are further treated to extract different features. The prominent features utilised for gesture recognition are an area, perimeter, Euclidian distance, centroid, etc. Three different signers database is used to extract feature values bounds. Ali Yawar Jung designs standard ISL database. Indian government frames this organisation and the database accepted across India from the year 2017.

We replicated the some ISL database using two more signers, and that database is also used to generalise feature values and bounds. The min and max value is used to create the feature bound. Feature vectors and universal bounds used for real-time hand gesture recognition. This feature vector values indicated in Table 6. The notations used in Table 6 are AYG: Ali Yawar Jung (The Indian Organization Developing Standard ISL Database), FS: First Signer, SS: Second Signer, UB: Universal Bound. Column second and third specifies extracted feature values of minimum and maximum area dented as min_A and max_A . Similarly, four and fifth represents extracted feature values of minimum, and maximum perimeter denoted in the table as min_P and max_P , Column sixth and seventh specify extracted feature values of minimum, and maximum Euclidian distance dented as min_ED and max_ED . Column eight, nine, ten and eleven represents extracted feature values of minimum and maximum centroid as min_C1 , min_C2 , max_C1 and , max_C2 .

Fig. 8 shows the different steps involved in real time hand segmentation by proposed adaptive skin colour model. The hand segmented from posture by blob analysis, and skin colour face blob omitted over skin colour hand blob by area feature. Further Fig. 8 shows the Recognition of ISL gesture four in real time using same adaptive skin colour model and feature extraction by segmenting open fingers.

Tables 7 and 8 indicate confusion matrix when signer 1 and signer 2 make gestures in front of the camera.

The average accuracy for two signers is 91.82 %. The algorithms track skin colour of hands as shown in Figs. 8 and 9. The bounds designed using Table 6 are deployed in the algorithm to recognise the ISL hand gestures. Table 8 indicates the confusion matrix of video dataset gesture recognition. On the contrary, gestures are shown in Table 9 with same bounds of Table 6 give an accuracy of 92.64% for the standard 10 ISL.

Table 5. Segmented binary hand gesture from posture

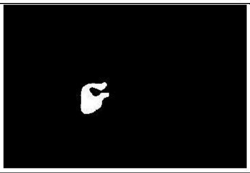
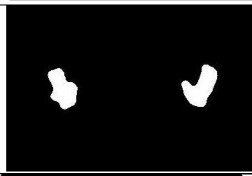
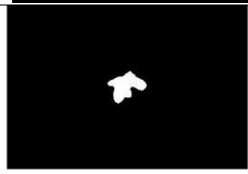
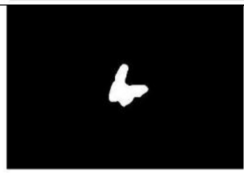
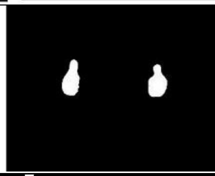
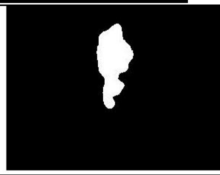
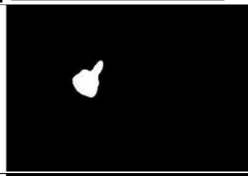
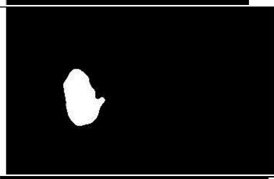
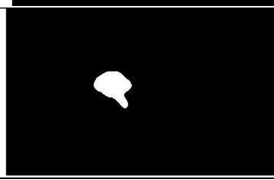
Sr. No.	ISL Gesture Name	Database Analysis	ISL Gesture	Segmented Binary Hand Gesture
01	Tenth	HGR with both hands with all ten fingers open		
02	Little	HGR with a single hand and two fingers open		
03	A Lot	HGR with both hands moving aside the face and all open fingers		
04	Enter	HGR with overlap both hands and lower hand moving front and back		
05	Late	HGR with mixing both hand and upper hand moving up and down		
06	Pass	HGR with both hand and open thumb		
07	Quite	HGR with a hand in front of the face		
08	Search	HGR with left hand aside face with an open little finger		
09	Wait	HGR with a single hand with an open palm		
10	Fail	HGR with a single hand with thumb moving downward		

Table 6. Feature Vectors and Bounds for ISL Hand Gestures

Col→	Area		Perimeter		Euclidian Distance		Centroid			
	1	2	3	4	5	6	7	8	9	10
Tenth	*min_A*	*max_A*	*min_P*	*max_P*	*min_ED*	*max_ED*	*min_C1*	*max_C1*	*min_C2*	*max_C2*
AYG	3711.00	5346.00	451.61	584.76	97.07	116.66	297.23	301.75	341.71	439.44
FS	2501.00	3099.00	427.91	531.95	79.33	88.82	217.04	290.78	265.48	306.39
SS	1787.00	2724.00	246.65	421.28	67.45	83.28	213.51	291.66	289.30	422.95
UB	1787.00	5346.00	246.65	584.76	67.45	116.66	213.51	301.75	265.48	439.44
ALittle	*min_A*	*max_A*	*min_P*	*max_P*	*min_ED*	*max_ED*	*min_C1*	*max_C1*	*min_C2*	*max_C2*
AYG	1253.00	1332.00	205.58	216.55	39.94	41.18	104.79	106.05	172.07	179.80
FS	829.00	908.00	172.27	190.17	32.49	34.00	110.50	111.52	189.78	194.74
SS	801.00	906.00	141.20	180.17	31.94	33.96	100.15	118.32	168.38	218.58
UB	801.00	1332.00	141.20	216.55	31.94	41.18	100.15	118.32	168.38	218.58
A Lot	*min_A*	*max_A*	*min_P*	*max_P*	*min_ED*	*max_ED*	*min_C1*	*max_C1*	*min_C2*	*max_C2*
AYG	3289.00	3492.00	386.05	407.02	91.49	94.27	292.77	295.88	297.16	308.50
FS	5437.00	5966.00	546.53	560.29	117.65	123.26	248.31	382.22	258.54	492.67
SS	2455.00	2663.00	366.59	408.89	79.06	82.30	311.22	316.08	443.95	497.47
UB	2455.00	5966.00	366.59	560.29	79.06	123.26	248.31	382.22	258.54	497.47
Enter	*min_A*	*max_A*	*min_P*	*max_P*	*min_ED*	*max_ED*	*min_C1*	*max_C1*	*min_C2*	*max_C2*
AYG	1378.00	1495.00	167.68	184.07	41.89	43.63	140.42	142.62	202.98	220.84
FS	904.00	1270.00	144.27	231.28	33.93	55.90	127.26	255.03	176.79	389.53
SS	1298.00	1673.00	201.68	232.79	56.71	65.15	255.23	266.31	207.81	496.30
UB	904.00	1673.00	144.27	232.79	33.93	65.15	127.26	266.31	176.79	496.30
Late	*min_A*	*max_A*	*min_P*	*max_P*	*min_ED*	*max_ED*	*min_C1*	*max_C1*	*min_C2*	*max_C2*
AYG	996.00	1901.00	144.51	226.17	35.61	49.20	142.61	150.15	202.45	221.32
FS	1258.00	1441.00	225.97	276.94	56.36	60.33	259.89	265.45	486.25	507.24
SS	1880.00	1977.00	212.75	259.28	48.93	50.17	173.20	178.19	284.83	287.83
UB	996.00	1977.00	144.51	276.94	35.61	60.33	142.61	265.45	202.45	507.24
Pass	*min_A*	*max_A*	*min_P*	*max_P*	*min_ED*	*max_ED*	*min_C1*	*max_C1*	*min_C2*	*max_C2*
AYG	2292.00	2474.00	315.18	333.97	76.38	79.36	288.68	293.08	306.10	377.86
FS	222.00	587.00	79.36	192.91	23.76	38.66	261.80	268.49	406.21	460.72
SS	1521.00	1627.00	225.34	248.75	62.23	64.35	252.34	259.87	394.82	471.41
UB	222.00	2474.00	79.36	333.97	23.76	79.36	252.34	293.08	306.10	471.41
Quite	*min_A*	*max_A*	*min_P*	*max_P*	*min_ED*	*max_ED*	*min_C1*	*max_C1*	*min_C2*	*max_C2*
AYG	3177.00	3703.00	272.45	357.36	63.60	68.66	142.06	145.20	108.29	130.02
FS	1330.00	1579.00	236.65	287.62	41.15	44.84	132.55	134.90	82.22	88.98
SS	1978.00	2115.00	310.69	356.39	50.18	71.41	125.92	249.79	109.16	278.49
UB	1330.00	3703.00	236.65	357.36	41.15	71.41	125.92	249.79	82.22	278.49
Search	*min_A*	*max_A*	*min_P*	*max_P*	*min_ED*	*max_ED*	*min_C1*	*max_C1*	*min_C2*	*max_C2*
AYG	1107.00	1404.00	138.23	172.95	37.54	42.28	91.03	141.51	134.28	202.67
FS	406.00	710.00	78.53	150.91	22.74	30.07	81.60	121.57	169.69	232.31
SS	562.00	840.00	122.43	144.67	26.75	32.70	95.49	142.72	183.87	222.02
UB	406.00	1404.00	78.53	172.95	22.74	42.28	81.60	142.72	134.28	232.31
Wait	*min_A*	*max_A*	*min_P*	*max_P*	*min_ED*	*max_ED*	*min_C1*	*max_C1*	*min_C2*	*max_C2*
AYG	2224.00	2686.00	213.64	272.94	53.21	58.48	79.15	153.66	111.42	201.73
FS	2654.00	2705.00	273.44	279.78	58.13	58.69	109.84	110.79	254.97	261.61
SS	1532.00	1559.00	195.30	198.71	44.17	44.55	127.33	128.76	262.11	267.27
UB	1532.00	2705.00	195.30	279.78	44.17	58.69	79.15	153.66	111.42	267.27
Fail	*min_A*	*max_A*	*min_P*	*max_P*	*min_ED*	*max_ED*	*min_C1*	*max_C1*	*min_C2*	*max_C2*
AYG	1168.00	1576.00	159.44	194.99	38.56	44.80	107.23	116.29	94.87	222.87
FS	872.00	1083.00	150.23	167.78	33.32	37.13	111.29	131.96	126.77	169.93
SS	1037.00	1083.00	145.98	157.15	36.34	37.13	146.73	149.17	258.53	270.05
UB	872.00	1576.00	145.98	194.99	33.32	44.80	107.23	149.17	94.87	270.05

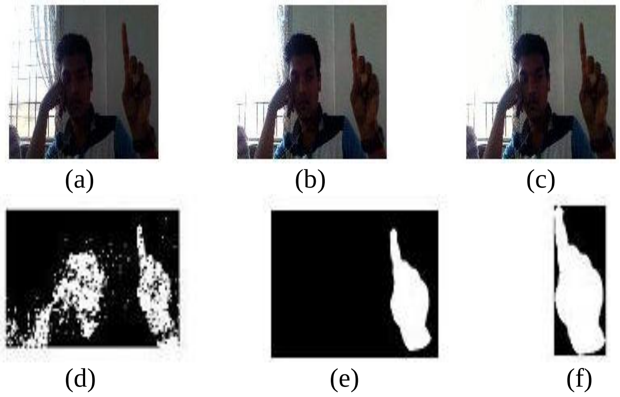


Figure. 8 Pre-processing steps incorporated in real time hand segmentation using adaptive skin colour modelling: (a) The original input image, (b) RGB compensated, (c) Light compensated, (d) Skin segmented, (e) Binary filtered, and (f) ROI cropped image respectively

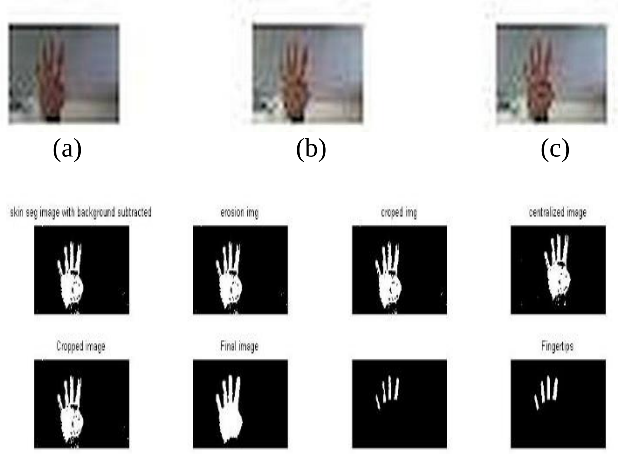


Figure. 9 Recognizing ISL number four using adaptive skin colour modelling: (a) Original input image, (b) RGB compensated, and (c) light compensated

Table 7. Confusion matrix of signer1, performing gestures in front of the camera

Sr. No.	Gesture Name	No. of Images	10TH	a little	a lot	enter	late	pass	quite	search	wait	fail	Wrong Detection	Accuracy
1	10TH	10	10	0	0	0	0	0	0	0	0	0	0	100%
2	a little	10	0	10	0	0	0	0	0	0	0	0	0	100%
3	A lot	15	0	0	14	0	0	0	0	0	0	0	1	93.33%
4	enter	13	0	0	0	11	1	0	1	0	0	0	0	84.62%
5	late	10	0	0	0	0	9	0	0	0	0	0	1	90%
6	pass	10	0	0	0	0	0	10	0	0	0	0	0	100%
7	quite	10	0	0	0	0	0	0	9	0	0	0	1	90%
8	search	10	0	0	0	0	0	0	0	8	0	0	2	80%
9	wait	10	0	0	0	0	0	0	0	0	10	0	0	100%
10	Fail	10	0	0	0	0	1	0	0	0	0	9	0	90%
Total no. of images		108											Overall Accuracy	92.79%

Table 8. Confusion matrix of signer 2, performing gestures in front of the camera

Sr. No.	Gesture Name	No. of Images	10TH	a little	a lot	enter	late	pass	quite	search	wait	fail	Wrong Detection	Accuracy
1	10TH	20	19	0	0	0	0	0	0	0	0	0	1	95%
2	a little	12	0	10	0	0	0	0	0	2	0	0	0	83.33%
3	A lot	10	0	0	9	0	0	0	0	0	0	0	1	90%
4	enter	31	0	0	0	29	0	0	0	1	0	1	0	93.55%
5	late	7	0	0	0	0	6	0	0	0	0	0	1	85.71%
6	pass	10	0	0	0	0	0	10	0	0	0	0	0	100%
7	quite	15	0	0	0	0	0	1	13	0	0	0	1	86.67%
8	search	10	0	0	0	0	0	0	0	8	0	0	2	80%
9	wait	10	0	0	0	0	0	0	0	0	10	0	0	100%
10	Fail	17	0	0	0	0	0	0	0	0	0	16	1	94.12%
Total no. of images		142											Overall Accuracy	90.84%

Table 9. Confusion matrix for Aliyawar Jung video dataset

Sr. No.	Gesture Name	No. of Images	10TH	a little	a lot	enter	late	pass	quite	search	wait	fail	Wrong Detection	Accuracy
1	10TH	11	11	0	0	0	0	0	0	0	0	0	0	100.00%
2	a little	10	0	9	0	0	0	0	0	0	0	0	1	90%
3	a lot	7	0	0	7	0	0	0	0	0	0	0	0	100.00%
4	enter	11	0	0	0	10	1	0	0	0	0	0	0	90.91%
5	late	27	0	0	0	0	23	0	0	0	1	0	3	85.19%
6	pass	18	0	0	0	0	0	16	0	0	0	0	2	88.89%
7	quite	29	0	0	0	0	0	1	27	0	0	1	0	93.10%
8	search	21	0	0	0	0	0	0	0	18	0	0	3	85.71%
9	wait	9	0	0	0	0	0	0	0	0	9	0	0	100%
10	fail	10	0	0	0	0	0	0	0	0	0	9	1	90%
Total no of images		153											Overall Accuracy	92.64%

4. Conclusion

A real-time skin colour segmentation is a prime concern in posture/hand gesture based sign language recognition. The proposed ASCM method separate posture/hand gesture without any marker on any background by taking into account foreground skin colour. The proposed work is segmenting dynamic posture/hand gesture done in front of the camera or from images or video database. The values of $YCgCr$ determined at runtime. The $YCgCr$ bound values are used to segment foreground skin colour from skin / non-skin colour background. The algorithm deployed on the open source Raspberry-Pi embedded image processing hardware platform adapt any skin tone /colour and segment face/ hand gestures of the signer. The overall accuracy including ISL standard database is 92.09%. In future, the recognition accuracy and time would be improved by incorporating additional features and utilising all 4 GPUs of R-Pi.

References

[1] P. Kakumanu, S. Makrogiannis, and N. Bourbakis, "A survey of skin-colour modelling and detection methods", *Pattern Recognit.*, Vol. 40, No. 3, pp. 1106–1122, 2007.

[2] G. Yang, H. Li, L. Zhang, and Y. Cao, "Research on a Skin Color Detection Algorithm Based on Self-adaptive Skin Color Model", In: *Proc. of the 2010 Int. Conf. Commun. Intell. Inf. Secur.*, pp. 266–270, 2010.

[3] Y. Luo and Y.-P. Guan, "Adaptive skin detection using face location and facial structure estimation", *IET Comput. Vis.*, Vol. 11, No. 7, pp. 550–559, 2017.

[4] Z. H. Al-Tairi, R. W. Rahmat, M. Iqbal Saripan, and P. S. Sulaiman, "Skin segmentation using YUV and RGB colour spaces", *J. Inf. Process. Syst.*, Vol. 10, No. 2, pp. 283–299, 2014.

[5] P. H. Chen, Y. C. Yang, and L. M. Chang, "Automated bridge coating defect recognition using adaptive ellipse approach", *Autom. Constr.*, Vol. 18, No. 5, pp. 632–643, 2009.

[6] J. Singha and K. Das, "Indian Sign Language Recognition Using Eigen Value Weighted Euclidean Distance-Based Classification Technique", *arXiv Prepr. arXiv1303.0634*, Vol. 4, No. 2, pp. 188–195, 2013.

[7] S. L. Phung, A. Bouzerdoum, and D. Chai, "Skin segmentation using colour pixel classification: analysis and comparison", *IEEE Trans. Pattern Anal. Mach. Intell.*, Vol. 27, No. 1, pp. 148–154, 2005.

[8] J. Yong, A. Zhauip, and T. Tan, "Adaptive skin detection using multiple cues", In: *Proc. of the International Conference on Image Processing*, pp. 901–904, 2004.

[9] N. Vandenbroucke, L. Macaire, and J.-G. Postaire, "Color pixels classification in a hybrid colour space", In: *Proc. 1998 Int. Conf. Image Process*, pp. 176–180, 1998.

[10] W. Chen, K. Wang, H. Jiang, and M. Li, "Skin colour modelling for face detection and segmentation: a review and a new approach", *Multimedia. Tools Appl.*, pp. 839–862, 2014.

[11] P. Dondi, M. Porta, and L. Lombardi, "Development of gesture-based human-computer interaction applications by fusion of depth and colour video streams", *IET Comput. Vis.*, Vol. 8, No. 6, pp. 568–578, 2014.

[12] E. Stergiopoulou, K. Sgouropoulos, N. Nikolaou,

N. Papamarkos, and N. Mitianoudis, "Real-time hand detection in a complex background", *Eng. Appl. Artif. Intell.*, Vol. 35, pp. 54–70, 2014.
[13] A. Y. Dawod, J. Abdullah, and M. J. Alam, "Adaptive skin colour model for hand segmentation", In: *Proc. of the ICCAIE 2010 - 2010 Int. Conf. Comput. Appl. Ind. Electron.*, No. Iccaie, pp. 486–489, 2010.
[14] M. Shoyaib, M. Abdullah-Al-Wadud, and O. Chae, "A skin detection approach based on the Dempster-Shafer theory of evidence", *Int. J. Approx. Reason.*, Vol. 53, No. 4, pp. 636–659, 2012.
[15] H. Hikawa and K. Kaida, "Novel FPGA implementation of hand sign recognition system with SOM-Hebb classifier", *IEEE Trans. Circuits Syst. Video Technol.*, Vol. 25, No. 1, pp. 153–166, 2015.
[16] X. Zhang, X. Chen, Y. Li, V. Lantz, K. Wang, and J. Yang, "A framework for hand gesture recognition based on accelerometer and EMG sensors", *IEEE Trans. Syst. Man, Cybern. Part ASystems Humans*, Vol. 41, No. 6, pp. 1064–1076, 2011.
[17] M. Zhao, P. Li, and L. Wang, "A novel complete face detection method in colour images", In: *Proc. of Image Signal Process, 2010 3rd Int. Congr.*, Vol. 4, pp. 1763–1766, 2010.
[18] R. Kaluri and P. Ch, "Sign Gesture Recognition Using Modified Region Growing Algorithm and Adaptive Genetic Fuzzy Classifier", *International Journal of Intelligent Engineering and Systems*, Vol. 9, No. 4, pp. 225–233, 2016.
[19] R. Kaluri and P. CH, "An Enhanced Framework for Sign Gesture Recognition using Hidden Markov Model and Adaptive Histogram Technique", *International Journal of Intelligent Engineering and Systems*, Vol. 10, No. 3, pp. 11–19, 2017.