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Gender Recognition System Design with help of fingerprint using Correlation and Ridge Density

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***Abstract*: The paper conducted on 200 subjects (100 males and 100 females) in the age group of 18–30 years. Ridge densities on the right- and left-hand thumbprints were determined using a newly designed layout and analyzed statistically, the proposed work results showed that females tend to have a higher thumbprint ridge density in both the areas examined, individually and combined. Applying the LR-test, the differences in the ridge densities of males and females at LoC (Left of Centre), RoC (Right of Centre) and Combined (LoC + RoC) were found to be statistically significant at p< 0.01 levels, proving the association between gender and fingerprint ridge density. Probability densities for men and women derived from the frequency distribution (at LoC, RoC and Combined) were used to calculate the likelihood ratio. Differences in the thumb ridge density can be used as an important tool for the determination of gender in cases where partial thumbprints are encountered as evidence. The work is done on MATLAB 2013b version & standard human fingerprint database is CASIA for genuine comparison.**

***Keywords*: LoC: Left of Centre, RoC: Right of Centre, LR: Likelihood Ratio, PDF: Probability density function, ARM: Association Rule Mining**

I-INTRODUCTION

Fingerprints are unique patterns, made by friction ridges (raised) & furrows (recessed), which appear on pads of fingers & thumbs. Prints from palms, toes & feet are also unique; however, these are used less often for identification, so this guide focuses on prints from fingers & thumbs. Proposed design of human fingerprint identification is an improvement of all previous designs of original objective of presented work is to develop a procedure which is significantly faster than old work & it should not have less identification rate. After doing a literature work & studies many research articles related to human fingerprint recognition, presented work is been developed. Proposed work is new procedure which include pre-processing of human fingerprint image based on new modified Correlation which helps to convert human fingerprint into a binary image & also perform image filtering with fine boundaries & clear features then previous Bayes's theorem based method on behalf of Likelihood ratio of Ridge density probabilities human fingerprint is identifies as Male or Female using correlation method. The work is done on MATLAB 2013b version & standard human fingerprint database is CASIA for genuine comparison.

II-METHODOLOGY

ridges from one corner of the square to the diagonally opposite corner were counted. Dots were not counted. Forks were counted as two ridges excluding the handle and a lake was counted as two ridges.[7] The tabulated values for both sides represented the ridge density in a 25-mm2 area. Various statistical calculations were performed on the obtained data. Posterior probability inferences of gender, based on ridge density values were made by calculating the likelihood ratio (LR) based on the Modified Baye's theorem. Proposed work identifies the probability of correlated Ridge and total count and then uses that probability in Modified Baye's theorem to calculate Likelihood Ratio (LR). The favoured odds were also calculated as:

$$\mathrm{LR} = \frac{\text{Probability of a given finger print originating from a male contributor (C)}}{\text{Probability of a given finger print originating from a female contributor (C}')}$$

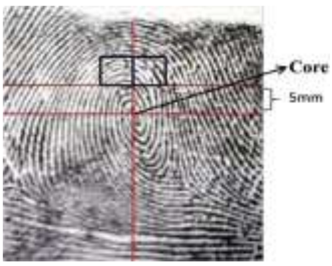


Figure 1 A fingerprint showing the areas (2 of 25 mm2) used for counting thumbprint ridge densities at the left of centre (LoC) and right of centre (RoC).

The presented design has four major parts : Database & human fingerprint Acquisition, Pre-Processing, Feature Extraction AND Classification Feature Extraction: figure 2 next shows Pre-processing & Features (LoC & RoC Ridge density) obtained for presented design from CASIA database.

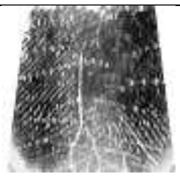
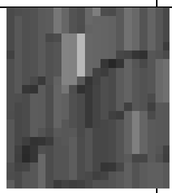
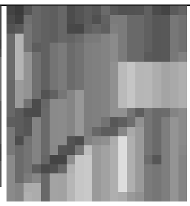
Original fingerprint	After pre-processing	LoC	RoC
			

Figure 2 CASIA database [10] Fingerprints & after Pre-processing & its binary LoC & RoC Ridge density

After finding LoC & RoC Ridge density as a binary image of all fingerprints of CASIA database [10] and, a 2D matrix variable is been developed for uploading all images of CASIA database [10] in MATLAB [11] environment, first of all fingerprints of various person is been converted into 1D matrix.

Correlation based Recognition: Correlation is a famous procedure for comparison of two signals & it commonly used for RADAR for detecting same signal which was transmitted from radar. Among all received signal reflected signal may there, to search that specific signal Correlation procedure uses, where original signal gets flipped convolve with all received signal & extreme output values found only for reflected received signal. & here shifting of distribution of components does not matter extreme output come only for most matching element does not matter positions. Same procedure is been used in presented design on human fingerprint images.

let $\mathbf{x(n)}$ is human fingerprint which needs to be recognised it has LoC & RoC Ridge density held as a 1D signal, it has total W = R x C elements. & $\mathbf{y_m(n)}$ is CASIA database [10] fingerprints, M is total number of fingerprints where:-

n=1, 2, 3 ....W

m=1, 2, 3, ... M

Correlation is denoted as ‘r’

$$\mathbf{r1(n)} = \sum_{\mathbf{k=0}}^{\mathbf{n}} \mathbf{x(k)x(k-n)}$$

$$\mathbf{r_m(n)} = \sum_{\mathbf{k=0}}^{\mathbf{n}} \mathbf{x(k)y_m(k-n)}$$

$$\mathbf{S1} = \sum_{\mathbf{n=0}}^{\mathbf{W}} \mathbf{r1(n)}$$

$$\mathbf{S_m} = \sum_{\mathbf{n=0}}^{\mathbf{W}} \mathbf{r_m(n)}$$

$$\mathbf{Df_m} = |\mathbf{S_m} - \mathbf{S1}|$$

$$\mathbf{(Val, K0)} = \mathbf{Min(Df_m)}$$

Where K0 is position of human fingerprint found in data base

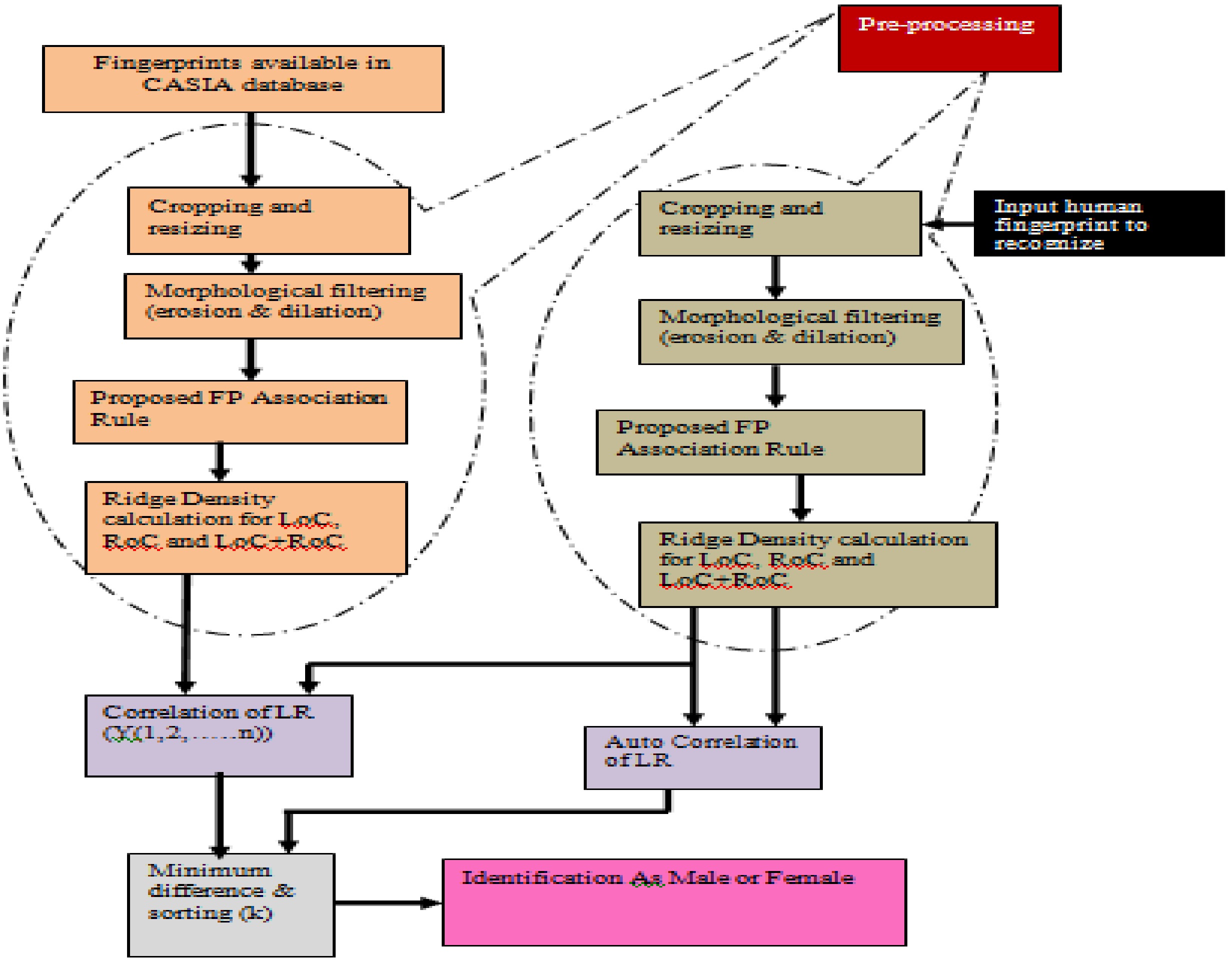


Figure 3 block diagram of proposed work

Figure 3 shown above shows block diagram of presented design it may be observed in diagram that human fingerprint Acquisition [7] for database & human fingerprint which is to be recognised is shown, after human fingerprint & CASIA database [10] acquiring pre-processing is been done on both CASIA database [10] & human fingerprint which is to be recognised. Pre-processing includes Cropping of central part of human fingerprint then a Morphological filtering which perform dilation then erosion this procedure significantly enhance quality of human fingerprint especially quality of latent fingerprint.

Also in Pre-processing the proposed FP based association mining rule applied to get the exact ridge densities of LoC, RoC and LoC + RoC this RD's are considers as the features of the fingerprints. At last the Correlation based identification procedure used for identification of test fingerprint the test fingerprint RD get auto correlated with itself and then test fingerprint will get Cross correlated with all CASIA database fingerprints, the minimum differ database fingerprint give information of sex of the test fingerprint.

III-RESULTS

Table 1 Descriptive statistics of the thumb ridge density in both males and females.

Ridge density (in a square of 25 mm^2)	**Male**			**Ridge density (in a square of 25 mm^2)**	**Female**		
	Left of Centre (LoC)	Right of Centre (RoC)	LoC+RoC		Left of Centre (LoC)	Right of Centre (RoC)	LoC+RoC
CASIA-M1	7.90963	11.6621	19.3317	CASIA-F1	16.97	15.71	32.44
CASIA-M2	12.4801	13.1403	25.3803	CASIA-F2	19.72	18.81	38.301
CASIA-M3	9.46502	14.3488	23.5739	CASIA-F3	17.1	16.91	33.77
CASIA-M4	10.6764	12.1789	22.6153	CASIA-F4	16.86	16.00	32.62
CASIA-M5	6.19328	9.9808	15.9341	CASIA-F5	16.64	14.21	30.62
CASIA-M6	8.69041	11.0204	19.4708	CASIA-F6	14.48	17.27	31.51
CASIA-M7	9.81188	12.9905	22.5624	CASIA-F7	12.76	13.15	25.68
CASIA-M8	12.6993	12.7127	25.172	CASIA-F8	15.111	12.14	27.01
CASIA-M9	9.05994	10.3661	19.186	CASIA-F9	14.53	16.25	30.55
CASIA-M10	7.31866	8.3173	15.396	CASIA-F10	13.24	15.38	28.38

CASIA-M11	4.67092	4.64689	9.07781	CASIA-F11	15.78	16.93	32.4845
CASIA-M12	11.8174	12.6157	24.1931	CASIA-F12	18.6064	15.0508	33.4172
CASIA-M13	13.3669	12.7058	25.8327	CASIA-F13	17.2168	15.4207	32.3975
CASIA-M14	6.45643	11.1538	17.3702	CASIA-F14	17.719	15.9255	33.4045
CASIA-M15	6.6787	9.70133	16.14	CASIA-F15	14.4285	16.3774	30.5659
CASIA-M16	4.91644	4.51901	9.19544	CASIA-F16	13.2664	12.6251	25.6515
CASIA-M17	7.10366	7.96388	14.8275	CASIA-F17	13.9184	14.3327	28.0111
CASIA-M18	6.4735	10.3745	16.608	CASIA-F18	17.0477	15.3609	32.1685
CASIA-M19	10.0599	9.628	19.4479	CASIA-F19	17.4225	15.289	32.4715
CASIA-M20	3.29358	5.32206	8.37564	CASIA-F20	14.2936	15.232	29.2855
CASIA-M21	7.91663	9.30992	16.9866	CASIA-F21	14.7966	14.3676	28.9243
CASIA-M22	6.44383	8.13528	14.3391	CASIA-F22	13.3207	15.0493	28.1301
CASIA-M23	9.50813	13.7433	23.0115	CASIA-F23	17.9264	16.4152	34.1016
CASIA-M24	11.5761	14.5558	25.8919	CASIA-F24	17.7098	17.4415	34.9113
CASIA-M25	10.4527	13.4297	24.6424	CASIA-F25	17.1616	16.9878	33.9094
CASIA-M26	9.33093	11.3734	20.4643	CASIA-F26	11.4546	15.9106	27.1252
CASIA-M27	12.1144	12.7478	24.6223	CASIA-F27	16.1849	16.684	32.6289
CASIA-M28	10.3572	8.50912	18.6263	CASIA-F28	15.7826	16.2095	31.7521
CASIA-M29	5.92033	8.21801	13.8983	CASIA-F29	14.8137	16.5439	31.1176
CASIA-M30	8.13107	7.07013	14.9612	CASIA-F30	16.1286	16.9919	32.8805
CASIA-M31	8.38106	7.86521	16.0063	CASIA-F31	14.2082	13.2735	26.2417
CASIA-M32	11.4938	10.5203	21.7741	CASIA-F32	15.0469	13.2073	28.0142
CASIA-M33	9.51569	9.95914	19.2348	CASIA-F33	17.883	17.9032	35.5462
CASIA-M34	4.37502	7.1543	11.2893	CASIA-F34	17.4315	19.6989	36.8904
CASIA-M35	6.41947	10.36	16.5394	CASIA-F35	15.4287	13.421	28.6097
CASIA-M36	8.03253	8.95651	16.749	CASIA-F36	15.3498	16.284	31.3938
CASIA-M37	7.44436	9.66824	16.8726	CASIA-F37	15.1278	15.6244	30.5122
CASIA-M38	10.6517	11.8045	22.2162	CASIA-F38	15.3084	15.7347	30.8031
CASIA-M39	13.6292	11.249	24.6382	CASIA-F39	15.7885	15.7304	31.2789
CASIA-M40	10.0854	8.33568	18.1811	CASIA-F40	10.8818	12.3656	23.0075
CASIA-M41	11.8057	10.7992	22.3648	CASIA-F41	17.719	15.9255	33.4045
CASIA-M42	11.372	10.5693	21.7014	CASIA-F42	14.4285	16.3774	30.5659
CASIA-M43	12.7214	12.3276	24.809	CASIA-F43	13.2664	14.6251	25.6515
CASIA-M44	12.5103	7.17861	19.4489	CASIA-F44	13.9184	14.3327	28.0111
CASIA-M45	3.67683	5.51368	8.95051	CASIA-F45	17.0477	15.3609	32.1685
CASIA-M46	6.10481	9.06498	14.9298	CASIA-F46	17.7098	17.4415	34.9113
CASIA-M47	7.02164	8.55325	15.3349	CASIA-F47	17.1616	16.9878	33.9094
CASIA-M48	5.23054	6.77596	11.7665	CASIA-F48	11.4546	15.9106	27.1252
CASIA-M49	8.59774	8.32261	16.6804	CASIA-F49	16.1849	16.684	32.6289
CASIA-M50	7.264	8.55	16.3349	CASIA-F50	15.7826	16.2095	31.7521

Table 1 CASIA-Male-Female Fingerprint Ridge density calculations

Male minimum LoC Ridge density observe is 4
Male maximum LoC Ridge density observe is 13
Male minimum RoC Ridge density observe is 4
Male maximum RoC Ridge density observe is 14
Male minimum LoC+RoC Ridge density observe is 9
Male maximum LoC+RoC Ridge density observe is 25
Female minimum LoC Ridge density observe is 10
Female maximum LoC Ridge density observe is 19
Female minimum RoC Ridge density observe is 12
Female maximum RoC Ridge density observe is 19
Female minimum LoC+RoC Ridge density observe is 23
Female maximum LoC+RoC Ridge density observe is 38

	Male	**Female**

Ridge density (in a square of 25 mm^2)	Left of Centre (LoC)		Right of Centre (RoC)		Left of Centre (LoC)		Right of Centre (RoC)	
	No. of samples	%	No. of samples	%	No. of samples	%	No. of samples	%
4	5	10	2	4				
5	2	4	2	4				
6	7	14	3	6				
7	6	12	6	12				
8	5	10	9	18				
9	6	12	7	14				
10	7	14	5	10	1	2		
11	5	10	5	10	2	4		
12	5	10	6	12	1	2	3	6
13	2	4	3	6	6	12	4	8
14			2	4	8	16	4	8
15					10	20	15	30
16					6	12	16	32
17					14	28	5	10
18					1	2	2	4
19					1	2	1	2
Total	50	100	50	100	50	100	50	100

Table 2 Frequency distribution of mean ridge density in 25 mm^2 at LoC and RoC region in male and female thumbprints.

Table 2 depicts the frequency distribution of ridge densities at the left and right of centre per 25 mm2 in males and females. It is observed that none of the males have a mean ridge density of more than 15 and there are no females who have mean ridge densities below 12, which shows a little variation from the results of Pattanawit Soanboon et al.[1].

Combined ridge density LoC + RoC (25 mm^2)	**Male**		**Female**	
	No. of samples	%	No. of samples	%
9	1	2		
10	0	0		
11	2	4		
12	2	4		
13	2	4		
14	3	6		
15	3	6		
16	7	14		
17	1	2		
18	2	4		
19	6	12		
20	3	6		
21	3	6		
22	3	6		
23	4	8	1	2
24	4	8	0	0
25	3	6	2	4
26			2	4
27			3	6
28			5	10
29			1	2
30			5	10
31			6	12
32			10	20
33			6	12
34			4	8
35			2	4
36			1	2

37			1	2
38			1	2
Total	50	100	50	100

Table 3 Frequency distribution of the combined mean ridge density (LoC+ RoC region) in male and female thumbprints.

Table 3 shows the frequency distribution of mean ridge densities of LoC and RoC combined. It is observed that none of the males have a mean ridge density of more than 27 and there are no females who have mean ridge densities below 23. Females have a significantly greater combined ridge density than males. A combined ridge density count was not achieved by others in the past. But our results suggest that combining the ridge densities at the LoC and RoC regions will improvise the result in terms of gender differentiation using thumbprints.
Probability densities for men (C) and women (C0) derived from the frequency distribution (at LoC and RoC respectively) were used to calculate the likelihood ratio [(C/C0) and (C0/C)] and posterior probabilities of gender designation for the given ridge count for subjects using Modified Baye's theorem21 (Tables 4.4 –4.6). At LoC, the statistical analysis of the likelihood ratio and the odds ratio shows that a ridge density of 612 ridges per 25 mm2 is more likely to be of male origin (p =0.90), whereas a ridge density of P13 ridges per 25 mm2 is more likely to be of female origin (p = 0.69) (Table 4.3). Posterior probability using Modified Baye'ss theorem shows that a fingerprint with a ridge density of 610 ridges per 25 mm2 will have a higher probability of belonging to a male (p= 0.99). Similarly, a ridge density of P16 ridges per 25 mm2 will be more indicative of females (p= 0.99). At RoC, the statistical analysis of the likelihood ratio and the odds ratio shows that a ridge density of 612 ridges per 25 mm2 is more likely to be of male origin (p =0.95), whereas a ridge density of P13 ridges per 25 mm2 is more likely to be of female origin (p = 0.64) (Table 7). Posterior probability using Modified Baye's theorem shows that a fingerprint with a ridge density of 611 ridges per 25 mm2 will have a higher probability of belonging to a male (p= 0.99). Similarly, a ridge density of P15 ridges per 25 mm2 will be more indicative of females (p= 0.98).

Ridge density at LoC	**Probability density**		**Likelihood Ratio**		**Ridge density at RoC**	**Probability**		**Likelihood Ratio**	
	Male(C)	Female (C')	C/C'	C'/C		Male(C)	Female(C')	C/C'	C'/C
4	0.05		999	0.001	4	0.02		999	0.001
5	0.02		999	0.001	5	0.02		999	0.001
6	0.07		999	0.001	6	0.03		999	0.001
7	0.06		999	0.001	7	0.06		999	0.001
8	0.05		999	0.001	8	0.09		999	0.001
9	0.06		999	0.001	9	0.07		999	0.001
10	0.07	0.01	7	0.14	10	0.05		999	0.001
11	0.05	0.02	2.5	0.4	11	0.05		999	0.001
12	0.05	0.01	5	0.2	12	0.06	0.03	2	0.5
13	0.02	0.06	0.33	3	13	0.03	0.04	0.75	1.333
14		0.08	0.001	999	14		0.04	0.001	999
15		0.10	0.001	999	15		0.15	0.001	999
16		0.06	0.001	999	16		0.16	0.001	999
17		0.14	0.001	999	17		0.05	0.001	999
18		0.01	0.001	999	18		0.02	0.001	999
19		0.01	0.001	999	19		0.01	0.001	999

Table 4 Probability densities and likelihood ratios derived from the observed ridge count at LoC and Roc.

Ridge density at LoC+RoC	Probability density		Likelihood Ratio	
	Male(C)	Female(C')	C/C'	C'/C
9	0.01		999	0.001
10	0.00		999	0.001
11	0.02		999	0.001
12	0.02		999	0.001
13	0.02		999	0.001
14	0.03		999	0.001
15	0.03		999	0.001
16	0.07		999	0.001
17	0.01		999	0.001
18	0.02		999	0.001
19	0.06		999	0.001
20	0.03		999	0.001
21	0.03		999	0.001
22	0.03		999	0.001
23	0.04	0.01	4	0.25
24	0.04	0.00	999	0.001
25	0.03	0.02	1.5	0.67
26		0.02	0.001	999
27		0.03	0.001	999
28		0.05	0.001	999
29		0.01	0.001	999
30		0.05	0.001	999
31		0.06	0.001	999
32		0.10	0.001	999
33		0.06	0.001	999
34		0.04	0.001	999
35		0.02	0.001	999
36		0.01	0.001	999
37		0.01	0.001	999
38		0.01	0.001	999

Table 5 Probability densities and likelihood ratios derived from the observed combined ridge count.

For the Combined ridge density (LoC +RoC), the statistical analysis of the likelihood ratio and the odds ratio shows that a ridge density of 625 ridges per mm2 is more likely to be of male origin (p= 0.96), whereas a ridge density of ridges per mm2 is more likely to be of female origin (p = 0.64) (Table 8). Posterior probability using Modified Baye's theorem shows that a fingerprint with a ridge density of ridges per mm2 will have a higher probability of belonging to a male (p = 0.99). Similarly, a ridge density of ridges per mm2 will be more indicative of females (p =0.99).

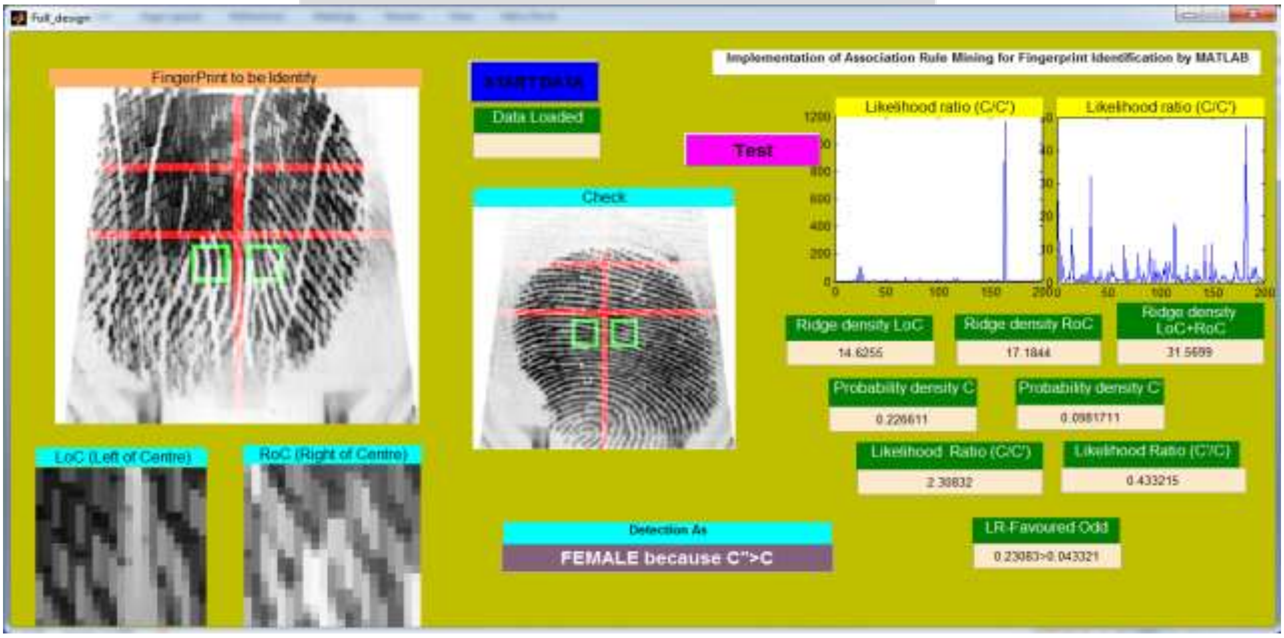


Figure 4 Data base Upload for Ridge LoC and RoC density extraction and calculation

Throughput: Simulation time obtained for presented design is 139.123 sec needed for 10x200 images of CASIA database [10] hence

$$\text{Image processed in 1 second} = \frac{10x200}{139.123} = 14.375768$$

Each image has 100x100 pixels of 8 bit each, hence total 100x100x8 bits in a single Image & in 1 second total 14.375768 images are been processed in presented work hence

$$\text{number of bit processsed in one seconds (throughput)} = \frac{100x100x8x14.375768}{1000000}\ \text{Mbps}$$
$$= 1.15006144\ \text{Mbps}$$

Identification Rate: Out of 1000 time of checking of human fingerprint 821 times we obtained human fingerprint identifies Male or Female perfectly.

$$\text{Identification Rate} = 100 - \frac{(1000-821)*100}{1000} = 82.1\%$$

Parameter	Proposed Work	Pattanawit Soanboon et al [1]
Time delay (Seconds)	139.123	142.58
Throughput (Mbps)	1.15	1.07
Identification rate %	82.1	81.36
Average LoC Density found (Female)	18.25	18.02
Average LoC Density found (Female)	17.98	18.21
Average LoC Density found (Male)	11.24	11.35
Average LoC Density found (Male)	11.37	11.29
Likelihood Ratio (C/C')	0.635	0.62

Table 6 Comparative Results

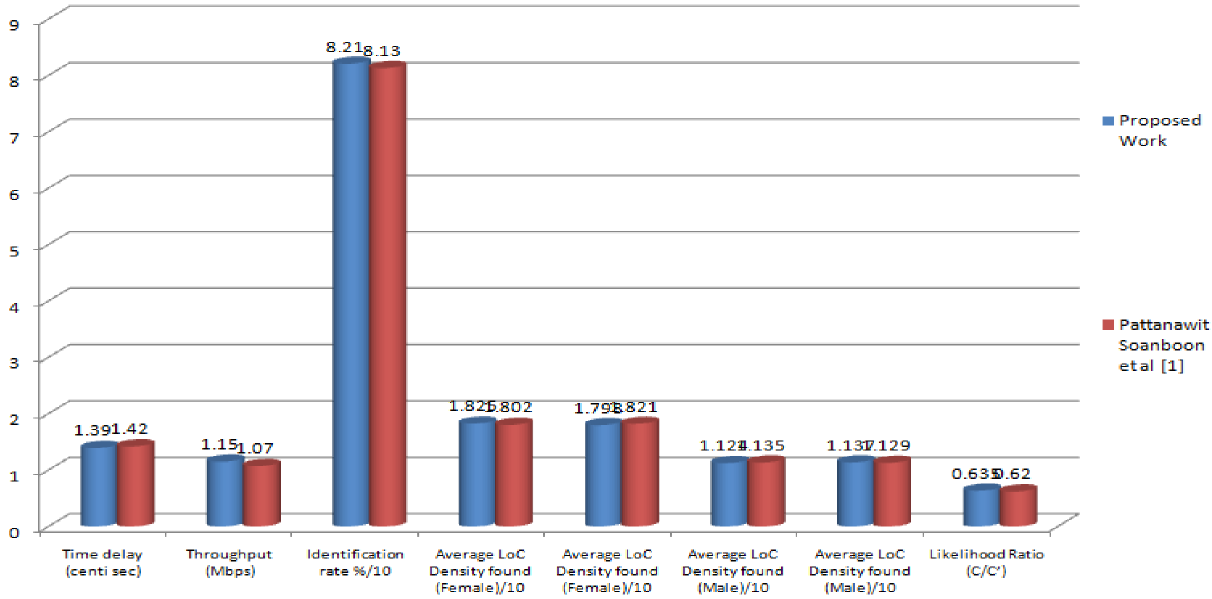


Figure 5 identification rate comparisons

From the table 6 above and figure 5 above it can be observe that proposed work Time for identification is better and sp overall throughput is also better. Proposed work identification rate is also better than previous work, and proposed work found better Density difference than previous work as proposed work average LR is 0.635 and previous work average LR is 0.62 only.

IV-CONCLUSION

Proposed work Time for identification is better and sp overall throughput is also better. Proposed work identification rate is also better than previous work, and proposed work found better Density difference than previous work as proposed work average LR is 0.635 and previous work average LR is 0.62 only. It was concluded that differences in the thumb ridge density can be used as an important tool for the determination of gender in cases where partial thumbprints are encountered as evidence either at the crime scene or on any document(s) of forensic significance.

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